Chapter 3
Pollution, Cancer Risk, and Vulnerable Populations

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Introduction

Cancer is no longer a problem just for wealthier countries. Statistics from GLOBOCAN 2012 suggest that more than half of cancer patients reside in developing countries and a far greater proportion of these patients die compared to those in developed countries due to limited health-care infrastructure for early detection and treatment of cancer [1–3]. The burden of cancer in low-income countries is most likely far worse than these numbers indicate as data collection is limited and tumor registries are largely absent. Many patients go undiagnosed and uncounted resulting in an unclear representation of the issue at hand.

There are also emerging differences in biologic behavior in certain cancer diagnoses. Cancers appear at younger ages than in developed countries and have more aggressive behavior. This often leads to earlier metastases and death, the reasons for which are not yet clear. Environmental pressures such as chronic infections and pollution are possible etiologies for these differences. In this chapter we will highlight the impact of pollution on the economically vulnerable as a potentially preventable cause of cancer and present two focus studies on populations in Ecuador and Rwanda.

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Vulnerable Populations and Cancer Prevention

In the context of public health, a group of people within a larger community who experience a disproportionately high risk of adverse health outcomes, including premature mortality, comprise a vulnerable population [4]. Poverty, neighborhood quality, nutritional status, race/ethnicity, and access to healthcare influence a wide range of health outcomes. Vulnerability is a consequence of limited access to or availability of resources relative to health status [4]. In the United States, individuals with low socioeconomic status, from minority racial and ethnic groups, or without insurance experience greater rates of cancer incidence and mortality and less frequently participate in recommended cancer screenings [5]. Cancer diagnosis and treatment present special challenges in these populations due to barriers to screening and reduced access to healthcare. Further, socioeconomic disadvantages may correspond to adverse conditions of daily life, such as food insecurity, increased hardship, or psychosocial stress, which significantly impact health and well-being [6]. Racial and ethnic minorities and economically disadvantaged individuals frequently present with a later stage of cancer diagnosis and tend to have poorer survival [7]. Within the global community, people living in low-resource countries can be broadly considered as vulnerable populations due to limited access to healthcare and higher mortality rates from conditions highly treatable in other settings.

Prioritization of and political commitment to cancer prevention and control may be lacking in low-resource settings, particularly in locations where indigenous infectious diseases pose a large risk to public health and safety. Low- and middle-income countries are estimated to contribute 80% of new cases of cervical cancer annually due in part to low vaccination rates for human papillomavirus and to challenges to screening in low-resource settings [8]. Incidence and mortality of cancers caused by infectious agents (e.g., cancer of the cervix or liver) remain high in less-developed countries while the incidence of cancers more commonly caused by environment risk factors rise [9]. Successful screening strategies require resources and infrastructure that are not easily implemented in low-resource settings. These barriers to diagnosis and care lead to an increased global burden of cancer among economically vulnerable populations, though innovative cancer screening strategies, like the one pairing community-based education with multimodal breast and cervical screening in rural Honduras [10], show promise and may prove useful for improving cancer screening practices in other low- and middle-income countries.

Environmental Justice in a Changing Chemical Landscape

Increasing levels of industrialization change the chemical backdrop of a country. When environmental protections and regulations do not keep pace, vulnerable populations are often at the greatest risk of adverse health consequences. Thus, vulnerable populations pose a special concern in the context of cancer and environmental justice. In tandem with an increased risk of cancer and cancer mortality among economically vulnerable populations, many environmental toxicants also disproportionately affect these groups (e.g., air pollution, lead, pesticides) [11–15]. Pesticides encompass a wide array of chemicals used to kill insects, vermin, weeds, or fungus [16]. Exposure to organochlorine pesticides [e.g., dichlorodiphenyltrichloroethane (DDT), hexachlorobenzene, hexachlorocyclohexane] tends to be greater among developing versus developed countries [17]. High- and middle-income countries produce pesticides for continued sale and marketing to low-income countries, though some of these chemicals have been banned for use within the producing country [18]. Protection of economically vulnerable populations across the world from pesticides will require cooperative efforts across governments and international borders to implement truly global bans of the most hazardous pesticides, improve protection of workers, and promote safer pest control [19].

Pesticide Safety in Low-Resource Settings

A lack of knowledge about the dangers of pesticides contributes to adverse health consequences of pesticide exposure, as does an inability to access proper supplies and disposal streams. A substantial knowledge base exists related to safe use of pesticides, including the use of proper personal protective equipment (PPE), techniques for safely mixing pesticides, procedures for storage and disposal, clean-up and hygiene practices to reduce exposure to workers and their families, and restricted entry intervals designed to prevent pesticide exposure to workers returning to the fields following application [20]. Many industrialized countries require training, licensing, and access to proper equipment for pesticide workers, but developing countries often lack these worker protections [19]. Communities surrounding agricultural operations are exposed to pesticides through spray drift, polluted water, and soil contamination related to inappropriate disposal of pesticides [19]. Researchers in Ghana have reported unsafe handling practices, such as using hands to mix pesticides, determining if the pesticide mix is correct by tasting it, or using inappropriate spraying tools [21–23]. In Ethiopia, pesticide safety education is uncommon among workers [24, 25], and many farmers report having never used PPE [26, 27]. Storage of pesticides within the domicile or reuse of containers for food or water storage, homes in close proximity to spraying activities, and lack of access to washing facilities also increase pesticide exposure for families of agricultural workers [19]. A survey of coffee and cotton farms in Tanzania revealed pesticide containers with missing labels or no mixing instructions and hazardous storage of pesticides in close proximity to food or fires [28]. Old or improper equipment, complex labels coupled with poor literacy, shortage of safe disposal options, inappropriate combination of products or use of products on the wrong crop type (e.g., cotton pesticides on produce), and lack of sufficient national regulations are common themes leading to increased pesticide exposure across low-resource countries [19]. These observations collectively underscore the critical need for pesticide safety education and regulation to protect economically vulnerable communities from both cancer and non-cancer health consequences of agricultural pesticides.

Pesticide Exposure and Cancer Risk Among Farmers, Families, and Children

Particularly among agricultural workers, the epidemiologic literature broadly supports associations between pesticide exposure and several types of cancer, including non-Hodgkin lymphoma, multiple myeloma, leukemia, brain, prostate, pancreas, breast, colon/rectum, kidney, and lung [29, 30]. Though workers tend to be at the greatest risk given their higher cumulative exposures to pesticides, research also suggests that living in an area of high pesticide use increases risk of several cancer types even for individuals not directly involved in agricultural activities [31]. Certain groups, including the developing fetus, infants, children, and older adults, are especially vulnerable to the effects of toxicants in the environment [32]. It is estimated that women in developing countries produce 60–80% of food and comprise more than 40% of the global agricultural workforce [19, 33]; thus pesticide exposure during the reproductive years is likely. A study based in Spain observed suggestive trends of increasing concentrations of placental organochlorine pesticides, such as DDT, with lower occupational social class [14], illustrating that even during pregnancy, economically vulnerable women may have increased risk of pesticide exposure. Hematopoietic and central nervous system cancers in childhood have been linked to early-life pesticide exposure [34]. A study based in Brazil suggested that the children of women exposed to pesticides during pregnancy were twice as likely to develop acute lymphoid leukemia and five times as likely to develop acute myeloid leukemia before reaching 1 year of age compared to children of unexposed mothers. Even stronger associations were observed among children of mothers exposed specifically to organophosphate pesticides or with mothers engaged in agricultural work during pregnancy [35]. A meta-analysis of 16 case-control studies further suggests that exposure to indoor insecticides corresponds to a 47% increased risk of leukemia and a 43% increased risk of lymphoma during childhood [36]. Preliminary research has indicated that in addition to prenatal pesticide exposure, preconception exposure to pesticides by either parent may lead to increases in childhood brain tumors [37], underscoring the need to protect agricultural workers and economically vulnerable populations from pesticide exposure.

Focus on Ecuador: Working Through Sociopolitical Barriers to Treat Cancer Amidst a Battle Over Oil and Biodiversity in Ecuador's Amazon

Since the discovery of oil in Yasuni National Park, Ecuador, in 1964, there has been relatively little attention paid to the effects of oil pollution on the plants, ecosystem, and indigenous communities of the Amazon. The oil contamination brought on by deliberately cheap and out-of-date technology used for extraction has been taking place for four decades, and it has wreaked havoc on the ecosystem. There has been a loss of biodiversity in the flora and fauna, as well as a poisoning of the communities that reside in the area. The lack of responsibility taken by both the government and the oil company Chevron (formerly Texaco) has led to many lawsuits, protests, and other forms of organized opposition [38]. Affected communities may benefit from an accessible and sustainable solution to health problems, such as cancer, that have resulted from this unopposed pollution. In this section, we will examine the effects of corrupt oil-government policies on indigenous communities, present the need for collaborative action regarding medical treatment, and explore areas of future research.

As background for the state of contamination in the Ecuadorean Amazon basin, there are a few independent studies that have supplied helpful data. According to an article written by Claudia Garcia [38], the "residents of the Ecuadorean Amazon sued Texaco -acquired by Chevron in 2001- accusing the company of dumping around 80,000 tons of oil and toxic residues on their land between 1964 and 1990 during operations in the Lago Agrio region of northeastern Ecuador. The dumping led to significantly increased rates of cancer, miscarriages and other health problems among the population close to the area" [38]. According to lawyer and activist Pablo Fajardo, even petro-carbon chemical tests completed and unlawfully manipulated by Chevron could not hide the excessively high levels of contamination in the soil and water. Despite these findings, there was little to no action to eradicate this contamination from the area. The potential for economic gain overshadowed the health of current and future populations in the area. This preference of money over human health is completely unsustainable and continues to be supported by industries such as oil.

The process of oil extraction involves many toxic by-products that result in negative effects on human health and the environment. The by-products and residues are put forth into the surrounding air, soil, and water and affect every living thing that makes contact with them. Crude itself also contains many toxic chemicals as crude oil is a complex mixture of many compounds, mostly hydrocarbons. The petroleum hydrocarbons of most toxicological interest are volatile organic compounds (benzene, xylene, and toluene). Benzene is a well-known cause of leukemia and perhaps other hematological neoplasms and disorders [39]. When crude stays in the ground as a true fossil fuel, these harsh compounds are subdued under the earth's crust. When extracted however, they are highly damaging to the environment and living things exposed to it. Yet, we keep drilling for this "liquid gold." This exemplifies the blatant disregard of many operations for medical research that proves negative effects, all for the pursuit of profit.

In a study titled *Exposures and cancer incidence near oil fields in the Amazon basin of Ecuador* by Sebastián et al. [39], the town of San Carlos in northeastern Ecuador is used as a case study for the effects of exposure to these chemicals. In San Carlos, there is almost constant exposure to crude or oil by-products. The oil companies have dumped leftover oil onto the roads, claiming it helps with rising dust (in an area with an average yearly rainfall of 40 in.). Oily roads combined with the 30 oil wells that surround the town and water supplies lead to inevitable daily exposure to crude chemicals. In addition to this, the oil wells surrounding the town have not practiced safe disposal of excess chemicals and instead dumped them into tributary rivers leading to the Napo River. The Huamayalu, Basura, Iniap, and Parker rivers also all run through the village of San Carlos. The town uses the water from the rivers for cooking, washing, bathing, etc. According to the map used in the case study, there are 25 oil wells, 11 within the town boarders, and an oil pumping station directly outside the town's perimeter. The residents of the town not only suffer constant exposure to toxic chemicals; they also spread that exposure to downstream communities through each of the rivers that run through it [38].

The people of San Carlos have endured this exposure for more than 20 years and have suffered many consequences from it [38]. Samples from the water used by the town showed grossly elevated levels of total petroleum hydrocarbons (TPHs) to range from 0.097 to 2.883 parts per million (ppm). For reference, the permitted limit for TPHs in drinking water according to European laws is 0.01 ppm. An article published through Amazon Watch titled *Chevron's Chernobyl in the Amazon* states that "unlike BP's Gulf spill (which received immediate legal action and clean-up efforts) that was a result of a single cataclysmic event, Texaco's oil extraction system in Ecuador was designed, built and operated on the cheap using substandard equipment from the outset [38]. This led to systematic pollution from multiple sources on a daily basis for almost three decades" [39], and yet, Chevron has still succeeded in avoiding responsibility for the damage.

Statistics collected by the San Carlos study showed increased incidences of cancers including stomach, liver, melanoma, leukemia, and more [38]. However, it seems that no one would commit to attributing these elevated rates of cancer to oil contamination. Despite the excess of cancer found in San Carlos and the high exposure to oil pollutants, the attribution of causality to this association has not been forthcoming [39]. Due to the profitability of the oil reserves, these cancer rates among many other ill-health effects seem to have been dismissed. This points to a serious need for action for the health of the people and the environment.

In looking at the *Summary of Independent Health Evaluations of Area of Ecuador's Rainforest Where Chevron Operated from 1964 to 1990* [39], there were three different studies that offered data for significantly increased cancer rates and risks in areas affected by oil pollution. As previously referenced, the piece titled *Chevron's Chernobyl in the Amazon* states that "the court-appointed independent expert in the ongoing trial estimated that Chevron is responsible for at least 1400 excess cancer deaths" [40]. However, these results were denied by Chevron, and the method of diagnosis and data collection was said to have little validity. Chevron also attempted to hide its alarmingly high petrochemical levels of by stating that they were below the US limit. As it turns out, they were just below the US limit for industrial waste water, not drinking water.

According to a study done by Harlee Strauss [41], "no cancer registry was available for the Amazon region and the closest place for diagnosis and treatment was Quito, a 12 h bus ride away" [41]. This made it difficult to place blame on a particular party. Due to the refusal of Chevron to take responsibility and the inaccessible treatment options, it seems that the next step is to offer accessible treatment to the people affected by the contamination. Screening programs to detect health-related problems earlier with appropriate referrals, similar to opportunistic screening clinics organized in other low-resource settings, have the potential to greatly improve health in the area [10] .

Focus on Africa: The Challenge of Defining the Problem in Rwanda: Is Indoor Air Pollution a Health Hazard?

Rwanda is a landlocked republic in Equatorial Africa. The capital Kigali is a typical African city with rapidly increasing development, urbanization, and motorization yet still high rates of open fireplaces and cooking indoors with wood, leaves, dung, and kerosene even in the capital city. Burning wood and other substances for domestic energy is a large source of indoor and outdoor pollution in Rwanda [42]. Suspended particulate matter has been measured and ranges daily from 175 ug/m^3 to as high as 2400 ug/m^3 [43]. For reference, the World Health Organization (WHO) recommended the value for short-term particulate matter exposure is 50 ug/m^3 or less [44]. The meteorological conditions in Kigali further contribute to this health risk by creating increased stability of the urban atmosphere due to the presence of urban heat islands. This results in a lower transportation and dispersion of the polluted air, hence causing accumulation of the airborne pollutants within the small valleys and the residential areas, respectively [43].

To understand how this increase in urbanization and air pollution may be affecting health in general and cancer incidence in particular, we generally turn to cancer registries; however there is no national tumor registry in Rwanda. A literature review of the burden of COPD in Africa revealed that of 22 articles relating to COPD in Africa, only 6 had spirometric data [45]. Only a small number of respondents answered the investigator's surveys despite evidence that they had been received further complicating the difficulty of data collection in a vast continent with communication challenges and limited resources. Indeed, the Global Burden of Cancer [46] used cancer registries, verbal autopsy studies, and other sources to report their findings. Tracheal, bronchus, and lung cancer was the leading cause of death in men and women. At the global level, incidence for women has risen slowly, whereas rates have fallen for men since the mid-1990s suggesting a domestic source of pollution rather than tobacco as the culprit. Lung cancer was the most common cause of death in absolute cases globally as well as in developing and developed regions, yet in Rwanda lung cancer incidence is reportedly <1% [46]. This low rate is highly suspect given that bronchoscopy and pathology services are very limited, there is 1 CT scanner for a country of 12 million, cardiothoracic surgery is unavailable in Rwanda, and chemotherapy is only offered to curable cancers [47]. Lung cancer is not curable without surgery; therefore most cases go undiagnosed, and true incidence is essentially unknown.

Indoor Smoke/Secondhand Smoke Exposure

If cancer rates from indoor air pollution cannot be determined, the next step would be to try to define the incidence of pulmonary diseases. Disease attributable to the environment can be expressed in deaths and in disability-adjusted life years

(DALYs). The latter measure combines the burden due to death and disability in a single index. Using such an index permits the comparison of the burden due to various environmental risk factors with other risk factors or diseases. The realization of how much disease and ill health can be attributed to modifiable environmental risks can contribute to identifying opportunities for prevention and should add impetus to global efforts to encourage sound preventive measures through available policies, strategies, interventions, technologies, and knowledge.

The national burden of disease due to indoor air pollution from solid fuel use was first assessed by the WHO in 2002 [48]. In addition to total deaths and disability-adjusted life years (DALYs) due to indoor air pollution, country-by-country estimates are also available for deaths due to acute lower respiratory infections (ALRI) among children as well as chronic obstructive pulmonary disease (COPD) and lung cancer among adults. Rwanda is among the 20 worst-affected countries [49]. More than 95% of households are exposed to indoor air pollution with 46 DALYs/1000 cap/yr. Total environmental burden of disease per year is 183 DALYs/1000 cap (world range lowest 13, highest 183) with 31% of deaths attributed to environmental risk factors and therefore preventable through healthier environments. Lung cancer rates in 2004 were reportedly low, but tumor registries still are very limited, and in 2004 there were little to no diagnostic capabilities.

Tracheal, bronchus, and lung cancers for men in regions with low smoking prevalence like sub-Saharan Africa are 5–10 times lower than in countries with historically high smoking prevalence like high-income North America, Europe, and East Asia [46]. Despite low smoking rates in Rwanda, lung disease is still highly prevalent, and lung cancer, as outlined above, is likely underdiagnosed. Genetic susceptibility may play a role, but preventable risk factors like household air pollution have also been identified as significant risk factors for lung cancer. According to the latest WHO data published in 2017, lung disease deaths in Rwanda reached 1157 or 1.87% of total deaths. The age-adjusted death rate is 25.79 per 100,000 of populations ranking Rwanda #68 in the world [50].

Awareness is rising, and Rwanda recently joined the International Climate and Clean Air Coalition announcing next steps to reduce pollutants [51]. Although Rwanda does not have many industries, old vehicles, diesel-powered generations, and biomass burning are major sources of pollution in the urban centers. To help reduce pollutants, the government recently increased taxes on old vehicles and introduced mandatory emission testing while urging Rwandans to use cooking gas in the home instead of biomass burning [51].

Conclusion

As the global burden of cancer rises and the cost of treatment approaches unaffordable for many regions of the world, the attention must start turning to prevention.

Vulnerable populations around the world are more susceptible to the harmful effects of pollution, and policies to improve the cleanliness of our air, water, and soil would be a well-spent investment.

The BreatheLife campaign (www.breathelife2030.org), a joint campaign led by the World Health Organization (WHO) and United Nations Environment and the Climate and Clean Air Coalition (CCAC), was launched in October 2016 to mobilize cities and individuals to protect our health and planet from the effects of air pollution and to bring together key messages in a flagship effort to put air quality on the top of health and development agendas. The campaign is not the *only* mode of communicating about air pollution – however it is a means of sharpening messages around technical data and finding new "entry points" for the conversation about air pollution in the virtual world of Internet and social media as well as in the mainstream press [52].

The key components of the campaign model include:

1. *Global campaign platform* – including an interactive website, social media outreach, and videos.
2. *Local campaign "accelerators"* – more intensive campaigns in particular cities, which generate grassroots actions at athletic events and Ted-talk style lectures that can both be promoted by, and inspire, the global effort. This has a multiplier effect insofar as there is evidence that local and national policymakers are often inspired by successful examples of similar actions in their country or region.
3. *Health and environment sector leadership* – it is critical to sensitizing policymakers and the public to both the health *and* climate impacts of air pollution and giving the campaign its unique focus on a people-centered agenda. Using this linkage, environmental policymakers also learn more about the negative health impacts of air pollution, and health policymakers learn more about the sustainability benefits of mitigation [52].

Currently about 14 countries and 26 city-based regions, 2 of which are in Africa, have joined the network, with outreach continuing every day.

Initial response to the campaign was overwhelming, and so one of the key challenges was to respond to success with further institutionalization of campaign tools and tactics. These included:

- Foundational work on the BreatheLife cities network – so as to provide a unique and valuable service to the cities that join
- Continued improvements in the website experience, reflecting new technical advances in data collection, assessment, and visualization, as developed by the WHO and its partners the Global Platform
- Maintaining a constant social media presence, tied strategically to key events
- Developing effective local partners and strategies for local campaigns in cities where the WHO and its partners are engaged in the Urban Health Initiative
- Future fundraising and engagement in new partnerships, including effective engagement with civil society [52]

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