PHYSICIANS FOR SOCIAL RESPONSIBILITY

Cancer and the Environment

WHAT HEALTH CARE PROVIDERS SHOULD KNOW

Consider for a moment the following disturbing facts about cancer in the U.S. (*1*):

- Cancer is the second leading cause of death, exceeded only by heart disease. Among children ages 1 to 14, cancer is the leading cause of death by disease.
- At current rates, invasive cancer will be diagnosed in half of all men and in one in three women in their lifetime.
- Almost 1.3 million new cases of invasive cancer will be diagnosed in 2002. Each day, more than 1,500 Americans will die of the disease.

These statistics are particularly troubling when one considers that the majority of cancer deaths are preventable. It is now believed that at least 60% of cancer deaths could be prevented through modification of personal behaviors, such as smoking cessation, dietary changes, and reducing sun exposure (*1*). Another significant cause of cancer is exposure to carcinogens in the environment—exposures that could be prevented by society, but over which the individual often has little or no control.

DO YOU HAVE THE ANSWERS?

Very often, news reports describe significant advances in the "War on Cancer." Increasingly, new cancer risk factors are identified, including exposure to chemicals in the environment. All this new information can leave the public confused and concerned and is likely to generate questions from your patients. "What are my chances of getting cancer?" "Are environmental pollutants making me sick?" "How can I protect my child from exposure to harmful chemicals?" Your colleagues and communities may also be seeking answers to these same questions. Do you have the information you need to help answer such questions? Do you have practical solutions to help protect your patients and community from the hazards of environmental carcinogens?

This primer is intended to provide you, the health professional, with the latest information on what is known about links between environmental chemical exposures and cancer, what we still need to learn, and what actions you can take to reduce the public health threat posed by carcinogens in the environment.

This document addresses the following key topics about cancer and the environment:

What We Know About Cancer and the Environment

Cancer has been linked to exposures to certain chemicals, biological agents (such as certain viruses), and physical agents (such as radiation). This primer focuses primarily on chemical carcinogens, including chemicals intentionally used in the home, workplace, agriculture, and other settings, and chemical residuals that pollute the ambient environment. In the U.S., more than 80,000 chemicals are produced or imported for use. Each year billions of pounds of synthetic chemicals and heavy metals are released into the environment as a result of industrial production, processing, use, or disposal. Potential carcinogens, including pesticides, solvents, and other products, are used in and around the home. Some carcinogens, such as arsenic and radon, occur naturally in the environment. In short, toxic chemicals are ubiquitous in the environment, and virtually everyone is involuntarily exposed daily to low levels of contamination in our air, drinking water, and food.

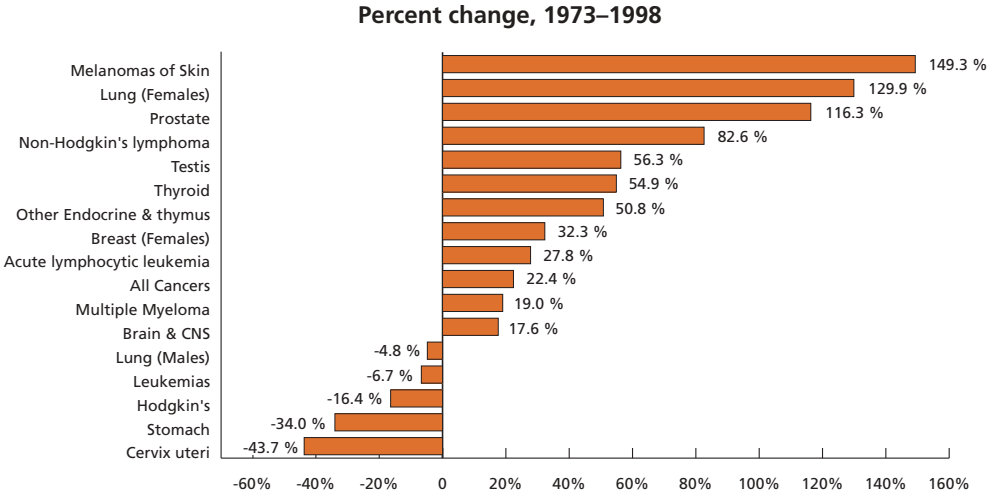
It has long been known that exposure to high levels of certain chemicals, such as those in some occupational settings, can cause cancer. There is now growing scientific evidence that exposure to lower levels of chemicals in the general environment is contributing to society's cancer burden. While there is much to learn about chemical carcinogenesis, the threat of harm to human health from toxic chemicals is clear. Preventive action to substantially reduce or eliminate these toxic exposures will reduce the burden of cancer and other human diseases.

CARCINOGENIC CHEMICALS ARE IN THE ENVIRONMENT AND THE HUMAN BODY

It is evident from human biological monitoring (*biomonitoring*) studies that many environmental contaminants, including potential carcinogens, are finding their way into people's bodies. *(Refer to inset on Biomonitoring for more information.)* Yet, the full extent of exposure to carcinogens in the environment has not been determined. The following sections briefly describe the most common types and sources of carcinogens found in homes, the ambient environment, and the human body.

Cancer Trends in the United States, 1973–1998

(Selected cancer sites, age-adjusted rates, all races)



Source: Based on data cited in "SEER Cancer Statistics Review 1973–1998," National Cancer Institute, 2001

Pesticides

In a typical year, more than 4 billion pounds of chemicals are used as pesticides in the U.S. (*3*). This includes almost 1 billion pounds of conventional pesticides (used in agriculture, industry, and in the home and garden), more than 2 billion pounds of chlorine and other disinfectants, and more than a half billion pounds of wood preservatives. Some of these chemicals have been shown to cause cancer in animals, and a growing body of scientific evidence links certain pesticides with increased risk for cancers in humans. Of the roughly 900 pesticide active ingredients registered in the U.S., (*3*) more than 160 have been classified as known or suspected carcinogens by the U.S. Environmental Protection Agency (EPA) and other organizations (*4*). While EPA has acted to ban or restrict the use of many known or suspected carcinogenic pesticides, many others remain in use. For example, certain chemicals widely used as wood preservatives, including arsenic, chromium, and creosote, are known or probable human carcinogens. Other suspected carcinogens are used in agriculture, and their residues can be found in the food supply. *(Refer to inset on Carcinogens in Food for more information.)*

Past use of highly persistent pesticides also poses a continuing health concern; for example, the organochlorine pesticide DDT has been banned from use in the U.S. but is still found in the environment worldwide. Because they degrade slowly, persistent pesticides accumulate in the food chain and are still common in the American food supply (*5*). Biomonitoring studies have detected a wide variety of persistent and non-persistent pesticides, including some known or suspected carcinogens, in human tissues and body fluids (*2,6*). These findings raise serious public health concerns because they indicate ongoing human exposure to carcinogens and potential carcinogens.

Industrial Chemicals, Wastes, and Waste Byproducts

Industrial facilities and uncontrolled waste disposal sites are major sources of carcinogenic chemicals in the environment. According to EPA's Toxics Release Inventory (TRI) program, which requires polluting industries to report their environmental

WHAT ARE WE LEARNING FROM BIOMONITORING?

Biological monitoring, or biomonitoring, is the laboratory analysis of blood, urine, serum, saliva, and other body fluids to identify the burden of certain chemicals present in the human body. Biomonitoring allows scientists to recognize the populations that are exposed to and are potentially affected by chemicals in the environment. One of the largest biomonitoring studies in the U.S. is now being conducted by the Centers for Disease Control and Prevention (CDC). The CDC is analyzing information about the health and diet of representative segments of the U.S. population, which is gathered annually as part of the National Health and Nutrition Examination Survey (NHANES). Each year, as part of this study, about 5,000 randomly selected people around the country volunteer to undergo interviews, physical examinations, and sampling of body fluids for extensive laboratory analyses.

The CDC biomonitoring study is producing evidence that the general population is being exposed to low levels of environmental contaminants, including potential carcinogens. Results of the first round of testing, which included 27 different environmental chemicals and metabolites, revealed detectable levels of several potential carcinogens in the blood and urine of the study population, including the heavy metals cadmium and lead and metabolites of the chemical di-2-ethylhexyl phthalate (2). CDC plans to update the report annually and aims to expand the number of chemicals examined by NHANES to about 100 over the next few years.

CARCINOGENS IN FOOD

According to recent estimates, up to 40% of human cancers may be related to diet (*7*). It is believed that a diet high in fat and low in fiber increases cancer risk. Less studied are dietary exposures to potential carcinogens present in the U.S. food supply. These include persistent chemicals such as DDT, dioxins and polychlorinated biphenyls (PCBs), and trace metals such as arsenic. A recent food survey detected the DDT metabolite, DDE, in about 20% of solid foods sampled (*9*). Fish consumption accounts for much of our dietary exposure to pesticides and dioxins (*5,8*).

While these findings should not discourage eating a variety of healthy foods, including fish, the presence of known and suspected carcinogens in our food supply nevertheless raises significant concerns. These concerns led Congress to pass the Food Quality Protection Act (FQPA) in 1996. Under this law, no pesticide residue would be allowed in any food unless industry could demonstrate that it represents a "reasonable certainty of no harm" to any consumer, including infants and young children.

The FQPA requires EPA to review existing pesticide food "tolerances" (the maximum levels of pesticide residues allowed on food), with priority given to those chemicals that pose the greatest public health risk. However, EPA has failed to meet many of the obligations of the FQPA, resulting in a legal challenge by environmental and health groups. A settlement reached in 2001 requires EPA to meet specific timelines for implementing the FQPA, including many requirements related to the most highly toxic and widely used pesticides. It is important that health professionals familiarize themselves with FQPA mandates, and continue to press EPA and Congress for more rapid progress in implementation. *(Details on the status of EPA's FQPA implementation and the settlement requirements can be found at www.epa.gov/oppfead1/fqpa/fqpastatus.htm.)*

releases, U.S. facilities released almost 8 billion pounds of chemicals into air, land, water, and underground injection wells in 1999 alone (*15*). This is likely an underestimate of actual releases, since EPA does not require reporting by all industrial sectors and sizes, nor does it require tracking of all chemicals. Of the 650 chemicals that are currently tracked by EPA, roughly one fourth are known or suspected carcinogens. Facilities such as mining and smelting operations, chemical manufacturing and processing plants, petrochemical plants, and medical and municipal waste incinerators release these toxic chemicals into air, water, and soil in the immediate environment, and dispose of large quantities of waste products. Large quantities of chemical wastes have been and continue to be disposed in uncontrolled waste dumps, often resulting in severe localized contamination of soil, groundwater, and surface water. *(Refer to inset on Carcinogens in Drinking Water for more information.)*

People living and working in the vicinity of industrial facilities and waste sites can be exposed to mixtures of many different toxic and carcinogenic pollutants, such as metals, solvents and other volatile organic chemicals, pesticides, PCBs, and combustion byproducts (e.g., dioxins and polycyclic aromatic hydrocarbons [PAHs]) (16,17). Dioxin (specifically 2,3,7,8-TCDD) is a byproduct of waste incineration and is one of the most potent carcinogens known. The Agency for Toxic Substances and Disease Registry (ATSDR) maintains a list of the 100 most threatening substances found at Superfund sites, based on toxicity and potential for human exposure. Of the top 50 chemicals on this list in 1997, three fourths had evidence of carcinogenicity in humans and/or animals (18).

Endocrine-Disrupting Chemicals

It has been hypothesized that endocrine-disrupting chemicals may contribute to the incidence of some hormone-related cancers (*22*). Endocrine disruptors are exogenous chemicals that interfere with the synthesis, secretion, transport, binding, action, or elimination of natural hormones in the body (*23*). Chemicals with endocrine-disrupting properties are used daily in industry, agriculture, and in the home, and are found as contaminants in our food and drinking water. They include organochlorine pesticides, dioxins, phthalates, and bisphenol-A (found in some plastics and cosmetics).

Animal studies have shown that endocrine-disrupting chemicals can cause effects even at low levels of exposure (*24*) and suggest that exposure prenatally or early in postnatal life can interfere with normal development of the endocrine system and may increase risk for cancer later in life (*22,25*). Many endocrine-disrupting chemicals have been shown to be carcinogenic, although the cancer-causing mechanism may or may not be related to endocrine disruption. Work remains to identify endocrine-disrupting chemicals and determine relationships between exposure and human disease. Relatively few synthetic chemicals have been evaluated for their potential effects on the endocrine system. As a result of Congressional mandates under the FQPA and Safe Drinking Water Act Amendments of 1996, EPA has initiated a screening program to identify pesticides, industrial chemicals, and other environmental pollutants with endocrine-disrupting activity. *(Refer to PSR's primer, Environmental Endocrine Disruptors, for more information.)*

CARCINOGENS IN DRINKING WATER

Drinking water can be a source of exposure to a number of potential carcinogens, including metals, agricultural and industrial chemicals, radioactive substances, and byproducts of chemical disinfection. Drinking water sources are vulnerable to contamination by agricultural runoff, chemicals used at home, industrial wastes, and many other sources. Naturally occurring carcinogens, such as arsenic and radon, contaminate groundwater in many parts of the country. Evidence is emerging that the use of disinfectants such as chlorine in public drinking water supplies contributes to the formation of potentially carcinogenic byproducts in tap water. Epidemiologic and toxicologic studies have suggested a link between long-term consumption of chlorinated water and an increased risk of certain cancers, including bladder cancer (*10*). Limited evidence also suggests potential increases in cancer risk associated with consumption of drinking water contaminated with nitrates (*10–12*) and triazine herbicides (*13,14*).

Levels of certain carcinogens and other contaminants in drinking water supplies are regulated under the Safe Drinking Water Act (enacted in 1974, amended in 1996). Currently, some two dozen chemicals are regulated because of their potential to cause cancer and other chronic diseases. Yet much more needs to be done to protect the public from exposure to contaminants in drinking water. A number of existing drinking water standards, such as those for arsenic and disinfection byproducts, may not fully protect public health. Many other potential carcinogens are not regulated at all. It is also important to recognize that the federal government does not regulate the quality of drinking water in domestic wells. Domestic wells are particularly vulnerable to contaminants that leach into groundwater, such as agricultural pesticides and chemicals in waste landfills. There is a critical need for health care providers to be actively involved in efforts to strengthen our nation's drinking water protections. *(For more information, refer to PSR's publications on drinking water and health, available at www.psr.org/toxics.html.)*

ENVIRONMENTAL CANCER RISK IS INFLUENCED BY MANY FACTORS

Tremendous strides have been made in understanding cancer and the many factors that increase cancer risk. It is now known that most cancers (as well as a variety of other chronic diseases) are caused by external—or environmental—factors, with only minor contributions from inherited genetic mutations (*26*,*27*). Environmental factors, broadly defined, include tobacco and alcohol use, nutrition, physical activity, sun exposure, viral infections, and chemical exposures. In addition, an individual's cancer risk is also influenced by innate factors such as age, immune function, hormonal status, and genetic predisposition. The following discussion addresses factors that are of particular significance to environmental chemical exposures and related cancer risks.

AIR POLLUTANTS AND CANCER: WHAT YOU CAN'T SEE CAN HURT YOU

Each year, lung cancer claims more than 150,000 American lives, due primarily to cigarette smoking (*1*). Exposure to secondhand tobacco smoke, classified by EPA as a known human carcinogen, is estimated to result in approximately 3,000 lung cancer deaths each year in nonsmoking adults (*19*). Hundreds of thousands of infants and children are also at risk of adverse effects from exposure to secondhand smoke, including lower respiratory tract infections, middle ear infections, and asthma. Although some local governments have enacted restrictions on smoking to protect the public from secondhand smoke, there is no such protection at the federal level.

Another significant cause of lung cancer deaths in the U.S. is exposure to radon gas and its decay products in indoor air. The National Research Council has estimated that some 15,000 to 22,000 lung cancer deaths each year are caused by breathing radon gas (*20*).

While cigarette smoke and radon exposure explain most lung cancer deaths, there is mounting evidence that exposure to other air pollutants also increases risk. Epidemiologic studies have found higher lung cancer risk among urban residents and persons living near industrial point sources compared to persons living in rural areas (*21*). According to EPA's TRI data, more than 2 billion pounds of toxic chemicals, including many known and suspected carcinogens, are released into our air each year from incinerators, power plants, mining operations, and other industrial facilities (*15*). Motor vehicle emissions are not included in this total, but can add significantly to air pollution in urban areas. Volatile organic compounds, nitrogen-containing and halogenated organics, PAHs, toxic metals, and many byproducts of incomplete combustion (e.g. dioxin) are all potential carcinogens that pollute our air. Carcinogenic substances can also attach to the surface of fine dust and soot particles in the air and penetrate deep into the lungs. (*For information on toxic pollutant releases in your community, go to www.scorecard.org*.)

The federal Clean Air Act (CAA), first enacted in 1970, has served as one of the most comprehensive efforts to protect human health from airborne pollution. One section of the CAA, called New Source Review, requires newly built facilities to install the best pollution control equipment to minimize negative effects of emissions on air quality. In addition, New Source Review requires "grandfathered" facilities to install modern pollution controls whenever they make significant modifications. With many power plants and industrial facilities that pre-date the CAA still in operation, New Source Review is the primary mechanism for requiring these older plants to clean up their operations. The CAA also empowers EPA to limit emissions of hazardous air pollutants from various sources. Such programs are essential to protecting human health from carcinogens in the air.

Contaminant Exposure

A person's risk of developing cancer from exposure to carcinogens is dependent on the cancer potency, persistence, and concentration of contaminants to which she or he is exposed, and the route, duration, and frequency of exposure. Although significant progress has been made in our understanding of these factors, important gaps remain.

There is a general lack of information on how much and what type of chemical exposure leads to cancer. Despite the widespread use of chemicals in the U.S., only a small fraction has been evaluated for potential carcinogenicity. The National Toxicology Program of the National Institutes of Health has identified 218 substances (chemical, biological, and physical agents) that are "known" or "reasonably anticipated" to cause cancer, and to which significant numbers of Americans are exposed in the home, workplace, general environment, or from use of certain drugs (*28*). Carcinogenicity is most commonly evaluated on the basis of high-dose exposures in adult laboratory animals, rather than low doses that typify most human environmental exposures. Furthermore, most carcinogenicity testing examines the effects of individual chemicals. Little is known about health effects and possible synergistic effects of chemical mixtures often found in the environment.

As a result of these gaps, the general population continues to be exposed involuntarily to large numbers of chemicals for which there is little or no information on human health effects. Much more extensive chemical testing and epidemiologic research is needed to determine potential health hazards from human exposure to environmental contaminants.

Genetic Susceptibility

Primary genetic factors (i.e., inherited germline mutations), are thought to account for only a small proportion (less than 10%) of all cancers (29–31). There is increasing evidence that gene-environment interactions are more important determinants of individual cancer risk. Some cancers may result from interactions between carcinogens and susceptibility genes, resulting in accrual of mutations throughout a lifetime. Susceptibility genes influence a person's susceptibility to external insults, such as environmental carcinogens. Certain DNA sequence variations, or polymorphisms, within these genes are thought to affect cell growth and regulation, chemical detoxification and metabolism, and DNA repair mechanisms, and thus an individual's susceptibility or resistance to cancer (27,32). Variants of multiple genes may each contribute a small portion toward a person's total risk. These gene variants only become risk factors for cancer when damaged by carcinogens. Research on gene-environment interactions promises to provide critical new information about what combinations of factors predispose people to diseases such as cancer.

POPULATIONS POTENTIALLY AT INCREASED RISK FOR ENVIRONMENTAL CANCER

Certain populations are disproportionately impacted by toxic chemicals. For example, infants and children, racial and ethnic minorities, and farm workers and farm families have potentially higher exposures to carcinogens in the environment. In some cases, these groups are also at increased cancer risk due to unique susceptibilities, as discussed in the following sections. Intervention to reduce or eliminate carcinogen exposures by these populations is likely to result in significant reductions in morbidity and mortality from certain cancers and other adverse health outcomes.

Childhood Cancers

Cancer is the leading cause of death by disease among children. Leukemia, lymphomas, and tumors of the brain and nervous system are among the most commonly occurring cancers in children under 14 years (*1*). Surveillance data gathered by the National Cancer Institute (NCI) since 1975 suggest that the incidences of some childhood cancers, including

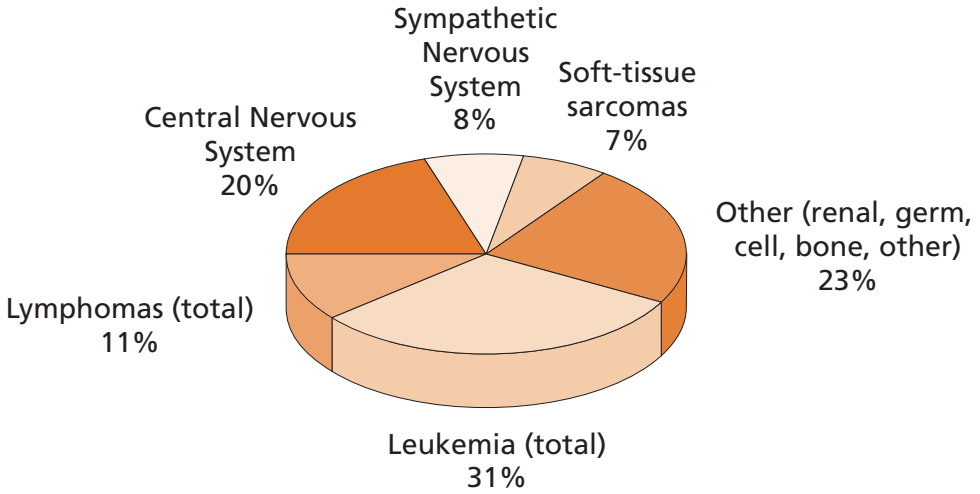
leukemias, brain and nervous system tumors, and soft-tissue sarcomas, are increasing (*33*). Some NCI scientists have argued that there have been no substantial changes in pediatric cancer rates during this period and that observed increases in brain cancer in the 1980s were due to introduction of better diagnostic techniques and changes in methods for tumor classification (*34,35*). However, there is a growing body of evidence that points to a role for environmental carcinogens, such as pesticides, industrial chemicals, and secondhand smoke, in some childhood cancers. Controversy aside, the fact remains that only a small proportion of childhood cancer is explained by known risk factors.

Epidemiologic studies have reported evidence linking childhood cancer risk and exposure of the parent or the child to a number of different environmental chemicals, including pesticides, industrial chemicals, and drinking water contaminants. Although the available studies have limitations, and there are inconsistencies in the findings, there is plausible evidence that exposures (pre- and postnatal) to pesticides may be associated with increased risk for several childhood cancers. These include leukemia, non-Hodgkin's lymphoma (NHL), neuroblastoma, and brain tumors (*36–40*). Most of the studies were nonspecific with regard to pesticide active ingredient, but they provide evidence of a potentially serious health threat to children. Exposure to certain drinking water contaminants (e.g., certain chlorination byproducts, zinc, cadmium, and arsenic) has also been linked with increased risk of childhood leukemia, although drinking water exposures and childhood cancer have not been extensively studied (*41*).

There is also evidence that parental exposure to toxic chemicals can contribute to increased cancer risk in offspring. A variety of mechanisms could be involved, including damage to germ cells from preconception exposures, transplacental exposure during pregnancy, exposure through breastfeeding, or transfer of chemicals from the workplace into the home. Recent studies have found increased risk of nervous system tumors in children of fathers occupationally exposed to pesticides (*42*); leukemia related to wood work by fathers (*42*); and leukemia associated with paternal exposure to solvents and

Percent Distribution of Childhood Cancers

Children under 15 years of age



Source: Based on data cited in "Cancer Incidence and Survival Among Children and Adolescents: United States SEER Program, 1975–1995," National Cancer Institute, 1999.

paints (*43*). Neuroblastoma has been linked to both paternal and maternal exposure to various industrial chemicals and wastes (*44,45*).

Children are particularly vulnerable to carcinogens for several reasons. They are often more highly exposed than adults, their systems are less able to detoxify many chemicals, and their rapidly developing bodies are highly vulnerable to effects of carcinogens and other toxic chemicals (*46*). With respect to exposure, infants and children have unique behavioral patterns and dietary needs that increase their contact with environmental chemicals. They crawl and play on ground surfaces where contaminants are often deposited. Children can come in contact with chemicals sprayed in the home or on lawns or by playing with pets treated for fleas and ticks. Infants and children also engage in frequent hand-to-mouth activity, and they eat more food, drink more water, and breathe more air (and associated contaminants) than adults, relative to body weight (*29,47*). Breastfeeding infants can also be exposed to chemicals in mother's milk, such as organochlorine pesticides, PCBs, and dioxins (*48*).

Physiological immaturity and rapid development in early childhood also increase vulnerability to the effects of carcinogens. Higher rates of cell proliferation during early development increase the potential for environmental carcinogens to disrupt development at critical periods (*49*). Many cancers diagnosed in childhood and early adulthood are thought to result from genetic mutations that either are inherited or occur *in utero*. In concept, these mutations lead to early childhood cancer because of rapid cellular proliferation early in life and other factors (*50,51*). Early exposures may also increase risk of cancer later in life by initiating damage during an extremely sensitive time in development and by allowing a longer latency period. Adolescents and young adults may also be more sensitive to effects of toxicants because epithelial cells of certain tissues are still rapidly proliferating (*29*).

Traditionally, the process used to evaluate cancer risks has been based largely on methods and assumptions relevant to adult models. However, because children are more susceptible than adults, it is essential that the cancer risk assessment process have as its basis the protection of children, as a highly sensitive subpopulation. EPA is currently revising its "Guidelines for Carcinogen Risk Assessment," in part to enhance protection for children's health. The public health community continues to urge that EPA's final revised guidelines fully address children's unique susceptibility to carcinogens.

Cancer in Populations Living Near Industrial Facilities and Uncontrolled Waste Sites

It has been estimated that approximately 41 million people, or roughly one in six Americans, live within a four-mile radius of the worst hazardous waste sites in the nation (i.e., Superfund sites on EPA's National Priorities List) (*16*). The same source estimated that 1.3 million young children live within one mile of the borders of these sites. As previously described, people living in such areas can be exposed to many different toxic and carcinogenic pollutants.

Epidemiologic studies suggest that residents living in industrial areas and near uncontrolled hazardous waste sites may be at increased risk for certain cancers. A review of health studies of persons living near such sites reported evidence of increased risk for bladder cancer and gastrointestinal cancers (*16*). Bladder cancer risk was also found to be elevated among persons living near sites where drinking water had been contaminated by organic solvents. Higher rates of leukemia were also reported among children of Woburn, Massachusetts, who were exposed to organic solvents through industrial contamination of municipal water (*16*). It should be noted that there are inherent uncertainties and limitations in such studies, including the lack of individual exposure data and difficulty controlling for other cancer risk factors over long latency periods. Industrial facilities are known to discharge a wide range

of potentially carcinogenic pollutants into the atmosphere. A review of epidemiologic studies in the U.S. and other countries (*52*) found evidence linking increased lung cancer risk and residential proximity to smelters, industrial complexes, and other local emission sources. Limited evidence was also found for higher risk of leukemia and lymphoma among persons living near industrial facilities in the U.S.

There is evidence that some racial and ethnic minorities and the socioeconomically disadvantaged are disproportionately impacted by environmental contamination. Persons in lower socioeconomic groups are more likely to live in polluted urban areas and near industrial facilities and uncontrolled toxic waste sites (*16*). It is also known that some ethnic and minority groups are at increased risk for certain cancers. Many studies have shown that African Americans have generally higher incidence and mortality rates for certain cancers than other racial and ethnic groups. African Americans have the highest incidence rates of cancer in the U.S. and are 33% more likely to die of the disease than Caucasians (*53*). Other ethnic groups in the U.S., including Hispanic Americans and some Asian American groups, also have higher rates of some cancers. Some of these differences in cancer risk can be explained by factors such as dietary habits, tobacco use, and limited access to health care (*50*). Although the role of environmental exposures in increased cancer risk among these groups is not well understood, the evident disparities raise serious public health and social concerns.

Cancer in Agricultural Populations

Farmers, farm workers, their families, and others living on or near farms are known to have higher than average exposure to agricultural pesticides and other chemicals, including solvents and nitrates from fertilizers. Although farmers have overall cancer risks that are lower than the general population, there is epidemiologic evidence that they experience higher than average risks for certain cancers (*54*). A number of studies have suggested that farmers may be at increased risk for a wide variety of cancers, including leukemia, NHL, multiple myeloma, soft-tissue sarcoma, and cancers of the stomach, brain, and prostate (*54,57*).

There are particular concerns for the health of children living in farming areas, because of their high potential for routine exposure to agricultural pesticides. Children of farmers and farmworkers can be exposed by contact with pesticide drift and residues carried into the home and yard, through work on the farm, or through consumption of contaminated food or drinking water (*55*). Migrant farm workers are also likely to have disproportionately high pesticide exposures, yet their health risks have received little attention from the scientific, medical, and regulatory communities (*56*).

Epidemiologic studies have linked exposures to certain classes of pesticides with increased risk for some types of cancer. The strongest evidence indicates that exposure to phenoxyacetic acid herbicides may be associated with increased risk of NHL and soft-tissue sarcoma. More limited evidence suggests possible associations between exposure to some insecticides and leukemia; triazine herbicides and ovarian cancer; certain herbicides and prostate cancer; and DDT and lung cancer (*54,57*). Higher rates of NHL have been reported in the farming states of the north-central and upper Midwest regions of the U.S. (*59*). A recent study found increased rates of several cancers (including prostate, kidney, pancreas, and other sites) in populations living in agricultural areas where chlorophenoxy herbicides (such as 2,4-D) had been heavily used (*58*). Epidemiologic studies have found associations between occupational exposure by farmers to phenoxy herbicides, particularly 2,4-D, and increased risk of NHL (*60*). A recent study in Sweden found increased risk of NHL among men exposed to herbicides (phenoxy herbicides and glyphosate) and fungicides (*61*).

Commonly used organophosphate insecticides may also contribute to development of NHL (*62,63*). Other organochlorine insecticides, organophosphate pesticides, and carbamates have also shown possible links to increased cancer risk (*57*).

ENVIRONMENTAL CONTAMINANTS HAVE BEEN LINKED TO CERTAIN CANCERS

A growing body of studies provides evidence that exposures to environmental pollutants are contributing to the burden of cancer in the U.S. and elsewhere. These studies reveal that certain pesticides, industrial chemicals, waste products, and air pollutants are likely to cause cancer. The following sections provide an overview of the evidence linking environmental exposures to increased risk of developing certain cancers.

Non-Hodgkin's Lymphoma

NHL is not a single disease, but a collection of various diseases for which the causes are largely unknown. It is estimated that in 2002 there will be almost 54,000 new cases and 24,000 deaths from NHL (*1*). The number of new NHL cases has nearly doubled since the early 1970s, although rates appear to have leveled off since the mid-1990s (*33*). Mortality rates also increased 45% over the same time period. Based on current 5-year survival rates, roughly half of those diagnosed with NHL will die from the disease (*33*).

Most cases of NHL cannot as yet be attributed to specific risk factors. Certain rare inherited genetic diseases, reduced immune function, and some viral infections such as human immunodeficiency virus (HIV) are known to increase risk for NHL, but account for only a fraction of all cases (*1*). A growing body of evidence is finding that exposure to certain pesticides and industrial chemicals may also play a role in this disease. Pesticide exposure has long been suspected as a cause of NHL among farmers and agricultural workers, as described in the previous section. Consumption of drinking water contaminated with nitrates has also been linked to elevated risk of NHL (*12*). Nitrate, a component of nitrogen-based fertilizers, is a common source water contaminant in agricultural areas. Nitrate can be converted to carcinogenic N-nitroso compounds in the body.

Epidemiologic studies also suggest that long-term exposures to some industrial chemicals could increase NHL risk. The highly potent carcinogen dioxin (specifically 2,3,7,8-TCDD) has a shown weak association with elevated risk of NHL (*64*). Dioxin is a common environmental contaminant that results from waste incineration and other combustion processes, pesticide production, and various other industrial processes. Dioxin is found as a contaminant in the herbicides 2,4-D and 2,4,5-T. One study reported a strong dose-response relationship between serum PCB concentrations and risk of NHL (*65*).

Breast Cancer

Breast cancer is the second leading cause of cancer deaths in women, following lung cancer (*1*). Breast cancer mortality is highest for African American women, although the causes of this disparity are not yet known. The incidence rates for breast cancer among women in the U.S. increased more than 40% from 1973 through 1998 and continued to increase an average of 1.2% per year from 1992 through 1998 (*66*).

The recent increases in breast cancer incidence may be due in large part to increased breast cancer screening and early detection, although other factors (e.g., the increasing number of women delaying childbirth or remaining childless and increases in hormone use) may also play a role (*66*). Inherited susceptibility through germline mutations, such as BRCA1 and BRCA2 gene mutations, account for less than 10% of all breast cancers (*67,68*). It is likely that multiple factors are involved in determining individual breast cancer risk, although fewer than half of breast cancer cases are explained by known risk factors (*69*). Many of the remaining cases might be explained by envi-

ronmental factors (*69*). Several chemicals and chemical classes have shown evidence of possible links to breast cancer, including various organic solvents, metals, and styrene (*67*).

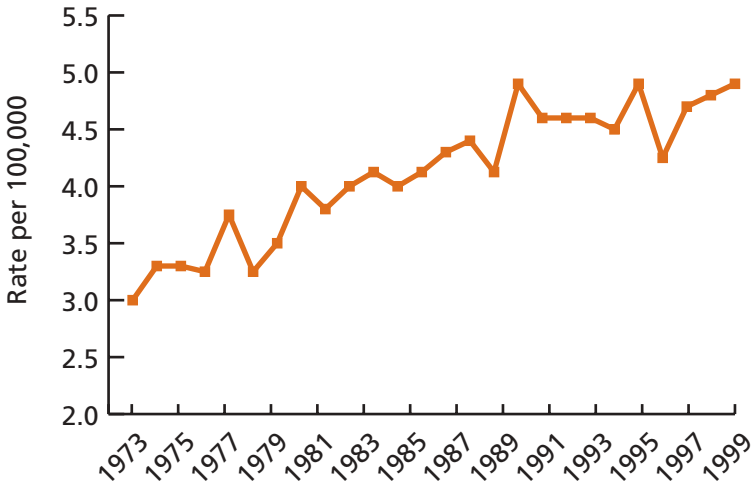
Hormonal factors, including cumulative lifetime exposure to estrogens, are known to affect the risk of breast cancer. In addition to endogenous hormones, women are also exposed to exogenous hormones including oral contraceptives, hormone replacement therapy, and hormone-like chemicals found in the environment and food. The evidence of a possible role for endocrine-disrupting chemicals in breast cancer remains unclear and controversial. Several studies have reported higher levels of certain endocrine-disrupting chemicals, such as DDE, PCBs, hexachlorobenzene, and dieldrin in women with breast cancer compared with healthy women (*70–72*). However, more recent studies have found no evidence of such an association, particularly for DDE and PCBs (*73–75*). Additional research is required to determine the role of endocrine disruptors, if any, in breast cancer risk. Until more conclusive results are available, however, prevention of exposure to hormone-mimicking substances is advisable as a precautionary measure.

Testicular Cancer

Dramatic increases in testicular cancer have been reported throughout the industrialized world, and the incidence of testicular cancer has doubled in the U.S. since 1973 (*33*). Testicular cancer is the most common malignancy among young men, with a peak incidence between 18 and 35 years of age (*76*). The causes for continuing increases are not yet known. Distinct geographic variations in testicular cancer incidence around the world have led to suggestions that dietary factors or environmental exposures may be involved in its etiology (*77*). Because testicular cancer is most often diagnosed in early adulthood, it is thought that the causes may originate in early life, perhaps even *in utero* (*78*). It has been postulated that exposure to endocrine-disrupting chemicals at critical stages of embryonic development may play a role in testicular cancer and certain other male reproductive disorders (*79–80*), although there is, as yet, no definitive evidence to support this suggestion. There is clearly a need for additional research to determine the causes for observed increases in testicular cancer (*73,76*).

Trends in Testicular Cancer Incidence

Age Adjusted Rates, 1973–1998 (all races)



Source: Based on data cited in "SEER Cancer Statistics Review 1973–1998," National Cancer Institute, 2001

Prostate Cancer

Prostate cancer is the most common cancer among men in the U.S. and the second leading cause of cancer deaths in men (*1*). Both incidence rates and mortality rates for prostate cancer have risen steadily in recent decades. A sharp rise in the incidence of prostate cancer began in the mid-1980s and has been largely attributed to increased use of prostate-specific antigen (PSA) screening (*81*). A recent study

TRACKING CHRONIC DISEASE AND MONITORING ENVIRONMENTAL EXPOSURE: A STEP IN THE RIGHT DIRECTION

There are critical gaps in our understanding of the links between environmental exposures and chronic diseases, including cancer. Reducing and preventing these diseases requires better information regarding the nature and extent of population exposures to chemicals in the environment and the role of such exposures in disease causation. To this end, there are renewed calls in the health community and in Congress to establish a nationwide health tracking network that would identify and monitor hazardous environmental agents, measure population exposures to these agents, and track health outcomes that may be related to exposures.

This nationwide health tracking network would use existing systems like the TRI and other statewide environmental surveillance programs to monitor environmental hazards in the air, soil and water; draw upon and expand the biomonitoring program at CDC; and incorporate various national and statewide chronic disease tracking systems like cancer registries. In FY 2002, Congress appropriated $17.5 million to the CDC to begin the planning and implementation process for this network. *(More information on chronic disease monitoring and tracking initiatives can be found on PSR's website at www.psr.org/mandtfs.html)*

found evidence that a significant proportion (42%) of susceptibility to prostate cancer is determined by inherited genetic defects (*26*).

There is limited evidence that chemical exposures may increase prostate cancer risk for some occupational cohorts , although this risk has not been linked to specific chemical agents (82,83). Further study is needed to determine whether low-level exposures to chemicals in the environment could contribute to increased risk of prostate cancer in the general population.

What We Still Need to Learn About Cancer and the Environment

Which chemicals and what level of chemical exposure lead to cancer?

Very little is known about the long-term effects of exposure to carcinogens at environmentally relevant concentrations. Scientists do know, however, that repeated exposures to low doses of carcinogens may increase susceptibility to cancer, by causing the accrual of genetic mutations over time. Carcinogenesis may result when these mutations affect specific genes involved in regulating cellular processes. There is also growing evidence that exposures to very low doses of some endocrine-disrupting chemicals can cause cancer, and that developing fetuses and infants may be particularly susceptible to damage caused by these chemicals. There is an urgent need to screen more chemicals for carcinogenic and endocrine-disrupting potential, and for more intensive investigation of the role of endocrine disruptors in early development. More epidemiologic studies are also needed to elucidate links between environmental exposures and disease, including determinations of relationships between contaminant dose and cancer risk.

Which genes determine our susceptibility to cancer from environmental exposures?

Scientists are only in the earliest stages of understanding genetic susceptibility to environmental agents. Additional studies are needed to identify which genes determine susceptibility to cancer, their

prevalence in the population, and the magnitude of disease risk associated with gene variants. The Environmental Genome Project (not connected to the Human Genome Project), administered by the National Institute of Environmental Health Sciences, is designed to answer these types of questions. A better understanding of genetic susceptibility and gene-environment interactions could lead to new strategies for preventing and controlling cancer, particularly for high-risk populations.

What effects do environmental carcinogens have on the developing fetus, infants and children?

Relatively little is known about the effects of environmental carcinogens on fetuses, infants, or children, compared with adults. More research is needed to better characterize chemical exposures and the physiological, biochemical, genetic, and developmental factors that are unique to infants and children. Most of the toxicologic and epidemiologic research has focused on adult populations, which differ in many ways from children. There is also an urgent need for more extensive testing of pesticides and industrial chemicals for potential carcinogenicity. Scientists already know, however, that infants and children are highly susceptible to the toxic effects of chemicals, and that *in utero* and early childhood chemical exposures can cause cancer to develop years later. Because children are at greater risk from toxic chemical exposures, relevant laws and regulations must include strong provisions for their protection, such as the model provided by the FQPA. *(Refer to inset on Carcinogens in Food for more information.)* This law requires that a safety factor be used in setting allowable exposure levels when there is insufficient information to determine effects of a substance on children's health.

Patient Questions & Answers

Q: Could exposure to environmental pollutants raise my risk of cancer? My child's risk of cancer?

A: Yes. Some chemicals in our environment can cause cancer in people who come into contact with them. Potentially harmful chemicals are found in products such as solvents, fuels, and pesticides, and in small amounts in the air people breathe, the water they drink, and the food they eat. Scientists do not yet know all the reasons why some people develop cancer, while other people do not. But they do know that certain chemicals can damage genetic material or cause changes in hormones, which can lead to cancer in some people. Children are especially sensitive to the harmful effects of chemicals. You can lower your family's cancer risk by limiting use of chemicals such as solvents and pesticides in and around the home.

Q: How does my diet affect my risk of cancer?

A: Eating a healthy, well-balanced diet is essential for overall good health. The American Cancer Society recommends a diet based largely on food from plant sources, including fruits, vegetables, and grains; limited consumption of high-fat foods, particularly fats from animal sources; an active lifestyle; and limited consumption of alcoholic beverages. By eating less animal fat, you can also reduce exposure to pollutants that tend to accumulate in fatty tissues, such as DDE, PCBs, and dioxin. Exposure to pesticides can also be reduced by eating organically grown fruits and vegetables

whenever possible. In addition to eating a healthy diet, you can reduce your cancer risk by decreasing sun exposure and not smoking cigarettes.

Q: How can I minimize my exposure and my family's exposure to carcinogens in and around the home?

A: Some chemical pesticides available to the public have the potential to cause cancer and other harmful health effects. You can reduce your exposure to potentially harmful pesticides by reducing the use of these products in the home, lawn, and garden. If you do use pesticides, carefully follow instructions and avoid using them around infants and small children or during pregnancy. Parents should also inquire about pesticide use in their child's school and urge schools to use the least toxic alternatives. For more information on ways to reduce exposure to pesticides, contact Beyond Pesticides (www.beyondpesticides.org) or EPA's Office of Pesticide Programs (www.epa.gov/pesticides).

Certain solvents used for home improvement projects and hobbies, such as methylene chloride (used in some paint strippers) and carbon tetrachloride, have the potential to cause cancer in humans. If you use chemicals in the home, choose less toxic alternatives, follow instructions on the label, avoid use around children, and use only in well-ventilated areas. Paints, solvents, and fuels stored in attached garages or areas inside the home are also a source of exposure. Whenever possible, these chemicals should be kept in a shed or other storage area away from the home.

Q: Is my tap water safe to drink?

A: Most municipal water suppliers provide drinking water that is safe for most individuals. EPA requires municipal systems to regularly test drinking water for a variety of pollutants, including many chemical carcinogens, and to treat water so that it meets established health standards. The federal government does not regulate all possible chemical contaminants in public supplies, and water treatment systems do not always remove all contaminants. Pollutants are sometimes found in drinking water at levels above those considered safe for human health. Each year, water utilities are required to send customers a drinking water quality report that lists contaminants detected in treated drinking water. Consumers should take the time to read these reports, and call their water utility, the EPA, or their health care provider with questions. Well owners should also know that the federal government does not regulate the quality of water from private wells. It is the consumer's responsibility to test well water to ensure that it does not contain unsafe levels of chemical and microbial pollutants. For more information about drinking water and health, contact EPA's Safe Drinking Water Hotline (1-800-426-4791) and go to PSR's web page "Drinking Water and Health" (www.psr.org/toxics.html).

What Is Being Done to Reduce Exposures to Carcinogens, and What Can Health Care Providers Do?

Although much is still unknown about environmental chemicals and their role in causing cancer, there is clear evidence that exposure to certain chemicals is contributing to the burden of cancer in the U.S. and around the world. While research efforts continue, we must move forward and take action to reduce this threat, based on the evidence before us. Most cancers are preventable. The precautionary principle urges that society act, even in the face of scientific uncertainty, to prevent cancer by reducing exposures to environmental carcinogens, especially for individuals at highest risk. *(For more information on the precautionary principle, link to http://www.sehn.org/precaution.html. PSR's Resolution Affirming the Precautionary Principle can be viewed at http://www.psrus.org/precprinc.html.)*

Many initiatives and programs to reduce our exposure to carcinogenic chemicals are underway in the U.S. and around the world. By Congressional mandate, EPA has implemented programs to reduce levels of toxic and carcinogenic chemicals in air (Clean Air Act), water (Clean Water Act and Safe Drinking Water Act), and food (Food Quality Protection Act), and by requiring more stringent control of pesticide use (Federal Insecticide, Fungicide and Rodenticide Act), and industrial processes and chemical releases (Toxic Substances Control Act and Resource Conservation and Recovery Act). EPA has established Guidelines for Carcinogen Risk Assessment to assist scientists in estimating cancer risks from environmental exposures. These guidelines, originally published in 1986, are currently being revised to reflect current understanding of the process of carcinogenesis and to bolster protections for children's health. In the international arena, more than 100 countries have signed a treaty, the Stockholm Convention on Persistent Organic Pollutants, to eliminate or limit the use of certain persistent organic pollutants, including known carcinogens such as PCBs, dioxins, and DDT.

These programs and others at the national, state, and local levels have made significant strides in reducing exposures to harmful chemicals. Yet much remains to be done to reduce the threat of environmental carcinogens. Existing regulations must be more effectively and consistently enforced, and more stringent controls are needed for the manufacture, use, and environmental releases of potential carcinogens. Chemical testing must be accelerated to identify potentially carcinogenic and endocrine-disrupting chemicals. Efforts to protect infants and children from these harmful exposures must be re-doubled.

The health care provider and other health professionals are vitally important to these efforts. The following are just some of the ways that health professionals can become involved:

- ***Identify patient exposures to toxic chemicals.*** A thorough health history by the health care provider can help to identify and prevent toxic chemical exposures in the home, workplace, school, and other settings. This information will help to identify persons who may be at particular health risk (e.g., pregnant women, infants and children, and highly exposed individuals). The ATSDR Case Study in Environmental Medicine entitled "Taking an Exposure History" can be found on the web at www.atsdr.cdc.gov/HEC/CSEM.
- ***Educate patients about the hazards of toxic chemicals.*** Health professionals can educate patients about health risks of toxic chemical exposure and offer practical suggestions for ways to reduce or prevent such exposures. Organizations such as Physicians for Social Responsibility,

Beyond Pesticides, and Environmental Defense are invaluable resources for practical suggestions on preventing toxic chemical exposures. (Refer to list of resources below.)

- ***Share your knowledge with your peers and your community.*** You can become a valuable resource on this issue for your peers, your community, and professional organizations. Give talks at Grand Rounds, conferences, and community meetings. You are a respected voice in your community—let your voice be heard. PSR offers a wide range of resources to assist health professionals in such activities. (Go to www.psr.org or call PSR for more information.)
- ***Become involved in local, state, and national advocacy efforts.*** As a health professional, your knowledge and your opinions are valued. Devote your knowledge and energy to efforts that will control or eliminate carcinogens and other toxic chemicals before they reach the environment. Inform yourself about potential environmental problems in your community. Press your elected officials for stronger chemical safety testing programs, new regulations to protect public health, and more vigorous enforcement of existing regulations. Encourage efforts to find less toxic, nontoxic, or nonchemical alternatives to current chemical uses.

For more information about carcinogens in the environment

- Physicians for Social Responsibility—www.psr.org or call (202) 667-4260.
- EnviroHealthAction—online resource and action center for health professionals. www.envirohealthaction.org.
- Mount Sinai School of Medicine, Center for Children's Health and the Environment—for information on toxic exposures and childhood illness. www.childenvironment.org or call (212) 241-7840.
- Environmental Defense—for information about toxic chemicals in your community. www.scorecard.org.
- Beyond Pesticides (formerly National Coalition Against the Misuse of Pesticides)—for information about pesticides and opportunities for action. www.beyondpesticides.org or call (202) 543-5450.
- U.S. EPA—for a wide range of information on regulatory programs, sources of chemical exposure, chemical health effects, and susceptible populations. www.epa.gov.
- National Institute of Environmental Health Sciences—valuable source of information on current research and chemical-specific information. www.niehs.nih.gov.
- Agency for Toxic Substances and Disease Registry—www.atsdr.cdc.gov or call (888) 422-8737.
  - Case Studies in Environmental Medicine—available for many toxic chemicals found in the environment. www.atsdr.cdc.gov/HEC/CSEM.
- Centers for Disease Control and Prevention—National Report on Exposure to Environmental Chemicals. Available online at www.cdc.gov/nceh/dls/report or call CDC at (866) 670-6052 (toll free).
- International Agency for Research on Cancer— for scientific information on classification of carcinogens. www.iarc.fr.

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