

# Ecology of Increasing Diseases: Population Growth and Environmental Degradation

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**Abstract** The World Health Organization (WHO) and other organizations report that the prevalence of human diseases during the past decade is rapidly increasing. Population growth and the pollution of water, air, and soil are contributing to the increasing number of human diseases worldwide. Currently an estimated 40% of world deaths are due to environmental degradation. The ecology of increasing diseases has complex factors of environmental degradation, population growth, and the current malnutrition of about 3.7 billion people in the world.

**Key words** Ecology · environmental degradation · increasing disease · malnutrition · pollution · population growth

## Introduction

The ecology of increasing diseases in humans is exceedingly complex because of the biology and diversity of infectious organisms and the effects of environmental degradation on the prevalence of disease (World Resources Institute 1998; Pimentel *et al.* 1998; McMichael 2001; World Health Organization 2003e; Weiss and McMichael 2004; United Nations Environment Programme 2005). Today, just six infectious diseases (acute respiratory infections, human immunodeficiency virus/autoimmune deficiency syndrome (HIV/AIDS), diarrhea, tuberculosis, malaria, and measles) cause approximately 90% of all

deaths from infectious diseases worldwide (WHO 2005c). About 40% of the deaths (62 million per year) are attributed to various environmental factors especially organic and chemical pollutants (Pimentel *et al.* 1998; Robbins 2000). In addition, more than 3.7 billion humans suffer from malnutrition (WHO 2004a), and 2.2 million infants and children die each year from diarrhea, which is caused largely by contaminated water and food (Population Resource 2004).

In this article, we assess the relationship between increasing population numbers and growing environmental degradation. In addition, we examine the effects of both factors on the current and future disease incidence throughout the world.

## Population Growth and Disease Transmission

Health hazards associated with population growth include emerging and re-emerging diseases, poor vector control, poor sanitation, water and food contamination, air pollution, and natural disasters (Daily and Ehrlich 1996; Sachs 2000). Based on the current human growth rate of 1.2%, the current world population of nearly 6.5 billion will double to 13 billion in the next 58 years, thereby greatly intensifying pollution and disease problems (PRB 2006). The US population is growing at twice the rate of China's population (PRB 2006; US Census Bureau 2004, 2005). In 70 years the US population is expected to double to 600 million, and will reach China's population of 1,300 million in another 70 years, based on current growth rates (PRB 2006).

Today nearly half of the world's population live in cities, and by 2025, it is projected that two thirds of the world's population will have settled in large urban areas (PRB 2005). Densely crowded urban environments, especially

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those without adequate sanitation, are of public health concern because they promote disease epidemics, like measles and new diseases and influenza.

The severe acute respiratory syndrome (SARS) disease resulted from the crowding of humans and their livestock in cities in China (National Institute of Allergy and Infectious Diseases 2004a). SARS probably originated in civet cats that were being cultured and eaten by Chinese farmers. Eventually the virus was passed to farmers and then other people. In the 2003 outbreak, there were more than 8,000 cases of SARS with about 774 deaths (NIAID 2004a).

#### Environmental Pollution and Degradation

Global increases in air, water and soil pollution exacerbate human exposure to environmental pollutants and malnutrition, resulting in an estimated 40% of the total human deaths each year (Pimentel *et al.* 1998). Even more harmful to human health than these sources of pollution are tobacco smoke and indoor cooking smoke (WHO 2004h). More than 4 billion humans suffer from continuous exposure to smoke from these sources (Bruce *et al.* 2002). Increasing automobile and energy use is also contributing to poorer air quality in urban areas and to the growing number of human illnesses and deaths worldwide (Union of Concerned Scientists 2004).

Many humans are regularly exposed to toxic chemicals, including mercury, benzene, and pesticides. Approximately 2.8 billion kilograms of toxic chemicals are released into the US environment annually (US Census Bureau 2004). Common household and industrial chemicals may cause learning disabilities in 5 to 10% of US children (Miller 2004; Shettler *et al.* 2000). Environmental factors, including various chemicals, ultraviolet and ionizing radiation, and tobacco and cooking smoke account for 75% of all cancers (Sharpe and Irvine 2004). Annually, approximately 10 million people are diagnosed with cancer with about 6 million cancer deaths reported worldwide (WHO 2004d). In the United States, cancer-related deaths increased from 331,000 in 1970 to about 563,000 in 2002 (USCB 2003). The majority of cancers are linked to the environment, including chemicals and radiation (National Cancer Institute 2004).

#### Water Pollution and Diseases

Waterborne infections account for 80% of all infectious diseases worldwide and 90% of all infectious diseases in developing countries (Epstein *et al.* 1994; Robbins 2000). Lack of sanitary conditions contributes to approximately 4 billion human diarrhea infections, resulting in more than 2 million deaths each year, mostly occurring in infants and young children (One World Health 2004). Even in

developed countries, waterborne diseases have major impacts. In the USA, they account for 900,000 infections and about 900 deaths each year (Seager 1995; Global Water Issues 2002).

Approximately 1.2 billion people in developing nations lack clean water because most household and industrial wastes are dumped directly into rivers and lakes without treatment, contributing to many waterborne diseases in humans (Gleick 1993; MacDonald 2001; WHO 2004e). Currently, about 50% of the developing world's population is exposed to polluted water sources (United Nations Educational Scientific and Cultural Organization 2004a). Approximately 2.5 billion people lack adequate sanitation, contributing to more than 5 million deaths each year of which more than half are children (United Nations 2001). Developing countries discharge approximately 95% of their untreated urban sewage directly into surface waters (United Nations 2003). For example, only 4.6% of India's 5005 cities and towns have sewers and wastewater treatment facilities (Eddy 2004). Often people use the untreated water downstream for drinking, bathing, and washing.

Agricultural runoff also threatens the world's drinking water with animal and chemical wastes. In the United States, nearly 50% of lake water is polluted by erosion runoff containing nitrates, phosphates, and other agricultural chemicals (Gleick 1993; Environmental Protection Agency 2002). An estimated 20% of rivers are impaired due to runoff from nearby intensive livestock operations (EPA 1998).

In some countries, drastic environmental changes have led to an explosion in diseases affecting humans. For example, the construction of dams and similar alterations to natural water flow has increased the number of snails that are intermediate hosts for schistosomiasis. Schistosomiasis is associated with contaminated fresh water and is expanding worldwide, currently infecting more than 200 million people, with death estimates of up to 200,000 per year (Special Programme for Research and Training in Tropical Diseases, TDR 2004). For example, the 1985 construction of a dam 100 km from the mouth of the Senegal River in West Africa was followed by an explosion in *Schistosoma mansoni* in the human population. By 1994, 72% of the population was infected whereas there had been no documented cases prior to the dam's construction (Morgan *et al.* 2001). Additionally, various models suggest that climate change could lead to the spread of schistosomiasis to more areas in Africa, Southeast Asia, and South America (Martens 1995). Schistosomiasis is relatively stable in Africa (it has been there longer) but continues to colonize new snail hosts in South America, increasing its distribution (DeJong *et al.* 2001).

Malaria is another water-related concern for human health. Currently more than 50% of the world's population

is exposed to malaria, nearly a 10% increase in just 10 years (Breman *et al.* 2004). Malaria infects more than 500 million humans each year, killing approximately 1.2 to 2.7 million per year (Breman *et al.* 2004; Snow *et al.* 2005). Approximately 90% of all malaria cases occur in Africa, as do approximately 90% of the world's malaria-related deaths (Breman *et al.* 2004). Of interest is the fact that urbanization appears to reduce the incidence of malaria (Hay *et al.* 2005). This may be due to a relative lack of breeding sites in urban areas.

Pesticides are one of the prime methods of malaria control. Dichloro-diphenyl-trichloroethane (DDT), when first used for treating homes, resulted in dramatic reductions in the incidence of malaria in people. For example, in South Africa the use of DDT has been highly successful from 1945 to 1995 and there has been no sign of DDT resistance in vectors over the 50-year period (Guaasekasan *et al.* 2005). However, when DDT was also used for agricultural purposes, it exposed most of the mosquito populations to DDT and the mosquitoes evolved high levels of resistance to DDT, making DDT relatively ineffective (ICAITI 1977). Most nations have abandoned the use of DDT for use in agriculture. Yet, DDT appears to be one of the most effective insecticides for controlling malaria when sprayed on the inside walls of houses and Chris Curtis of the London School of Hygiene and Tropical Medicine reports no serious environmental problems when treating the inside of houses (Curtis 2002). Mosquitoes do not develop resistance because the quantities used are small; spraying is required only once or twice a year, and only a few mosquitoes (those inside houses) are actually exposed to DDT (Walker *et al.* 2003; Shapiro 2004). Additionally, the negative effects usually associated with DDT, such as bird kills, are greatly reduced by using only small quantities of DDT inside houses (Pimentel 2005). However, it must be emphasized that DDT is a hazardous chemical (John Rappole, personal communication, Smithsonian Nation Zoological Park, Front Royal, VA.). Since most mosquito bites occur after dark when people are inside their homes the use of DDT could dramatically reduce the incidence of malaria in endemic areas (Walker *et al.* 2003; Shapiro 2004).

A major concern in Africa is that malnourished people are more susceptible to malaria. Young children who are malnourished are twice as likely to die compared with well-nourished children (Caulfield *et al.* 2004).

Environmental changes, including increased water pollution, have fostered much of the increase and high incidence of malaria. Deforestation in parts of Africa has exposed land to sunlight and promotes the development of temporary pools of water with more neutral pH than puddles in forested areas where organic matter is abundant and pH is acidic (pH 4.5–5.5). The new pools facilitate the

breeding of human-biting, malaria-transmitting mosquitoes (Coluzzi 1994; Patz *et al.* 2000). Moreover, changing land use activity allows new mosquito species to move in and proliferate. For example, between 1971 and 1986 Brazil experienced a 76% increase in malaria transmitted by mosquitoes (Patz *et al.* 2000). As a result of mining operations, migrants help malaria pathogens to migrate between deforested areas (Patz *et al.* 2000). In addition, global warming is improving environmental conditions for mosquito proliferation, malaria, and other diseases (Epstein *et al.* 1998; Patz 2002). In sub-Saharan Africa the average person in an endemic area receives 121 bites from malaria-infected mosquitoes each year (Hay *et al.* 2005). In addition, mosquito vectors are evolving resistance to insecticides, while the protozoan pathogens are evolving resistance to anti-malarial drugs, reducing the effectiveness of the control efforts (Lambert 2004; Whitty *et al.* 2004).

#### Atmospheric Pollution and Diseases

Each year, air pollutants kill about 3 million people worldwide (WHO 2002c). Respiratory diseases such as asthma, acute respiratory infections, and lung cancer are strongly linked to environmental contaminants such as tobacco smoke, indoor smoke from cooking with biomass, and emissions from vehicle exhaust, power plants and other industrial processes. Respiratory diseases disproportionately affect vulnerable populations such as infants, children, women, the poor, and people in developing countries (WHO 2002c). An estimated 2.1 million children, younger than 5 years, die from acute respiratory infections worldwide (WHO 2003c).

Air pollution is a significant source of respiratory disease in the world, with 50% of chronic respiratory illness probably associated with air pollution (Ourplanet 2004). In most developed nations, the primary source of outdoor pollution is vehicle exhaust and power plant emissions. About 20% of the lung cancer deaths in the USA are caused by particulate matter from vehicle exhausts (Pearce 2002).

In cold-climate developing countries, like parts of China and the former Soviet Union, the prime source of outdoor air pollution is coal-powered home heating and automobile exhausts. In developing nations with warm climates, dust and vehicle exhaust are the prime sources of air pollution (Lvovsky 2001). Indoor air pollution from open cooking fires and tobacco smoke is an equally lethal source of respiratory disease, especially in rural areas in developing countries (WRI 1998). By 1993, air pollution levels in all 20 of the world's largest cities exceeded World Health Organization guidelines (WHO/UNEP 1992). Further, the highest levels of air pollution are found in developing countries.

The Environmental Protection Agency's limit for particulate matter (PM) in the air has a diameter of greater than 10  $\mu\text{g}$  (PM10), and this particulate matter is strongly linked to respiratory disease. Los Angeles, with the highest PM10 level in the USA, averages less than 50  $\mu\text{g}/\text{m}^2$  (Samet *et al.* 2000). However, in heavily polluted cities in the developing world, like Beijing and New Delhi, fine particulate matter averaged more than 300  $\mu\text{g}/\text{m}^3$  (Alberini *et al.* 1997).

Air pollution is excessive in China, which has seven of the ten most polluted cities in the world (Energy Information Agency 2003). If air pollution in China could be brought within Chinese air quality standards, approximately 178,000 premature deaths from respiratory diseases in urban areas could be prevented each year (McDonalds 2005). From 1955 to 1984, the prevalence of respiratory diseases occurred at a rate five times higher in China than in the USA, making respiratory diseases the leading cause of death in China (Zimmerman *et al.* 1996; WRI 1998).

In general, air pollutants exacerbate asthma, which ultimately can become severe enough to cause death. Worldwide, the incidence of asthma has increased, with between 100 and 150 million people suffering from asthma (WHO 2000c). In the USA, asthma is one of the most chronic diseases in children, affecting about 5 million children annually (Keeler *et al.* 2002).

Globally, but especially in developing nations where people cook with coal, fuelwood, dung, and other biomass resources over open fires, nearly 4 billion humans suffer continuous exposure to smoke (Bruce *et al.* 2002). This smoke contains more than 4,000 hazardous chemicals including many carcinogens (DeKoning 1985). Fuelwood cooking smoke is estimated to cause the death of 1.6 million children each year worldwide (WHO 2002c). Because women do most of the cooking, they are twice as likely as men to be diagnosed with respiratory illness (Ezzati and Kammen 2001).

Smoking is another major contributor to respiratory illness. Currently there are 1.3 billion tobacco smokers worldwide (WHO 2005b). More than 4,000 hazardous chemicals are produced in cigarette smoke, 200 of which are highly toxic (LSC 2004; LungUSA 2004). In the long term, the carcinogenic compounds in tobacco smoke are linked to a heightened risk of cancer among children exposed to environmental tobacco smoke (ETS) in their childhood (D'Souza 1997). Each year between 150,000 and 300,000 cases of lower respiratory tract infections in infants and young children up to 18 months are attributed to ETS (EPA 1992).

At present 4.9 million people worldwide die annually from smoking (Von Schirnding *et al.* 2000) with projections suggesting that 10 million will die per year by 2025, 70% of whom will reside in developing countries (Jenkins *et al.* 1997). In the USA, about 440,000 people die each year

from smoking related illnesses, which is about 20% of all US deaths (Center for Disease Control 2004c). The number of smokers worldwide is expected to double by 2010 (UNESCO 2004b).

Skin cancer is another threat to global human health. Between 2 and 3 million non-melanoma skin cancers and 132,000 melanoma skin cancers occur globally each year (WHO 2002d). Skin cancer incidence is doubling about every 17 years in the USA (Health Link 2004). The American Cancer Society reported about 800,000 cases of non-melanoma skin cancers in 1995, and in 2001 the number of cases had risen to more than 1 million (Health Link 2004). The WHO predicts a 10% increase in skin cancer incidence in the USA by the year 2050 (WHO 2003b, e).

The rise in skin cancer incidence is associated with anthropogenic pollution. As the ozone layer decreases, this increases cancer-inducing UV-B radiation (McMichael 1993; Martens and McMichael 2002; McKenzie *et al.* 2003). Exposure to sunlight, including UV-B radiation, accounts for 70% of skin cancers in the USA (SoRelle 2004).

The use of leaded gasoline is another source of concern related to atmospheric pollution. Lead poisoning causes anemia, kidney problems, and brain damage. Children exposed to lead are particularly at risk for brain damage and reduced learning capabilities (Canfield *et al.* 2004). Currently, an estimated 1.7 million children in the USA are exposed to hazardous levels of lead and have blood levels above the acceptable level of 10  $\mu\text{g}/\text{dl}$  (Council on Environmental Quality 1996; CDC 2004g).

#### Chemical Pollution and Disease

Newly developed technologies increase the varieties, potencies, and quantities of chemicals that are released into the air, soil, and water each year. The release of chemicals has damaged many important ecosystems and caused serious disease problems in humans. The USA releases over 2.8 billion kilograms per year of toxic chemicals (USCB 2004). Over 85,000 industrial chemicals are used in commerce and an additional 2,300 chemicals are added each year (Zeeman *et al.* 1996; Lucier and Schecter 1998). The biological activity and human toxicity of most of these chemicals is unknown (Thornton *et al.* 2002).

Chemical exposures contribute to a variety of serious human diseases, including cancer, birth defects, immune system defects, reduced intelligence, behavioral abnormalities, decreased fertility, altered sex hormones, altered metabolism, and specific organ dysfunctions (Carpenter *et al.* 2002). Americans of all ages carry a burden of at least 116 chemicals extraneous to their bodies, some of which were banned more than three decades ago, such as DDT and BHC (CDC 2003a). Other chemicals found in virtually every person are lead, mercury, dioxins, and PCBs

(Carpenter *et al.* 2002). These chemicals find their way into our bodies through the air we breathe, the water we drink, our food, and our every day environmental exposure. In fact, 48 states have advisories limiting fish consumption because of contamination, like mercury, found in fish (Anderson *et al.* 2004). In Oklahoma, ponds tested from 2000 to 2003 by the Environmental Protection Agency have been found to have mercury levels above the 0.5 ppm that can be dangerous for pregnant women and children (Tyree 2006). Despite advisories, currently 6% of women of childbearing age in the USA have potentially hazardous levels of mercury in their blood, which can cause developmental and neurological defects in fetuses (Jones *et al.* 2004). Coal-fired power plants are the largest source of mercury pollution.

In studies conducted in California and New Mexico, 16% of those surveyed were allergic or sensitive to common chemicals (Kreutzer *et al.* 1999). The cost of multiple chemical sensitivity (MCS) to society is high when the effects of lost productivity, health care, and support for disabled workers are totaled (Ashford and Miller 1998; McCampbell 2002). Between 33 and 77 million people in Bangladesh are at risk of poisoning from naturally occurring arsenic in wells dug very deep (Arsenic 2005). The scale of this impact is greater than the Bhopal accident in India that killed 8000, injured over 120,000, and has an ongoing health impact (Vosters 2003).

Perhaps of more serious concern to public health are cancers resulting from chemicals. About 10 million new cancer cases are diagnosed each year worldwide (Eaton 2003). Some cancers are linked to the use of polluted water 70% of the water in five of China's seven major river systems is unsuitable for human use (The Economist 2004). In the USA, 1.4 million cases of cancer were reported in 2004 (USCB 2004). A woman's lifetime risk of breast cancer has increased from 1 in 22 in 1940 to one in seven today (Evans 2004).

The risks associated with chemical exposures are compounded by immunosuppressive activities of some chemicals. These chemicals increase the risk of infectious diseases (Van Loveren *et al.* 1995; WHO 1999). Pesticides are one class of hazardous chemicals. Worldwide about 3 billion kilograms of pesticides are used per year, with about 0.5 billion kilograms applied per year in the USA (Pimentel 2005). Although the total quantity of pesticide use has not increased significantly during the past decade, the toxicity of individual pesticides has increased from 10- to 100-fold compared with those in use in 1950 to 1960 (Pimentel 1997). In 1990, the number of work-related pesticide poisonings in the developing world was estimated to be 25 million cases per year with approximately 220,000 fatalities (Jeyarathnam 1990; Richter 2002). Approximately 99% of the global deaths related to pesticides occur in developing countries (WHO/UNEP 1990).

The number of human pesticide poisonings in the USA was reported in 1990 to be about 67,000 per year in one study (Litovitz *et al.* 1990); later, the number was reported to have increased to more than 300,000 per year (Klein-Schwartz and Smith 1997). This may reflect the higher toxicity of the new pesticides in use today, compared with the early pesticides, as well as the increased pesticide drift problem. Aircraft application of pesticides causes the most serious drift problem, with 40% to 60% of the pesticide applied drifting away from the target area (Cox 1995). Aerially applied pesticides are estimated to drift up to 1,600 m from the application site and may drift up to 80 km downwind (Cox 1995). In California, 51% of the agricultural pesticide poisonings were the result of pesticide drift (Kegley *et al.* 2003).

Approximately 57% of non-fatal pesticide poisonings reported in the USA involve children younger than 6 years (Sanborn *et al.* 2002). For example, in Washington State, reports confirm that dietary doses of pesticides were exceeded in 44% to 56% of the children with non-fatal pesticide poisoning (Sanborn *et al.* 2002).

#### Land Degradation Effect on Disease Incidence

Soil is contaminated by a wide array of chemicals and pathogens. Humans may acquire chemical pollutants and pathogens directly from the soil (i.e., by contact with the soil) or indirectly, through food and water contamination. At times, soil particles themselves may be pollutants, entering the eyes, nose, and mouth and acting as irritants or allergens.

Exposed soil is highly susceptible to wind and water erosion. Wind erosion can cause serious health problems by blowing into the air soil particles and microbes into the air, which irritate the respiratory tract and eyes, and aggravate allergies and asthma. In China, farmland erosion and desertification has led to Beijing experiencing 11 dust storms during one year (WHO 2002b). Many types of pathogens have been recorded in blowing soil. For example, 19 pathogen species that infect humans have been recorded in blowing soil in various regions of the earth, including anthrax, TB, flu virus, and hantavirus (Griffin *et al.* 2001). Erosion disperses toxic chemicals, such as heavy metals and pesticides, leading to contaminated food and water resources. Soil depth is also critical to food crop production. For example, reducing soil depth by 25 cm was found to reduce crop productivity by about 60% (Stallings 1964).

As the human population expands and land is cleared of trees, loss of forest cover can contribute to an increase in the prevalence of human infections by helminthes, such as hookworms. After deforestation in Haiti, hookworm infections rose from zero to 12% of the population in 1990 and

15% in 1996 (Lilley *et al.* 1997). Children suffer greater morbidity from helminth infections than adults because children need more protein than adults per kilogram of body weight; under severe parasitic infections, they may be unable to utilize protein efficiently enough to remain healthy.

Many helminth species that infect humans are found in soil contaminated by human feces, thereby exacerbating the cycle of exposure. Worldwide, more than 2 billion people are infected with one or more helminth species, either by direct penetration or by consumption of contaminated food or water (Hotex *et al.* 1996). In locations where sanitation is poor and people are overcrowded, such as parts of urban Africa, up to 90% of the population may be infected with one or more helminth species (Wamae and Mwanza 2000). In China, approximately 600 million people (nearly half the population) have water that is contaminated by human and animal wastes (The Economist 2004).

#### Food Contamination, Disease, and Malnutrition

Although it is difficult to estimate, annually about 2.1 million people die from diarrheal diseases worldwide (WHO 2002e). In industrialized nations, approximately 360 million foodborne disease cases occur annually and in developing nations an estimated 1.9 billion annually (WHO 2002e). In the United States, approximately 76 million foodborne diseases occur in humans each year, causing 5,000 deaths (Mead *et al.* 1999; DeWaal *et al.* 2000; NIAID 2002a). In addition, foodborne diseases cost the U.S. \$5 to \$6 billion each year (Table I).

Poultry, hogs, cattle, and other livestock are easily contaminated with *Salmonella* and various *Escherichia coli* and *Campylobacter* microbes, especially when the animals are crowded together in livestock facilities with inadequate waste disposal systems (Lederberg *et al.* 1992; Altekruse *et al.* 1997). Additional microbial contamination can result from unsanitary conditions during slaughtering, processing, and handling. In the USA, hen eggs and poultry have been identified as the main source of *Salmonella enteritidis*, which can cause severe gastrointestinal illnesses and sometimes death in humans, especially among children and the infirm (Prior and Solnick 2000; WHO 2002d). Over the past 10 years *S. enteritidis* infections have increased significantly on several continents (WHO 2002d).

The proliferation of confinement livestock has unknown consequences on human health. A study conducted in Milford, Utah by the Utah District of Health Department studied the period of 1992–1998 when a 44,000 head sow operation (with a target of 120,000 sows) was constructed. The town of Milford experienced a fourfold increase in diarrhea cases and threefold increase in respiratory illnesses. These rates were significantly higher than those

found in similar populations and in the state as a whole (Thu 2000).

*Staphylococcus* and *Salmonella* are two airborne pathogens in or near livestock facilities. These airborne microbes can infect farm workers and people living downwind from the livestock facility (Thu 2002). Thus, diarrhea and various infections are common near large livestock facilities. (Thu 2002). Foodborne illnesses are estimated to cause from \$6.5 to \$34.9 billion in damages and treatment costs each year (Guelph University 2005).

Malnutrition, which includes inadequate intake of calories, protein, iron, iodine, and numerous essential vitamins, is a major disease related to environmental degradation (Myers and Kent 2001). The World Bank World Development Report estimated that deficiencies of vitamin A, iron, and iodine waste as much as 5% of global gross domestic product (GDP), while addressing these deficiencies would cost just 0.3% of global GDP (World Bank 1993). Malnutrition prevails in regions in which the overall food supply is inadequate, where populations lack economic resources to purchase food, and where political unrest and instability interrupt food supplies. In addition, rapidly expanding human populations intensify the food-supply problems by diminishing the per capita availability of cropland (Pimentel and Pimentel 2003).

In 1950, 500 million people (20% of the world population) were malnourished (Grigg 1993). Today more than 3.7 billion people (nearly 60% of the world population) suffer from malnutrition (WHO 2004a)—the largest number in history. Each year, approximately 6 million children under the age of 5 die from malnutrition (Food and Agriculture Organization 2002). Even in the USA, over 11% of all households experienced food insecurity during 2002 and 3.5% of those households has at least one family member who went hungry (Nord *et al.* 2003). Malnutrition at an early age can lead to physical and mental underdevelopment as an adult; this underdevelopment facilitates a poverty trap where people are stuck at a low-level of productivity, at a great cost to society and the environment (Academy of Natural Sciences 2004).

Vitamin A malnutrition diminishes and impairs the immune responses to infectious diseases in children. Vitamin A supplements have been shown to decrease mortality by 30% in vitamin A deficient children ages 6 months to 5 years (Stephensen 2001). Each year, vitamin A deficiency causes approximately 2.5 million deaths (International Development Research Centre 2004). Vitamin A shortages can also cause mental disabilities in children (Obasanjo 2004; Academy of Natural Sciences 2004). More than 13 million people suffer night blindness or total blindness from a lack of vitamin A (Academy of Natural Sciences 2004).

**Table I** Economic Costs of Diseases in the USA Environmentally Induced Infectious Diseases vs Behavioral Expenses

Environmental	
Disease	Financial cost (per year)
Intestinal infections	\$23 billion (direct medical costs and lost productivity) <sup>a</sup>
Foodborne diseases	\$ 5–6 Billion in medical and productivity costs (\$1 billion to <i>E. coli</i> <sup>b</sup> )
Influenza	\$17 (pandemics could cost from \$ 71 to \$167 Billion <sup>c</sup> )
Antibiotic-resistant bac. infect.	\$4 Billion in treatment costs and increasing (May be as high as \$30 Billion) <sup>d</sup>
Tuberculosis	\$1 Billion <sup>e</sup>
Malaria prevention	\$2 Billion <sup>f</sup> (Target Budget for Africa—Actual is \$545.5 million)
Digestive diseases	\$80 Billion (\$27 billion more in first two items) <sup>g,h</sup>
Asthma	\$14.5 Billion (2000 estimate up from \$6.2 billion in 1990) <sup>i</sup>
Smoking related costs	\$75–97 Billion <sup>j,k</sup>
Cancer	\$189.5 billion (\$64.2 billion medical costs, \$115.3 lost productivity) <sup>l</sup>
Arthritis	\$86 billion (\$51 billion in direct costs) <sup>m</sup>
Total	~\$500 Billion
Behavioral/genetic	
STDs (excluding AIDS)	\$5–10 Billion <sup>a,n</sup>
Hepatitis B virus infection	\$154–720+ Million in direct and indirect costs <sup>a,n</sup>
Hepatitis C virus	\$5.5 Billion
AIDS	\$20 Billion <sup>o</sup>
Cardiovascular	\$329 Billion (\$129 billion in lost productivity) <sup>p,j</sup> (\$260 billion from heart disease and stroke) <sup>q</sup>
Inactivity	\$76.6 Billion
Obesity	\$48 Billion (excluding \$22 billion in related heart disease) <sup>f</sup>
Alcohol abuse	\$100 Billion (\$4.5 billion in direct medical costs of related diseases) <sup>s</sup>
Diabetes	\$132 Billion (\$92 billion in direct costs) <sup>t</sup>
Total	~660 Billion (rounding down for overlap)
Combined total (conservative)	\$1.16 Trillion

<sup>a</sup>NSTC 1995<sup>b</sup>USDA 2002<sup>c</sup>WHO 2003a<sup>d</sup>NIAID 2000<sup>e</sup>American Lung Association of Texas 2004<sup>f</sup>WHO 2004f<sup>g</sup>NIH 1994<sup>h</sup>Sandler *et al.* 2002<sup>i</sup>National Committee for Quality Assurance 2001<sup>j</sup>CDC 2004f<sup>k</sup>American Lung Association 2004<sup>l</sup>NIH 2002<sup>m</sup>USCB 2004<sup>n</sup>NIAID 1998<sup>o</sup>Kaiser Family Foundation 2004<sup>p</sup>WHO 2004b<sup>q</sup>CDC-OC 1997<sup>r</sup>Nutristrategy 2004<sup>s</sup>US Health and Human Services 2002<sup>t</sup>NDIC 2002

Similarly, iron intake per person has been declining during the past 10 years, especially in developing countries (WHO 2004g). Globally, from 4 to 5 billion people are iron deficient and 2 billion suffer from anemia (WHO 2004g). Worldwide, an estimated 9 million deaths can be attributed to iron deficiency (WHO 2004g). In addition, about 1.6 billion people live in iodine-deficient environments and suffer from iodine deficiency disease (United Nations 2004). Iodine deficiency also causes mental disabilities in children (United Nations 2004).

Malnutrition, complicated by parasitic infections, is frequently found in poverty-stricken areas with inadequate sanitation. In developing nations, more than one third of the infectious disease burden is due to malnutrition (Mason *et al.* 2004). For children, malnutrition increases their susceptibility to infectious diseases and death by 42 to 57% (Pelletier *et al.* 1994). Malnourished individuals, especially children, are seriously affected by parasitic infections because these infections also reduce nutrient availability. The presence of intestinal parasites frequently diminishes

appetite and food intake, and also increases the loss of nutrients by causing diarrhea and dysentery. Hookworms, for instance, can suck as much as 30 ml of blood from an infected person each day, gradually weakening individuals and lowering their resistance to other diseases (Hotez and Pritchard 1995). Latham *et al.* (1990) measured the caloric gain that Kenyan schoolboys obtained once given treatment to eliminate their multiple helminth infections. Based on these data, it is possible to estimate the daily amount of food intake that is necessary to offset the helminth infections. The daily recommendation for children 9 to 13 years is about 2,000 kcal (Institute of Medicine 2002). The Kenyan schoolboys gained about 86 kcal per meal per day. At the average of three meals per day, this accounts for a gain of 258 kcal once the helminth infection was eradicated. Thus, prior to treatment, the schoolboys utilized between 12 and 14% of their daily food intake to offset the effects of their helminth infections which is probably average. We estimate the range of food lost to parasitic infections to be between 10 and 20% of an individual's daily food intake.

#### Drug Resistance in Microbes

Drug resistance and rapid genetic changes in microbes contribute to global disease outbreaks, diminishing the ability of humans to successfully ward off or control illness (NIAID 2004b). Many microbe types have evolved resistance to antibiotics (Antibiotic Resistance 2004; Levy and Marshall 2004). The bacteria resistant to antibiotics cost the USA more than \$4 billion in added treatments and lost productivity each year (Table I). The evolution of drug resistance in microbes can be surprisingly rapid. In 1979, only 6% of the European *Pneumococcus* strains were resistant to penicillin, but one decade later that percentage had grown to 44% (Platt 1996). Currently in the USA, more than 90% of the *Staphylococcus aureus*, one of the most common disease-producing microbes, are resistant to penicillin and similarly effective antibiotics (American Society of Microbiology 1994). A study of 113 French pig farmers reported that nasopharyngeal carriage of *S. aureus* resistant to macrolide was more frequent in farmers than non-farmers. The large-scale antibiotic use associated with today's industrial livestock farming, in addition to antibiotic drug resistance in bacteria gaining entrance to the human food chain, pose serious public health problems (CDC 2005). Rapid increase in drug resistance by disease organisms is caused by the widespread use and overuse of 300 antibiotics by the medical profession (ASM 1994). In addition, eight times more antibiotics are used in livestock production than are used to treat humans (UCS 2001). The concurrent overuse of antibiotics for both humans and livestock enhances selection for drug-

resistant microbes, further exacerbating the problem of antibiotic resistance.

#### Reemerging Diseases

The worldwide increase in tuberculosis results from population crowding and drug resistance. Currently an estimated 2 billion people worldwide are infected with TB, with an estimated 3 million deaths annually (NIAID 2002b; WHO 2004b). In the USA, an estimated 10 to 15 million people (mostly foreign-born nationals) are infected with latent TB, but do not display the symptoms (NIAID 2002b).

Each year about 8 million people worldwide develop TB (NIAID 2002b). Drug-resistant TB strains and reduced medical treatment account for this increase. TB infections are further complicated by the use of illegal drugs and the rise of HIV infections, both of which help to spread the disease and lead to frequent reinfection. Tuberculosis is rapidly increasing in the Russian Federation. From 1990 to 2000, the number of reported cases per year has increased from 51 to 90 per 100,000 people (CDC 2004e).

Influenza or flu is one of the most serious virus diseases in the world. From 300 million to 900 million people are infected with the flu which resulting in 250,000 to 500,000 deaths each year (WHO 2003a). In the USA, 200,000 people are hospitalized from the flu, with about 36,000 deaths each year (CDC 2004a). Another cause for concern is avian influenza, a highly pathogenic form of the flu virus that has passed from birds to humans in isolated cases, and represents a potentially serious threat as it is particularly deadly, with a mortality rate of 76% in recent human outbreaks in Southeast Asia (WHO 2005a).

The flu costs the USA about \$17 billion per year in medical and lost productivity costs each year (Table I). Flu vaccine to treat one person costs about \$10.40; thus, everyone in the USA could be treated at a cost of \$3.1 billion (Stanford 2004). However, a flu pandemic in the USA could cost the nation from \$71 to \$167 billion in health care and lost productivity costs (WHO 2003a).

Brucellosis is another resurgent communicable disease. The causative bacteria, *Brucella* spp., infect cattle, sheep, goats, and some wild mammals worldwide and are harbored in an animal's udder. Humans usually contract the disease from infected animals or contaminated dairy products. Roth *et al.* (2003) report that the number of cases of brucellosis is increasing, especially in developing countries, with about 360,000 cases reported per year.

#### Newly Emerging Diseases

Changes in biological diversity, evolution of parasites, and invasion by exotic species all frequently result in disease



outbreaks. Several new and emerging diseases are listed in Table I. For example, an emerging rodent-related disease that is related in part to increasing human numbers, is the hantavirus pulmonary syndrome; this disease is estimated to have caused approximately 227 deaths in children between 1995 and 2003 (CDC 2004d). By the end of 1994, 135 cases of hantavirus pulmonary syndrome were recognized in the U.S. and Canada, with a human mortality rate of 50% (CDC 1994).

A new disease introduced in 1999 into the USA is West Nile virus, which is transmitted by our native house mosquitoes (CDC 2004b). Four years later the disease had spread to 46 states with 9,862 reported infections and 264 deaths (CDC 2004b). The West Nile reservoir host is birds but humans can be infected (Rappole *et al.* 2000). In 2004, the number of West Nile infections had declined to about 1,400 cases with about 64 deaths per year (CDC 2004b). The reason for the decline in infections and deaths is unknown. However, West Nile confirms that the spread of new diseases is now a major public health problem (Pimentel *et al.* 2000; Epstein *et al.* 2003).

In the USA, Lyme disease is the most widespread vector-borne disease, with infections reported in 47 states (CDC 2001). The bacterium that causes Lyme disease, *Borrelia burgdorferi*, is a spirochete similar to the one that causes syphilis in humans (National Center for Biotechnology Information 1999). It is thought to have existed in the USA without incident until major ecological changes took place; suburban areas expanded, white-tailed deer populations exploded, along with increases in the deer mouse and deer tick populations (UNEP 2005). Spreading dramatically since the initial description of the disease in 1976, Lyme disease now infects nearly 24,000 people in the USA each year and the incidence of the infection continues to grow (Table II).

Another rapidly increasing disease is HIV/AIDS (Table II). The growing human population, especially the increased number of people in urban areas, has coincided with the spread of HIV and AIDS (UNAIDS 2004). From 1979–1980, an estimated 115 people worldwide were infected with HIV, but by the year 2003, about 40 million were infected with HIV (UNAIDS 2004; Table III). In 2003, almost 5 million people became newly infected with HIV, the greatest number in any one-year since the beginning of the epidemic (UNAIDS 2004). The total number of HIV/AIDS deaths during 2003 is reported to be 3 million (UNAIDS 2004; Table III).

HIV/AIDS infections are especially widespread in certain parts of the world. For example, from 25 to 28 million people are living with HIV/AIDS in sub-Saharan Africa and the epidemic is growing rapidly in Asia (UNAIDS 2004). In the USA, the number of new cases of AIDS peaked in 1993 at about 80,000 and has declined in 2002 to about 42,000 per year (CDC 2003e). The number of USA deaths peaked at about 50,000 per year and then declined by 2002 to about 17,000 per year (CDC 2003e). The worldwide costs of HIV/AIDS treatment are estimated to be \$7 to \$10 billion for low and middle-income countries (Global Fund 2004). This figure, however, continues to rise, as an estimated \$12 billion will be needed to effectively respond to the epidemic in 2005 and \$20 billion in 2007 (Kaiser Family Foundation 2004; Table I). On average, worldwide AIDS care-related expenses can amount to one third of a household's income and is a major contributor to poverty (UNAIDS 2004).

Currently there are five known hepatitis viruses that cause inflammation of the liver, although new hepatitis viruses are being discovered, such as F, G, and X. Hepatitis A and E are the most easily transmissible, yet the most serious hepatitis virus worldwide is HBV or hepatitis B

**Table II** Specified Number of Human Disease Cases in the USA (USCB 2003)

Disease	1990	2001	%growth
Botulism	92	155	68.5
Chlamydia	308,139 <sup>a</sup>	783,000	254
Cryptosporidiosis	2,566 <sup>b</sup>	3,785	47.5
<i>Escherichia coli</i> 0157:H7	2,139 <sup>c</sup>	3,287	53.7
Haemophilus influenza	1,180 <sup>d</sup>	1,597	35.3
Lyme disease	11,700	24,000 <sup>e</sup>	105
Rabies, animal	4,826	7,150	48.2
Whooping cough	4,600	7,600	65.2
Skin cancer	800,000 <sup>f</sup>	1,000,000	25.0

<sup>a</sup> For 1990, CDC (1990)

<sup>b</sup> For 1997

<sup>c</sup> For 1995

<sup>d</sup> For 1995

<sup>e</sup> For 2002, CDC (2003d)

<sup>f</sup> For 1995

**Table III** Human Public Health Problems and Deaths from Diseases Each Year Worldwide

Disease	Number of affected people $\times 10^6$	Number of deaths $\times 10^3$
Diarrhea	2,000 <sup>a</sup>	4,000 <sup>a</sup>
Tuberculosis	2,000 <sup>b</sup>	3,000 <sup>c</sup>
Influenza	300–900 <sup>d</sup>	250–500 <sup>d</sup>
Tobacco smoke	1,300 <sup>e</sup>	4,907 <sup>f</sup>
Indoor smoke solid fuels	4,000 <sup>g</sup>	2,000 <sup>f</sup>
Asthma	100–150 <sup>f</sup>	2,100 <sup>f</sup>
Measles	45 <sup>h</sup>	1,100 <sup>h</sup>
Ascariasis	1,000 <sup>i</sup>	3 <sup>j</sup>
Filariasis	120 <sup>k</sup>	–
Schistosomiasis	200 <sup>l</sup>	15 <sup>m</sup> –200 <sup>l</sup>
Malaria	500 <sup>n</sup>	1,200 <sup>o</sup> –2,700 <sup>p</sup>
Trichuriasis	800 <sup>q</sup>	3 <sup>j</sup>
Dengue fever	20–100 <sup>r</sup>	19 <sup>j</sup>
Onchocerciasis (river blindness)	18 <sup>s</sup>	–
Helminths	2,000 <sup>t</sup>	–
Malnutrition	3,700 <sup>j</sup>	18,000 <sup>u</sup>
Japanese encephalitis	0.3–0.05 <sup>v</sup>	14 <sup>j</sup>
HIV/AIDS	40 <sup>w</sup>	3,000 <sup>w</sup>
Hepatitis B	400 <sup>x</sup>	132 <sup>j</sup>
Cancer	10 <sup>y</sup>	6 <sup>y</sup>
Syphilis	11.8 <sup>z</sup>	157 <sup>j</sup>
Typhoid	16 <sup>aa</sup>	600 <sup>aa</sup>

<sup>a</sup> Palaniandy and Lucey (2002).

<sup>b</sup> WHO (2004c)

<sup>c</sup> NIAID (2002b)

<sup>d</sup> WHO (2003a)

<sup>e</sup> WHO (2004h)

<sup>f</sup> WHO (2002c)

<sup>g</sup> Bruce *et al.* (2002)

<sup>h</sup> Layne (2004)

<sup>i</sup> Medline Plus (2004)

<sup>j</sup> WHO (2004a)

<sup>k</sup> WHO (2000a)

<sup>l</sup> TDR (2004)

<sup>m</sup> WHO (2002a)

<sup>n</sup> Nchinda (1998) and Breman *et al.* (2004)

<sup>o</sup> Breman *et al.* (2004)

<sup>p</sup> Nchinda (1998)

<sup>q</sup> CDC (2003c)

<sup>r</sup> Shepard *et al.* (2004)

<sup>s</sup> WHO (2000b)

<sup>t</sup> Hotez *et al.* (1996)

<sup>u</sup> IGS (2001)

<sup>v</sup> CDC (2003b)

<sup>w</sup> WHO (2002b)

<sup>x</sup> Lin and Kircher (2004)

<sup>y</sup> WHO (2004d)

<sup>z</sup> WHO (2001)

<sup>aa</sup> WHO (2003d)

(Palmer 2000). There are about 400 million carriers of HBV and more than 130,000 deaths per year worldwide (Lin and Kircher 2004; WHO 2004a). Hepatitis B infections in the USA cost the nation more than \$720 million in

direct and indirect costs (Table I). Additionally, there are about 170 million carriers of Hepatitis C or HCV with about 50,000 deaths per year (WHO 2004a).

The 8,000 deaths per year in the USA from HCV outnumber the 6,000 deaths from HBV in both North and South America per year (WHO 2004a: National AIDS Treatment Advocacy Project 2003). There are more deaths due to HCV because there is no vaccine. Although the incidence of HCV is declining, only about 5% of the infected people know that they have HCV. Thus, HCV is sometimes termed the “silent epidemic” (Palmer 2000).

## Conclusion

A growing number of people who lack basic needs, such as access to clean water and food, are more susceptible to diseases driven by malnourishment, and overpopulation, and air, water, and soil pollutants, further stresses humans and increases disease prevalence.

Our review confirms that many factors influence the increasing prevalence of human disease now occurring worldwide. Currently, 40% of global deaths result from diverse environmental factors, including chemical pollutants, tobacco smoke, and malnutrition. Today, six infectious diseases cause 90% of all deaths worldwide. Deaths due to several infectious diseases have also been increasing in the USA, with a cost to the nation of several billions dollars each year.

To help prevent infectious diseases, people need to be educated, especially in dealing with water pollution and AIDS. For AIDS control, condoms and other protected sex have proven highly effective.

In addition, global climate change appears to be creating an environment more hospitable for some diseases and disease vectors. Climate change may also increase the susceptibility of food crops to some pests, which in turn could intensify problems of food shortages and malnutrition that already exist in the world.

To prevent disease, poverty and malnutrition from worsening, the growing imbalance between the escalating human population and the earth’s environmental degradation and limited resources must be addressed. Thus, a comprehensive, fair population-limiting policy combined with an effective environmental management program is essential. Relying on increasing diseases and malnutrition to limit human numbers in the world diminishes the quality of life for all humans, and is a high risk policy.

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