

Part 2.

Environmental Management

THE INTERCONNECTION BETWEEN THE BUILT ENVIRONMENT ECOLOGY AND HEALTH

H. S. KOREN

*Carolina Environmental Program,
University of North Carolina, Chapel Hill, NC 2759-1105, USA*

C. D. BUTLER

*National Centre for Epidemiology and Population Health, Australian
University, Canberra, ACT, 0200 AUSTRALIA*

Abstract:

The built environment (BE) affects ecosystems, ecosystem services and human health and well being. While, formally, the BE ranges from the smallest hut to the largest city, this chapter focuses upon the health effects of urban areas, which increasingly are the preferred human habitat. Urban areas have many attractive and beneficial influences to human well-being. But at the same time, many effects of urban areas are harmful to well-being, and many are not even recognized as such. Most publications about these topics have described the effects of the BE separately, on *either* ecosystems *or* on human health. The interconnectivity between these two effects relative to BE is rarely studied. This paper focuses on the mutual influence and interactions between three related aspects of the BE which can impact ecosystems *and* human health: transportation, land use, and life style. It also explores some of the links between the BE, human health, and human security.

Transportation, especially when based on systems of private cars burning fossil fuels, is often the most important cause of air pollution in both developed and developing countries. Air pollution has many adverse health effects, including asthma and cardiovascular disease. Transport systems based largely on the use of private cars are a major contributor to global warming and to ecosystem degradation. This occurs directly, as the operation of vehicles releases greenhouse gases causing global climate change which is associated with altered temperature and rainfall patterns and rising sea levels. Warmer ocean temperatures are projected to increase the frequency and intensity of extreme weather events. These effects can also harm cold water fisheries, and otherwise degrade aquatic habitats. The heat-retaining nature of road surfaces and many buildings, together with the loss of vegetation, contributes to “heat islands” sometimes exacerbated by particulate-dense air pollution. Heat islands may create a double burden of pollution as people respond reactively, for example with air conditioning, rather than within urban redesign, such as exchanging black for green surfaces, fewer roads and more rooftop gardens. Transportation is therefore having an impact on ecohealth as well as human health, and these are interconnected.

Land use is greatly affected by urban sprawl practices that are responsible for degrading habitats, for altering ecosystem function, and for reducing biodiversity. Sensitive and critical habitats are often fragmented or sacrificed for roads, suburbs and industrial estates. Urban conurbations also pollute reservoirs, ground water, and stream networks with chemicals and pathogens, with numerous adverse health effects. Habitat loss and fragmentation are two of the most direct impacts of development on previously undeveloped land. Habitat fragmentation and an increased proximity of forest, agricultural land and human populations can promote interaction among vectors, pathogens, and hosts, and in some cases lead to increased infectious disease, including Lyme disease. Deforestation continues to increase in many developing countries, in part to supply affluent urban populations. These illustrations demonstrate that not unlike the transportation factor the BE also affects landuse, incurring major impacts on ecosystems and human health.

Changes in life style are a direct consequence of the effects of transportation and land use associated with many BEs. High automobile dependency is often characterized by reduced physical activity, and by diminished personal relationships between individuals and groups, a quality known as “social capital”. A lack of physical activity combined with excessive caloric consumption commonly leads to overweight or obesity, in turn increasing the risk of many diseases, including Type II diabetes, hypertension, asthma, and cancer. The life style of many BEs exerts a toll on quality of life, including by increased noise disturbance, decreased air clarity and reduced contact with varied and stimulating natural ecosystems.

Human security is a widely recognized component of human well-being (Millenium Ecosystem Assessment 2003). Though the World Health Organization (WHO) definition of health does not explicitly include security, the WHO conceptualization of health is much broader than the absence of physical and mental disease (WHO 1948). It follows that if human health is adversely affected by the BE, then human security will also be reduced, though it is acknowledged that many other factors also influence security. Some of the factors which influence non-health aspects of security, such as the level of crime or interpersonal violence, are also likely to be influenced by the BE, including through the quality and level of social capital and psychological health. As well, the health or wellness of a person is likely to influence that person’s resilience in the face of threat. In general, healthy people will feel more secure. Finally, the community level of health can influence security, by influencing one’s perception of personal disease risk, including in some cases, vector borne diseases.

In conclusion, adverse effects of the BE, including reduced air and water quality, degraded ecosystems and biodiversity, and the spread and emergence of infectious disease, are relevant to security. The quality of human life and the integrity of ecosystems are affected not only by direct stressors created by the BE which can affect them separately, but also by stressors derived from one or the other, thereby demonstrating the close interconnectedness between the environment and human health. This paper, therefore, highlights the complexity and the interconnections between the BE, ecosystem and human health, and security.

1. Introduction

1.1 ECOLOGY, HEALTH AND SOCIETY

Many paradigms have been used to explain health and disease, particularly of epidemics-- sicknesses affecting large numbers of people at the same time. These causal paradigms have included evil spirits, misdeeds, and the spells of malevolent enemies (Ahmad, 1998; Rahman, 1998). More recently, epidemics were often attributed to "miasmas" - large bodies of toxic air, often found near swamps and flooded areas. In the late 19th century, the miasmatic paradigm fell from favor, replaced by reductionist explanations stimulated by the growing power of epidemiology and microbiology. An impressive sequence of discoveries distinguished and explained, for the first time, epidemic diseases from cholera (Davey-Smith, 2002) to malaria (Nye and Gibson, 1997), yellow fever, tuberculosis (Ryan, 1993), polio, lung cancer and Minimata disease (Watts, 2001) due to infectious and toxic agents such as tobacco smoke and mercury. Most importantly, these causal models enabled effective methods of control, such as reducing mosquitoes, microbes and smoking. (Susser and Susser, 1986).

Powerful as these advances were, some theorists argued that other causal models still retained validity. These workers argued, for example, that causation could be considered as having both "proximal" and "distal" explanations, and that the appropriate explanation is a matter of the "focal depth" sought by the investigator (McMichael, 1999). Others argued that causal models that focused on individual behaviour did not always lend themselves as readily to public health improvements as did explanations of behavior at population levels (Rose, 1990).

The explosion of knowledge in medical science has led to numerous epidemiological sub-specialisations, each focusing on branches of knowledge formed from a single trunk. These branches have names such as infectious, genetic, nutritional, environmental and social epidemiology. All are valid and yet none is complete. Ecological explanations for health and disease are, similarly, incomplete. Yet, this paper argues, ecological models of causation usefully complement these other, related, causal models.

The interconnection among the environment, ecosystems and human activity has been the subject of numerous publications and meetings (DiGulio and Monosson, 1996; DiGulio and Benson, 2002; Fisher, 2001; Aron and Patz, 2001, Koren and Crawford-Brown, 2004). It is becoming increasingly clear that numerous issues that were previously thought of as independent of the environment are intimately connected to it. Human health, the economy, social justice, ecological processes and national security all have important environmental aspects whose magnitude and interconnections are not generally reflected in public policy. A system of public policy with two defining characteristics has evolved. First, human and ecological health protection generally have been treated as separate domains of policy, with significant differences in both the analytic methods used to characterize risks and the policies developed for risk reduction. Second, individual human health risks (e.g., of malaria, schistosomiasis or cholera) have been analyzed in isolation. The objective of risk assessment is to support decision making by assessing risks of adverse effects on

human health and the environment from chemicals, physical factors, and other environmental stresses. With increased recognition of the need to more effectively protect both humans and the environment, it is time to consider a move to a more integrated, "holistic" approach to risk assessment. The positioning of humans as a part of a broader ecology can be traced to ancient peoples, including the Greeks and Native Americans, but the modern relationship between ecosystems, humans, "wellness" and disease owes much to René Dubos, a microbiologist who discovered gramicidin, the world's first antibiotic, when Dubos was working in New York in 1939. Unfortunately, gramicidin proved toxic to humans. In his later life, Dubos became well-known for his work to protect the global environment, including at the world's first great summit about this, held in Stockholm in 1972 (Ward and Dubos, 1972).

Box 1. The concept of ecosystem "services" (Daily, 1997; Millennium Assessment, 2003) has been developed to complement the more fundamental argument that ecosystems should be preserved because of their own "existence value" (Fox, 1990). Supporters argue that the concept that ecosystems provide "services" to humans adds a utilitarian reason for their protection. They suggest that many of the links between natural and human systems were once widely understood, by different forms of "folk ecology" (Ramakrishnan et al, 1998; Atran et al, 1999; Berkes, 2003). But urbanization has created a human world with contact between people and nature that is less common and less intimate than the past, disrupting the understanding of these connections, and partially insulating many humans from adverse ecosystem change.

Ecosystem "services" include the more obvious "provisioning" benefits of food, fibre and fuel. They also include the less well-known "regulating" services. For example, the excessive clearing of a forest can contribute to both flooding during heavy rain and aridity during periods of dryness, while an intact forest will reduce both of these extremes by acting as a sponge that both absorbs and releases water. Other regulating services include erosion control, climate modification, and water and air purification. As well, ecosystems provide important spiritual, recreational, and cultural "services." Many people find psychological and spiritual refreshment through contact with special and even sacred aspects of nature, such as visual landscapes, wilderness, the seashore and special groves and springs. Finally, ecosystems provide "supporting" services that make all of the others possible. These include soil formation, nutrient recycling and pollination. For example, pollinators from intact forest patches have been shown to substantially increase the yield of coffee in adjacent plantations (Ricketts et al, 2004). There is a growing concern that the quality and quantity of key ecosystem services are declining in many regions and in the world as a whole, especially in relation to the still growing global population (Crutzen, 2002; Millennium Ecosystem Assessment, 2003). There are particular concerns over the long-term capacity of global food production, including deep sea and coastal fisheries, and for the productivity of dryland ecosystems. More broadly, there are concerns over adverse social changes in response to, and perhaps exacerbating, ecosystem service depletion. The Millennium Ecosystem Assessment is an attempt to measure, forecast and respond to these concerns.

Less well known are essays in which Dubos prophesized that urbanization would lead to a greater tolerance of "starless skies, treeless avenues, shapeless buildings, tasteless bread, and joyless celebrations," and that this urbanization would harm human health (Moberg and Cohn, 1991).

Many of the issues and concerns raised by Dubos and others have been amplified and endorsed by the global environmental movement. There are increasing signs that these concerns are being appreciated by health researchers (Daszak et al. 2000, Frumkin 2001, DiGulio and Benson 2002, Jackson LE 2003, Jackson RJ, 2003, Frumkin et al. 2004). In the last decade a growing number of studies have found links between health and macro-environmental issues, such as emerging infectious diseases, climate change, and ecosystem "services" (see box 1).

In parallel, there has been an increased appreciation that good health is more than the absence of physical and psychological symptoms, including subjective feelings of contentment and security. A new paradigm is emerging in which health is viewed as a central component of well-being, where health is seen as contextual as well as individual, and where the natural environment is appreciated as a source of sustenance to be maintained (Epstein et al, 2003) rather than an enemy to overcome, or a mine to exhaust.

This paradigm, sometimes called "ecohealth," is still little known (Rappport, 1997). As mentioned, it is related to other health paradigms and complements rather than substitutes these causal models. Supporters of ecohealth argue that this new field has much to offer at diagnostic, therapeutic and preventative levels. For example, if good health – even partly – depends on regular exposure and contact with non-human species, then insights from ecohealth may lead to changes to urban design that are not only aesthetically pleasing, but beneficial to health and well-being.

Groundbreaking studies have shown that hospital patients cure faster if their window faces trees instead of unattractive walls of buildings (Ulrich, 1984). Prison inmates are healthier when their windows face the outside landscape (Moore 1981) and ordinary citizens viewing savanna-like settings report feelings of tranquility, peacefulness or relaxation (Hanna and Coussens, 2001). Contact with pets improves health for survivors of myocardial infarction (Friedman and Thomas, 1995), reduces the incidence of minor health problems when comparing pet owners to petless subjects (Serpell, 1991), and improves the health of isolated and aged individuals (Siegel 1990).

Other insights from ecohealth include the "spillover" of animal microorganisms into human populations because of close contact (Daszak et al, 2000), the adverse impact to human, animal and economic health because of large-scale land-clearing due to fires, climate change and altered ecosystems in many places around the globe including South East Asia, South America and Africa (Epstein, 1999) and indirect effects to human health because of economic decline subsequent to ecosystem degradation. The emergence of variant Creutzfeldt Jacob Disease, initially in the UK, occurred because of animal husbandry practices that flouted basic ecological principles – most obviously by forcing normally vegetarian cows to become cannibals (Prusiner, 1997). Other examples of links between intensive farming practices and periodic emergences of epidemic diseases that can infect humans include influenza (Oxford et al, 2002) and SARS (Webster, 2004).

The clinician can attempt to cure or alleviate these diseases in individual patients, and the public health physician can use means such as vaccines, quarantine and masks to quell epidemics. Social epidemiologists can describe how the illness varies by neighborhood and social class. However, effective control of many diseases will also benefit from the insights from ecohealth, including urban as well as rural and jungle settings.

1.2 HEALTH, SECURITY, AND HUMAN WELL-BEING

Outside health circles, the broad definition of health as “a state of complete physical, mental and social well being and not merely the absence of disease or infirmity” (WHO, 1948) is little appreciated; instead, health is often seen as a medical condition requiring pills and surgery. However, as Dubos recognized, health, which lexicologically is related to “wholeness” is far more than the absence of disease. There are many overlaps between the WHO definition of health and the more recently developed concept of human well-being (Millenium Ecosystem Assessment, 2003), including human security, an element vital to both. Like the air we breathe every few seconds, security is most obvious by its absence. Security takes many forms, such as having reliable access to food, shelter, warmth, physical safety, confidence, companionship, friendship and love. Security underlies peace of mind and enables planning. It makes us more fully human. Security is also related to ecosystems and to other aspects of our environment, including the BE. For example, certain spaces can be perceived as alien and threatening, reducing security.

Excessively rapid change, including the loss of familiar landmarks, also reduces security. Many indigenous populations have insecure access to their local ecosystems, upon which every facet of their lives depends. Sometimes, their resultant despair seems to be transmitted through multiple generations. Now, as the world faces unprecedented anthropogenic environmental change, some sectors are sensing a new form of insecurity, taking the form of concerns over climate change, lost species, adequate water (including quality) and new diseases.

1.3 HEALTH, WELL-BEING, AND THE BUILT ENVIRONMENT

The built environment (BE) has been defined to comprise urban design, land use, and the transportation system, encompassing patterns of human activity within the physical environment (Handy et al. 2002). Patz et al. (2004) have recently stated that “the 2000 Census shows that 80% of the U.S. population now lives in metropolitan areas, with 30% living in cities of 5 million or more. The environmental issues posed by such large population centers have profound impacts on public health beyond the city limits.” But, as well, the BE has many impacts on public health *within* the city limits.

The fields of city and urban planning/design and landscape architecture have generated a wealth of literature on the *physical* consequences of urban land use (U.S. EPA 2001). The state of ecosystems has also been extensively studied (e.g., <http://www.heinzctr.org/ecosystems/>). In contrast, the literature on the *health* effects from the BE is relatively limited. This chapter attempts to fill some of this gap.

1.4 URBAN SPRAWL

Urban sprawl entails the encroachment and diffusion of the periphery of a city across more and more rural land (Jackson 2003). Although largely driven by increasing population, together with sufficient financial means (“white flight”), the process is also motivated at least partly by a desire for bucolic contentment. Such a statement is seemingly attainable by a life spent in the more affordable and less densely populated urban fringe, which sometimes offers a glimpse to surrounding farmland and forest.

Most planners and government rely on roads to cope with the ever-increasing distances caused by sprawl, in turn increasing the commuter pressure on more central roads, planned and built by earlier generations. Generally, roads are cheaper to construct and operate than public transport systems, especially in cities that cover very large, but comparatively less densely populated areas, and where cultural constraints also limit the attraction and economic viability of public transport systems.

As well as land, sprawl consumes significant amounts of other natural and man-made resources, including systems for delivering water and power, and for removing wastes. Importantly, sprawl usually adds to the total cost of travel and infrastructure provision, thus offsetting some of the efficiencies made possible in more densely populated BEs.

1. 5 THE BUILT ENVIRONMENT AND ENVIRONMENTAL HEALTH

Formally, the built environment, itself a specialized form of ecosystem, includes all buildings, spaces and products that are created or modified by people (U.S. EPA 2001). It thus includes homes, schools, workplaces, parks and factories. As well, the reach of the BE extends, tentacle-like, in all directions, encompassing overhead electric transmission lines, underground waste disposal pipes and (sometimes) subway trains, and across the country as highways (Health Canada, 1997).

In its broadest sense, environmental health comprises those aspects of human health, disease, and injury that are determined or influenced by factors in the environment. Traditionally, this discipline has focused upon the study of the direct pathological effects of various chemical, physical, and biological agents. Increasingly, environmental health embraces the effects on health of the broad physical and social environment, including housing, urban development, land use and transportation, industry, and agriculture (U.S. Department of Health and Human Services, 2000).

2. Discussion

2.1 TRANSPORTATION: ENVIRONMENTAL AND HEALTH CONSEQUENCES

While vehicular travel has many benefits, such as mobility, privacy, convenience, and flexibility, it also has many unintended adverse environmental consequences, many of which only become obvious beyond a threshold number or density. One very important negative consequence is degraded air quality. The U.S. Environmental Protection Agency (EPA) has established National Ambient Air Quality Standards

(NAAQS) to protect public health, including the health of sensitive populations such as children and the elderly, from adverse effects of poor air quality (U.S. EPA 2001). Motor vehicles emit a variety of pollutants each of which contributing a large portion of CO and ozone precursors in particular. Vehicle travel also kicks up large quantities of particulate matter (PM) from roads (especially on unpaved roads in rural areas). Cars also emit hazardous air pollutants (HAP) or air toxics known or suspected to cause cancer and other serious health effects in humans and ecosystem damage. Persistent air toxics are of particular concern when aquatic ecosystems, as toxic levels can magnify up the food chain.

One of the most serious public and environmental health issues in Western countries is the worsening epidemic of asthma. In the United States the prevalence of asthma has doubled in the last twenty years (Mannino et al., 1998). More than 17 million people now report having the disease (Center for Disease Control and Prevention, 1998). Asthma has increased most rapidly in children less than 14 years old, who also account for the highest overall rates of asthma among the population at large. Trends toward increased prevalence, deaths, and costs of the disease have also been observed in many other countries (Kuehni et al, 2001).

Genetic susceptibility, viral and parasitic infections, and allergic status have long been known to be related to asthma incidence or severity (Koren, 1997). However, the dramatic increase in the frequency of asthma has also led investigators to consider other possible causal factors, including diet, lifestyle, air pollution and broad environmental factors (von Mutius, 2003). The role of some air pollutants in worsening symptoms in people with asthma is beyond any doubt. Increases in ambient levels of ozone (O₃), sulfur dioxide (SO₂), nitrogen dioxide (NO₂), and particulate matter less than 10 microns aerodynamic diameter (PM₁₀), as well as suspended sulfates, have been correlated with emergency department visits and hospital admissions for asthma. In a recent study, a team of scientists recruited a group of 3,535 school-age children in Southern California who did not have asthma, and followed them for five years (McConnell et al. 2002). The results of this and another study conducted in adults (McDonnell et al. 1999) found that chronic exposure to ozone not only worsens symptoms among people with asthma, but can also lead to the onset of the disease, among both children and adults. Evidence from the past 10 years also shows that sudden increases in ambient air pollution can cause as much cardiovascular as respiratory morbidity and mortality (Pope et al. 2004).

Another adverse health effect associated with the BE and with air pollution is the heat island effect. Urban areas have been shown to be warmer by 6-8° F than surrounding areas. This effect occurs because surfaces like dark roads and roof tops absorb heat from the sun and radiate heat back into the atmosphere. In addition urban areas are usually poor in vegetation that would provide shade and cool air. Excessive heat, especially in populations that are not inured to it (Frumkin 2002, 2004; Kalkstein 2002) is responsible for various health effects including fainting, hyperventilation and edema. Heat exhaustion is a more severe condition and presages fatal heat stroke. Heat may further contribute to the adverse effects of air pollution. Increased temperatures raise energy consumption, especially from air conditioners, thus triggering more emission of pollutants from fossil fuel burning power plants (U.S. EPA 2001).

There is growing agreement that the large volumes of “greenhouse gases” (especially carbon dioxide) released by human activity such as the burning of oil, gas and coal, are not only substantially altering the atmosphere, but causing global climate change. Predicted effects include altered temperature and rainfall patterns and rising sea levels. Warmer ocean temperatures are projected to increase the frequency and intensity of extreme weather events. Together, these effects are predicted to alter global patterns of land use, ecosystems and human activity. Transportation is a significant and growing source of greenhouse gas emissions. In the US, carbon emissions from transportation are projected to grow by 47.5 percent over the period 1996-2020 (U.S. EPA 2001).

Motor vehicle transport also has adverse effects upon water quality and ecosystems. Highway maintenance involves activities that can adversely affect the environment, such as road salting, use of solvents, and pesticides. Highway de-icing can adversely affect roadside vegetation, soil structure, drinking water supplies, and aquatic life. Paved roads and parking lots, both of which are necessary to support vehicular use, create the majority of impervious areas in the landscape. Impervious surfaces impede the recharge of groundwater from rainwater, funnel toxic chemicals into waterways, and can increase erosion, flooding and changed water temperatures (Jackson 2002). In turn, these effects can harm cold water fisheries, and otherwise degrade aquatic habitats. It is therefore evident that transportation can have far reaching effects on both ecosystem health as well as on human health which are closely interconnected.

2.2 LAND USE CONSEQUENCES FOR ECOSYSTEMS AND HEALTH

Development uses land space and modifies habitats and ecosystems. Land consumption rates in the United States, already high, are rapidly increasing. More land was developed during the five-year period from 1992–1997 than during the 10-year period that preceded it (U.S. EPA 2001). In addition to directly destroying areas of natural habitat, development usually fragments habitat and increases the invasion of introduced species, altering ecosystem function and changing biodiversity. However, development can sometimes take account of ecology, leading to the preservation of critical habitats such as wetlands, and creating greenways and buffer zones around sensitive habitat, thus preserving ecosystem integrity and create amenities for adjacent neighborhoods. Habitat loss and fragmentation are two of the most direct impacts of development on previously undeveloped land. Habitat fragmentation and an increased proximity of forest, agricultural land and human populations can promote interaction among vectors, pathogens, and hosts (Koren and Crawford-Brown, 2004), and in some cases lead to increased infectious disease, including Lyme disease in the northeastern part of the U.S. (LoGiudice et al. 2003). In other parts of the world changes in agricultural practices, made more intensive to feed large and growing urban populations, have contributed to the emergence of Nipah virus in Malaysia, cryptosporidiosis in Western countries, and a range of food-borne diseases in many parts of the world (Epstein et al. 2003, Patz et al. 2004). Deforestation continues to increase in many developing countries, in large part to provide materials to the BE.

In the U.S., approximately 75% of people live in coastal watersheds, with coastal urbanization and agricultural and industrial development increasing at rapid rates. As mentioned, urban development affects water quality through alterations to the natural flow of water within a watershed, particularly by increasing impervious surfaces and channeling stormwater runoff. The EPA estimates that 36 percent of the nation's lakes, rivers, and estuaries are impaired by pollution. Stormwater is often polluted by pathogens, pesticides, fertilizers from yards and farms, and a variety of other substances that have accumulated on impervious surfaces (Jackson 2003). According to research published in 2001 by Johns Hopkins University, more than 50 percent of waterborne disease outbreaks in the U.S. between 1948 and 1994 were preceded by extreme rainfall events (Curriero et al. 2001). Accelerating nutrient- and pathogen-enriched wastewater discharge accompanying coastal development is putting unprecedented pressure on estuaries that receive and process the bulk of land-based runoff. This has led to increased primary productivity or eutrophication, the symptoms of which pose a significant threat to coastal resources, ecological, and human health (Paerl 2002). Eutrophic conditions are evidenced by surface algal scums, reduced water clarity, odors, and dense algal growth on shallow water substrates. Algal blooms block the light needed by submerged aquatic vegetation, and also reduce oxygen availability. As a result, the habitat for juvenile fish and shellfish is reduced. Septic systems in low density suburban and rural residential development also reduce groundwater quality. Toxin producing dinoflagellates are found throughout the marine world and can cause a range of health effects from acute neurologic diseases (such as ciguatera and paralytic shellfish poisoning) to chronic dementia (such as amnesic shellfish poisoning from domoic acid). Disease is associated predominantly with the ingestion of contaminated fish and shellfish. However, disease can also occur through epidermal contact and inhalation (Baden et al., 1995). In the latter route, dinoflagellates are lysed by the surf and release toxins that may cause conjunctival irritation, rhinorrhea and nonproductive cough in persons who are close to the water (Morris et al., 1991). Cyanobacterial toxins have been associated with contact irritation after bathing in marine waters (Codd et al., 1989). This is yet another example of how the environment and human health are tightly linked. This linking is an important factor that needs to be considered in the context of public policies and risk assessment.

2.3 LIFE STYLE, QUALITY OF LIFE, AND HEALTH

A hallmark of urban sprawl is increased automobile travel (Frumkin 2002, 2004). Sprawl increases the distances between shopping, school, and places of employment and residence, and rarely if ever is provided with good public transport. Many parts of recently constructed BEs are centered on the automobile, in contrast to older cities and towns, which developed in an era when cars were either non-existent or rare, and where commercial and residential areas were mostly within walking distance.

For instance, parking lots are built as close as possible to their destinations in order to increase convenience and safety for motorists. Millions of Americans use a car to run almost every errand, and clearly appreciate the autonomy that car ownership offers. But the resultant automobile dependency has many adverse health effects. One

of the strongest explanations for the declining health status of the U.S. population is its significant and continuing decline in physical activity. A sedentary life style is a well-established risk factor for cardiovascular disease and stroke, whereas physical activity prolongs life (Frumkin 2002, 2004). It is established that physical activity is protective against diabetes, hypertension, high cholesterol and some forms of cancer. In fact, Lagerros et al. (2004) have shown an association of moderate or vigorous recreational physical activity during adolescence and young adulthood with reduced breast cancer risk. Other studies have found that obesity increases the risk for cancer of the esophagus, colon, rectum, and breast (Key et al. 2004, Moore et al. 2004).

Lack of physical activity, combined with excessive caloric intake, is an important cause for being overweight, the prevalence of which has increased substantially in recent decades in many countries. From 1976 through 1994, the prevalence of overweight children and adolescents in the U.S. almost doubled (Jackson 2003). The death rate amongst overweight people is as much as 2.5 times higher than that of non-obese people. Obesity co-morbidities are a major problem as well, with an estimated \$75 billion spent annually to treat these maladies. A major risk factor for obese people is Type II diabetes, and the current epidemic of Type II diabetes tracks closely with the increase in being overweight (Mokdad et al. 2004). It is most disturbing that the prevalence of overweight children and adolescents is increasing, probably at a greater rate than among adults. The increased prevalence of obese children is already reducing the average age of onset of Type II diabetes, and this is likely to cause an immense economic and health burden in the years to come, as the complications of Type II diabetes, including heart, kidney and eye disease, also become manifest at a younger age. This is likely even if the treatment of diabetes improves; of much greater benefit would be lifestyle changes that reduce obesity.

Automobile transport systems also generate substantial noise. Even moderate noise levels can cause serious psychological, social and other adverse effects including stress reactions which can lead to hormonal changes, increased blood pressure, increased risk of heart attacks and decreased well-being and quality of life (Riediker and Koren 2004). Reduced visibility consequent to air pollution decreases the recreational value of scenic sites. The clean air act of the USA appreciates these aesthetic and recreational aspects by including visibility as a factor for setting secondary national ambient air quality standards (U.S. EPA 2001, Riediker and Koren 2004).

Many aspects of the life style in the BE exert a toll on mental health. Stress-related problems accrue from long hours of commuting (Gee and Takeuchi 2004). Commuting stress may affect well-being and social relationships both on the roads and off the roads. As described above, there is also growing evidence that appreciation of the aesthetics of and connectivity to nature seem to positively influence human health (Frumkin 2001). In a recent article, Jackson (2003) has written: "Parks and gardens have long been noted for their restorative effects on both mental and physical health. E.O. Wilson has coined the term biophilia to express the apparently innate human attraction to nature, citing a widely-shared evolutionary explanation that relates pleasing, park-like settings to prehistoric cues for water and shelter."

Life style and quality of life are directly affected by degradation of landuse practices and transportation. Renewed appreciation of these issues may lead to future

BEs that encourage greater physical exercise, less automobile dependency and greater contact and interaction with both our fellow human beings and with nature, including more locally accessible and better protected sensitive habitats.

3. Conclusions

Understanding the relationships among population growth, development, security, the environment, human health and ecosystems is an important area of both scientific inquiry and environmental policy. The objective of risk assessment is to support decision-making by assessing risks of adverse effects on human health and the environment from biological, chemical, and physical factors, and other environmental stresses. For practical reasons, the methodologies for human health and ecological risk assessment developed independently. The potential applicability of understanding the complex interconnection between the environment and health and incorporating it into integrated human and ecological risk assessments makes this issue important and timely.

The BE presents society with a multitude of issues with consequences for the environment and human health. Most articles that discuss the BE focus on impacts on either the environment (e.g., <http://www.heinzctr.org/ecosystems/>) or human health and quality of life (e.g., Frumkin 2002, 2004) but seldom examine or recognize the interconnectivity that exists between the two entities. In this paper we have emphasized the effects of the BE on the environment considering the effects both on ecosystems and on human health and pointing out the interconnectivity between them. It is not further reasonable to separate ecohealth from human health. It is evident from the work reviewed in this paper that changes in the environment such as those due to the BE inevitably have consequences for ecosystems and human health.

The BE has many direct and indirect environmental effects. Stressors arising as a result of the BE directly affect habitat, ecosystems, endangered species, and water quality through land use changes, habitat fragmentation, and replacement of natural cover with impervious surfaces (Frumkin 2002, 2004; Jackson 2003). Development patterns and practices also indirectly affect environmental quality since the BE influences the travel decisions that people make. Many development patterns encourage increased use of motor vehicles, which is associated with decreased physical activity, leading to obesity and consequent increases in Type II diabetes, and cardiovascular disease, and increased cancer, as well as increased air pollution, including greenhouse gases that contribute to global climate change. Air pollution and climate change, in turn, can adversely affect respiratory illnesses, heat island effect, water quality and habitat.

This paper points out that the BE affects transportation, and land use, which consequently affect life style. These lead directly or indirectly to adverse health effects (Koren and Crawford-Brown 2004). Urban sprawl in particular has caused major changes in the life style of citizens in many countries. As well, sprawl appears to erode the sense of purpose that neighborhoods once delivered, damaging social capital and in turn reducing human wellness, security and quality of life (Riediker and Koren 2004).

In conclusion, there is significant evidence that compact, mixed-use development focused on mass transit can reduce vehicle travel and air pollution from motor vehicles. There is ample evidence that the BE matters to communities- not just for social and economic reasons, but also for environmental reasons of national concern. Issues related to our BE are growing in importance and, if left unaddressed, will make it difficult to meet national and global environmental goals. A richer and more detailed understanding of the BE and sprawl could yield development strategies that address the social, economic, fiscal, political, and environmental impacts of such growth.

4. Acknowledgment

The authors would like to thank Drs. Doug Crawford-Brown (UNC), and Laura Jackson (EPA) for their thoughtful and critical review.

5. Disclaimer

The research described in this article has been reviewed by the National Health and environmental effects Research Laboratory, US Environmental Protection Agency, and approved for publication. Approval does not signify that the contents necessarily reflect the views and policies of the Agency, nor does mention of trade or commercial products constitute endorsement or recommendation for use.

6. References:

1. Ahmad K. (1998) WHO to improve epilepsy management in Africa. *The Lancet*, 355:1704.
2. Aron JL, Patz JA, eds. (2001) Ecosystem change and public health: a global perspective. Baltimore, MD, USA: Johns Hopkins University Press.
3. Atran S, Medin D, Ross N, et al. (1999) Folkecology and commons management in the Maya Lowlands. *Proceedings of the National Academy of Sciences*, 96(13):7598-7603.
4. Baden, DA, Fleming, LA and JA Bean. (1995) "Marine Toxins", *Handbook of Clinical Neurology*. 21:141-175
5. Berkes, F., 2003: *Sacred Ecology. Traditional Ecological Knowledge and Resource Management*. Taylor and Francis, Philadelphia, PA.
6. Center for Disease Control and Prevention, National Center for Health Statistics (1998)
7. Codd, GA, Bell, SG and WP Brooks (1989) Cyanobacterial toxins in water. *Water Sci Technol.*, 21:1-13.
8. Crutzen, P.J., 2002: Geology of mankind. *Nature*, 415, 23.
9. Curriero, F.C. Patz J.A., Rose, J.B., LeI, S. (2001). The association between extreme precipitation and waterborne disease outbreaks in the United States. *Am J Public Health*, 91(8): 1194-9
10. Daily GC, ed. (1997) *Nature's Services: Societal Dependence on Natural Ecosystems*. Washington, DC: Island Press.
11. Daszak P, Cunningham AA, Hyatt AD. (2000) Emerging infectious diseases of wildlife-- threats to biodiversity and human health. *Science*, 287:443-449.
12. Davey-Smith G. Commentary: Behind the Broad Street pump: aetiology, epidemiology and prevention of cholera in mid-19th century Britain. *International Journal of Epidemiology*, 2002;31:920-932.
13. DiGulio RT and WH Benson eds. (2002). *Interconnections Between Human Health and Ecological Integrity*. Society of Environmental Toxicology and Chemistry (SETAC), Pensacola, FL, USA.
14. DiGulio, R.T. and E. Monosson eds. (1996). *Interconnections Between Human Health and Ecosystem Health*. Chapman and Hall, London.
15. Epstein P. (1999) Climate and health. *Science*, 285:347-348.

16. Epstein, P.R., E. Chivian, and K. Frith, 2003: Emerging Diseases Threaten Conservation [editorial]. *Environmental Health Perspectives*, 111(10): A506-507.
17. Fisher, WS (guest editor) 2001. Human and Ecological Risk Assessment: Indicators in Health and Ecological risk Assessment (special Issue). Eds. BL Johnson, EL Calabrese, BG Callahan, PM Chapman, and RA Pastorok. HERA 7(5), October 2001. CRC Press.
18. Fox W. (1990) Toward a Transpersonal Ecology. Developing New Foundations for Environmentalism. Boston: Shambhala.
19. Friedmann E, Thomas SA. (1995) Pet ownership, social support, and one-year survival after acute myocardial infarction in the cardiac arrhythmia suppression trial (CAST). *American Journal of Cardiology*, 76:1213-1217.
20. Frumkin, H. (2001). Beyond toxicity: Human health and the natural environment. *Am J Prev Med*, 1:20(3), 234-244.
21. Frumkin H. (2002) Urban sprawl and public health. *Public Health Rep.*, 117(3): 201-17.
22. Frumkin H, L.Frank, and R. Jackson eds. (2004) Urban Sprawl and Public Health: Designing, Planning, and Building for Healthy Communities. Island Press, Washington.
23. Gee GC, Takeuchi DT. (2004) Traffic stress, vehicular burden and well-being: a multilevel analysis. *Soc Sci Med*. 59(2):405-14.
24. Handy SL, Boarnet MG, Ewing R, Killingsworth RE. (2002) How the built environment affects physical activity.
25. Hanna K, Coussens C. (2001) Rebuilding the Unity of Health and the Environment: A New Vision of Environmental Health for the 21st Century. Washington, D.C.: National Academy Press.
26. Health Canada. (1997) Health and the environment: Partners for life. Ottawa, Health Canada.
27. Jackson RJ. (2003) The impact of the built environment on health: an emerging field. *Am J Public Health*, 93(9):1382-4.
28. Jackson, L.E. (2003) The relationship of urban design to human health and condition. *Landscape and Urban Planning*, 64, 191-200.
29. Kalkstein LS. (2000) Saving lives in extreme weather in summer [editorial]. *BMJ*; 321(7262):650-651.
30. Key TJ, Schatzkin A, Willett WC, Allen NE, Spencer EA, Travis RC. (2004). Diet, nutrition and the prevention of cancer. *Public Health Nutr*, 7(1A):187-200.
31. Koren HS, Crawford-Brown D. (2004) A framework for the integration of ecosystem and human health in public policy: two case studies with infectious agents. *Environ Res.*, 95(1):92-105.
32. Koren, H.S. Environmental Risk Factors in Atopic Asthma. (1997) I. Genetic and Environmental Factors in Atopic Diseases. *Int. Arch Allergy Immunol*, 113: 65-68.
33. Kuehni CE, Davis A, Brooke AM, Silverman M. (2001) Are all wheezing disorders in very young (preschool) children increasing in prevalence? *The Lancet*, 357:1821-1825.
34. Lagerros YT, Hsieh SF, Hsieh CC. (2004) Physical activity in adolescence and young adulthood and breast cancer risk: a quantitative review. *Eur J Cancer Prev.*, 13(1):5-12.
35. LoGiudice K, Ostfeld RS, Schmidt KA, Keesing F. (2003) The ecology of infectious disease: effects of host diversity and community composition on Lyme disease risk. *Proc Natl Acad Sci U S A*, 100(2):567-71.
36. Mannino DM, Homa DM, Pertowski CA, Ashizawa A, Nixon LL, Johnson CA, Ball LB, Jack E, Kang DS. (1998) Surveillance for asthma--United States, 1960-1995. *MMWR CDC Surveill Summ.*, 24;47(1):1-27.
37. McConnell R, Berhane K, Gilliland F, London SJ, Islam T, Gauderman WJ, Avol E, Margolis HG, Peters JM (2002) Asthma in exercising children exposed to ozone: a cohort study. *The Lancet*, 359(9304):386-91.
38. McDonnell WF, Abbey DE, Nishino N, Lebowitz MD (1999) Long-term ambient ozone concentration and the incidence of asthma in nonsmoking adults: the AHSMOG Study. *Environ Res.*, 80(2 Pt 1):110-21.
39. McMichael AJ. (1999) Prisoners of the proximate. Loosening the constraints on epidemiology in an age of change. *American Journal of Epidemiology*, 149(10): 887-897.
40. Millenium Ecosystem Assessment (2003) Ecosystems and human well-being. In: Ecosystems and Human Well-being. Washington: Island Press: 71-84
41. Moberg CL, Cohn ZA. (1991) René Jules Dubos. *Scientific American*, 264(5):32-38.
42. Mokdad AH, Ford ES, Bowman BA, Dietz WH, Vinicor F, Bales VS, Marks JS. (2003) Prevalence of obesity, diabetes, and obesity-related health risk factors, *JAMA*, 1289(1):76-79.

43. Moore LL, Bradlee ML, Singer MR, Splansky GL, Proctor MH, Ellison RC, Kreger BE. (2004) . BMI and waist circumference as predictors of lifetime colon cancer risk in Framingham Study adults. *Int J Obes Relat Metab Disord.*, 28(4):559-67
44. Morris, PD, Campbell, DS, Taylor, TJ and JI Freeman. (1991) Clinical and epidemiological features of neurotoxic shellfish poisoning in North Carolina. *Am J Pub Health*, 81:471-474.
45. Nye, E. and M. Gibson, (1997): *Ronald Ross: Malarialogist and polymath*. MacMillan, London.
46. Oxford JS, Sefton A, Jackson R, Innes W, Daniels R, Johnson N. (2002) World War I may have allowed the emergence of "Spanish" influenza. *The Lancet Infectious Diseases*, 2(2):111-114.
47. Paerl HW. (2002) Connecting atmospheric nitrogen deposition to coastal eutrophication. *Environ Sci Technol.*, 36(15):323A-326A.
48. Patz JA, Daszak P, Tabor GM, Aguirre AA, Pearl M, Epstein J, Wolfe ND, Kilpatrick AM, Foutopoulos J, Molyneux D, Bradley DJ (2004) Working Group on Land Use Change and Disease Emergence. Unhealthy landscapes: Policy recommendations on land use change and infectious disease emergence. *Environ Health Perspect.*, 112(10):1092-8.
49. Pope CA 3rd, Burnett RT, Thurston GD, Thun MJ, Calle EE, Krewski D, Godleski JJ.(2004) Cardiovascular mortality and long-term exposure to particulate air pollution: epidemiological evidence of general pathophysiological pathways of disease. *Circulation*, 6:109(1):71-7.
50. Prusiner SB. (1997) Prion diseases and the BSE Crisis. *Science* 278:245-251.
51. Rahman F. (1998) Angels and spirits in the world of illness. *The Lancet* 352: 1218-1219.
52. Ramakrishnan, P., K. Saxena, and U. Chandrashekara, 1998: *Conserving the Sacred: For Biodiversity Management*. UNESCO, Oxford, IBH, New Delhi, 480 pp.
53. Rapport, D.J., (1997): The dependency of human health on ecosystem health *Ecosystem Health*, 3(4), 195-196
54. Ricketts TH, Daily GC, Ehrlich PR, Michener CD. (2004): Economic value of tropical forest to coffee production. *Proceedings of the National Academy of Science*, 101(34):12579-12582.
55. Riediker M, Koren HS. (2004) The importance of environmental exposures to physical, mental and social well-being. *Int J Hyg Environ Health*, 207(3):193-201.
56. Rose G (1990) Reflections on changing times. *BMJ*, 301:683-687.
57. Ryan F. (1993) *The Forgotten Plague : How The Battle Against Tuberculosis Was Won--And Lost*. 1st American ed. Boston: Little Brown.
58. Serpell J. (1991) Beneficial effects of pet ownership on some aspects of human health and behaviour. *Journal of the Royal Society of Medicine*, 84:717-20.
59. Siegel J. (1990) Stressful life events and use of physician services among the elderly: the moderating role of pet ownership. *Journal of Personality and Social Psychology*, 58:1081-1086.
60. Susser M, Susser E. (1996) Choosing a future for epidemiology: I Eras and paradigms. *American Journal of Public Health*, 86:668-673.
61. *The State of the Nation's Ecosystems* (2002). Cambridge University Press. <http://www.heinzctr.org/ecosystems/>
62. Ulrich RS. (1984) View through a window may influence recovery from surgery. *Science*, 224:420-421.
63. U.S. Department of Health and Human Services. (2000) *Healthy People 2010*. Washington, DC, U.S. Department of Health and Human Services
64. U.S. Environmental Protection Agency Office of Policy, Economics, and Innovation, Our built and natural environment, January 2001. Publication No.: EPA 231-R-01-002. <http://www.smartgrowth.org>
65. von Mutius E (2003) A conundrum of modern times that's still unresolved. *Eur Respir J.*, 22(5):719-20.
66. Ward B, Dubos RJ. (1972) *Only One Earth; the Care and Maintenance of a Small Planet*. [1st] ed. New York: Norton.
67. Watts J. (2001) Mercury poisoning victims could increase by 20 000. *The Lancet*, 358, 1349.
68. Webster RG. (2004) Wet markets—a continuing source of severe acute respiratory syndrome and influenza? *The Lancet*, 363:234-236.
69. WHO (1948). "Preamble to the Constitution of the World Health Organization as adopted by the International Health Conference, New York, 19-22 June, 1946; signed on 22 July 1946 by the representatives of 61 States (Official Records of the World Health Organization, no. 2, p. 100) and entered into force on 7 April 1948."