



Role of Environmental Factors in Increased Cancer Incidences and Health Impacts 28

Anita Khokhar and Priyanka Sharma

Abstract

Cancer incidence and mortality are rapidly growing worldwide. The International Agency for Research on Cancer (IARC) estimates that one in five men and one in six women worldwide will develop cancer over the course of their lifetime and that one in eight men and one in 11 women will die from their disease. However, countries are facing an overall increase in the absolute number of cancer cases. Asia accounts for nearly half of the new cancer cases and more than half of cancer deaths. There are more than 100 types of cancers. Cancers are a large group of diseases in which there is unregulated, abnormal growth of cells with invasion of the nearby organs and potential to spread to distant parts of the body as well. Some of the changes in the DNA which occur in cancers are caused naturally, whereas some others are caused due to damage caused by exposure to various environmental factors. These exposures may be alcohol, tobacco, diet, physical activity cancer-causing substances, radiation exposure, sunlight, obesity, infectious agents, pollution, radon, workplace and household exposure, ultraviolet light, etc. The current chapter intends to cover the global burden of cancers, etiology of cancers, epidemiology of various cancers, evidence from research, role of different environmental exposures in cancers, and strategies for prevention and control of these factors. Although we may not be able to control and prevent many of the environmental exposures, better understanding of these will help us prepare better strategies to intervene in our fight against cancers.

A. Khokhar (✉) · P. Sharma

Department of Community Medicine, Vardhman Mahavir Medical College, Safdarjung Hospital, New Delhi, India

© The Author(s), under exclusive license to Springer Nature Singapore Pte Ltd. 2022

671

S. Arora et al. (eds.), *Biotechnological Innovations for Environmental Bioremediation*, https://doi.org/10.1007/978-981-16-9001-3_28

Keywords

Environmental carcinogens · Cancer etiology · Cancer impact · Cancer prevention

28.1 Global Burden of Cancers

As per Global Cancer Observatory (GLOBOCAN), there were an estimated 18 million new cases and 9.5 million deaths due to cancer worldwide in 2018 which is expected to rise to 29 million new cases and 16.3 million deaths by the year 2040 (International Agency for Research on Cancer. World Health Organization 2018a). Incidence rates and mortality rates for all cancers combined worldwide are higher by 20% and 50%, respectively, among men as compared to women. The largest share to cancer incidence and mortality is contributed by Asia which can partly be attributed to its substantial population burden. The proportion of cancer deaths is comparatively higher than incidence in Asian and African continents. However, almost all the countries are experiencing an overall increase in the absolute number of cancer cases (International Agency for Research on Cancer. World Health Organization 2018b).

The cumulative risk of developing cancer and dying from it before the age of 75 years is 20% and 10.6%, respectively. One in five men and one in six women worldwide will develop cancer and one in eight men and one in 11 women will die from their disease over the course of their lifetime. The countries with higher Human Development Index (HDI) have greater cumulative risks, both for cancer incidence and mortality, than low or medium HDI nations. Top five leading cancers in terms of incidence are lung (11.6%), breast (11.6%), colorectum (10.2%), prostate (7.1%), and stomach (5.7%) for both sexes. However, lung (18.4%), colorectum (9.2%), stomach (8.2%), liver (8.2%), and breast (6.6%) are the leading cancers in terms of mortality. The most commonly occurring cancer and cause of cancer death are lung among males and breast among females (International Agency for Research on Cancer. World Health Organization 2018b) (Fig. 28.1).

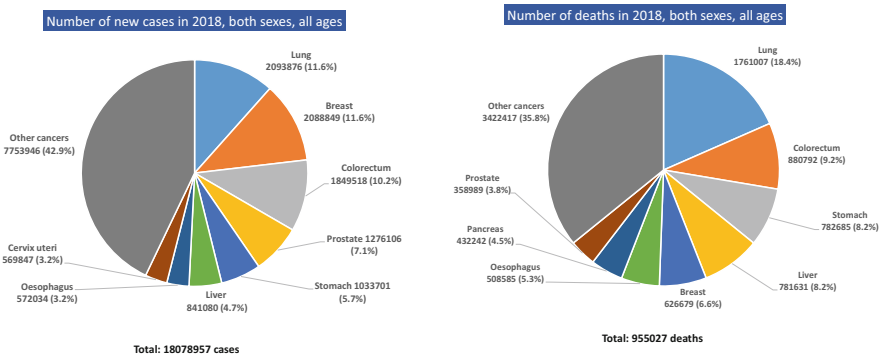


Fig. 28.1 Incidence and mortality due to different types of cancers in both sexes and all ages. (Source: IARC, WHO, GLOBOCAN 2018a)

28.2 Impact of Cancer

Cancer, whether in early stages or during terminal advanced disease state, impacts not only an individual suffering from the disease, but also the people involved in care including spouse, other family members and friends and the society as whole. The impact is multidimensional as it envisages physical, psychosocial, economic, and legal impact. Physical impact in patients manifests as symptoms like pain, sleep disturbances, fatigue, cachexia, neuropathy, and cognitive problems. It affects their overall quality of life and mental well-being (Naughton and Weaver 2014). One's general sense of orderliness and security is disrupted by cancer diagnosis. The negative stigma associated with the disease and fear and uncertainty about future, fear of pain, suffering and abandonment, loss of control, identity, loved ones, and hope leads to plethora of emotional and psychological turmoil (Gorman 2018). Depression and anxiety are common presentations not only in cancer patients but also among cancer survivors (Naughton and Weaver 2014). The family members and friends do not remain untouched as cancer diagnosis and treatment of a loved one invade their sense of security and disrupt family structure, and a feeling of helplessness, distress, anxiety, and uncertainty engulfs them. Family fears loss of relationship, loss of control, sorrow, pain, and suffering of the patient. Recurrence and periods of remissions followed by exacerbations add to the misery. The patient progressively becomes weaker, and family members may react with detachment with fear of reinvestment required at their level for patient care with meager possibility of positive outcome (Gorman 2018).

The diagnosis, treatment, and palliative care of the cancer has a significant impact on finances of the patient and his/her family, both for the insured and uninsured ones; however, impact is higher among uninsured ones due to their sociodemographic vulnerability and late-stage presentation at the time of diagnosis which requires extensive and more expensive therapeutic care (American Cancer Society 2020). Loss of wages, unemployment, poor socioeconomic status, travel costs, requirement of special nutrition and supplements, etc., are ancillary costs adding further to the financial expenditure related to cancer (The University of Texas. MD Anderson Cancer Center 2020; Fenn et al. 2014). The financial burden aggravates the psychosocial hardship of the patients and their families and makes many of them impoverished with time. For a society, cancers cause huge economic impact and the costs are increasing with time. As per International Agency for Research on Cancer (IARC) report, the total annual economic cost of cancer in 2010 was about US\$1.16 trillion (International Agency for Research on Cancer. World Health Organization 2014a).

28.3 Etiology of Cancer

Cancer is not a single disease, rather constituted by a large number of diseases, and it begins when anomalous cells start growing uncontrollably, invade other parts of the body, and/or spread to other organs, by going beyond their usual boundaries. The

process of spread of cancer from one organ to another is called metastasis which is among the leading causes of cancer deaths. Cancers can start in virtually any organ or tissue of the body (World Health Organization 2020b). Malignancy and neoplasm are other words used for cancers. Usually, benign lesions progress to malignant tumors through a multistage process which involves sequential agglomeration of mutations modifying the DNA sequence in genes which control proliferation and death of cells and maintain genetic integrity. These genetic mutations can either lead to loss of function of tumor suppressor genes like BRCA1 and BRCA2 in breast cancer or activation of certain genes converting them into oncogenes like KRAS and LMYC in lung cancer (International Agency for Research on Cancer *n.d.*, pp. 84–125). Besides these genetic mutations, another mechanism for cancer development involves epigenetic changes in which chromatin conformation is modified. Chromatin is the cellular structure that wraps up the DNA and regulates its access (International Agency for Research on Cancer 2008).

Genetic and epigenetic changes affect each other and work in parallel to generate sequential changes. Accumulation of multiple genetic and epigenetic changes occurring during the course of evolution of cell from normal to malignant, and their cumulative effect results in emergence of malignant cell population (International Agency for Research on Cancer *n.d.*, pp. 84–125). There are more than 23,000 genes in human genome, but genetic mutation or epigenetic changes mainly target few hundreds of them which are important regulators of cell division, proliferation, and death, and this leads to creation of conglomeration of dysregulated cells which do not follow normal cell growth and behavior rules, hence rightly called as “outlaw” cells and, if they survive, lead to development of malignancy (International Agency for Research on Cancer 2008).

There are innumerable ways that can lead to such genetic and epigenetic changes. Many chemical agents, radiations, viruses, and other environmental factors have been found to mutate or damage DNA which on accumulation progress to become cancerous. Chemical carcinogens can be classified as genotoxic or non-genotoxic. Most common mechanism of action of genotoxic chemical carcinogens is binding to nucleophilic sites of DNA resulting in formation of adducts, and replication of such DNAs can either lead to mutations evident from sequence changes or chromosomal aberrations by rearrangements of DNA. This becomes an irreversible genetic damage ensuing either in permanent DNA change, which is transmissible or in altered chromosomes resulting in loss of information. This is the “initiation” step of carcinogenesis (International Agency for Research on Cancer *n.d.*, pp. 84–125). On the other hand, there are certain chemicals that are non-genotoxic carcinogens. They do not cause DNA structural modifications or genetic changes directly, but induce carcinogenesis by cytotoxicity, cellular proliferation, hormonal effects, or epigenetic mechanisms. An important way to distinguish genotoxic and non-genotoxic carcinogens is the use of gene mutation assays and cytogenetic assays (Nohmi 2018). Similar to chemical carcinogens, ultraviolet (UV) radiations cause double mutations in DNA as they bridge together two adjacent cytosines, an amino acid in DNA structure, and lead to the formation of dipyrimidine dimer. Ionizing radiations, on the other hand, break single or double strands of DNA. Infection with

human papilloma virus (HPV) leads to production of viral genes mainly E6 and E7 through host cell machinery. These viral genes bind to and deactivate tumor suppressor proteins, namely p53 and pRB and enzymes, thereby deregulating host cell growth cycle, and final outcome is cellular proliferation and delayed differentiation of host cell (Burd 2003).

IARC has classified about hundreds of agents found in environment in different categories of carcinogens based on assessment of risk of carcinogenicity in humans. The list has about 120 agents listed as confirmed carcinogens, 88 as probable carcinogens, 313 agents as possible carcinogens, and 499 agents as non-carcinogen to humans (International Agency for Research on Cancer. World Health Organization 2020). The next section provides description about most of the confirmed carcinogens, their routes of exposure, and cancer sites associated with them; however, the description of other categories of carcinogens is beyond the scope of this chapter.

28.4 Confirmed Carcinogens

28.4.1 Diet-Related Factors

28.4.1.1 Salted Fish: Chinese-Styled

Salted fish is prepared by a variety of methods including treatment of fish with dry salt or aqueous salt solution which is followed by sun drying. When this salted fish is partially decomposed for softening before or during the process of salting, this is called as Chinese-styled or Cantonese marine salted fish. Salted fishes are found to have high levels of sodium and micro-organisms including those producing aflatoxins, *N*-nitrosodimethylamines (NDMA), polynuclear aromatic hydrocarbons (PAHs), and many other contaminants which are known carcinogens. Chinese-styled salted fish causes nasopharyngeal carcinoma among consumers, and the risk significantly increases with increase in amount of consumption with stronger association found for consumption during childhood (International Agency for Research on Cancer. World Health Organization 2012h).

28.4.1.2 Processed Meat

Meat that is transformed through fermentation, curing, salting, smoking, or any other process for increasing the shelf life or enhancing flavor is called processed meat. This includes cured meat pieces, fresh industrial processed meat products, fermented sausages, pre-cooked ready to eat products, and dried meat (Fig. 28.2). Processed meat also contains many chemical additives, namely salt, nitrate and nitrite, ascorbic acid, phosphates, antioxidants, preservatives, monosodium glutamate, and food colors. Procedures involving direct contact with hot surface or flame at high temperatures like barbecuing, pan frying, and grilling produce high levels of carcinogens like heterocyclic aromatic amines, nitrosoamines, and PAHs in processed meat. Heme iron present in meat can cause cytotoxicity and mediates formation of nitrosamines and lipid oxidation products. Environmental carcinogens like dioxins, lead, heavy metals, and brominated flame retardents can also



Fig. 28.2 Processed meat

contaminate meat through air, water, and animal feed. Processed meat causes colorectum cancer. Stomach cancer and processed meat consumption are also found to be positively associated (International Agency for Research on Cancer. World Health Organization 2018e).

28.4.2 Tobacco

28.4.2.1 Smoked Tobacco

Smoked tobacco products include numerous types of cigarettes, cigars, pipes, bidis, and water pipes (Fig. 28.3). More than 5300 compounds are identified in tobacco smoke out of which about 70 are carcinogenic in either humans or animals which include PAHs, nitrosamines, aldehyde, phenols, and volatile hydrocarbons. Levels of carcinogens are higher in cigars compared to cigarettes, while bidis contain comparable levels of nitrosamines. These cause cancers by many complex mechanisms, and most of them are not fully understood. Some of the mechanisms include in formation of DNA adducts, oxidative damage, inflammation, tumor promotion, co-carcinogenesis, and activation of cellular proliferation. Tobacco smoke causes cancers of the lung, naso-, oro-, and hypopharynx, nasal cavity and accessory sinuses, oral cavity, larynx, esophagus, stomach, colorectum, pancreas, kidney, ureter, urinary bladder, liver, uterine cervix, ovary, and myeloid leukemia. Female breast cancer is also associated with tobacco smoking. Parental smoking on the other hand causes hepatoblastoma and is found to be associated with childhood leukemia (International Agency for Research on Cancer. World Health Organization 2012ao).

28.4.2.2 Secondhand Smoke (SHS)

Smoke released from burning tip of a cigarette or other burned tobacco product between puffs, also known as sidestream smoke (SS), and smoke exhaled by the



Fig. 28.3 Cigarette packet

smoker, known as mainstream smoke (MS), together constitute secondhand smoke. It is also named as environmental tobacco smoke, involuntary smoking, or passive smoking. The constituents of SS and MS differ only quantitatively. SHS gets rapidly diluted and dispersed into indoor environment, and its constituents' composition varies with time and environmental conditions. The carcinogens present in it are acrolein, benzopyrene, and nitrosamines. SHS is present in all the environments where smoking takes place, and the exposure setting differs between populations. About one-fifth of males and one-third of females were estimated to be exposed to SHS globally in 2016 (Drope et al. 2018). Secondhand smoke causes lung cancer and is positively associated with larynx and pharynx cancer (International Agency for Research on Cancer. World Health Organization 2012aq).

28.4.2.3 Smokeless Tobacco

Smokeless tobacco means usage of unburned tobacco products in finished products and used either orally by chewing, sucking, gargling, and applying to gum and teeth or through inhalation of fine mixtures by nostrils (Fig. 28.4). Chemical composition of tobacco varies with tobacco species, growing, curing, processing, and storage. Highest prevalence of tobacco use among men and women was present in Southeast Asian Region (SEAR) (World Health Organization 2019a). Carcinogenic compounds present in smokeless tobacco include tobacco-specific *N*-nitrosamines, *N*-nitrosamine acids, volatiles nitrosamines, PAHs, aldehydes, acrolein, and



Fig. 28.4 Smokeless tobacco products



Fig. 28.5 Betel quid

uranium. Smokeless tobacco causes cancer of oral cavity, esophagus, and pancreas (International Agency for Research on Cancer. World Health Organization [2012an](#)).

28.4.3 Betel Quid and Areca Nut

Betel quid, commonly called as pan, is a quid wrapped in betel leaf in which quid indicates a substance or mix of substances, placed and retained in mouth and commonly swallowed. Common constituents of pan are betel leaf, areca nut, slaked lime, and catechu with or without tobacco which can be supplemented with sweetening agents, condiments, etc. (Fig. 28.5). Pan masala is ready to chew dry powdered mixture of areca nut, lime, catechu, unspecified spices without betel leaf, and tobacco and is sold commercially in India (Ramchandani et al. [1998](#)). When

tobacco is added to it, it is called gutka (Nair et al. 2004). Many alkaloids like arecoline, arecaidine, and tannins are present in areca nut. Reactive oxygen species and nitrosamines are produced due to betel quid chewing with areca nut. It causes continuous local irritation of buccal epithelium, resulting in chronic inflammation, cytokine production, and oxidative stress. Betel quid with or without tobacco is a carcinogen on its own. Tobacco containing betel quid causes oral cavity, pharynx, and esophageal cancer, while betel quid without tobacco causes oral cavity and esophageal cancer and is associated with liver cancer (International Agency for Research on Cancer. World Health Organization 2012ak).

28.4.4 Alcohol

Mainly consumed beverage types are beer, spirits, and wine which can be prepared commercially or at home at local levels. Alcohol content in beverages differs based on type and country and is indicated by percentage by volume. It can range from 2.3% to 10% in beer, 8–15% in wine, and 20–40% in spirit and is mainly composed of ethanol and water, but some volatile and non-volatile compounds may also be present (Fig. 28.6). Certain contaminants or toxins may be present in alcoholic beverages including pesticides, benzenes, nitrosamines, lead, cadmium, arsenic, and chromium and acetaldehyde is produced in body as first product of ethanol metabolism. About 2.3 billion people were current drinkers in 2016. In Europe, Americas, and Western Pacific regions, more than half of the population consumes alcohol (World Health Organization 2018). Alcohol consumption causes cancers of oral cavity, pharynx, larynx, esophagus, colorectum, liver, and female breast. Pancreas cancer is also found to be associated with alcohol consumption. Its metabolite acetaldehyde causes cancer of esophagus and upper aerodigestive tract (International Agency for Research on Cancer. World Health Organization 2012al).

28.4.5 Outdoor Air Pollution

Air pollution is defined as the presence of one or more substances at concentrations or durations exceeding the natural levels, with potential to cause adverse effects. Exposure to outdoor air pollutants occurs continuously including periods of indoor stay, though composition and levels of pollutants may differ. These pollutants can be in gaseous form or consists of particulate matter (PM). PM is a suspension of liquid or solid matter miniscule particles of size of few micrometers to nanometers. Gaseous pollutants include ozone, nitrogen oxides, sulfur oxide, and volatile organic compounds like aldehydes and aromatics. PM is classified on basis of size and chemical composition. The pollutants can be primary, if emitted directly or secondary, if formed in atmosphere. Fossil fuel and biomass combustion, automobile emissions, chemical plants, and industries are some of the man-made contributions to air pollution. Natural sources include wildfires, lightning, sea sprays, volcanoes, wind and dust storms, plants, and microbial activities. Spatial variations exist in levels and composition of pollutants with higher levels in urban areas and places near



Fig. 28.6 Alcohol

roads and industries. Seasonal and diurnal variations also exist. Outdoor air pollution causes lung cancer and is positively associated with cancer of urinary bladder. Particulate matter in outdoor air pollution also causes lung cancer (International Agency for Research on Cancer, World Health Organization 2016b).

28.4.6 Coal Combustion Indoor

When using small and simple combustion devices such as household cooking and heating stoves, coals are difficult to burn without substantial emission of pollutants

and a substantial fraction of the fuel carbon is converted to products of incomplete combustion. The products that are formed can be present in the gas phase, the particle phase, or both, depending on their volatility and include carbon monoxide, nitrogen dioxide, benzene, formaldehyde, PAHs, PM, and large number of compounds that are precursor components of photochemical smog, such as aldehydes. Coal also contains contaminants from its mineral deposits, such as sulfur, arsenic, silica, fluorine, lead, or mercury. During combustion, these contaminants are released into the air in their original or oxidized form. In households that use sulfur-rich coals, sulfur dioxide is present at elevated levels. Indoor emissions from household combustion of coal cause cancer of the lung (International Agency for Research on Cancer. World Health Organization 2012am).

28.4.7 Biological Agents

28.4.7.1 Epstein–Barr Virus (EBV)

EBV belongs to Lymphocryptovirus genus, gammaherpesvirus subfamily, and is a human herpesvirus with double-stranded DNA and linear genome. EBV-1 and EBV-2 are the two main types of EBV identified in humans (Sample et al. 1990). Humans are the only natural hosts for the virus, and route of transmission is oral via saliva. Transmission through transfusion has also been documented (de-Thé et al. 1975). Exposure is associated with socioeconomic factors (Evans 1971) like overcrowding, poor sanitation (de-Thé et al. 1975), and hygiene, low socioeconomic status, and larger family size. Age at primary infection differs worldwide and is responsible for resulting clinical manifestation. Primary infection during early childhood, common in developing countries due to overcrowding and practice of pre-chewing food for infants, is either subclinical or presents as respiratory illness, while if acquired during late childhood or adolescence, can manifest as infectious mononucleosis which is common in developed countries (Rickinson and Kieff 1996), where likely mode of transmission is intimate oral exposure (Hjalgrim et al. 2007). Infection with EBV causes Burkitt lymphoma, immunosuppression-related non-Hodgkin lymphoma, extranodal NK/T-cell lymphoma (nasal type), Hodgkin lymphoma, and cancer of the nasopharynx. Also, a positive association has been observed between exposure to EBV and lymphoepithelioma-like carcinoma (International Agency for Research on Cancer. World Health Organization 2012ae).

28.4.7.2 *Helicobacter pylori* (*H. pylori*)

Helicobacter belongs to Helicobacteraceae family and *Helicobacter* genus with about 23 validated species. Human species is *H. pylori*, gram-negative bacilli, which are spiral or slightly curved and have 2–6 unipolar flagella. It targets gastric mucus-secreting cells. Blood group antigen A is the main cell receptor responsible for its adherence to target cells. Once infection has occurred, it persists for life in the absence of treatment, and at the present, no vaccine is available. Global prevalence of *H. Pylori* infection is more than 50% but inter-country variations exist (Hooi et al. 2017), with prevalence being higher in developing countries with an exception of eastern European countries. Infection rates are also higher in older age groups (The

EUROGAST Study Group 1993) and differ by race/ethnicity and socioeconomic factors. Low socioeconomic status associated with unhygienic conditions, overcrowding, and large number of young children in home during childhood increases the risk of infection (Malaty and Graham 1994; Goodman et al. 1996). Humans are only significant reservoir of the bacteria (Oderda 1999). Primary route of transmission is person-to-person contact. Other possible routes are oral–oral, feco-oral, waterborne, and iatrogenic transmission. Chronic infection causes non-cardia gastric carcinoma and low-grade B-cell MALT gastric lymphoma. Esophageal adenocarcinoma is also linked with chronic infection; however, data is insufficient to confirm this association (International Agency for Research on Cancer. World Health Organization 2012af).

28.4.7.3 Human Immunodeficiency Virus (HIV) Type 1

It is a retrovirus, contains two copies of single-stranded RNA, belonging to the family Retroviridae, and is strongly associated with acquired immunodeficiency syndrome (AIDS). There were an estimated 38 million people living with HIV all over the world, with a prevalence of 0.7 among adults aged 15–49 years in the year 2019 (World Health Organization 2020c, d). The prevalence varies from 3.7 in African region to 0.1 in Eastern Mediterranean and Western Pacific region (World Health Organization 2020d). Natural hosts for virus are humans. Main routes of transmission are blood contact, sexual intercourse, and mother to child, and the probability of transmission is different for all these routes. Highest probability is for blood transfusion and mother-to-child transmission and lowest for heterosexual route. The use of condoms, mode of sexual exposure, viral load, stage of HIV infection, penile circumcision, co-existing other sexually transmitted diseases (STDs), and mucosal inflammation are all related to varying risk of sexual transmission with high viral load and genital ulceration being the major determinants. Blood contact can occur during blood transfusion, occupational exposure by needle stick injury or splash exposure to mucus membranes, and through intravenous (IV) drug use by sharing the needles. Regarding mother-to-child transmission, it has been observed that in the absence of any intervention, the transmission risk during in utero, intra-partum or breastfeeding, from HIV-positive mother to infant, ranges from 15% to 45% (World Health Organization 2020e). HIV-1 infection causes cancers of cervix, anus, conjunctiva, non-Hodgkin and Hodgkin lymphoma, and Kaposi sarcoma. Cancers of vulva, vagina, penis, hepatocellular carcinoma, and non-melanoma skin cancer are found to be associated with HIV-1 infection (International Agency for Research on Cancer. World Health Organization 2012aj).

28.4.7.4 Hepatitis B Virus (HBV)

This is a DNA virus belonging to family Hepadnaviridae, which consists of ten genotypes, which differ in virological characteristics and geographic distribution and infects only humans (Cao 2009).

It is highly infectious and gets transmitted through percutaneous and permucosal exposure to infected blood, semen, and vaginal fluids. Highest concentrations are found in blood and wound secretions and lowest in saliva (Margolis et al. 1997). It

does not spread by air, water, or food. Modes of transmission is similar to those for HIV-1, including mother-to-child, child-to-child, blood transfusion, unsafe injection practices, and sexual contact. Perinatal transmission mainly occurs during time of birth, in utero transmission is rare, and it does not spread by breastfeeding (Beasley et al. 1975). Child-to-child transmission occurs through contact of skin sores, breaks in skin or mucus membranes with blood or skin sore secretions (Margolis et al. 1997), through saliva by bites, skin breaks, or during pre-mastication of food (Scott et al. 1980; MacQuarrie et al. 1974; Williams et al. 1997; Beasley and Hwang 1983). Spread can also take place from fomites like towels and toothbrushes (Department of Health and Human Services. Centers for Disease Control and Prevention. Division of Viral Hepatitis 2010). Multiple sexual partners, prostitution, and unprotected intercourse are risk factors for sexual transmission. Infections can be acute symptomatic or asymptomatic and can progress to chronic infection. In 2015, an estimated 257 million people were living with chronic HBV infection, and more than half of the proportion of infections was contributed by African and Western Pacific regions (World Health Organization 2017). Less than 5% of people who are infected in adulthood develop chronic infections, and 25–30% chronically infected adults develop cirrhosis and/or liver cancer (World Health Organization 2020f). Around 45% world population lives in high endemicity areas for HBV chronic infection, 43% in moderately endemic, and 12% in low endemic areas (Mahoney 1999). Infection endemicity varies due to age at infection and modes of transmission. In high endemicity areas, infections are acquired perinatally or child-to-child, prevalence of liver cancer and cirrhosis is very high and acute infections are not common. In intermediate endemicity areas, pattern of transmission is mixed and infant, child, and adult transmissions co-exist, while in areas with low endemicity, infection is acquired during adolescence or young adulthood and is mainly confined to high-risk groups of IV drug users, homosexual men, healthcare workers, and patients having regular blood transfusions or dialysis (Hou et al. 2005). Chronic infection with HBV causes hepatocellular cancer either directly or indirectly through chronic necroinflammation known as cirrhosis and is observed to be associated with cholangiocarcinoma and non-Hodgkin lymphoma (International agency for Research on Cancer. World Health Organization 2012q).

28.4.7.5 Hepatitis C

Hepatitis C virus belongs to Flaviviridae family, hepacivirus genus, and contains six genotypes, which have different geographical distributions. Man, higher primates, and members of tree shrew genus are susceptible to infection (Shimizu et al. 1998; Sung et al. 2003; Pachiadakis et al. 2005). Transmission occurs through blood and blood products transfusion, organ transplants, unsafe injection practices, IV drug abuse, occupational exposures, and perinatal and sexual route, although the rate of transmission differs. Co-existing HIV infection increases the risk of perinatal transmission. The role of cosmetic procedures like tattooing and body piercing in transmission is not confirmed (Alter 2002; Hwang et al. 2006). About 15–27% of chronically infected people develop cirrhosis, and accelerated progression to severe liver disease is observed among males, late age at infection, alcohol intake, and

co-infection with HBV or HIV (Lauer and Walker 2001; Perz et al. 2006; Alter 2007). About 71 million people across the world were estimated to be living with chronic HCV infection in 2019 with highest prevalence of HCV being reported from Eastern Mediterranean and European region (World Health Organization 2017). It is responsible for hepatocellular carcinoma and non-Hodgkin lymphoma and is found to be associated with cholangiocarcinoma (International Agency for Research on Cancer. World Health Organization 2012ag).

28.4.7.6 Human Papillomavirus (HPV)

It belongs to Papillomaviridae family, double-stranded DNA virus, which infects only humans and mainly targets stratified epithelium of mucosa or skin. HPV 16 is the most common type out of all the HPV types. Infection peaks among women age less than 25 years and more than 45 years. Main mode of transmission is skin-to-skin or skin-to-mucosa contact, and major route is sexual transmission, while other routes include perinatal transmission and may be fomites or medical procedures. The use of condoms and circumcision is found to be protective, while having multiple sex partners elevates the risk (Burchell et al. 2006; Dunne et al. 2006). The role of smoking, oral contraceptive pills, age at first intercourse, other sexually transmitted infections (STIs), and parity is unclear. Persistent infection with carcinogenic types and re-infection with HPV-16 increases risk of cancer. HPV-16 causes cancer of cervix, vagina, vulva, anus, penis, oral cavity, tonsil, and oropharynx and is associated with laryngeal cancer. HPV-18 is responsible for cervical cancer and is found to be associated with cancer of penis, vulva, anus, larynx, and oral cavity. HPV 31, 33, 35, 39, 45, 51, 52, 56, 58, and 59 cause cervical cancer and are observed to be linked to vulvar and anal cancer (International agency for Research on Cancer. World Health Organization 2012r).

28.4.7.7 Human T-Cell Lymphotropic Virus Type 1 (HTLV-1)

It is a member of delta-type retrovirus group, and natural infection is only found in humans. Close to 20 million people were estimated to be infected with HTLV-1 (de Thé and Kazanji 1996). Prevalence is higher in women, in low socioeconomic strata, among people with history of blood transfusion and populations with low geographic mobility, and it increases with age. Main modes of transmission are vertical through breastfeeding, parenteral, and sexual. Breastfeeding for longer durations, unprotected intercourse, sexually transmitted diseases (STDs), multiple sexual partners, injecting drug use, and blood transfusions increase the risk. It causes adult T-cell leukemia and lymphoma with lifetime risk of development being 2–4% among carriers of infection, and time period for the development of cancer from initial infection is 40–60 years (International Agency for Research on Cancer. World Health Organization 2012e).

28.4.7.8 *Opisthorchis viverrini* (*O. viverrini*) and *Clonorchis sinensis* (*C. sinensis*)

Both of them belong to same genus *Opisthorchis* but different species. Humans and other fish-eating mammals like dogs and cats are definite hosts (Wang 1983;

Harinasuta 1984; Rim 2005; Lun et al. 2005). Freshwater snails are first intermediate hosts, and fishes are secondary intermediate hosts. Humans and other mammals are infected by eating raw or undercooked freshwater fish containing infective form of fluke. Adult flukes reside in biliary system. Poor educational status, lack of sanitation resulting in sewage drainage into water bodies, use of animal or human feces as fertilizer, contamination of dinner sets from infected fish, and non-existent control measures are the factors associated with transmission. *C. sinensis* can survive up to 26 years (Attwood and Chou 1978) and *O. viverrini* up to 10 years in humans (Harinasuta 1984). Globally about 45 million people are infected with these flukes combined with 35 million from *C. sinensis* and rest ten million from *O. viverrini*. Chronic infection with both of these flukes causes cholangiocarcinoma (International Agency for Research on Cancer. World Health Organization 2012f).

28.4.7.9 Schistosoma Hematobium

These are parasitic flukes of genus *Schistosoma* of which six species are of main pathological importance to humans (Webster et al. 2006). The intermediate host is freshwater snail, and definite host is human. When human host comes in contact with water-containing larva, the larva penetrates the skin, reaches liver, and matures into adult worms which produce eggs. Half of the produced eggs get trapped in tissues of urinary bladder. Life span of adult worm can range from 3 to 40 years (Warren et al. 1974; Chabasse et al. 1985). Infection subsides with death of adult worm, but in endemic areas re-infection occurs frequently. It is mostly found in rural areas in natural ponds, streams, and lakes; however, due to population growth, migration, and creation of man-made reservoirs and irrigation systems, urban infection is also on rise (Mott et al. 1990; McManus and Loukas 2008). Man–water contact behavior and snail population can affect focal distribution. Infection peaks in age group of 5–15 years, and there are gender differences due to behavioral, cultural, religious, and professional factors (Jordan and Webbe 1993). Schoolage children, fishermen, irrigation workers, farmers, women, and other groups using infested water for domestic use are the main risk groups (World Health Organization 2020g). Co-infection with hepatitis, climatic conditions, and household clustering increases the risk. Chronic infection with this fluke causes cancer of the urinary bladder (International Agency for Research on Cancer. World Health Organization 2012ai).

28.4.7.10 Kaposi Sarcoma Herpes Virus (KSHV)

This is a gamma 2 herpes virus with double-stranded DNA genome, and natural hosts are humans. Primary route of transmission is through saliva, and other reported routes are blood transfusion, organ transplantation, and IV drug use. Infection peaks at age of 6–10 years (Whitby et al. 2000; Mbulaiteye et al. 2004). Risk factors are infection in mothers or other family members, HIV infection, number of sexual partners, source of water, and insect bites (Plancoulaine et al. 2000; Coluzzi et al. 2003; Dedicoat et al. 2004; Mbulaiteye et al. 2005; Malope et al. 2007; Minhas et al. 2008). Many co-factors act along with KSHV to cause cancer including HIV co-infection and other immunodeficient states. Other suggested co-factors are malaria and other parasitic infections, exposure to onco-weeds, and fine volcanic

soils (Ziegler 1993; Serraino et al. 2003; Whitby et al. 2007; Lin et al. 2008). It causes Kaposi sarcoma and primary effusion lymphoma (International Agency for Research on Cancer. World Health Organization 2012ah).

28.4.8 Radiation

28.4.8.1 X-Ray and Gamma Radiation

X-rays and gamma rays are electromagnetic radiations, which differ in their origin and energies with gamma rays having highest energy. Exposure to these rays can be through naturally via terrestrial sources including soil and building materials (UNSCEAR), medical uses, nuclear explosions and accidents, nuclear weapon production, nuclear power production, and occupational exposures during industrial operations, military activities, flying and medical procedures and nuclear power production and recycling of fuel (UNSCEAR). In medical field, these are used for diagnosis and radiotherapy. Even though dose for diagnostic procedures is lower than therapeutic dose, diagnostic procedures are main source for exposure in medical use. With increasing use of computed tomography (CT), interventional radiology, and other diagnostics, the level of exposure due to medical use is increasing (Fig. 28.7). Fluoroscopy delivers higher doses than radiography. These radiations cause cancer of esophagus, salivary glands, stomach, colon, lung, kidney, female breast, basal cell of skin, bone, urinary bladder, brain and CNS, thyroid, and leukemia except chronic lymphocyte leukemia (CLL). In utero exposure is also carcinogenic. Cancer of rectum, pancreas, liver, ovary, prostate, non-Hodgkin lymphoma, and multiple myeloma are associated with their exposure (International Agency for Research on Cancer. World Health Organization 2012n).



Fig. 28.7 X-ray and CT machines

28.4.8.2 Solar Radiation and Ultraviolet Radiation (UVR)

Solar radiation is mainly optical radiation and consists of infrared, visible light, and ultraviolet radiations. About 5% of terrestrial radiation is UV radiation. UV component of terrestrial radiation from midday sun comprises 95% UVA and 5% UVB. Major part of UVB and UVC from extra-terrestrial radiation is removed by ozone in stratosphere. Air pollutants and tropospheric ozone can decrease UVR. Clouds also attenuate solar radiation. During summers, about 75% of total daily amount of UVR is received between 9:00 and 15:00 sun time and about 20–30% between 11:00 and 13:00 sun time. Seasonal variation occurs in temperate regions, and annual exposure dose of UVR decreases with increasing distance from equator. Total solar irradiance and contribution by different wavelength radiations vary with altitude. With increasing altitude, sun burning effectiveness of sunlight increases. Two-thirds of sun's energy entering into atmosphere penetrates the ground, and reflection from certain ground surfaces may contribute significantly to total amount of scattered UVR. Contribution from surface reflection varies with type of surface with grass lawn scattering 2–5%, sand reflecting 10–15%, fresh snow 80–90%, and white foam in sea about 30%.

Artificial sources of exposure can increase annual cumulative exposure. Indoor tanning devices emit both UVA and UVB. UVB phototherapy is used in the treatment of many dermal conditions. Hospital staff working with unenclosed phototherapy equipment have potential exposure risk if protective measures are not taken. Electric arc welders may get acute ocular overexposures.

Solar radiation causes squamous cell carcinoma of skin, basal cell carcinoma of skin, and cutaneous malignant melanoma. Positive association has been found with lip cancer, ocular melanoma, conjunctival squamous cell carcinoma. UV-emitting tanning devices cause ocular melanoma and cutaneous malignant melanoma. UV-emitting tanning devices cause ocular melanoma and cutaneous malignant melanoma and positive association has been found with squamous cell carcinoma of skin (International Agency for Research on Cancer. World Health Organization 2012m). Other radioactive carcinogens are mentioned in Table 28.1.

28.4.9 Toxins: Aflatoxins

Aflatoxin B, G, mycotoxin cyclopiazonic acid and M1, a metabolite of aflatoxin B1, are the important toxins responsible for carcinogenesis. *Aspergillus flavus* and *A. parasiticus* are the major fungus that produce largest proportion of aflatoxins found in foodstuffs across the globe. Another fungus *A. australis* also produces aflatoxins, but is limited in its geographic distribution to southern hemisphere and Australian peanut soils. Maize, peanuts, and cottonseeds are the chief hosts for *A. flavus*, and spices and tree nuts are less commonly affected. However, small amounts of aflatoxins may be detected in other foods. *A. parasiticus* has similar food hosts except maize. *Aspergillus* invades plants and developing seed or nut of maize, cottonseed, and peanuts before harvest which results in high levels of toxins in them which are difficult to eliminate. Other crops can be protected from aflatoxin

Table 28.1 Other radioactive agents, their exposure, and cancers caused by them (International Agency for Research on Cancer. World Health Organization 2012)

Carcinogen	Use and exposure	Cancer
Plutonium-239	Used in production of nuclear weapons and mixed oxide fuels. Most commonly exposed group is people working in production of these weapons and fuels. Other people get exposed due to accidents.	Bone, lung, and liver
Thorium-232 and its decay products	Used as a radiographic contrast agent in medical practice in form of thorotrast. Miners can also be exposed.	Gallbladder, liver, extrahepatic bile ducts, leukemia except CLL. Associated with pancreatic and prostatic cancers.
Radium-224/226/228 and its decay products	Major exposure is found in radium watch-dial painters due to practice of pointing the tip of paintbrush by lips. Other exposed groups include patients suffering from tuberculosis, ankylosing spondylitis, and other diseases treated with high doses of injected Radium 224. Radium has been found in drinking water also.	Bone sarcomas. Radium 226 additionally causes cancer of paranasal sinuses and mastoid process.
Radon-222 and its decay products	Natural radioactive gas present in small quantities in rocks and soils. Underground miners are at elevated risk for exposure. Indoor radon exposure is also observed.	Lung cancer. Positive association with leukemia.
Fission products including Strontium-90	Gets deposited in environment and food products due to release from nuclear facilities and in water due to discharge of nuclear waste into rivers.	Leukemia, solid cancers.
Radioiodine including Iodine-131	Atmospheric nuclear weapon tests, routine, or accidental releases from nuclear power plants, and nuclear weapon production facilities are the sources. Radioactive iodine is used in medical settings for treatment of thyrotoxicosis and thyroid cancer.	Exposure to short-lived radioisotopes of iodine including I-131 during childhood and adolescence causes thyroid cancer, and risk enhances if children are iodine deficient at time of exposure. Positive association is found with cancer of salivary gland, digestive tract, bone, and soft tissue sarcoma and leukemia.
Phosphorous-32 as Phosphate	Pure beta particle emitter. Used for polycythemia vera.	Acute leukemia in patients with polycythemia vera.
Neutron radiation	Exposure group includes atomic bomb survivors, who were exposed to fission neutrons, nuclear workers, and airline crew. It is also used in treatment for many cancers.	NA Inadequate evidence among humans.

production by eluding the post-harvest contamination through drying and good storage practices. Aflatoxin M1 is found in milk of animals who feed on foods containing aflatoxin B. Exposure occurs through diet and occupational sources. Consumption of maize and peanuts as dietary staples can result in daily intakes ranging from nanograms to micrograms. Levels of aflatoxins in food products mainly depend on food type, source, storage conditions, and climate. Occupational exposure occurs while handling and processing of contaminated grains and animal feed, and toxins are found to be present in workplace air samples also. These toxins cause hepatocellular carcinoma in humans (International Agency for Research on Cancer. World Health Organization 2012g).

28.4.10 Hormones and Chemotherapeutic Agents

28.4.10.1 Oral Contraceptive Pills (OCPs)

Combined OCPs contain estrogen, along with progestogen to prevent pregnancy. Other therapeutic purposes include treatment for acne and premenstrual disorders. They are usually given in a monthly cycle in which pill is taken for about 20–22 days, followed by pill-free interval of 7 days to allow for withdrawal bleeding. Emergency contraceptives contain a comparatively high dose of estrogen (Fig. 28.8). Apart from oral preparations, transdermal formulations and intravaginal contraceptive rings are also available. There were about 151 million users of OCPs containing either estrogen and progestogen combination or progestogen alone for contraception in the year 2019, and the number of users varies within countries (Department of Economic and Social Affairs. United Nations 2019). The use of OCPs, especially those containing high doses of estrogens, causes hepatocellular carcinoma, breast cancer, and in situ and invasive cancer of uterine cervix. However, a protective effect against ovarian, colorectal, and endometrial cancer has also been observed. Progestogen-only contraceptives are possible human carcinogen as evidence is insufficient at present (International Agency for Research on Cancer. World Health Organization 2012ap).



Fig. 28.8 Progesterone only and combined OCPs

28.4.10.2 Estrogen Menopausal Therapy (EMT)

The use of estrogen alone for women during time around menopause to treat menopausal symptoms and prevent conditions like osteoporosis and ischemic heart disease, which are common in postmenopausal period, is classified as postmenopausal estrogen therapy. It can be given orally, through injections, transdermally, by implants, or can be applied locally and topically to relieve urogenital symptoms. Combinations with an androgen or an anxiolytic are also commercially available. Dose of estrogens varies according to indication and route of administration. Treatment for climacteric symptoms usually starts in peri-menopausal period and commonly lasts from 2 to 5 years. Treatment for other conditions can last for 10 or more years. This causes cancer of endometrium and ovary and is found to be associated with breast cancer. However, a protective effect against colorectal cancer is also observed (International Agency for Research on Cancer. World Health Organization 2012k).

28.4.10.3 Estrogen-Progestogen Menopausal Therapy

Progestogen along with estrogen is commonly used globally for conditions mentioned in section J.2. It was initiated because of two main reasons, firstly due to increasing incidences of endometrial cancer and secondly to better control uterine bleeding, among postmenopausal women with intact uterus on EMT. Treatment regimen can consist of daily administration of estrogen with intermittent, periodic, or daily progestogen administration. Indications are similar as for EMT. Combined therapy causes cancer of breast and endometrium (International Agency for Research on Cancer. World Health Organization 2012j). Other chemotherapeutic carcinogens are mentioned in Table 28.2.

28.4.11 Dusts and Fibers

28.4.11.1 Asbestos (All Forms)

Asbestos is a naturally occurring mineral silicate fiber. It is used in flooring, roofing, friction materials, gaskets, cement pipes and sheets, electrical and thermal insulation, paper, plastics, textiles, mastics, thread, fiber jointing, coating and compounds and millboard. It can be found in nature as large natural deposits or as contaminants in other minerals. Mining, milling of ore, screening, crushing, manufacture and use of asbestos products, demolition of buildings containing asbestos products and transport and disposal of asbestos-containing waste lead to release into air. Water contamination occurs through rock erosion, asbestos-containing waste pile erosion, wastewater run-off from industries, corrosion of asbestos cement pipes, and annihilation of roofing made up of asbestos. In similar ways, soil can also be contaminated through rock erosion and dumping asbestos-containing waste into landfills. Exposure to humans occurs through ingestion and inhalation. Occupational exposures are common among mine workers and asbestos-manufacturing industries' workers. Fibers on hair or clothing can be carried to home and expose family members of these workers. Asbestos causes mesothelioma and cancer of lung, larynx, and ovary

Table 28.2 Other chemotherapeutic agents, their use, and cancers caused by them (International Agency for Research on Cancer. World Health Organization 2012i)

Carcinogen	Uses	Cancer
Diethylstilbestrol (non-steroidal synthetic estrogen)	Prevention of abortions, treatment of menopausal symptoms, atrophic vaginitis, vulvar dystrophy, female hypogonadism, dysfunctional menstrual cycles, emergency contraceptive, prevention of postpartum breast engorgement, and as a livestock growth stimulant. Rarely in breast and prostate cancer.	Positive association with endometrial cancer. Exposure during pregnancy causes breast cancer women. In utero exposure causes vaginal cancer and cervical clear cell adenocarcinoma and is associated with squamous cell cancer of cervix and testicular cancer.
Tamoxifen	Prevention and treatment of breast cancer among women, treatment of breast cancer among males and for anovulatory infertility.	Endometrium. Protective against breast cancer among women.
Cyclosporine	Used in organ and tissue transplantation, for prevention of graft rejection, prophylaxis, and treatment of graft-versus-host disease, treatment of chronic allograft rejection, management of severe rheumatoid arthritis, psoriasis, atopic dermatitis, to increase tear production.	Skin (squamous cell carcinoma), cancer at multiple other sites, and non-Hodgkin lymphoma
Mechlorethamine, oncovin, procarbazine, prednisone (MOPP)	For treatment of Hodgkin lymphoma	Lung, AML
Semustine [1-(2-Chloroethyl)-3-(4-methylcyclohexyl)-1-nitrosourea, Methyl-CCNU	Treatment of primary and metastatic brain tumors, Lewis lung tumor, L1210 leukemia, cancers of digestive tract, Hodgkin lymphoma, malignant melanoma, and epidermoid carcinoma of lung.	Acute myeloid leukemia
Chlorambucil	Treatment of CLL, Waldenstrom macroglobulinemia, indolent non-Hodgkin lymphoma, Hodgkin lymphoma, polycythemia vera.	Acute myeloid leukemia
Treosulfan	Treatment of ovarian cancer, malignant melanoma, and breast cancer. Used for bone marrow ablation before stem cell transplantation.	Acute myeloid leukemia

(continued)

Table 28.2 (continued)

Carcinogen	Uses	Cancer
Methoxsalen (8-methoxypsoralen) plus ultraviolet A radiation	Produced naturally by various plants (celery, figs, limes, parsnips). Used in psoriasis, cutaneous T-cell lymphoma, idiopathic vitiligo, chronic graft-versus-host disease, treatment of rejection after solid organ transplantation.	Skin (squamous cell carcinoma)
Melphalan	Treatment of multiple myeloma, advanced ovarian adenocarcinoma, childhood neuroblastoma, early and advanced breast cancer, polycythemia vera, regional arterial perfusion in localized malignant melanoma, and localized soft tissue sarcoma of extremities.	Acute myeloid leukemia
Busulfan	For palliative treatment of chronic myelogenous leukemia, polycythemia vera, in myelofibrosis, primary thrombocytopenia and in conditioning regimen to prepare patients for stem cell transplantation.	Acute myeloid leukemia.
Thiotepa	Treatment of residual tumors, as adjuvant therapy for prophylaxis of superficial bladder cancer, palliative treatment of adenocarcinoma of the breast and ovary, to control pleural, pericardial, or peritoneal effusions caused by metastatic tumors.	Leukemia
Cyclophosphamide e	In treatment of several malignant diseases, CLL, Lymphoma, soft tissue, estrogenic sarcoma, solid tumors.	Bladder and acute myeloid leukemia
Chlornaphazine	Treatment of Hodgkin lymphoma, control of polycythemia vera.	Urinary bladder
Azathioprine	Prevention of rejection of kidney allografts, management of rheumatoid arthritis, acute lymphocytic leukemia.	Skin cancer (squamous cell carcinoma) and non-Hodgkin lymphoma

(continued)

Table 28.2 (continued)

Carcinogen	Uses	Cancer
Etoposide + cisplatin + bleomycin	Treatment of tumors of the testis, small cell cancer of the lung, and in acute leukemias.	Acute myeloid leukemia.
	Bleomycin malignant disease particularly squamous cell carcinomas, including those of the cervix and external genitalia, esophagus, skin, and head and neck; Hodgkin lymphoma and other lymphomas; malignant neoplasms of the testis and malignant effusions. In carcinoma of the bladder, lung, and thyroid, and some sarcomas, including Kaposi sarcoma. Cisplatin treat metastatic ovarian tumors, cervical tumors, lung cancer, advanced bladder cancer, and squamous cell carcinoma of the head and neck.	
Phenacetin	As an analgesic and antipyretic for humans and animals, stabilizer for hydrogen peroxide in hair-bleaching preparations.	Renal pelvis, Ureter.

and has positive associations with cancer of stomach, pharynx, and colorectum (International Agency for Research on Cancer. World Health Organization 2012b).

28.4.11.2 Silica Dust

It is available commercially in three categories, namely sand and gravel, diatomites, and quartz crystals. Silica is used in glass manufacture, foundry, ceramics, hydraulic fracturing applications and abrasives, as a gemstone jeweler, in electronics and optical components industry, in pesticides, paints and polishes, in insulators, packing material, and in filtration. Silica is present in rocks and soil and gets released into environment by natural and anthropogenic activities. Exposure route for humans is through inhalation from quartz-containing products like cosmetics, cleansers, talcum powder, mortar, paint, putty, caulk, art clays, and glazes. Ingestion of quartz particle-containing potable water can also lead to exposure. Workers working in mining, construction, farming, quarrying, demolition of masonry and concrete, production of ceramics, glass, foundry processes, etc., get occupational exposure to silica dust. This dust causes lung cancer (International Agency for Research on Cancer. World



Fig. 28.9 A carpenter being exposed to wood dust

Table 28.3 Dust and fiber agents, their exposure, and cancers caused by them (International Agency for Research on Cancer. World Health Organization 2012a)

Carcinogen	Exposure	Cancer
Erionite	Naturally occurring, found in sediments of volcanic tuffs which contributes to non-occupational exposure. Occupational exposure through mining and production.	Mesothelioma
Leather dust	Occupational exposure occurs in footwear industry and leather tanning and processing industry.	Nasal cavity and paranasal sinuses
Wood dust	Occupational exposure among workers involved in various wood-related industries like furniture, plywood, logging, sawmills, and particleboard manufacture (Fig. 28.9). Highest exposure in construction sector and furniture industry. General population gets exposed by woodworking during repair and building works in homes but duration of exposure is usually short.	Nasal cavity, paranasal sinuses, and nasopharynx

Health Organization 2012c). Other dust and fiber carcinogens are mentioned in Table 28.3.

28.4.12 Metals

Many metals have been classified as human carcinogens by IARC. Metals naturally occur in environment in mineral rocks, soils, volcanic eruptions or are produced in industries for various uses. Natural activities like winds, volcanic activity, weathering of rocks, leaching into soil, and water usually takes place and contaminates water, air, and vegetation. Anthropogenic activities like mining, burning of fossil fuels, smelting, waste incineration, and effluents from industries are other major sources of environmental contamination. Usual route of exposure for general public is ingestion and inhalation. Occupational workers employed in industries producing and using these metals get exposed through inhalation, ingestion, and dermal route.

28.4.12.1 Arsenic

Arsenic is commonly being used in wood preservatives, pharmaceuticals, glass-making industry, agricultural chemicals, and mining, semiconductor, and metallurgical industries. In medicine, it was used for treatment of leukemia, chronic bronchial asthma, psoriasis, and in some antibiotics. Agricultural pesticides, herbicides, defoliants, cotton desiccants, insecticides, feed additives for swine and poultry, etc., contain arsenic. Contamination of soil, air, and water occurs naturally by volcanic activity, windblown dusts, exudates from vegetation, low-temperature volatilization and by anthropogenic sources through burning of fossil fuels, mining and smelting of non-ferrous metals, and use of arsenic-based pesticides. It is found in air in industrial, urban, and suburban areas, in deep well, and other sources of oxygenated water, as contamination in groundwater and soil. Highest arsenic content has been found in seafood, meats, poultry, cereals, dairy products, fruits, and vegetables. Arsenic compounds cause cancer of the lung, urinary bladder, and skin (International Agency for Research on Cancer. World Health Organization 2012d).

28.4.12.2 Chromium

It is used as pigment for textile dyes, paints, inks, and plastics, in corrosion inhibitors, wood preservatives, metal finishing, chrome plating, leather tanning, and as an impurity in Portland cement. It can be generated during casting, welding, and cutting operations. Anthropogenic activities and leaching of wastewater cause contamination of the drinking water. Tobacco smoke also contains chromium. The general population residing in the vicinity of anthropogenic sources of chromium (VI) may be exposed through inhalation of ambient air or ingestion of contaminated drinking water. Its compounds cause lung cancer, and positive associations have been observed with cancer of nose and nasal sinuses (International agency for Research on Cancer. World Health Organization 2012p). Other carcinogenic metals are shown in Table 28.4.

Table 28.4 Carcinogenic metals, their uses, and cancer caused by them (International Agency for Research on Cancer. World Health Organization 2012a)

Carcinogen	Uses	Cancer
Beryllium	Used in industries of aerospace, automotive, defense, biomedical, fire prevention, energy and electrical, sporting goods, telecommunications, manufacturing, consumer products, scrap recovery, and recycling.	Lung
Cadmium	Used in batteries, pigments, coatings, and plating and stabilizer in plastic.	Lung. Positive association with cancer of kidney and prostate.
Nickel	Used in electroplating, ceramics, pigments, in manufacture of alloy steel and stainless steel, manufacture of nickel-cadmium and nickel-metal hydride batteries, in petrochemical and metallurgical industry.	Lung, nasal cavity and paranasal sinuses.

28.4.13 Occupational Exposures

28.4.13.1 Painting

Paint contains finely divided pigment particles, dyes, fillers, a binder or resin, a volatile solvent or water, and some additives. The solvents include xylene, toluene, alcohols, ketones, aliphatic compounds, esters, and glycol ethers. Pigments can be chromate, azo-based, or lead-based, and the most common pigment is white titanium dioxide and carbon black. Azo-based pigments were found to have 2-naphthylamine, benzidine, 4-aminobiphenyl, and 4-chloro-ortho-toluidene. Resins include cellulose-based, vinyl, acrylic, alkyd, phenolic, polyester, polyurethane, silicone oils, styrene-butadiene, and chlorinated rubber derivatives. Solvents encompass a wide range of petroleum and coal tar distillates, esters, glycols, alcohols, glycols, and a broad range of chemical mixtures. Additives include plasticizers, rheological agents, driers, biocides, surfactants, anti-skinning agents, corrosion inhibitors, defoamers, and UV stabilizers. Workers employed in painting industry get exposure to all the abovementioned chemicals through inhalation, dermal route, and ingestion during their production, application, removal, stripping from wood and metal surfaces. Exposure to silica, asbestos, and diisocyanate is also a probability as painters may get exposed by being a bystander to construction and demolition activities. Occupational exposure as a painter causes mesothelioma, lung, and urinary bladder cancer. A positive association has been observed with maternal exposure during pre-conception and pregnancy with childhood leukemia in the child (International agency for Research on Cancer. World Health Organization 2012z).

28.4.13.2 Welding

The process of joining metals through coalescence is called welding which can be classified as arc or gas welding, depending on the method used to generate arc. Arc welding uses electricity, while gas welding uses acetylene or hydrogen. Other processes which are closely related to welding and usually performed by welders



Fig. 28.10 Welding process

include flame cutting, brazing, gouging, soldering, and plasma arc or carbon arc cutting. Sheet metal workers, blacksmiths, mechanics, toolmakers, firefighters, etc., are also exposed to welding fumes. It has been estimated that number of people exposed to welding fumes might be 10 times more than the number of occupationally designated welders. The welding process involves exposure to gases, fumes, ionizing and non-ionizing radiation, and co-exposures to asbestos and solvents (Fig. 28.10). Gases encountered during welding comprise argon, carbon dioxide, helium, acetylene, propane, butane, ozone, carbon monoxide, hydrogen fluoride, and nitrogen oxides. Fumes consist of silicates, metal oxides, chromium, nickel, and fluorides. Concentration of welding fumes varies according to type of welding process, presence of coatings, metal welded, arc time, and personal and workplace characteristics. Inhalation is the main route of exposure. Welding fumes cause lung cancer and are associated with kidney cancer, while UV radiation from welding is causative for ocular melanoma (International Agency for Research on Cancer. World Health Organization 2018d). Other occupational exposures and cancers caused by them are mentioned in Table 28.5.

28.4.14 Chemicals

28.4.14.1 Benzene

Benzene is used in manufacture of organic chemicals like phenol, styrene, aniline, alkylbenzenes, etc. It is naturally present in petroleum products and added to unleaded gasoline. It is also used as an ink component in printing industry, in chemical and drug industries, rubber, plastics, dye, detergent, lubricants, and pesticides manufacture. Occupational exposure occurs while working in these industries and while crude-oil refining. Workers employed at service stations involved in transport and dispensing of gasoline, street workers, taxi drivers, etc.,

Table 28.5 Occupations, implicated exposures, and cancers caused by them (International agency for Research on Cancer. World Health Organization 2012s)

Occupation	Exposed to	Cancer
Aluminum production	PAHs, sulfur dioxide and fluorides, aluminum fluoride, fibrous sodium aluminum tetrafluoride particles, fluorspar, alumina, carbon monoxide, carbon dioxide, various trace metals, such as vanadium, chromium and nickel, asbestos, extreme heat, and high static magnetic fields.	Bladder and lung
Auramine production	Dimethyl-aniline, formaldehyde, sulfur, ammonium chloride, ammonia, benzidine, 1-naphthylamine, 2-naphthylamine, magenta, aniline.	Urinary bladder
Hematite mining (International agency for Research on Cancer. World Health Organization 2012o)	Radon	Lung
Coke production	PAHs, asbestos, silica, amines, arsenic, cadmium, lead, nickel, vanadium, hydrocarbons, sulfur dioxide, sulfuric acid, and aldehydes.	Lung
Isopropyl alcohol production	Propylene, sulfuric acid, isopropanol, diisopropyl and isopropyl hydrogen sulfates, diisopropyl ether, propanal, acetone, sulfur oxides, polymeric oils, and residues.	Nasal cavity
Magenta production	Aniline, ortho- and para-toluidine arsenic acid, benzidine, 1-naphthylamine, 2-naphthylamine, auramine.	Urinary bladder
Graphite and silicon carbide synthesis work with Acheson process (International Agency for Research on Cancer. World Health Organization 2017c)	Fibrous silicon carbide	Lung
Coal gasification	PAHs, asbestos, silica, amines, arsenic, cadmium, lead, nickel, vanadium, hydrocarbons, sulfur dioxide, sulfuric acid, and aldehydes.	Lung

(continued)

Table 28.5 (continued)

Occupation	Exposed to	Cancer
Coal tar distillation	Benzene, toluene and xylene isomers, tri- and tetra-methylbenzenes, indene, hydrindene, coumarone, phenol, cresols, pyridine, picolines, methylpyridines, dimethylpyridines, naphthalene, thionaphthene, indene, methyl-naphthalene isomers, biphenyl, acenaphthene, fluorine, anthracene, phenanthrene, pyrene, fluoranthene, PAH.	Skin (including, but not limited to, cancer of the scrotum).
Iron and steel founding	Silica, carbon monoxide, PAHs, chromium, nickel, phenol, formaldehyde, isocyanates, and various amines	Lung
Rubber production	<i>N</i> -nitrosamines, polycyclic aromatic hydrocarbons, solvents, and phthalates, cyclohexane-soluble compounds.	Leukemia, lymphoma, cancer of urinary bladder, lung, and stomach. Positive association with cancer of prostate, esophagus, and larynx.
Chimney sweep workers	Soot, sulfur dioxide, arsenic, organic solvents, PAHs and their derivatives, oxides, salts, metals, sulfur and nitrogen compounds, water, and other adsorbed liquids and gases.	Skin (observed in the scrotum), and lung.

**Fig. 28.11** Petrol filling stations

also get exposed. Benzene contaminates environment mainly through release from industries, gasoline filling stations, and automobile exhaust (Fig. 28.11). General population get exposed through air having tobacco smoke or contaminated with

benzene in heavy traffic areas and near gasoline filling stations, through contaminated water or eating contaminated food. Benzene causes acute myeloid leukemia and acute non-lymphocytic leukemia and is found to be associated with multiple myeloma, acute and chronic lymphocytic leukemia, and non-Hodgkin lymphoma (International agency for Research on Cancer. World Health Organization 2012u).

28.4.14.2 Formaldehyde

It is mainly used in production of resins that are further used in wood production, synthetic fiber industries, pulp and paper industry, production of plastics and coatings, paints, varnishes, and in textile finishing. It is also used in manufacture of many other chemicals. Formalin, an aqueous solution of formaldehyde, is used as a disinfectant and preservative. Formaldehyde naturally occurs in environment, fruits, and some foods and is produced in humans and other mammals. It is produced from motor vehicle emissions, tobacco smoke, and combustion processes in incineration plants, power plants, wood stoves, refineries, and kerosene heaters. Formaldehyde can be absorbed from skin from cosmetics and other consumer products. These together constitute occupational and non-occupational exposure to this chemical. It causes cancer of nasopharynx and leukemia and has positive association with sinonasal cancer.

28.4.14.3 Vinyl Chloride

Its main use is in manufacture of polyvinyl chloride for plastic piping. Vinyl chloride is also utilized in many consumer goods, transport sector, floor coverings, electrical applications, cosmetics, drugs, manufacture of solvents, and resins. Environmental sources include emissions and effluents from plastic industry, accidental releases, mainstream tobacco smoke, and in landfill gas and groundwater due to degradation of solvents deposited in landfills. It causes hepatocellular carcinoma and angiosarcoma of liver (International agency for Research on Cancer. World Health Organization 2012x).

28.4.14.4 Sulfur Mustard

This compound exists in gaseous form and is used in biological studies, in medicine for psoriasis treatment and in wars. It was used in past as antineoplastic agent, but was a failure. Occupational exposure occurs during its storage and destruction, construction work on soils having mustard gas deposits as contaminants in military bases, in excavated ammunition dumps, during fishing due to marine dumping of the gas in past, in laboratories, and during armed conflicts. It can contaminate water and air also, thereby exposing general population. Sulfur mustard causes lung cancer and is positively correlated with laryngeal cancer (International agency for Research on Cancer. World Health Organization 2012ab).

28.4.14.5 Trichloroethylene

It is mainly used as a cleaning and degreasing agent for metal parts in industries of furniture and fixture, fabricated metal products, transport equipment, electric and

electronic equipment, and miscellaneous manufacturing industries. Trichloroethylene is also used as an anesthetic, production of chlorofluorocarbons and other chemicals, in spotting agents to remove spots from garments, in plastics, paper, printing and glass, textiles, in waterless dyeing, as an extraction agent for fats and oils, paint-related products and lubricants, etc. Industrial emissions are the main source of environmental contamination. Occupational exposure is primarily through degreasing. It causes cancer of kidney and has been found to be associated with liver cancer and non-Hodgkin lymphoma (International Agency for Research on Cancer. World Health Organization 2014c).

28.4.14.6 Ethylene Oxide

Ethylene oxide is used for production of mono-ethylene glycol, as a sterilizing agent for drugs, hospital equipment, disposable and reusable medical items, foods, packaging materials, museum artifacts, books, furs, clothing, scientific equipment, aircraft, railcars, beehives, etc., and as an insecticide and fumigant. It is also found in mainstream tobacco smoke, fossil fuel combustion smoke, skincare products and as a residue in spices, and other food products which are main exposure sources for general population. Hospital patients get exposed through medical equipment during dialysis. Evidence establishing causal association of its exposure with lymphatic and hematopoietic cancers and breast cancer is limited among humans (International agency for Research on Cancer. World Health Organization 2012w).

28.4.14.7 1,3 Butadiene

This chemical is used in synthetic rubber and polymer production, which are used in endless products like clothing, automobiles, computers, packaging, etc. It is also used in production of many petrochemicals. Exposure occurs among workers employed in these operations. Although butadiene is present widely in ambient air, elevated levels occur in proximity to wood and bush fires, municipal structural fires, vehicle emissions, cigarette smoking, and gasoline volatilization. It causes cancer of hematolymphatic organs (International agency for Research on Cancer. World Health Organization 2012t).

28.4.14.8 Benzo[a]pyrene and Other Polycyclic Aromatic Hydrocarbons (PAHs)

These are the contaminants present ubiquitously in environment including air, water, soil, and food. Major sources include incomplete combustion or pyrolysis of organic material, tobacco smoke, coal tar-based pharmaceutical products, motor vehicle exhaust, residential and commercial heating with coal, wood, or other biomass, industrial emissions, and forest fires. Barbecued/boiled/grilled and smoke-cured meats, baked, fried and roasted foods, cereals, grains, bread, and vegetables grown in contaminated soil lead to food-borne exposure to PAHs (Fig. 28.12). Occupational exposure occurs in coal and coke industries, power plants, during aluminum production, roofing and paving, chimney sweeping, wood impregnation with creosote, and carbon electrode manufacture. It is a confirmed human carcinogen (International agency for Research on Cancer. World Health Organization 2012v).



Fig. 28.12 Barbequed food and biomass fuel combustion

28.4.14.9 Mineral Oils, Untreated or Mildly Treated

These oils are refined from crude petroleum oils and contain aromatic hydrocarbons. They can be used as lubricant in engine oils, gear oils, transmission fluids, metal-working fluids, hydraulic fluids and as non-lubricant in printing inks, agricultural spray oils, and tyre oils. Both these applications are potential generators of oil aerosols, leading to occupational exposure. These are also used in food and pharmaceutical preparations, which expose general population to mineral oils. Untreated or

mildly treated mineral oils cause cancer of the skin (observed in the scrotum) (International agency for Research on Cancer. World Health Organization 2012y).

28.4.14.10 Fluoro-Edenite

These are the fibers, existing naturally in quarries in volcanic areas and thereby contaminating environment naturally. They are used in building materials and unpaved roads which lead to their release into air and water. General population living near quarries is exposed through inhalation. Quarry and construction workers' exposure contributes to occupation sources of exposure. It causes mesothelioma (International Agency for Research on Cancer. World Health Organization 2017b).

28.4.14.11 Shale Oils

These have been used in paraffin waxes, burning oil for lamps, for medicinal purposes, to prepare gasoline, diesel oils, lubricants, kerosene, coke, gas turbine fuel oil, high sulfur petroleum fuel oil, to generate electric power, and as a refinery feedstock. They cause skin cancer (observed in scrotum) (International agency for Research on Cancer. World Health Organization 2012aa).

28.4.14.12 Engine Exhaust: Diesel

Burning of fuel leads to formation of PAH, elemental carbon, carbon monoxide, nitrogen oxides, soot, hydrocarbons and unburned/partially burned oil and ash. The exhaust from engines also contains partially burned lubricating oil and ash from metallic additives in wear metals and lubricating oil. Occupational exposure occurs in workers employed in mining, construction, railroad and transportation industries, heavy goods vehicle's drivers, mechanics, bus garage and other bus workers, and firefighters. General population gets exposed through traffic contribution to air pollution, diesel generators, at seaports, etc. Traffic contaminants enter indoor air also, thereby exposing people there. Diesel engine exhaust causes lung cancer and is found to be positively associated with urinary bladder cancer (International Agency for Research on Cancer. World Health Organization 2014b).

28.4.14.13 2,3,7,8-Tetrachlorodibenzo-Para-Dioxin (TCDD), 2,3,4,7,8-Pentachloro-Dibenzofuran (PeCDF) and 3,3',4,4',5-Pentachlorobiphenyl (PCB)

TCDD has no known commercial application. It occurs as a contaminant in some herbicides and is used as a research chemical, pesticide, in incineration of sewage sludge and municipal, hospital, and hazardous waste, for metal processing, and paper pulp bleaching. It is also released from combustion of fuels, vehicle exhaust, and forest fires. These sources lead to contamination of air, sediments, surface, and groundwater and soil. Apart from accidental and occupational exposures, general population gets exposure through eating milk, fish, meat, eggs, and related products. TCDD is carcinogenic for all cancers combined and is positively associated with soft tissue sarcoma, non-Hodgkin lymphoma, and cancer of the lung.

PeCDF is manufactured commercially only for scientific research purposes. Combustion and incineration from cement kilns and hazardous waste, metal

smelting, refining and processing, pulp bleaching, chemical manufacture, and existing reservoirs are sources of environmental release. Contaminated food is the main route of human exposure, followed by inhalation and dermal absorption.

PCB was used in electrical industry, in hydraulic fluids, paints, plastics, and in manufacture of organic chemicals. The use, combustion, and disposal of these products lead to release into all environmental compartments including soil, air, water, sediments, and biota (International agency for Research on Cancer. World Health Organization 2012ac). Other chemical carcinogens are mentioned in Table 28.6.

28.5 Prevention Measures for Cancers

Prevention measures for any disease can be categorized into primary, secondary, and tertiary prevention measures. For cancers, the control spectrum is more or less similar including primary prevention, early diagnosis and screening, multimodal treatment, survivorship, and palliative care. For each of these domains, the availability of highly effective interventions mostly in high-income countries has reduced the burden of cancers in them. About one-third to half of the total cancers globally can be prevented with currently available knowledge and technology (World Health Organization 2020a). In further sections, the individual preventive measures are discussed in detail.

28.5.1 Primary Prevention

The measures aimed to prevent a disease from occurring and target a susceptible population or specific individuals are categorized under primary level preventive measures. These measures either increase immunity of individuals or decrease the risk exposure (Kisling and Das 2020). For cancers, primary prevention includes all actions, which lower the risk of cancer development (International Agency for Research on Cancer. World Health Organization 2019a).

Specific protection measures to increase the immunity of the individual against a biological carcinogen include immunization. Vaccines for human papillomavirus and hepatitis B are available which provide protection against them, thereby reducing the chances of cancer development. For HPV, three vaccines including a bivalent, a quadrivalent, and a nonavalent vaccine depending on number of strains it provides protection against are currently being marketed in various countries. These are highly potent for prevention against infection with two main virus types 16 and 18 which cause about two-thirds of cervical cancers globally. They also prevent precancerous cervical lesions associated with these virus types. In most of the countries which recommend HPV vaccination, young adolescent girls in age group of 9–14 years are the primary target group and immunization schedule varies with recipient's age. A two dose schedule at 0 and 6 months is recommended for females less than 15 years of age, and three dose schedule at 0, 2, and 6 months is

Table 28.6 Chemical carcinogens, their use in industries, and cancers caused by them (International Agency for Research on Cancer. World Health Organization 2012i)

Chemical	Industries	Cancer
Strong inorganic acid mists	Manufacture of phosphate fertilizer, lead batteries, soap and detergents, cellulose fibers and films, inorganic pigments and paints, applications in petroleum refining, mining, metallurgy, and ore processing, in the synthesis of inorganic and organic chemicals, synthetic rubber and plastics, in processing of pulp and paper, and in water treatment. Exposure also occurs during copper smelting, and pickling and other acid treatment of metals.	Larynx. Positive association with lung cancer.
Aristolochic acid (International agency for Research on Cancer. World Health Organization 2012ad)	Extract of Aristolochia species. Used in traditional Chinese medicine as diuretics, anti-inflammatory and edema treatment, slimming agent.	Urinary bladder.
4,4'-Methylenebis (2-chloroaniline) (MOCA)	Manufacture of castable urethane rubber products (e.g., shock absorption pads and conveyor belting). In the laboratory, as a model compound for studying carcinogens.	Urinary bladder
Ortho-toluidine	Synthesis of herbicides, in manufacture of more than 90 dyes and pigments, synthetic rubber and rubber-vulcanizing chemicals, pharmaceuticals, pesticides, and other chemicals, in clinical laboratory as an ingredient in a reagent for glucose analysis, for tissue staining. Significant non-occupational exposures to ortho-toluidine may result from the use of some hair dyes, the local anesthetic prilocaine, or tobacco smoke.	Urinary bladder
Pentachlorophenol (International Agency for Research on Cancer. World Health Organization 2019b)	Used as wood preservative, herbicide, algicide, defoliant, germicide, fungicide, molluscicide and could be found in ropes, paints,	Non-Hodgkin lymphoma.

(continued)

Table 28.6 (continued)

Chemical	Industries	Cancer
	adhesives, canvas, leather, insulation, and brick walls, in tanneries. Also used in textiles and other fabrics. It is a persistent organic pollutant.	
Coal tar pitch	Used in electrode manufacture, roofing, and paving. Roofers are primarily exposed to PAHs. Other exposures include silica, diesel exhaust, asbestos, and organic solvents.	Lung. Positive association with cancer of the bladder.
1,2 Dichloropropane (International Agency for Research on Cancer. World Health Organization 2017a)	In production of propylene, carbon tetrachloride, and tetrachloroethylene, as textile stain remover, paint and stain removers, oil and paraffin extractant, scouring compound, metal cleaner, metal degreaser, as grain and soil fumigant, in insecticides, solvent or diluent in coatings, inks, glues, and adhesives.	Biliary tract (confirmed as cholangiocarcinoma).
Lindane (International Agency for Research on Cancer. World Health Organization 2018c)	As insecticides to treat wood and wooden structures, seed, crops, and livestock, in baits and seed treatments for rodent control, in treatment for control of head lice and scabies.	Non-Hodgkin lymphoma
2-Naphthylamine	Manufacture of dyes, in rubber industry, to produce 2-chloronaphthalene, in laboratory research. Indirect exposure through gases produced during incomplete combustion of organic material. 2-Naphthylamine has been detected in fumes of heated cooking oils.	Urinary bladder
Polychlorinated biphenyls (International Agency for Research on Cancer. World Health Organization 2016a)	Used in dielectric fluids in capacitors and transformers, paint additive, permanent elastic sealants, flame-retardant coatings, in inks, adhesives, dyes for carbonless duplicating paper, conveyor belts, rubber products, pesticide fillers, plasticizers,	Malignant melanoma. Positive associations with non-Hodgkin lymphoma and cancer of the breast.

(continued)

Table 28.6 (continued)

Chemical	Industries	Cancer
	immersion oil for microscopes, cutting and lubricating oils, wire insulators, metal coatings, in fluorescent lights. Environmental contamination through improper handling of electronic waste (e-waste) and dismantling of ships.	
4-Aminobiphenyl	Used as rubber antioxidant, dye intermediate, in detection of sulfates, food colorant. Occupational exposure occurs with exposure to benzidine and benzidine-based dyes, from which 4-aminobiphenyl can be metabolically released. It has been detected in fume from cooking oils.	Urinary bladder.
Benzidine and dyes metabolized to benzidine	In production of large number of dyes, particularly azo dyes for wool, cotton, and leather, in clinical laboratories for detection of blood, as rubber compounding agent, in manufacture of plastic films, for detection of hydrogen peroxide in milk, and for quantitative determination of nicotine. Some food colorants such as tartrazine and sunset yellow FCF also contain it.	Urinary bladder.
Bis(chloromethyl)ether; chloromethyl methyl ether (technical grade)	Used to manufacture dodecylbenzyl chloride, water repellants, plastics, ion-exchange resins, polymers, flame-retardant fabrics, as a chloromethylating reagent, as a laboratory reagent, for surface treatment of vulcanized rubber.	Lung

advocated for females receiving first dose at or after the age of 15 years and for immunocompromised and HIV infected individuals (World Health Organization n.d.-c). Hepatitis B vaccination is now a part of immunization programs of almost all the countries (Fig. 28.13). It is recommended to vaccinate all infants within 24 h of birth with first dose of vaccine which is to be followed by 2 or 3 doses to complete the primary schedule. Protection is possibly lifelong (World Health

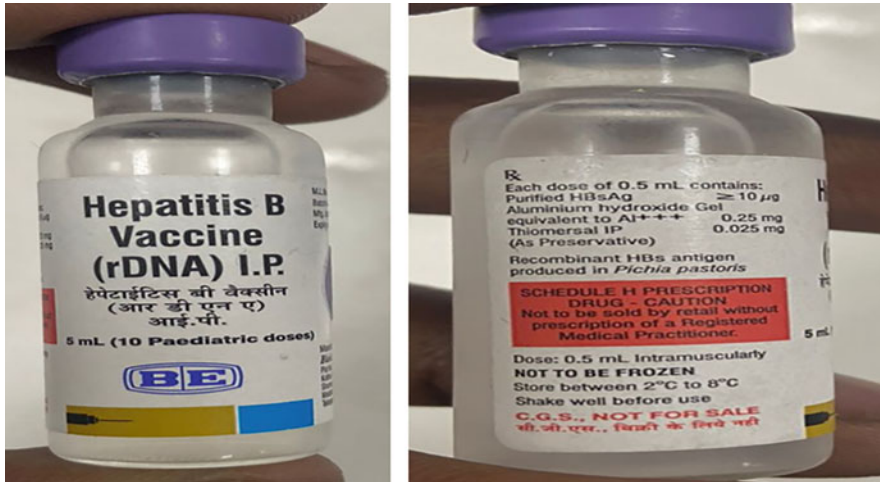


Fig. 28.13 Hepatitis B vaccine

Organization [n.d.-b](#)). Full vaccination schedule consists of three vaccine doses, with first two doses given at least 4 weeks apart and third dose 1–12 months later (World Health Organization [n.d.-d](#)).

The second approach to primary prevention is interventions, which decrease the risk exposure. Health education aiming at altering the risky behaviors among general population or high-risk groups is a part of primary prevention. It is a vital component of programs for cancer control and is found to be effective in modifying lifestyle behaviors (Van Parijs 1986). It should generate awareness about common carcinogens, their effects, and resulting cancers. People should be sensitized about consequences of tobacco and alcohol use, poor genital hygiene, indulging in unsafe sexual practices, use of infected needles, and occupational exposures. They should be encouraged to alter such behaviors and practices to lessen the exposure to incriminated carcinogens and development of cancer. Tobacco use in any form including second-hand smoke needs to be avoided. Many infections that lead to cancer have specific transmission routes and can be prevented by modifying risk-enhancing behaviors. People should keep a check on unnecessary radiation exposures. As the evidence is growing in favor of obesity and inadequate physical activity as potential carcinogen and it has been found that obesity contributes to approximately 12 types of cancers, importance of maintaining a healthy weight and regular physical activity as per international recommendations should also be stressed upon simultaneously. Breastfeeding should be promoted as it is found to be protective against breast cancer among mothers and overweight and obesity among breastfed children, thereby protecting against cancers associated with overweight and obesity. Certain dietary exposures increase the risk of cancer development by contributing to obesity and overweight. This includes sugar and sweetened drinks, red meat, and fast food (Research [n.d.](#)). They should be consumed in limited

quantities, if cannot be excluded from the diet. In place of them, people should be encouraged to include wholegrain, fiber, fruits, and vegetables in their diet which have shown protective effect against certain cancers and help in weight management (Research n.d.). Many nutritional supplements are marketed as providing protection against cancers. Such food myths should be busted with focused health education strategies. Supplements such as beta-carotene can increase the risk of lung cancer, and none of the other supplements except calcium for colorectal cancer have been proven to be protective against any type of cancer (Research n.d.).

Legislations, regulations, and public health policies which regulate the limits of chemicals and pollutants in environment and occupational settings (United States Department of Labor. Occupational Safety and Health Administration n.d.-b) safe disposal of industrial wastes, prohibition of discharge of industrial effluents into rivers are also an example of primary prevention measure. Other legislation and policies which regulate the public behavior like prohibition of smoking in public places, placing age restrictions on purchase of alcohol and tobacco, raising taxes, banning the use of pesticides containing carcinogens, and banning unsupervised tanning beds are also employed by many countries (World Health Organization n.d.-e).

For occupational cancers, complete elimination of the carcinogen and substituting it with a non-carcinogenic material in industries is the topmost control measure (Fig. 28.14). This approach can be used in few cases where risk of using a substance exceeds its benefits (US Department of Health and Human Services. Public Health Service. Centres for Disease Control. National Institute for Occupational Safety and Health 1986). It can be achieved with help of setting occupational standards and implementing strict enforcement of labor laws. However, this is not always feasible due to non-availability of any substituent agent. Engineering controls which include

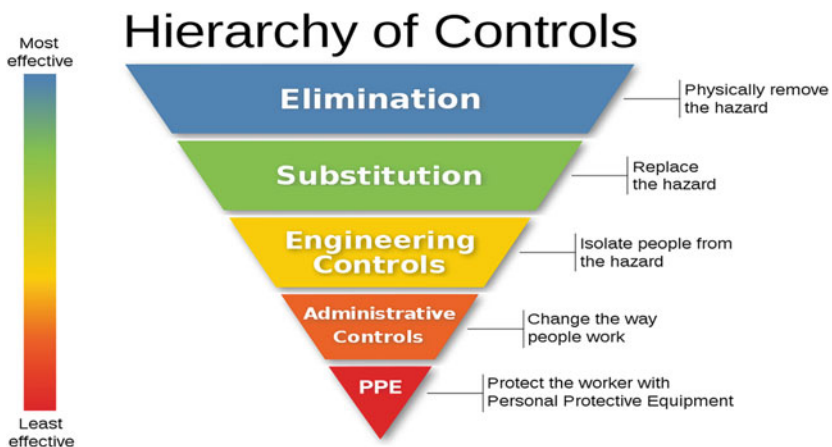


Fig. 28.14 Hierarchy of control measures for occupational hazards by National Institute for Occupational Safety and Health (United States Department of Labor. Occupational Safety and Health Administration n.d.-a)

ventilation and enclosure of such environment where a carcinogen is being used or generated are next in hierarchy for control of exposures. When all of these measures are not possible, the last and least effective approach is use of personal protective equipment which reduces the exposure to a certain limit only (United States Department of Labor. Occupational Safety and Health Administration [n.d.-a](#)). Continuous and periodic evaluation of exposure, hazard recognition and identification and surveillance activities should supplement these control measures. Workers should be made aware about their exposures and associated risks and should be empowered to access the required information.

28.5.2 Secondary Prevention

Apparently, healthy individuals, who might have subclinical disease, are targets for secondary prevention, and it employs measures for early disease detection when a person usually is asymptomatic or in early phases with minimum signs and symptoms (Kisling and Das [2020](#)). This can help identify and mitigate precancerous lesions and early identification of cancers, thereby aiding in more successful treatment (International Agency for Research on Cancer. World Health Organization [2019a](#)). In low resource settings and among vulnerable populations, late-stage presentations due to delay in accessing cancer care are common resulting in poor prognosis, decreased likelihood of survival, more painful and costly treatment, increased incidence of avoidable cancer deaths, and disability. This can be done thorough screening and early detection. Screening is, therefore, an important public health strategy in all settings (World Health Organization [n.d.-a](#)). Periodic examination in certain occupations and industries serves the similar purpose as screening and early detection by identifying cancers in initial stages. Although most of the occupational cancers follow a long latent period to develop after initial exposure, nonetheless, association of certain cancers with specific occupations and industries can be helpful in designing periodic examinations in such settings.

Screening aims to presumptively identify unrecognized disease or defect by systematic application of a screening test. The test should be such that which can be applied rapidly in a presumably asymptomatic population and can distinguish probably diseased people from probably healthy individuals (Porta and Sander Greenland [2008](#)). Screening is followed by diagnostic tests to confirm the presence or absence of disease. Some of the cancers may be detected sufficiently early through screening resulting in decrease in cancer risk, reduced incidence of more invasive cancers, and prevention of cancer deaths through cure. Screening can be organized or opportunistic and can be for general population or only for high-risk groups. However, screening is not completely harmless and potential risk of over-diagnosis should be considered before employing it. Provision of screening services should be complemented by awareness generation strategies under early detection programs among general population and healthcare professionals about early signs and symptoms of the disease to increase the utilization of such services (World Health Organization [2007](#)).

Few of the countries have integrated screening of common cancers in their ongoing healthcare programs. For example, Centers for Disease Control and Prevention (CDC) in USA supports screening for breast, lung, cervical, and colon cancer. For breast cancer, women in age 50–74 years are recommended to get a mammogram every 2 years as regular mammograms can reduce the risk of dying from breast cancer. MRI, clinical breast examination, and breast self-awareness can also be used (Division of Cancer Prevention and Control. Centres for Disease Control and Prevention 2020a). For cervical cancer, for women in age group of 21–29 years, only PAP test is recommended and screening should start at age of 21 years. For women 30–65 years of age, either PAP test or HPV test or a combination of both can be used to screen. If PAP test result is normal, next test will be done after 3 years and if HPV or co-test results are normal, next test will be done after 5 years (Division of Cancer Prevention and Control. Centres for Disease Control and Prevention 2019). Colorectal cancer screening is usually done after age of 50 years by stool tests, colonoscopy, flexible sigmoidoscopy, and CT colonography (Division of Cancer Prevention and Control. Centres for Disease Control and Prevention 2020b). Screening for lung cancer is done for people with history of heavy smoking, who are current smokers or have quit within last 15 years and are in age group of 55–80 years. Low-dose computed tomography is recommended for screening (Table 28.7) (Division of Cancer Prevention and Control. Centres for Disease Control and Prevention 2020c).

In India, opportunistic and population-based screening is advocated under the NPCDCS, for breast, cervical, and oral cavity cancer which are to be screened once in 5 years in population of age 30 years or more. For cervical cancer, VIA is recommended, and for oral cavity cancer, oral visual examination is to be conducted at primary healthcare levels (Ministry of Health and Family Welfare 2016).

Under National Health Service (NHS) in UK, screening for breast, cervical, and bowel cancer, is offered to general population. Cervical cancer screening is done among women aged 25–64 years of age with once in 3 years for 26–49 years age group and once in 5 years for 50–64 years age group. Breast cancer screening is offered to women of age 50–70 years and women above age of 70 years can self-refer themselves. For bowel cancer, home testing kit is given to population aged

Table 28.7 Screening recommendations by CDC for US population

Cancer	Screening methods available	Age group	Population
Breast	Mammography, MRI, clinical breast examination, breast self-examination	50–74 years	Women
Cervical	Pap smear, HPV, VIA, VILI	21 years or more	Women
Colorectal	Stool tests, colonoscopy, flexible sigmoidoscopy, CT colonography	50–75 years	All
Lung	Low-dose computed tomography	55–80 years	Heavy smokers at present or within last 15 years

between 60 and 74 years and bowel scope screening is offered to population above 55 years of age (NHS 2018).

The screening tests are usually followed by diagnostic tests which are in general more invasive and confirmatory. Laboratory tests using blood or tissue sample for tumor markers, imaging modalities including X-rays, ultrasonography, computerized tomography (CT) scan with or without contrast, magnetic resonance imaging (MRI), nuclear scans, bone scans, and positron emission tomography (PET), and biopsy are commonly employed diagnostic tests for cancers which also help in staging the disease (National Institutes of Health. National Cancer Institute 2019a).

28.5.3 Tertiary Prevention

Tertiary prevention measures come into play once the disease has been diagnosed as it aims to either stop or slow the disease progression and reduce the disease severity and associated sequelae. It includes various measures, namely chemotherapy, radiotherapy, rehabilitation, and screening for complications (Kisling and Das 2020). In cancers, tertiary prevention implies measures used to reduce the impact of long-term disease and disability which occur due to cancer or its treatment (International Agency for Research on Cancer. World Health Organization 2019a).

The treatment modalities for various types of cancers include surgery, chemotherapy, radiation therapy, hormone therapy, immunotherapy, targeted therapy, and stem cell transplant. They can either be used alone or in combination depending on type of cancer, the site involved, stage of the disease, and potential side effects. Precision medicine, a relatively novel concept, is an approach that is based on genetic understanding of the disease in an individual and helps doctors to choose treatments best suited for the person. It is, therefore, aptly called as personalized medicine (National Institutes of Health. National Cancer Institute n.d.).

Palliative care, a part of tertiary prevention, does not cure the disease but makes the patient feel better and improves their quality of life continuing through the treatment and beyond (Fig. 28.15). This is applicable in early course of the disease and should traverse through the disease progression till the terminal phase (palliative care module). It encompasses treating or preventing the symptoms and side effects of cancer treatment including pain management, helping them with emotional and spiritual problems, and addressing the concerns of the patient and family members (National Institutes of Health. National Cancer Institute 2020). Palliative care prepares patients and their loved ones for physical changes that may occur during terminal stages, helps them cope with emotional issues and different thoughts arising during the disease course, and provides support to family members. Research has shown beneficial effects of palliative care on patients and their family members' health and well-being (National Institutes of Health. National Cancer Institute 2017). Once the disease is advanced and is no more amenable to treatment, the treating physician may advise the patient to be shifted to a hospice or end-of-life care (National Institutes of Health. National Cancer Institute 2019b).

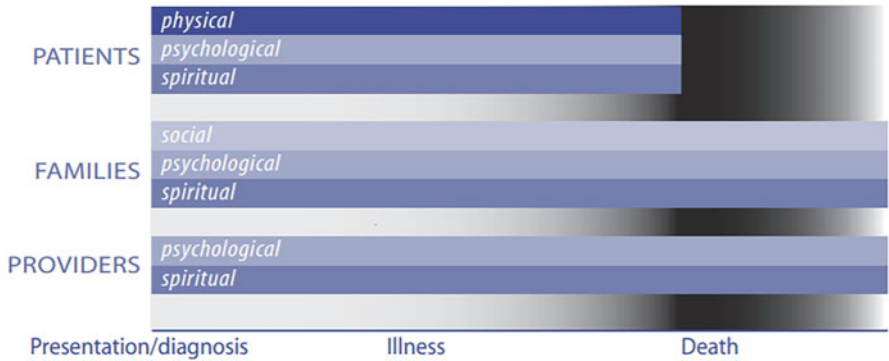


Fig. 28.15 Quality of life dimensions of palliative care (World Health Organization 2002)

Rehabilitation, on the other hand, is a group of interventions that are required when an individual is likely to experience or is currently experiencing restrictions in everyday functioning due to certain conditions including chronic diseases such as cancers. It is a person-centered health strategy which helps them to maintain or restore their daily living activities, accomplish meaningful life roles, and maximize well-being. It can be delivered through other health programs or specialized rehabilitation programs (World Health Organization 2019b).

References

Alter M (2002) Prevention of spread of hepatitis C. *Hepatology* 36(5):S93–S98

Alter MJ (2007) Epidemiology of hepatitis C virus infection. *World J Gastroenterol* 13(17): 2436–2441

American Cancer Society (2020) *Cancer-Facts-and-Figures-2020_2.Pdf*. Atlanta. <https://www.cancer.org/content/dam/cancer-org/research/cancer-facts-and-statistics/annual-cancer-facts-and-figures/2020/cancer-facts-and-figures-2020.pdf>

Attwood H, Chou S (1978) The longevity of *Clonorchis sinensis*. *Pathology* 10:153–156

Beasley RP, Hwang LY (1983) Postnatal infectivity of hepatitis B surface antigen-carrier mothers. *J Infect Dis* 147(2):185–190

Beasley RP, Stevens CE, Shiao IS, Meng HC (1975) Evidence against breast feeding as a mechanism for vertical transmission of hepatitis B. *Lancet* 2(7938):740–741

Burchell A et al (2006) Chapter 6: Epidemiology and transmission dynamics of genital HPV infection. *Vaccine* 24:52–61

Burd E (2003) Human papillomavirus and cervical cancer. *Clin Microbiol Rev* 16(1):1–17. <https://doi.org/10.1128/CMR.16.1.1>

Cao G-W (2009) Clinical relevance and public health significance of hepatitis B virus genomic variations. *World J Gastroenterol* 15(46):5761–5769. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2791267/>

- Chabasse D, Bertrand G, Leroux JP, Gauthey NHP (1985) Developmental bilharziasis caused by *Schistosoma mansoni* discovered 37 years after infestation. *Bull Soc Pathol Exot Filial* 78(5): 643–647
- Coluzzi M, Calabrò ML, Manno D, Chieco-Bianchi L, Schulz TF, Ascoli V (2003) Reduced seroprevalence of Kaposi's sarcoma-associated herpesvirus (KSHV), human herpesvirus 8 (HHV8), related to suppression of *Anopheles* density in Italy. *Med Vet Entomol* 17(4): 461–464
- Dedicoat M, Newton R, Alkharsah KR, Sheldon J, Szabados I, Ndlovu B, Page T, Casabonne D, Gilks CF, Cassol SA, Denise Whitby TFS (2004) Mother-to-child transmission of human herpesvirus-8 in South Africa. *J Infect Dis* 190(6):1068–1075
- Department of Economic and Social Affairs. United Nations (2019) Contraceptive Use by Method 2019. <https://www.un.org/en/development/desa/population/publications/pdf/family/ContraceptiveUseByMethodDataBooklet2019.pdf>
- Department of Health & Human Services. Centers for Disease Control and Prevention. Division of Viral Hepatitis (2010) When someone close to you has chronic hepatitis B. <https://www.cdc.gov/hepatitis/HBV/PDFs/HepBWhenSomeoneClose.pdf>
- Division of Cancer Prevention and Control. Centres for Disease Control and Prevention (2019) Cervical cancer. What should I know about screening. https://www.cdc.gov/cancer/cervical/basic_info/screening.htm. Accessed 23 Sep 2020
- Division of Cancer Prevention and Control. Centres for Disease Control and Prevention (2020a) Breast Cancer. What is breast cancer screening. https://www.cdc.gov/cancer/breast/basic_info/screening.htm. Accessed 23 Sep 2020
- Division of Cancer Prevention and Control. Centres for Disease Control and Prevention (2020b) Colorectal (colon) screening. What should I know about screening. https://www.cdc.gov/cancer/colorectal/basic_info/screening/. Accessed 23 Sep 2020
- Division of Cancer Prevention and Control. Centres for Disease Control and Prevention (2020c) Lung cancer. Who should be screened for lung cancer? https://www.cdc.gov/cancer/lung/basic_info/screening.htm. Accessed 23 Sep 2020
- McManus AL, Donald P (2008) Current status of vaccines for schistosomiasis. *Clin Microbiol Rev* 21(1):225–242
- Drope J et al (eds) (2018) The tobacco atlas, 6th edn. American Cancer Society, Inc. and Vital Strategies, Atlanta. https://files.tobaccoatlas.org/wp-content/uploads/2018/03/TobaccoAtlas_6thEdition_LoRes.pdf
- Dunne E et al (2006) Prevalence of HPV infection among men: a systematic review of the literature. *J Infect Dis* 194(8):1044–1057
- Evans AS (1971) The spectrum of infections with Epstein-Barr virus: a hypothesis. *J Infect Dis* 124(3):330–337
- Fenn KM et al (2014) Impact of financial burden of cancer on survivors' quality of life. *J Oncol Pract* 10(5):332–338. <https://doi.org/10.1200/JOP.2013.001322>
- Goodman KJ, Correa P, Tenganá Aux HJ, Ramírez H, DeLany JP, Guerrero Pepinosa O, Quiñones ML, Parra TC (1996) *Helicobacter pylori* infection in the Colombian Andes: a population-based study of transmission pathways. *Am J Epidemiol* 144(3):290–299
- Gorman LM (2018) Section I. Psychosocial impact along the cancer continuum. In: Psychosocial book. Oncology Nursing Society, Pittsburgh, PA, pp 3–23. <https://www.ons.org/sites/default/files/2018-10/Psychosocial%20Nursing%20Care%20Along%20the%20Cancer%20Continuum%20Sample%20Chapter%20%281%29.pdf>
- Harinasuta CTH (1984) *Opisthorchis viverrini*: life cycle, intermediate hosts, transmission to man and geographical distribution in Thailand. *Arzneimittelforschung* 34(9B):1164–1167
- Hjalgrim H, Friborg J, Melbye M (2007) The epidemiology of EBV and its association with malignant disease. In: Arvin A, Campadelli-Fiume G, Mocarski E, Moore PS, Roizman B, Richard Whitley KY (eds) *Human herpesviruses: biology, therapy, and immunoprophylaxis*. Cambridge University Press, Cambridge. <https://www.ncbi.nlm.nih.gov/books/NBK47424/>

- Hooi JKY, Lai WY, Ng WK, Suen MMY, Underwood FE, Tanyingoh D, Malfetheriner P, Graham DY, Wong VWS, Wu JCY, Chan FKL, Sung JY, Kaplan GG, Ng SC (2017) Global prevalence of *Helicobacter pylori* infection: systematic review and meta-analysis. *Gastroenterology* 153(2): 420–429. <https://pubmed.ncbi.nlm.nih.gov/28456631/>
- Hou J, Liu Z, Gu F (2005) Epidemiology and prevention of hepatitis B virus infection. *Int J Med Sci* 2(1):50–57
- Hwang LY, Kramer JR, Troisi C, Bull L, Grimes CZ, Lyerla R et al (2006) Relationship of cosmetic procedures and drug use to hepatitis C and hepatitis B virus infections in a low-risk population. *Hepatology* 44(2):341–351
- International Agency for Research on Cancer (2008) Mechanisms of carcinogenesis. IARC, Lyon. https://www.iarc.fr/wp-content/uploads/2018/07/wcr_2008_5.pdf
- International Agency for Research on Cancer (n.d.) Mechanisms of tumor develop. IARC, Lyon. <https://doi.org/10.1146/annurev.pathol.4.110807.092158>
- International Agency for Research on Cancer. World Health Organization (2012a) IARC monographs on the evaluation of carcinogenic risks to humans. Arsenic, metals, fibres and dusts. A review of human carcinogens. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100C.pdf>
- International Agency for Research on Cancer. World Health Organization (2012b) IARC monographs on the evaluation of carcinogenic risks to humans. Arsenic, metals, fibres and dusts. A review of human carcinogens. Asbestos (chrysotile, amosite, crocidolite, tremolite, actinolite, and anthophyllite). IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100C-11.pdf>
- International Agency for Research on Cancer. World Health Organization (2012c) IARC monographs on the evaluation of carcinogenic risks to humans. Arsenic, metals, fibres and dusts. A review of human carcinogens. Silica dust, crystalline, in the form of quartz or cristobalite. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100C-14.pdf>
- International Agency for Research on Cancer. World Health Organization (2012d) IARC monographs on the evaluation of carcinogenic risks to humans. Arsenic, metals, fibres and dusts. A review of human carcinogens. Arsenic and arsenic compounds. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100C-6.pdf>
- International Agency for Research on Cancer. World Health Organization (2012e) IARC monographs on the evaluation of carcinogenic risks to humans. Biological agents. A review of human carcinogens. Human T-cell lymphotropic virus type-1. IARC, Lyon. https://publications.iarc.fr/_publications/media/download/5211/c64b24ada0b2e9f82919_dfa7c7f058994abca3e1.pdf
- International Agency for Research on Cancer. World Health Organization (2012f) IARC monographs on the evaluation of carcinogenic risks to humans. Biological agents. A review of human carcinogens. *Opisthorchis viverrini* and *Clonorchis sinensis*. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100B-13.pdf>
- International Agency for Research on Cancer. World Health Organization (2012g) IARC monographs on the evaluation of carcinogenic risks to humans. Chemical agents and related occupations. A review of human carcinogens. Aflatoxins. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100F-23.pdf>
- International Agency for Research on Cancer. World Health Organization (2012h) IARC Monographs on the evaluation of carcinogenic risks to humans. Personal habits and indoor combustion. A review of human carcinogens. Chinese-style salted fish. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100E-12.pdf>
- International Agency for Research on Cancer. World Health Organization (2012i) IARC monographs on the evaluation of carcinogenic risks to humans. Pharmaceuticals. A review of human carcinogens. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100A.pdf>

- International Agency for Research on Cancer. World Health Organization (2012j) IARC monographs on the evaluation of carcinogenic risks to humans. Pharmaceuticals. A review of human carcinogens. Combined Estrogen-Progestogen menopausal therapy. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100A-18.pdf>
- International Agency for Research on Cancer. World Health Organization (2012k) IARC monographs on the evaluation of carcinogenic risks to humans. Pharmaceuticals. A review of human carcinogens. Estrogen-only menopausal therapy. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100A-17.pdf>
- International Agency for Research on Cancer. World Health Organization (2012l) IARC monographs on the evaluation of carcinogenic risks to humans. Radiation. A review of human carcinogens. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100D.pdf>
- International Agency for Research on Cancer. World Health Organization (2012m) IARC monographs on the evaluation of carcinogenic risks to humans. Radiation. A review of human carcinogens. Solar and ultraviolet radiation. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100D-6.pdf>
- International Agency for Research on Cancer. World Health Organization (2012n) IARC monographs on the evaluation of carcinogenic risks to humans. Radiation. A review of human carcinogens. X- and γ -Radiation. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100D-7.pdf>
- International Agency for Research on Cancer. World Health Organization (2012o) IARC monographs on the evaluation of carcinogenic risks to humans. Radiation. A review of human carcinogens. Internalized α -particle emitting radionuclides. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100D-9.pdf>
- International Agency for Research on Cancer. World Health Organization (2012p) IARC monographs on the evaluation of carcinogenic risks to humans. Arsenic, metals, fibres and dusts. A review of human carcinogens. Chromium (VI) compounds. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100C-9.pdf>
- International Agency for Research on Cancer. World Health Organization (2012q) IARC monographs on the evaluation of carcinogenic risks to humans. Biological agents. A review of human carcinogens. Hepatitis B virus. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100B-7.pdf>
- International Agency for Research on Cancer. World Health Organization (2012r) IARC monographs on the evaluation of carcinogenic risks to humans. Biological agents. A review of human carcinogens. Human Papillomaviruses. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100B-11.pdf>
- International Agency for Research on Cancer. World Health Organization (2012s) IARC monographs on the evaluation of carcinogenic risks to humans. Chemical agents and related occupations. A review of human carcinogens. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100F.pdf>
- International Agency for Research on Cancer. World Health Organization (2012t) IARC monographs on the evaluation of carcinogenic risks to humans. Chemical agents and related occupations. A review of human carcinogens. 1,3 Butadiene. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100F-26.pdf>
- International Agency for Research on Cancer. World Health Organization (2012u) IARC monographs on the evaluation of carcinogenic risks to humans. Chemical agents and related occupations. A review of human carcinogens. Benzene. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100F-24.pdf>
- International Agency for Research on Cancer. World Health Organization (2012v) IARC monographs on the evaluation of carcinogenic risks to humans. Chemical agents and related occupations. A review of human carcinogens. Benzo[a]pyrene. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100F-14.pdf>

- International Agency for Research on Cancer. World Health Organization (2012w) IARC monographs on the evaluation of carcinogenic risks to humans. Chemical agents and related occupations. A review of human carcinogens. Ethylene oxide. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100F-28.pdf>
- International Agency for Research on Cancer. World Health Organization (2012x) IARC monographs on the evaluation of carcinogenic risks to humans. Chemical agents and related occupations. A review of human carcinogens. Formaldehyde. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100F-29.pdf>
- International Agency for Research on Cancer. World Health Organization (2012y) IARC monographs on the evaluation of carcinogenic risks to humans. Chemical agents and related occupations. A review of human carcinogens. Mineral oils, untreated or mildly treated. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100F-19.pdf>
- International Agency for Research on Cancer. World Health Organization (2012z) IARC monographs on the evaluation of carcinogenic risks to humans. Chemical agents and related occupations. A review of human carcinogens. Occupational exposure as a painter. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100F-35.pdf>
- International Agency for Research on Cancer. World Health Organization (2012aa) IARC monographs on the evaluation of carcinogenic risks to humans. Chemical agents and related occupations. A review of human carcinogens. Shale oils. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100F-20.pdf>
- International Agency for Research on Cancer. World Health Organization (2012ab) IARC monographs on the evaluation of carcinogenic risks to humans. Chemical agents and related occupations. A review of human carcinogens. Sulfur mustard. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100F-30.pdf>
- International Agency for Research on Cancer. World Health Organization (2012ac) IARC monographs on the evaluation of carcinogenic risks to humans. Chemical agents and related occupations. A review of human carcinogens. 2,3,7,8-Tetrachlorodibenzo-para-dioxin, 2,3,4,7,8-Pentachlorodibenzofuran and 3,3',4,4',5-Pentachlorobiphenyl. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100F-27.pdf>
- International Agency for Research on Cancer. World Health Organization (2012ad) IARC monographs on the evaluation of carcinogenic risks to humans. Pharmaceuticals. A review of human carcinogens. Plants containing aristolochic acid. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100A-23.pdf>
- International Agency for Research on Cancer. World Health Organization (2012ae) IARC monographs on the evaluation of carcinogenic risks to humans. Biological agents. A review of human carcinogens. Epstein-Barr virus. IARC, Lyon. <https://doi.org/10.1002/art.1780240601>
- International Agency for Research on Cancer. World Health Organization (2012af) IARC monographs on the evaluation of carcinogenic risks to humans. Biological agents. A review of human carcinogens. Helicobacter pylori. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100B-15.pdf>
- International Agency for Research on Cancer. World Health Organization (2012ag) IARC monographs on the evaluation of carcinogenic risks to humans. Biological agents. A review of human carcinogens. Hepatitis C virus. IARC, Lyon. <https://doi.org/10.1002/9780470755075.ch23>
- International Agency for Research on Cancer. World Health Organization (2012ah) IARC monographs on the evaluation of carcinogenic risks to humans. Biological agents. A review of human carcinogens. Kaposi sarcoma herpesvirus. IARC, Lyon. https://publications.iarc.fr/_publications/media/download/5208/5c63fd49ae59d6651edd6d6e5545ce647d9feba8.pdf
- International Agency for Research on Cancer. World Health Organization (2012ai) IARC monographs on the evaluation of carcinogenic risks to humans. Biological agents. A review of human carcinogens. Schistosoma haematobium. IARC, Lyon. https://publications.iarc.fr/_publications/media/download/5213/0af93f5baeb3dbe936665b0e9e7288bcc7d499f.pdf

- International Agency for Research on Cancer. World Health Organization (2012aj) IARC monographs on the evaluation of carcinogenic risks to humans. Biological agents. A review of human carcinogens. Human immunodeficiency virus-1. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100B.pdf>
- International Agency for Research on Cancer. World Health Organization (2012ak) IARC monographs on the evaluation of carcinogenic risks to humans. Personal habits and indoor combustion. A review of human carcinogens. Betel quid and areca nut. IARC, Lyon
- International Agency for Research on Cancer. World Health Organization (2012al) IARC monographs on the evaluation of carcinogenic risks to humans. Personal habits and indoor combustion. A review of human carcinogens. Consumption of alcoholic beverages. IARC, Lyon. <https://doi.org/10.1177/000271622310900115>
- International Agency for Research on Cancer. World Health Organization (2012am) IARC monographs on the evaluation of carcinogenic risks to humans. Personal habits and indoor combustion. A review of human carcinogens. Indoor emissions from household combustion of coal. IARC, Lyon
- International Agency for Research on Cancer. World Health Organization (2012an) IARC monographs on the evaluation of carcinogenic risks to humans. Personal habits and indoor combustion. A review of human carcinogens. Smokeless tobacco. IARC, Lyon. <https://doi.org/10.3322/canjclin.39.1.62-a>
- International Agency for Research on Cancer. World Health Organization (2012ao) IARC Monographs on the evaluation of carcinogenic risks to humans. Personal habits and indoor combustion. A review of human carcinogens. Tobacco smoking. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100E-6.pdf>
- International Agency for Research on Cancer. World Health Organization (2012ap) IARC monographs on the evaluation of carcinogenic risks to humans. Pharmaceuticals. A review of human carcinogens. Combined estrogen-progestogen contraceptives. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100A-19.pdf>
- International Agency for Research on Cancer. World Health Organization (2012aq) IARC monographs on the evaluation of carcinogenic risks to humans. Personal habits and indoor combustion. A review of human carcinogens. Second-hand tobacco smoke. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono100E-7.pdf>
- International Agency for Research on Cancer. World Health Organization (2014a) World cancer report. IARC, Lyon. <https://publications.iarc.fr/Non-Series-Publications/World-Cancer-Reports/World-Cancer-Report-2014>
- International Agency for Research on Cancer. World Health Organization (2014b) IARC monographs on the evaluation of carcinogenic risks to humans. Diesel and gasoline engine exhausts and some nitroarenes. A review of human carcinogens. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono105.pdf>
- International Agency for Research on Cancer. World Health Organization (2014c) IARC monographs on the evaluation of carcinogenic risks to humans. Trichloroethylene, tetrachloroethylene, and some other chlorinated agents. A review of human carcinogens. Trichloroethylene. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono106.pdf>
- International Agency for Research on Cancer. World Health Organization (2016a) IARC monographs on the evaluation of carcinogenic risks to humans. Polychlorinated biphenyls and polybrominated biphenyls. A review of human carcinogens. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/08/mono107.pdf>
- International Agency for Research on Cancer. World Health Organization (2016b) IARC monographs on the evaluation of carcinogenic risks to humans. Outdoor air pollution. IARC, Lyon. http://publications.iarc.fr/_publications/media/download/4317/b1f528f1fca20965a2b48a220f47447c1d94e6d1.pdf
- International Agency for Research on Cancer. World Health Organization (2017a) IARC monographs on the evaluation of carcinogenic risks to humans. Some chemicals used as

- solvents and in polymer manufacture. A review of human carcinogens. 1,2-Dichloropropane. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono110-03.pdf>
- International Agency for Research on Cancer. World Health Organization (2017b) IARC monographs on the evaluation of carcinogenic risks to humans. Some nanomaterials and some fibres. A review of human carcinogens. Fluoro-edenite. IARC, Lyon
- International Agency for Research on Cancer. World Health Organization (2017c) IARC monographs on the evaluation of carcinogenic risks to humans. Some nanomaterials and some fibres. A review of human carcinogens. Silicon carbide. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/06/mono111-03.pdf>
- International Agency for Research on Cancer. World Health Organization (2018a) All cancers. Source GLOBOCAN 2018. IARC, Lyon. <https://gco.iarc.fr/today/data/factsheets/cancers/39-All-cancers-fact-sheet.pdf>
- International Agency for Research on Cancer. World Health Organization (2018b) Cancer tomorrow. IARC, Lyon. https://gco.iarc.fr/tomorrow/graphic-isotype?type=0&type_sex=0&mode=population&sex=0&populations=900&cancers=39&age_group=value&apc_male=0&apc_female=0&single_unit=500000&print=0. Accessed 23 Sep 2020
- International Agency for Research on Cancer. World Health Organization (2018c) IARC monographs on the evaluation of carcinogenic risks to humans. DDT, Lindane and 2,4-D. A review of human carcinogens. IARC, Lyon. <https://monographs.iarc.fr/wp-content/uploads/2018/07/mono113.pdf>
- International Agency for Research on Cancer. World Health Organization (2018d) IARC monographs on the evaluation of carcinogenic risks to humans. Welding, molybdenum trioxide, and indium tin oxide. A review of human carcinogens. Welding. IARC, Lyon. <https://publications.iarc.fr/569>
- International Agency for Research on Cancer. World Health Organization (2018e) IARC Monographs on the evaluation of carcinogenic risks to humans. Personal habits and indoor combustion. A review of human carcinogens. Red meat and processed meat. IARC, Lyon. <https://doi.org/10.1103/PhysRevA.86.012307>
- International Agency for Research on Cancer. World Health Organization (2019a) IARC handbooks of cancer prevention. Preamble for screening. IARC, Lyon
- International Agency for Research on Cancer. World Health Organization (2019b) IARC monographs on the evaluation of carcinogenic risks to humans. Pentachlorophenol and some related compounds. A review of human carcinogens. IARC, Lyon. https://publications.iarc.fr/_publications/media/download/5717/3507e6ef7631cd3e073e5cb65415daa0b524989c.pdf
- International Agency for Research on Cancer. World Health Organization (2020) IARC monographs on the identification of carcinogenic hazards to humans. Agents classified by the IARC monographs, vol 1–127. IARC, Lyon. <https://monographs.iarc.fr/agents-classified-by-the-iarc/>. Accessed 23 Sep 2020
- Jordan P, Webbe G (1993) Epidemiology. In: Jordan P, Webbe G, Sturrock R (eds) Human schistosomiasis. CAB International, Wallingford, pp 87–158
- Kisling LA, Das M (2020) Prevention strategies. StatPearls Publishing, Treasure Island, FL. <https://www.ncbi.nlm.nih.gov/books/NBK537222/>
- Lauer G, Walker B (2001) Hepatitis C virus infection. *N Engl J Med* 345(1):41–52
- Lin CJ, Katongole-Mbidde E, Byekwaso T, Orem J, Charles S, Rabkin SMM (2008) Intestinal parasites in Kaposi sarcoma patients in Uganda: indication of shared risk factors or etiologic association. *Am J Trop Med Hyg* 78(3):409–412
- Lun Z-R, Gasser RB, Lai D-H, Li A-X, Zhu X-Q, Yu X-B, Fang Y-Y (2005) Clonorchiasis: a key foodborne zoonosis in China. *Lancet Infect Dis* 5(1):31–41
- MacQuarrie MB, Forghani B, Wolochow DA (1974) Hepatitis B transmitted by a human bite. *JAMA* 230(5):723–724
- Mahoney F (1999) Update on diagnosis, management, and prevention of hepatitis B virus infection. *Clin Microbiol Rev* 12(2):351–366

- Malaty HM, Graham DY (1994) Importance of childhood socioeconomic status on the current prevalence of *Helicobacter pylori* infection. *Gut* 35(6):742–745. <https://pubmed.ncbi.nlm.nih.gov/8020796/>
- Malope BI, Pfeiffer RM, Mbisa G, Stein L, Ratsikhopha EM, O’Connell DL, Sitas F, Patrick MacPhail DW (2007) Transmission of Kaposi sarcoma-associated herpesvirus between mothers and children in a South African population. *J Acquir Immune Defic Syndr* 44(3):351–355
- Margolis HS, Alter MJ, Hadler S (1997) Viral hepatitis. In: Evans AS, Kaslow R (eds) *Viral infections of humans: epidemiology and control*, 4th edn. Plenum Publishing Corporation, New York, NY, pp 363–418
- Mbulaiteye SM, Pfeiffer RM, Engels EA, Marshall V, Bakaki PM, Owor AM, Ndugwa CM, Katongole-Mbidde E, Goedert JJ, Biggar RJ, Whitby D (2004) Detection of kaposi sarcoma-associated herpesvirus DNA in saliva and buffy-coat samples from children with sickle cell disease in Uganda. *J Infect Dis* 190(8):1382–1386
- Mbulaiteye SM, Biggar RJ, Pfeiffer RM, Bakaki PM, Gamache C, Owor AM, Katongole-Mbidde E, Ndugwa CM, Goedert JJ, Denise Whitby EAE (2005) ‘Water, socioeconomic factors, and human herpesvirus 8 infection in Ugandan children and their mothers. *J Acquir Immune Defic Syndr* 38(4):474–479
- Minhas V, Crabtree KL, Chao A, M’soka TJ, Kankasa C, Bulterys M, Charles D, Mitchell CW (2008) Early childhood infection by human herpesvirus 8 in Zambia and the role of human immunodeficiency virus type 1 coinfection in a highly endemic area. *Am J Epidemiol* 168(3): 311–320
- Ministry of Health and Family Welfare G. of INHM (2016) Operational guidelines. Prevention, screening and control of common non-communicable diseases: hypertension, diabetes and common cancers (Oral, breast, cervix). Part of comprehensive primary health care. https://dghs.gov.in/WriteReadData/userfiles/file/Publication/Operational%20Guidelines%20on%20Prevention,%20Screening%20and%20Control%20of%20Common%20NCDs_1.pdf
- Mott KE, Desjeux P, Moncayo A, de Ranque P (1990) Parasitic diseases and urban development. *Bull World Health Organ* 68(6):691–698
- Nair U, Helmut Bartsch JN (2004) Alert for an epidemic of oral cancer due to use of the betel quid substitutes gutkha and pan masala: a review of agents and causative mechanisms. *Mutagenesis* 19(4):251–262. <https://pubmed.ncbi.nlm.nih.gov/15215323/>
- National Institutes of Health. National Cancer Institute (2017) Palliative care in cancer. <https://www.cancer.gov/about-cancer/advanced-cancer/care-choices/palliative-care-fact-sheet>. Accessed 23 Sep 2020
- National Institutes of Health. National Cancer Institute (2019a) How cancer is diagnosed. <https://www.cancer.gov/about-cancer/diagnosis-staging/diagnosis>. Accessed 23 Sep 2020
- National Institutes of Health. National Cancer Institute (2019b) Questions to ask your doctor about advanced cancer. <https://www.cancer.gov/about-cancer/advanced-cancer/questions>. Accessed 23 Sep 2020
- National Institutes of Health. National Cancer Institute (2020) Choices for care when treatment may not be an option. <https://www.cancer.gov/about-cancer/advanced-cancer/care-choices>. Accessed 23 Sep 2020
- National Institutes of Health. National Cancer Institute (n.d.) Types of cancer treatment. <https://www.cancer.gov/about-cancer/treatment/types>. Accessed 23 Sep 2020
- Naughton M, Weaver K (2014) Physical and mental health among cancer survivors: considerations for long-term care and quality of life. *North Carolina Med J* 75(4):283–286. <https://doi.org/10.18043/ncm.75.4.283>
- NHS (2018) NHS screening. <https://www.nhs.uk/conditions/nhs-screening/>. Accessed 23 Sep 2020
- Nohmi T (2018) Thresholds of genotoxic and non-genotoxic carcinogens. *Toxicol Res* 34(4): 281–290. <https://doi.org/10.5487/TR.2018.34.4.281>
- Oderda G (1999) Transmission of *Helicobacter pylori* infection. *Can J Gastroenterol* 13(7): 595–597. <https://pubmed.ncbi.nlm.nih.gov/10519958/>

- Pachiadakis I, Pollara G, Chain BM, Naoumov N (2005) Is hepatitis C virus infection of dendritic cells a mechanism facilitating viral persistence? *Lancet Infect Dis* 5(5):296–304
- Perz JF, Armstrong GL, Farrington LA, Hutin YJF, Bell BP (2006) The contributions of hepatitis B virus and hepatitis C virus infections to cirrhosis and primary liver cancer worldwide. *J Hepatol* 45(4):529–538
- Plancoulaine S, Abel L, van Beveren M, Tréguët DA, Joubert M, Tortevoye P, de Thé G, Gessian A (2000) Human herpesvirus 8 transmission from mother to child and between siblings in an endemic population. *Lancet* 356(9235):1062–1065
- Porta M, Sander Greenland JML (eds) (2008) A dictionary of epidemiology. Fifth, International Epidemiological Association, 5th edn. Oxford University Press, Oxford. <https://doi.org/10.1093/oxfordjournals.aje.a114344>
- Ramchandani AG, D'Souza AV, Borges AM, Bhisey RA (1998) Evaluation of carcinogenic/co-carcinogenic activity of a common chewing product, pan masala, in mouse skin, stomach and esophagus. *Int J Cancer* 75:225–232. <https://onlinelibrary.wiley.com/doi/epdf/10.1002/%28SICI%291097-0215%2819980119%2975%3A2%3C225%3A%3AAID-IJC10%3E3.0.CO%3B2-C>
- Research W. C. R. F. A. I. for C (n.d.) Recommendations and public health and policy implications. Continuous Update Project. Analysing research on cancer prevention and survival. WCRF, London. <https://www.wcrf.org/sites/default/files/Recommendations.pdf>. Accessed 23 Sep 2020
- Rickinson AB, Kieff E (1996) Epstein-Barr virus. In: Fields BN, Knipe DM, Howley PM (eds) *Fields virology*, 3rd edn. Lippincott-Raven, Philadelphia, PA, pp 2397–2446
- Rim H (2005) Clonorchiasis: an update. *J Helminthol* 79:269–281
- Sample J, Young L, Martin B, Chatman T, Kieff E, Rickinson AEK (1990) Epstein-Barr virus types 1 and 2 differ in their EBNA-3A, EBNA-3B, and EBNA-3C genes. *J Virol* 64(9):4084–4092. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC247870/>
- Scott RM, Snitbhan R, Bancroft WH, Alter HJ, Tingpalapong M (1980) Experimental transmission of hepatitis B virus by semen and saliva. *J Infect Dis* 142(1):67–71
- Serraino D, Corona RM, Giuliani M, Farchi F, Sarmati L, Uccella I, Andreoni MGR (2003) Infection with human herpesvirus type 8 and kaposi's sarcoma in a central Italian area formerly endemic for malaria. *Infection* 31(1):47–50
- Shimizu YK, Igarashi H, Kiyohara T, Shapiro M, Wong DC, Purcell RH et al (1998) Infection of a chimpanzee with hepatitis C virus grown in cell culture. *J Gen Virol* 79:1383–1386
- Sung VMH, Shimodaira S, Doughty AL, Picchio GR, Can H, Yen TSB et al (2003) Establishment of B-cell lymphoma cell lines persistently infected with hepatitis C virus in vivo and in vitro: the apoptotic effects of virus infection. *J Virol* 77(3):2134–2146
- The EUROGAST Study Group (1993) Epidemiology of, and risk factors for, *Helicobacter pylori* infection among 3194 asymptomatic subjects in 17 populations. *Gut* 34(12):1672–1676. <https://www.ncbi.nlm.nih.gov/pmc/articles/PMC1374460/>
- de Thé G, Kazanji M (1996) An HTLV-III vaccine: from animal models to clinical trials? *J Acquir Immune Defic Syndr Hum Retrovirol* 13:191–198
- The University of Texas. MD Anderson Cancer Center (2020) Legal & Financial Impacts of Cancer. Cancer treatment costs not covered, benefits provided by their employer. The University of Texas. MD Anderson Cancer Center, Austin, TX. <https://www.mdanderson.org/patients-family/life-after-cancer/legal-financial-impacts.html>. Accessed 23 Sep 2020
- de-Thé G, Day NE, Geser A, Lavoué MF, Ho JH, Simons MJ, Sohier R, Tukei P, Vonka V, Zavadova H (1975) Sero-epidemiology of the Epstein-Barr virus: preliminary analysis of an international study - a review. *IARC Sci Publ* 11:3–16
- United States Department of Labor. Occupational Safety and Health Administration (n.d.-a) Recommended practices for safety and health programs. Hazard prevention and control. Select controls according to a, or indirectly introduce new hazards. OSHA, Washington, DC. <https://www.osha.gov/shpguidelines/hazard-prevention.html>. Accessed 23 Sep 2020

- United States Department of Labor. Occupational Safety and Health Administration (n.d.-b) Safety and health topics. Carcinogens. OSHA, Washington, DC. <https://www.osha.gov/carcinogens/solutions>. Accessed 23 Sep 2020
- US Department of Health and Human Services. Public Health Service. Centres for Disease Control. National Institute for Occupational Safety and Health (1986) Proposed national strategies for the prevention of leading work-related diseases and injuries. Occupational Cancers
- Van Parijs LG (1986) Public education in cancer prevention. *Bull World Health Organ* 64(6): 917–927
- Wang Y (1983) Clonorchis sinensis. In: Zhao HX (ed) Human parasitology. People Health Press, Beijing, pp 451–463
- Warren KS, Mahmoud AA, Cummings P, Murphy DJ, Houser H (1974) Schistosomiasis mansoni in Yemeni in California: duration of infection, presence of disease, therapeutic management. *Am J Trop Med Hyg* 23(5):902–909
- Webster BL, Southgate VR, Littlewood DTJ (2006) A revision of the interrelationships of Schistosoma including the recently described Schistosoma guineensis. *Int J Parasitol* 36(8): 947–955
- Whitby D, Luppi M, Sabin C, Barozzi P, Di Biase AR, Balli F, Cucci F, Weiss RA, Boshoff C, Torelli G (2000) Detection of antibodies to human herpesvirus 8 in Italian children: evidence for horizontal transmission. *Br J Cancer* 82(3):702–704
- Whitby D, Marshall VA, Bagni RK, Miley WJ, McCloud TG, Hines-Boykin R, Goedert JJ, Conde BA, Nagashima K, Mikovits J, Dittmer DP, Newman DJ (2007) Reactivation of Kaposi's sarcoma-associated herpesvirus by natural products from Kaposi's sarcoma endemic regions. *Int J Cancer* 120(2):321–328
- Williams I, Smith MG, Sinha D, Kernan D, Minor-Babin G, Garcia E, Robertson BH, Di Pentima R, Shapiro CN (1997) Hepatitis B virus transmission in an elementary school setting. *JAMA* 278(24):2167–2169
- World Health Organization (2002) National cancer control programmes. Policies and managerial guidelines, 2nd edn. WHO, Geneva. <https://apps.who.int/iris/bitstream/handle/10665/42494/9241545577.pdf?sequence=1%20&%20isAllowed=y>
- World Health Organization (2007) WHO guide for effective programmes: cancer control. Knowledge into action. Early detection. WHO, Geneva. https://www.ncbi.nlm.nih.gov/books/NBK195408/pdf/Bookshelf_NBK195408.pdf
- World Health Organization (2017) Global hepatitis report. WHO, Geneva
- World Health Organization (2018) Alcohol. Global status report on alcohol and health 2018. WHO, Geneva. <https://apps.who.int/iris/bitstream/handle/10665/274603/9789241565639-eng.pdf?ua=1>
- World Health Organization (2019a) WHO launches new report on global tobacco use trends. During nearly the past two, use 2000–2025, 3rd edn. WHO, Geneva. <https://www.who.int/news-room/detail/19-12-2019-who-launches-new-report-on-global-tobacco-use-trends>. Accessed 23 Sep 2020
- World Health Organization (2019b) Rehabilitation. WHO, Geneva. <https://www.who.int/news-room/fact-sheets/detail/rehabilitation>. Accessed 23 Sep 2020
- World Health Organization (2020a) Who report on cancer. Setting priorities, Investing wisely and providing care for all. World Health Organization, Geneva
- World Health Organization (2020b) Cancer. WHO, Geneva. https://www.who.int/health-topics/cancer#tab=tab_1. Accessed 23 Sep 2020
- World Health Organization (2020c) Global health observatory data repository. Number of people (all ages) living with HIV. Estimates by WHO region. WHO, Geneva. <https://apps.who.int/gho/data/view.main.22100WHO?lang=en>. Accessed 23 Sep 2020
- World Health Organization (2020d) Global health observatory data repository. Prevalence of HIV among adults aged 15 to 49. Estimates by WHO region. WHO, Geneva. <https://apps.who.int/gho/data/view.main.22500WHOREG?lang=en>. Accessed 23 Sep 2020

- World Health Organization (2020e) Hepatitis B. WHO, Geneva. <https://www.who.int/news-room/fact-sheets/detail/hepatitis-b>. Accessed 23 Sep 2020
- World Health Organization (2020f) HIV/AIDS. Mother-to-child transmission of HIV. The transmission of HIV from, from 15%25 to 45%25. WHO, Geneva. <https://www.who.int/hiv/topics/mtct/en>. Accessed 23 Sep 2020
- World Health Organization (2020g) Schistosomiasis. WHO, Geneva. <https://www.who.int/news-room/fact-sheets/detail/schistosomiasis>. Accessed 23 Sep 2020
- World Health Organization (n.d.-a) Cancer. early diagnosis. WHO, Geneva. <https://www.who.int/cancer/prevention/diagnosis-screening/en/>. Accessed 23 Sep 2020
- World Health Organization (n.d.-b) Immunization, vaccines and biologicals. Hepatitis B. WHO, Geneva. <https://www.who.int/immunization/diseases/hepatitisB/en/>. Accessed 23 Sep 2020
- World Health Organization (n.d.-c) Immunization, Vaccines and Biologicals. Human papillomavirus (HPV). WHO, Geneva. <https://www.who.int/immunization/diseases/hpv/en/>. Accessed 23 Sep 2020
- World Health Organization (n.d.-d) International travel and health. Hepatitis B. Vaccine. WHO, Geneva. <https://www.who.int/ith/vaccines/hepatitisB/en/>. Accessed 23 Sep 2020
- World Health Organization (n.d.-e) Primary prevention of cancer through mitigation of environmental and occupational determinants. In: International Conference on Environmental and Occupational determinants of Cancer: Interventions for primary prevention. Asturias, Spain. WHO, Geneva, pp 1–6. https://www.who.int/phe/news/events/international_conference/Background_interventions.pdf
- Ziegler JL (1993) Endemic Kaposi's sarcoma in Africa and local volcanic soils. *Lancet* 342(8883): 1348–1351



Anita Khokhar is currently working as Director Professor in the Department of Community Medicine, Vardhman Mahavir Medical College and Safdarjung Hospital, New Delhi 110029, India. Dr. Khokhar graduated from Lady Hardinge Medical College, Delhi, and pursued MD in Preventive and Social Medicine from Maulana Azad Medical College, New Delhi, India. For over 15 years, she has been actively involved in work related to breast cancer and its early detection with preventive oncology being an area of special interest. She has written a book for women from all walks of life for providing information on various issues related to breast. She has also contributed chapters in various books and has published over 70 national and international scientific papers. She has received many awards in the field of medicine including “Asian Achiever’s Award 2020 in the field of Preventive Medicine.” She may be reached at khokharanita@gmail.com.



Priyanka Sharma has done her MBBS, MD (Community Medicine), from VMMC and Safdarjung Hospital, DNB (PSM), from NEB and is currently pursuing MBA in Disaster Management. She has 13 research publications and contributed a chapter on industrial disasters in Textbook of Occupational Health. Her research interest includes maternal and child health, non-communicable diseases including cancers, and school health.