Fairhaven College: Urban Health & Sustainability

Urban Health Problems

Air and Water Quality

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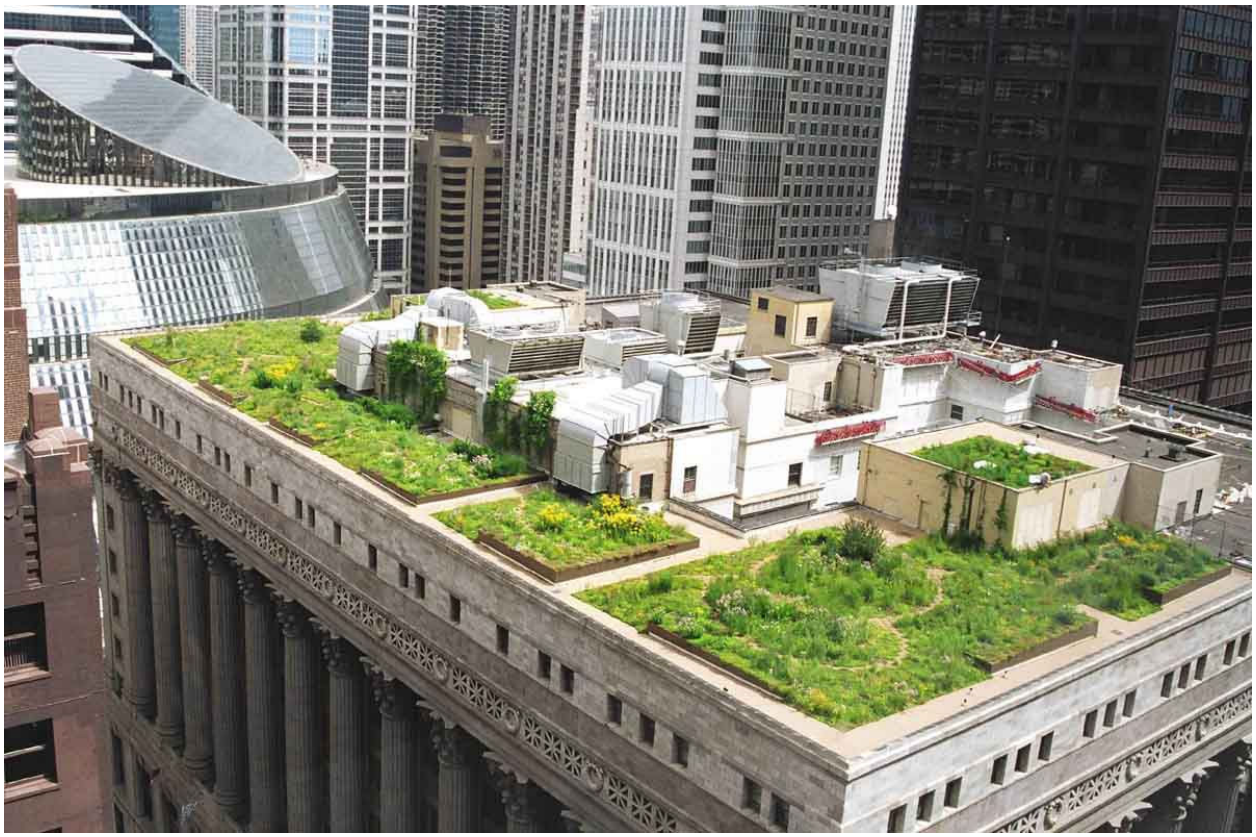

Modern cities face many issues such as pollution, congestion, low water and air quality, and deteriorating building conditions. This paper focuses on the health of urban residents as related to deteriorating quality of air and water caused by increased development and sprawl.
Front image: "Chicago City Hall roof" http://greeningtheinnercity.ca/tag/green-collar-jobs/

The relationship between Western human society and "the city" has developed into a complex history drawing upon human psychological and physical connection to cities as they have altered in function and form over the centuries. Through the progression in actuality was more complex, basically cities developed as agriculture became more efficient and could sustain a higher population while requiring fewer farmers. This allowed other professions to emerge such as craftsmen and tradesmen, who could exchange their goods for food. For this trade and commerce to occur the need for a central market came into play. Early cities were often times simply central markets connected along mainland and coastal trade routes. With the industrial revolution production and the workers moved to the cities. Prior to this much work was done at home or at a small workshop. As cities increased in population and density, problems of infectious disease, waste disposal, clean water, and poverty emerged. Cities have been marked as pestilent centers of disease, filth and poverty which is still a sentiment held towards modern cities today. In the 1700s, starting with England, the industrial revolution introduced the use of fossil fuel as a source of energy. Progressing into the 1800s, the cities of England and North America primarily turned into centers of industrial production, combining toxic factory sites and the residences of the workers who could not afford to live outside of the city. The pollution from factories added another destructive environmental and health impact within cities, and the semblance of these early industrial sites marks the most negative aspect of cities today:

> Oil joined coal as a heavily used fossil fuel, and also contaminated city streets and properties, creating 'ecological wastelands' as early as the Reconstruction era. Most industrial waste was dumped into streams, rivers, and harbors, carrying on the tradition established with sewage, dead animals, garbage and other refuse.[1]

Although cities have often been viewed as centers of disease and pestilence, they have also functioned as vibrant hubs of culture, politics, art and trade. In the modern world, cities function as international networking centers and remain the epitome of culture and social revolution. Cities in developed nations today deal with an onslaught of environmental and public health problems. They continue to be places of infectious disease, social contentions, poverty and severe income inequality. With urban sprawl cities changed functions to a certain degree in terms of the most significant issues that are now focused. Cities today face problems mainly in the areas of air quality, water quality, and housing quality. Air quality, both indoor and outdoor, is one of the biggest problems that cities face and contributes significantly to

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[1] Howard Frumkin, Lawrence Frank, and Richard Jackson, *Urban Sprawl and Public Health: Designing, Planning, and Building for Healthy Communities* (Washington, DC: Island Press, 2004), 58.

health issues such as asthma, lung cancer and a newly identified illness called sick building syndrome.[2] Air quality is impacted by transportation systems and the prevalence of urban sprawl. Water quality, and quantity, is of great importance in cities primarily due to the high density of people that need water. Urban runoff contributes significantly to pollution of a city, as the majority of land is covered with imperious surface. Water management in cities is critical due to large number of humans that can be affected once the water source is contaminated and its connection with waste management.

Cities continue to be places in which poverty, crime, immigrants, and ethnic populations concentrate. Income inequality is highest within cities, which contributes to social tensions and disparities in housing quality; many cities have neighborhoods of low quality housing that poorer residents occupy adjacent to wealthier neighborhoods that house the upper-middle class. Poor housing quality can be a serious health factor, a problem which affects the lower classes most significantly. In the United States beginning in the 1950s, there was a de-urbanization trend as people began to relocate to suburbs. These suburbs offered middle-classed Americans a chance at fresh air, green laws, and large single-family residences away from the noise of the city. Along with the many heath impacts created by this sedentary lifestyle, such as increased obesity and diabetes, cities and their residents who remained also suffered from this migration to the suburbs. When many middle-class families leave a city, those who remain tend to be lower-class racial minorities and immigrants. Cities are left with a decreased tax-base to help maintain infrastructure. This leads to poor housing, deteriorating commercial sectors and an overall unclean and unsightly city. When middle-class Americans leave the city for the suburbs, the network of roads connecting the suburbs expands, allowing residents to avoid the congested city altogether. This causes businesses to move themselves to the suburbs, thus drawing one more commodity away from the city proper. In order to have healthy and safe cities there must be a strong tax-base to maintain infrastructure and a busy commercial sector to supply close by residents with everything they need. The environmental and human impact of cities remains a serious problem society has to face. From the toxic cleaning products used in stuffy office buildings to the pollution emitted by industrial factories, cities have multiple levels of impact. If cities can be designed and built properly, they are the most sustainable form of living through high-density residences and mixed-land use. Currently, despite the increasing momentum of the green building and sustainable cities movements, human health is severely impacted by urban living.

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[2] Tom Daniels, "Taking the Initiative: Why Cities are Greening Now," In *Growing Greener Cities: Urban Sustainability in the Twenty-First Century,* Ed. Eugenie L. Birch and Susan M. Wachter (Philadelphia: University of Pennsylvania Press, 2008).

Despite improved air quality compared to pollution levels for several years after the beginning of the industrial revolution, both indoor and outdoor air quality remains a serious threat to the health of urban residents. Outdoor air pollution is caused by vehicle emissions and building usage and construction. There is an odd dichotomy that when cities are less dense, things are farther and require heavy car usage that increases pollution, while at the same time extremely high densities could result in higher concentrations of pollution within the city. Buildings in cities require huge amounts of energy for heating and cooling, increasing fuel and energy consumption that releases pollutants into the air. Inside air quality can be an issue due to poor ventilation, mold accumulation, dust, and chemicals that slowly leech out of various building materials and furniture over time. Air pollutants can cause and worsen numerous health problems such as asthma, cancers, bronchitis, and emphysema.[3] They also contribute to climate change and what is known as the Urban Heat Island Effect, which has serious health implications. As urban sprawl increases and cities are less dense, it is more difficult to develop a mass transit system, and people become more reliant on their cars, which increases pollution from vehicle emissions. More modern cities have been designed around the use of cars, rather than being designed around pedestrian use. Low density cities like Los Angles, which is known for high concentrations of smog, issue air quality warnings where residents are told to stay indoors to avoid breathing toxic outside air. The EPA monitors and controls a number of pollutants under the National Ambient Air Quality Standard. NAAQS does not cover certain air pollutants like Benzene, Formaldehyde, and Toluene that can cause cancer, respiratory disease and blood disease; it also doesn't cover some heat trapping green-house gases such as Carbon Dioxide, Nitrous Oxides, and Methane that are produced when burning fossil fuels.[4] Ozone from vehicle emissions is expected to be a significant contributor to fatalities in the near future as climate change worsens.[5] Buildings in the US contribute approximately 38% of the nation's total CO^2 emissions due mainly to energy consumption for heating and cooling.[6]

The Urban Heat Island Effect refers to the phenomenon of increased temperatures felt solely in a metropolitan area compared to its cooler rural surroundings. Temperature differences are felt especially at night when heat retained in surfaces radiates outward and gets trapped in atmosphere

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[3] Tom Daniels, "Taking the Initiative: Why Cities are Greening Now," In *Growing Greener Cities: Urban Sustainability in the Twenty-First Century,* Ed. Eugenie L. Birch and Susan M. Wachter (Philadelphia: University of Pennsylvania Press, 2008).

[4] Rachel Weinberger, "Growing Greener, New York Style," In *Growing Greener Cities: Urban Sustainability in the Twenty-First Century,* Ed. Eugenie L. Birch and Susan M. Wachter (Philadelphia: University of Pennsylvania Press, 2008), 86.

[5] Tord Kjellstrom, et al., "Urban Environment Health Hazards and Health Equity," *Journal of Urban Health: Bulletin of the New York Academy of Medicine* 84, no. 1 (2007), http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1891648/pdf/11524_2007_ Article_9171.pdf (accessed January 20, 2011).

[6] "Indoor Air Quality (IAQ): Indoor Air Facts No. 4 (revised) Sick Building Syndrome," U.S. Environmental Protection Agency, http://www.epa.gov/iaq/pubs/sbs.html (accessed November 24, 2010).

close to the surface, rather than dissipating into the cooler night air. The EPA estimates that the temperatures in a city of one million or more can be at most 5.4°F warmer than surrounding areas and up to 22°F higher at night.[7] Urban heat islands are caused when surface land is modified from open land and vegetation to development that uses dry, impermeable, heat-retaining materials.[8] Tall buildings have large surface areas in which to reflect and absorb heat, and block wind that could cool the area. Urban heat island effect is also caused by waste heat generated by cars, air conditioning and industry; these sources also contribute to the presence of pollutants that can alter the atmosphere's radiative properties.[9] Higher temperatures from the heat island effect causes a huge demand for energy to cool buildings, and this raises air pollutants and green houses gases that cause smog, or ground-level ozone, to form.[10] Ozone is formed when Nitrogen Oxides interact with Volatile Organic Compounds in the presence of heat and sunlight.[11] Nitrogen Oxides, along with sulfur dioxide, carbon monoxide, mercury, and particulate matter, are generated from burning fossil fuels for energy. These pollutants not only cause smog, but also fine particulate matter and acid rain. Health impacts from the heat island effect are general discomfort, respiratory problems, heat exhaustion and cramps, heat-stroke and heat-related mortality. Children, older adults, and those with pre-existing conditions are at a higher risk of experiencing health complications from extreme temperatures.[12] It is speculated that the heat island effect could increase the severity and length of heat waves that make the risk of heat-related health problems worse. These effects are worse in cities of mid to high latitude because of the extreme variation of temperatures among the different seasons. Extreme heat waves in Europe during 2003 resulted in the deaths of over 40,000 people who were mostly older adults of lower-income.[13] In the US an average of 1,000 people die each year from extreme heat.[14] The urban heat island effect also impacts water quality by causing water to flow directly off of hot pavement into streams, which can increase average water temperatures and lead to loss of aquatic life.

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[7] "Indoor Air Quality (IAQ): Indoor Air Facts No. 4 (revised) Sick Building Syndrome," U.S. Environmental Protection Agency, http://www.epa.gov/iaq/pubs/sbs.html (accessed November 24, 2010).

[8] "Heat Island Effect: Basic Information," EPA, http://www.epa.gov/heatisld/about/index.htm (accessed February 7, 2011).

[9] "Urban Heat Island," Wikipedia, http://en.wikipedia.org/wiki/Urban_heat_island (accessed February 7, 2011).

[10] "Heat Island Effect: Basic Information," EPA, http://www.epa.gov/heatisld/about/index.htm (accessed February 7, 2011).

[11] Howard Frumkin, Lawrence Frank, and Richard Jackson, *Urban Sprawl and Public Health: Designing, Planning, and Building for Healthy Communities* (Washington, DC: Island Press, 2004).

[12] "Heat Island Effect: Heat Island Impacts," EPA, http://www.epa.gov/heatisld/impacts/index.htm (accessed February 7, 2011).

[13] Tord Kjellstrom, et al, "Urban Environment Health Hazards and Health Equity," *Journal of Urban Health: Bulletin of the New York Academy of Medicine* 84, no. 1 (2007), http://www.ncbi.nlm.nih.gov/pmc/articles/PMC1891648/pdf/11524_2007_Article_9171.pdf (accessed January 20, 2011).

[14] **E16:** "Urban Heat Island," Wikipedia, http://en.wikipedia.org/wiki/Urban_heat_island (accessed February 7, 2011).

Air quality inside buildings is as important as outdoor air quality, especially considering that Americans spend the majority of their time indoors. The EPA estimates that indoor pollution levels can be as much as 2-5 times higher than those outside, signaling that improving indoor air quality is essential to improving the health of urban residents.[15] Residents of low-income often live in substandard inner-city housing. Without higher income residents to provide a strong tax-base the government often doesn't have the money to properly keep up infrastructure of older urban buildings. Gentrification of these run-down areas results in displacement of the poor as rents increase proportionally to rising land values. The health hazards of low-income housing include lead-based paint, cockroach feces, temperature extremes caused by inadequate air circulation, and unsafe stairs and windows. Although these problems are not limited to low-income housing, they are most commonly found there.[16] In general, indoor air pollution sources include building materials, furnishings, cleaning, maintenance or personal care products, heating and cooling systems, and humidification devices. Contaminants include dust mites, cockroaches, pet dander, second hand smoke, and chemicals.[17] A new, medically recognized condition has appeared as a result of poor air quality of the built environment. After spending prolonged amounts of time indoors people can develop "Sick Building Syndrome" (SBS), also known as "multiple chemical sensitivity".[18,19] A related condition is one known as "Building Related Illness" (BRI). SBS is characterized by health problems that appear to be linked to spending time in a building, but there is no clear cause or specific illness. Symptoms of SBS include headache, eye, nose and throat irritation, dry cough, dry or itchy skin, dizziness and nausea, fatigue, and inability to concentrate.[20] BRI on the other hand presents with symptoms of identifiable illnesses and can be linked directly to certain contaminants in the building. Symptoms of BRI are cough, chest tightness, fever, chills, and muscle pain. The first cause of SBS is poor ventilation in buildings, where ventilation systems do not disperse air effectively compared to the number of building occupants. Ventilation standards that require a certain amount of outside air be brought into the building each minute for each building occupant were lowered with the oil embargo in the 1970s in an effort to conserve energy. This resulted in many poorly constructed

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[15] "Indoor Air Quality (IAQ): Indoor Air Facts No. 4 (revised) Sick Building Syndrome," U.S. Environmental Protection Agency, http://www.epa.gov/iaq/pubs/sbs.html (accessed November 24, 2010).
[16] Encyclopedia of Public Health, "Urban Health," Enotes, http://www.enotes.com/public-health-encyclopedia/urban-health (accessed January 20, 2011).
[17] "Indoor Air Quality (IAQ): Indoor Air Facts No. 4 (revised) Sick Building Syndrome," U.S. Environmental Protection Agency, http://www.epa.gov/iaq/pubs/sbs.html (accessed November 24, 2010).
[18] Ibid.
[19] Nicole Wong, "Sick Building Syndrome," Technorati, http://technorati.com/lifestyle/green/article/ sick-building-syndrome/ (accessed February 9, 2011).
[20] "Indoor Air Quality (IAQ): Indoor Air Facts No. 4 (revised) Sick Building Syndrome," U.S. Environmental Protection Agency, http://www.epa.gov/iaq/pubs/sbs.html (accessed November 24, 2010).

ventilation systems.[21] Another cause of SBS comes from chemicals both inside and outside a building. Outdoor pollutants come from vehicle exhaust and building exhausts (bathrooms and kitchens) that enter through poorly designed intake vents and windows.[22] Indoor pollutants come from various sources such as adhesives, carpeting, upholstery, certain wood varnishes, copy machines, pesticides and cleaning products. These products contain colorless and odorless volatile organic compounds that leach out over time into the atmosphere. Combustion byproduct of carbon monoxide and nitrogen dioxide come from unvented or poorly located kerosene/gas space heaters, fireplaces, and woodstoves.[23] Laser-printers emit fine particulate matter that finds its way into lung tissue.[24] In a poorly ventilated space, these chemicals can accumulate in high concentrations. Long term exposure to certain chemicals causes serious health problems such as chronic respiratory disease, lung cancer, heart disease, and brain and kidney damage. Children exposed to chemicals as they grow can have impaired lung capacity and minor brain damage.[25] The World Health Organization suggests tentative connections between indoor air pollution and fetus development that can result in low birth weight, heart conditions and certain cancers. Due to the disproportionate amount of time that women, compared to men, spend indoors cooking and cleaning, their exposure to indoor air pollutants and the compounding health risks is higher.[26] Biological contaminants, another leading cause of SBS, include bacteria, mold, pollen, and viruses. These contaminants can accumulate in residual water on ceilings, floors, drain pipes, or humidifiers and are responsible for cough, tightness of chest, fever, chills, and common allergy symptoms. Legionnaire's disease and Pontiac fever are both caused by the bacteria Legionella.[27] Animals can also be sources of biological contaminants; rat and mice urine contains a protein that is a strong allergen that can become airborne when urine dries. To reduce biological contaminants buildings and ventilation systems must be well maintained to reduce moisture buildup and humidity of the building.[28] Older buildings, especially those built during the oil embargo, are at particular risk to cause SBS; the EPA

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[21] "Indoor Air Quality (IAQ): Indoor Air Facts No. 4 (revised) Sick Building Syndrome," U.S. Environmental Protection Agency, http://www.epa.gov/iaq/pubs/sbs.html (accessed November 24, 2010).
[22] Ibid.
[23] Ibid.
[24] Nicole Wong, "Sick Building Syndrome," Technorati, http://technorati.com/lifestyle/green/article/ sick-building-syndrome/ (accessed February 9, 2011).
[25] "Indoor & Outdoor Air Pollution," Lawrence Berkeley National Laboratory, http://www.lbl.gov/Education/ELSI/pollution-main.html (accessed February 9, 2011).
[26] World Health Organization, "Indoor Air Pollution and Health," WHO Media Centre, http://www.who.int/mediacentre/factsheets/fs292/en/index.html (accessed February 9, 2011).
[27] "Indoor Air Quality (IAQ): Indoor Air Facts No. 4 (revised) Sick Building Syndrome," U.S. Environmental Protection Agency, http://www.epa.gov/iaq/pubs/sbs.html (accessed November 24, 2010).
[28] Environmental Protection Agency, "An Introduction to Indoor Air Quality (IAQ)," http://www.epa.gov/iaq/biologic.html (accessed February 9, 2011).

offers information and resources to encourage citizens to monitor and improve air quality in homes and businesses.

In an effort to improve air quality in urban areas, cities must be designed and planned properly to decrease the pollution levels that contribute to the heat island effect and impair human health. The urban heat island effect can be reduced by increasing foliage in cities and avoiding materials that have high heat capacities. Light colored surfaces reflect heat rather than trap it. Green roofs and increased vegetation cover help cool air and filter pollutants. Alexander Garvin notes that "It is estimated that if a city's tree canopy is increased by 5 percent, temperatures will drop between 2 and 4 degrees Fahrenheit, because tree foliage reduces the ambient air temperature."[29] Trees and plants cool the air when they transpire, which is when they release water through evaporation into the atmosphere. When air temperatures drop, less energy is consumed to cool air artificially using air conditioning systems. Trees also reduce pollution by filtering the air and removing some dust contaminants.[30]

Acquiring clean drinking water has been a pressing social issue throughout history as we have continued to develop, forming permanent settlements with increasingly large numbers of people. Modern cities face the task of both supplying water to and dealing with waste from a massive number of highly concentrated people. Early cities struggled with water-borne diseases due to high densities of people living in unsanitary conditions. Even into the 19th century, water-borne diseases were still prevalent. Sanitation and microorganisms were not understood concepts until fairly recently in human history. The medieval times are marked by images of filth and pestilence, where garbage and waste was thrown into the streets of cities and dead animals lay on the side of the road; and all of this eventually flowed into the surrounding water ways. Typhus, dysentery, typhoid fever, and cholera are all diseases that wiped out people by the thousands paralleling the growth of cities.[31] The diseases spread quickly through water contaminated with human and animal waste. Cholera is the best known of these diseases, and outbreaks still occur in developing countries that lack proper sanitation and clean water. There have been seven recorded separate Cholera pandemics, beginning in 1817 in Calcutta and ending in 1823 after spreading to all of India, parts of Asia, the Middle East, eastern Africa, and the Mediterranean. The outbreak of the second pandemic reached England in 1831, and spread to New York and Detroit by 1832 with European immigrants. The third and generally agreed upon worst pandemic swept through Asia,

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[29] **N:** Alexander Garvin, "Greening Cities: A Public Real Approach," In *Growing Greener Cities: Urban Sustainability in the Twenty-First Century,* Ed. Eugenie L. Birch and Susan M. Wachter (Philadelphia: University of Pennsylvania Press, 2008), 71-72.
[30] **N:** Alexander Garvin, "Greening Cities: A Public Real Approach," In *Growing Greener Cities: Urban Sustainability in the Twenty-First Century,* Ed. Eugenie L. Birch and Susan M. Wachter (Philadelphia: University of Pennsylvania Press, 2008).
[31] Kathy Jesperson, "A History Lesson: Contaminated Water Makes a Deadly Drink," West Virginia University: On Tap, http://www.nesc.wvu.edu/old_website/ndwc/ndwc_DWH_2.html (accessed February 25, 2011).

Europe, North America, and Africa between 1852 and 1859. During this pandemic it was finally discovered that the disease was spread through contaminated water.[32] As sanitation improved in cities, the outbreaks of waterborne diseases decreased. While pollution from waste is still a problem, one of the largest sources of water pollution is from urban run-off carrying contaminants directly into water systems.

The natural water cycle, or hydrological cycle, is the process of water circulating between the ground, atmosphere, and bodies of water. Development, and the increase of impervious surfaces, disrupts this cycle, leading to a decrease in clean water and healthy waterways.[33] Water is stored in places like oceans, lakes, rivers, groundwater, and the atmosphere, and it is replaced over time through the hydrological cycle. Disrupting the cycle changes the replacement rate of water, along with where it is stored, thus altering this renewable resource into a non-renewable one.[34] Impervious surface is the largest disruptor of this cycle, and refers to land coverage that does not allow water to seep into soil. These surfaces include roads, parking lots, rooftops, patios, swimming pools, and basketball courts. When rain falls on these surfaces it picks up pollutants and rather than seeping into the soil, this surface water flows into drain pipes that carry it directly into rivers and streams.[35] As shown in figure 1, the natural hydrological cycle is a complex and balanced system. In this natural cycle, when there is rain fall, some of it evaporates back into the atmosphere, some is absorbed into the soil, and the rest is surface water that travels into oceans and lakes through a system of streams and rivers. Vegetation helps reduce the amount and rate of water falling directly onto the ground, and it also protects against soil erosion through root system. Increased development causes an increase in surface water, a decrease in water that seeps into the ground, and removes the vegetation that protected against soil erosion. A serious problem that urban areas face is local stream degradation. This is caused by surface run-off that flows directly into waterways with great volume and velocity, causing soil on banks to be pushed into streambeds, which often times leading to clogged water channels.[36] Eutrophication is a problem that occurs in bodies of water around urban areas that receive the run-off after rainfalls. Urban run-off contains more organic material (such as minerals and chemicals from fertilizers) that would be naturally

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[32] "Cholera's Seven Pandemics: Disease has killed millions since 19th century," CBCNews, http://www.cbc.ca/news/health/story/2008/05/09/f-cholera-outbreaks.html (accessed February 25, 2011).
[33] Emily Ruby, "How Urbanization Affects the Water Cycle," California Water & Land Use Department, http://www.coastal.ca.gov/nps/watercyclefacts.pdf (accessed February 15, 2011).
[34] Michael Pidwirny, "The Natural Spheres: The Hydrologic Cycle," *Fundamentals of Physical Geography, 2nd Edition,* http://www.physicalgeography.net/fundamentals/5c_1.htm (accessed February 26, 2011).
[35] Emily Ruby, "How Urbanization Affects the Water Cycle," California Water & Land Use Department, http://www.coastal.ca.gov/nps/watercyclefacts.pdf (accessed February 15, 2011).
[36] Ibid.

present, and this leads to large algae blooms that consume large amounts of oxygen and then decompose when that oxygen is gone.[37] Eutrophication refers to this depletion of oxygen levels in water, which often leads to "dead zones" in lakes and oceans. Dead zones are areas where no aquatic life, animal or plant, is present due to the high toxicity and low oxygen levels in the water. Increased surface water also reduces the amount of groundwater, which is water that settles into the cracks and pores of the earth's ground and dissipates into streams, valleys, and wetlands over time. The fewer cracks and pores allowing for the infiltration of water, the less groundwater there is; many cities, such as Albuquerque in New Mexico, rely on groundwater as their source for fresh drinking water.[38, 39] Figure 2 shows a comparison of the water distribution in the natural water cycle versus the urban water cycle. With increased impervious surfaces, the amount of water absorbed and filtrated into the ground is greatly reduced, while the amount of run-off directly into bodies of water is greatly increased. Along with this surface-water increase, the water is picking up many harmful pollutants and particles of garbage that is carried directly into streams and rivers as well.

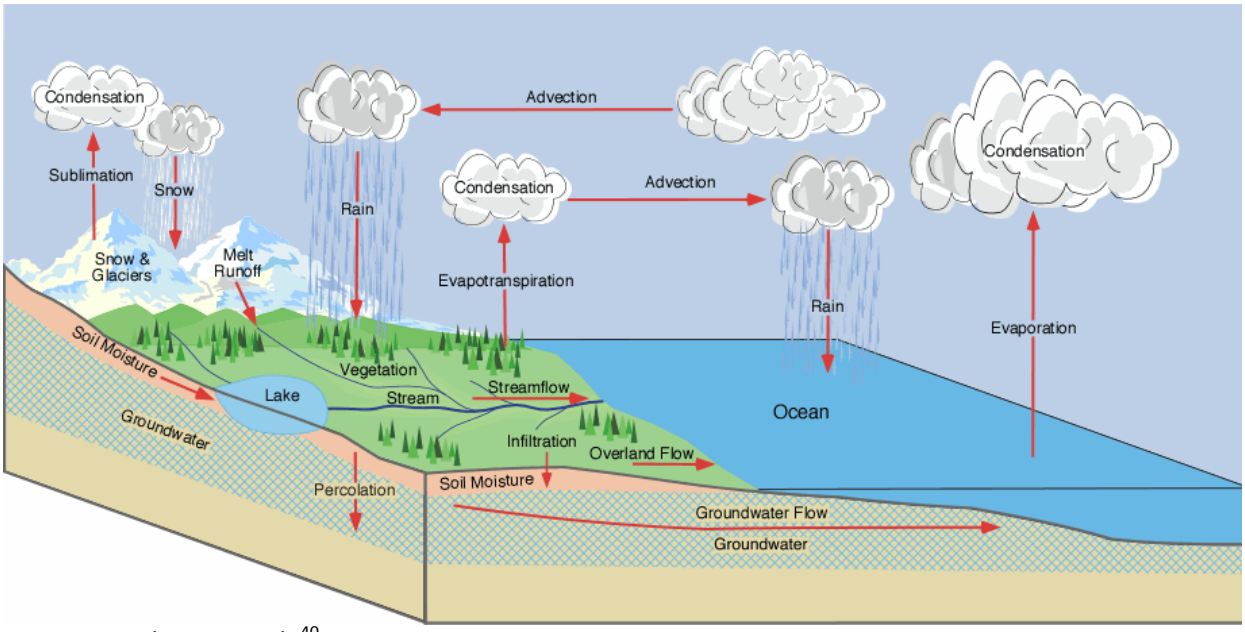

Fig. 1 Natural water cycle[40]

[37] Wikipedia, "Urban Runoff," Wikipedia.org, http://en.wikipedia.org/wiki/Urban_runoff (accessed February 15, 2011).
[38] Natural Sciences Program, "Groundwater & Surface Water," University of New Mexico, http://www.unm.edu/~natsci/water.htm (accessed February 26, 2011).
[39] Geocaching.com, "Highland Creek," Groundspeak Inc, http://www.geocaching.com/seek/cache_details.aspx?guid=27fe8aba-f7af-434b-8238-bd2677132899 (accessed February 26, 2011).
[40] "Figure 5c-1: The hydrological cycle," diagram, PhysicalGeography.net under The Natural Spheres: The Hydrological Cycle, http://www.physicalgeography.net/fundamentals/5c_1.html (accessed February 26, 2011).

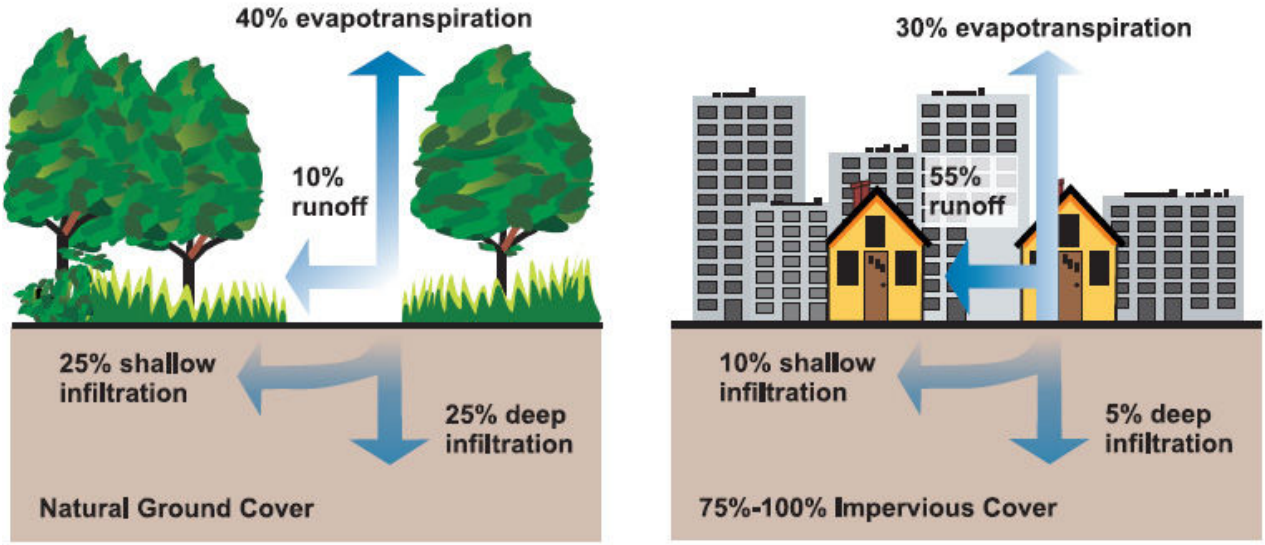

Fig. 2 Water distribution between natural and urban systems[41]

Urban run-off contains numerous chemical and biological contaminants that are deposited directly into water systems, contributing to the declining quality of water in the United States as well as cities all over the globe. This run-off picks up motor oil, combustion by-products, cleaning solvents, fertilizer, pesticides, road salt, heavy metals, and various other sources of toxic chemicals that have accumulated on roof, road, and parking lot surfaces. This runoff is collected into drain pipes that is often times combined with sewer systems, thus mixing storm water runoff with waste in sewers that is taken to sewage treatment plants. When heavy rains fall, this leads to sewer overflows, causing sewage and storm water runoff to be dumped directly into water-ways, bypassing treatment facilities.[42] While some pollutants are naturally occurring substances, they can still cause damage when deposited in water at high concentrations. Nitrates and Nitrites are necessary parts of the nitrogen cycle and are naturally occurring. Humans have greatly increased the levels of Nitrate/Nitrite in the environment to one that is unsafe and found as a contaminant in most water. This increase comes from human and animal waste, plus the use of Nitrogen-based fertilizer.[43] According to the EPA, water can be contaminated through naturally occurring substances and human activity. Natural contaminants include microorganisms from wildlife and soil, nitrates/nitrites in soil, heavy metals found in rocks such as arsenic, cadmium, chromium, lead, and selenium. Human contamination includes bacteria and nitrates from human and

[41] "Natural_&_impervious_cover_diagrams_EPA," diagram, Carteret Country Home Builders Association, http://www.carterethba.com/?p=1330 (accessed February 26, 2011).
[42] T.L. Pedersen, **"**Urban Runoff as a Source of Contamination in Drinking Water," Extoxnet, http://extoxnet.orst.edu/faqs/safedrink/urban.htm (accessed February 15, 2011).
[43] **C12:** "Case Studies in Environmental Medicine (CSEM): Nitrate/Nitrite Toxicity: What are Nitrate and Nitrite?" ATSDR, http://www.atsdr.cdc.gov/csem/nitrate/nitrate.html (accessed March 3, 2011).

animal waste, heavy metals, fertilizer, pesticide, industrial products and waste, household waste, and water-treatment chemicals from wastewater treatment plants. Industrial product and waste sources include factories, gas stations, chemical processing/manufacturing plants, landfills, dry cleaners, and leaking storage tanks. Household wastes include cleaning chemicals, car oil, and paint. Other household contaminants can come from personal care products like shampoo and soap that flow down the drain during a shower. Cleaning products and substances that would be classified as hazardous material (such as old nail polish) are constantly poured down sink drains mostly due to lack of knowledge concerning what these products are made from and the impact this action has upon the environment.[44] Found in human waste, and produced in medicine manufacturing plants as waste-by products, pharmaceuticals make their way into water systems as well. Lead and copper shed from household plumbing can contaminate water as it flows through pipes.[45] Chemicals from pesticides, herbicides, and insecticides can find their way into urban watersheds from surrounding farmland. These chemicals can also be found within city limits on personal lawns and urban gardens. These contaminants are harmful to the ecosystem, and they accumulate in human bodies, contributing to numerous illnesses and health conditions.

Thousands of unregulated chemicals are produced by various sources and contaminate the water that supports life. People drink this water, ingesting toxins that are bio-accumulative to varying degrees in the human body; fish are exposed to these contaminants and then people eat these fish and absorb those toxins as well. According to the USGS, Volatile Organic Compounds contaminate the shallow ground water in many cities within the United States. The most common ones that are found are the following:

- Trichloroethene (TCE) (Solvent)
- Tetrachloroethene (PCE) (Solvent)
- Tethylene chloride (Solvent)
- Methyl tert-butyl ether (MTBE) (Gas additive)
- Chloroform (Solvent/disinfection by-product from water treatment)[46]

These solvents have been identified by the EPA as possible carcinogens and can cause liver damage.[47] These are simply ones that the USGS believes are most common. Table 1 below details a wider range of contaminants found in municipal drinking water; the EPA has identified these and thousands more as

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[44] EPA: Office of Water, "Water on Tap: What you need to know," http://water.epa.gov/drink/guide/upload/book_waterontap_full.pdf (accessed February 15, 2011).
[45] Ibid.
[46] "Water quality and nonpoint sources in urban watersheds," USGS, http://water.usgs.gov/nawqa/informing/urbanization.html (accessed March 3, 2011).
[47] "Drinking Water Contaminants," EPA, http://water.epa.gov/drink/contaminants/ (accessed March 3, 2011).

possible threats to health, most of which cannot be removed by conventional water filtration systems. All chemicals found in urban runoff contribute to or cause kidney/liver damage, nervous system damage, reproductive problems, increased risk of cancer, developmental delays in children, blood disorders, skin conditions, and digestive disorders. Although the EPA regulates concentration levels in drinking water, testing is not frequent enough to reflect the daily fluctuations of toxin levels. Cities and towns that are in close proximity to manufacturing plants have higher levels of certain pollutants that are by-products from the factory and escape into the water systems of that city. Parkersburg, West Virginia is the town next to DuPont's Teflon manufacturing plant.[48] Although they are only a small town, this is a good example of how water contaminants are higher in areas closer to industrial and manufacturing facilities, and how this has a drastic effect upon resident's health. Water contamination that affects small towns can also affect large cities further down steam of a water source. Watersheds are complex systems, and contamination that comes from agricultural areas can easily become a problem in an urban area that receives water from the outlying rural streams and aquifers. Workers at DuPont's plant were most affected by exposure to PFOA, for which Teflon is the trade name. Children of workers exposed to PFOA displayed a number of physical deformities such as cleft palates and nostril and tear duct deformities, which have all been linked to this chemical.[49] Although the town of Parkersburg was in close proximity to a source of high contamination, it has been shown the chemicals in water spread quickly to other areas within a watershed, and that even low doses of these chemicals can have dramatic health effects.

Table 1[50]

Chemical	Source	Health impacts
Benzene	Discharges from factories, leaches from gas storage tanks and landfills	Anemia, decreased blood platelets, increased risk of cancer
Benzo(a)pyrene (PAHs)	Leaches from lining of water storage tanks and distribution lines	Reproductive difficulties and increased risk of cancer
Beryllium	From metal refineries and coal factories, also from electrical and defense industries	Intestinal lesions
Cadmium	Corrosion of galvanized pipes, natural deposits, metal refineries, batteries, and paints	Kidney damage
Chlorine	Water additive used to control microbes – water treatment plants	Anemia; in infants, young children and fetuses can impact nervous system
Copper	Corrosion of household plumbing systems; erosion of natural deposits	Short term effects: gastrointestinal distress; long term effects: liver and kidney damage
Cryptosporidium	Human and animal waste	Diarrhea, vomiting, cramps, and other intestinal problems
Cyanide	Discharge from steel/metal factories,	Nerve damage and thyroid problems

[48] Rick Smith and Bruce Lourie. *Slow Death by Rubber Duck*. Toronto: Vintage Canada, 2010.
[49] Ibid, 80.
[50] "Drinking Water Contaminants," EPA, http://water.epa.gov/drink/contaminants/ (accessed March 3, 2011).

	plastic and fertilizer factories	
Dichlorobenzene class of chemicals	Discharge from industrial chemical factories	Various compounds cause different problems, but they vary among these: liver/kidney/spleen damage, anemia, increased risk of cancer, reproductive problems, weight loss
Ethylbenzene	Discharge from petroleum refineries	Liver or kidney damage
Lead	Corrosion of household plumbing	Physical and mental development delays in children; kidney problems and high blood pressure in adults
Legionella	Naturally occurs in water, and reproduces in heating systems	Causes Legionnaire's disease which is a specific type of pneumonia
Nitrate/Nitrite	Fertilizers, leaches from septic tanks, sewage, natural deposits	Causes illness in infants below 6 months of age who drink water with high levels, if untreated death can occur. Symptoms: shortness of breath and blue-baby syndrome
Vinyl Chloride	Leaches from PCV pipes	Increased risk of cancer

Waste management is an important issue in water quality of cities. Many sewer systems in US cities are now outdated and were not built to accommodate today's larger populations. It is estimated that approximately 20 million people fall ill each year from water contaminated with untreated waste that carries bacteria and pathogens.[51] New York City began building a sewage system in 1849 and most of the gravity-controlled original pipes are still being used. In New York, rainwater flows into drains and combined with waste water to be treated. The treated water flows into the Hudson River. Due to deforestation and land development, soil around cities has an extremely low absorption capacity, reducing the amount of rainwater that is naturally absorbed into the ground and puts added pressure upon sewer systems.[52] The Clean Water Act was in part aimed at improving the nation's sewers to prevent health threats, and congress even provided $60 billion in funding to cities for sewer system improvements. This had little effect on eliminating overflows though, and the EPA estimates that to do so could need upwards of $400 billion over the course of ten years.[53] Air quality issues rely a good deal on improving individual cities, buildings, and car fuel-economy, but water quality problems lie at the foundation of a city and have extensive impacts on surrounding areas. Water from cities eventually flows into rivers, and subsequently into oceans where it is disperses on a global scale due to oceanic movements. One of the problems US cities face today is a lack of enforced water quality standards combined with deteriorating and water treatment facilities and sewage systems. The Safe Drinking Water Act of 1974 allowed the EPA to create national water quality standards, quality monitoring,

[51] Charles Duhigg, "As Sewers Fill, Waste Poisons Waterways," *NYTimes.com*, November 22, 2009, http://www.nytimes.com/2009/11/23/us/23sewer.html (accessed February 25, 2011).
[52] Ibid.
[53] Ibid.

treatment, and reports to the public concerning water contaminants.[54] The EPA as a government agency does not have an effective means of enforcing these requirements, and as a result there are hundreds of violations nationwide every year. Clean Water Act as well has reports of numerous violations, the majority of which result in no penalty to the violators. Charles Duhigg reported in his New York Times article on Atrazine contamination that after reviewing EPA data, it was discovered that the Safe Water Drinking Act was violated in 2008 at least once by approximately 40% of US water systems.[55] In addition to this, the EPA requires the public to be informed of contamination levels in the water only if the yearly average is above the levels seemed safe; this means that short periods of extremely high levels of contaminants will be present in drinking water without residents being notified.[56] As for sewer systems, the same story is true; between 2006 and 2009, over 9,400 of the total 25,000 sewer systems in the US illegally dumped untreated or semi-treated biological and chemical waste into open bodies of water.[57]

Over the past several years, as individuals and governments alike become more aware of the environmental and health impacts of cities, cities and buildings are being redesigned and rebuilt to improve air quality, water quality, and quality of life of residents. Green building is one key feature of improving cities, which has the potential to lower energy use, counteract the heat island effect and depollute air and water. Although some initial costs of green building can be higher, the long term maintenance costs are lower, which makes it a more economically efficient method of building. Green building also eliminates some cause of sick building syndrome through improved ventilation and non-toxic materials. For lower income families, green building can ease financial burdens by reducing utility and maintenance costs. Green building can also be useful for high-rise office buildings, which often require large amounts of energy for lighting and air conditioning. Green building utilizes natural light and ventilation and reduces the occupants' exposure to harmful chemicals and biological contaminants. Greening a city is another effective method in combating air quality and water quality issues that lead to deteriorating health of urban residents. This involves installing green roofs, planting trees, and converting unused space to community gardens. Vegetation provides multiple benefits to cities; it filters air, aids in water absorption, reduces urban runoff, and lowers average temperatures. Alexander Garvin reported that if a city increases its vegetation by 5%, it can cause an average temperature drop of 2-4

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[54] Tom Daniels, "Taking the Initiative: Why Cities are Greening Now," In *Growing Greener Cities: Urban Sustainability in the Twenty-First Century,* Ed. Eugenie L. Birch and Susan M. Wachter (Philadelphia: University of Pennsylvania Press, 2008), 19-20.
[55] Charles Duhigg, "Debating How Much Weed Killer Is Safe in Your Water Glass," *NYTimes.com*, August 22, 2009, http://www.nytimes.com/2009/08/23/us/23water.html?_r=1 (accessed February 25, 2011).
[56] Ibid.
[57] Charles Duhigg, "As Sewers Fill, Waste Poisons Waterways," *NYTimes.com*, November 22, 2009, http://www.nytimes.com/2009/11/23/us/23sewer.html (accessed February 25, 2011).

degrees Fahrenheit.[58] As temperatures drop in a city, the need for air conditioning is less, which thus reduces emissions that contribute to those increased temperatures. By designing cities to be mixed-use and allowing residents to be less car-dependent, a city can become more beneficial to its residents and less of a destructive mark on the earth. Heavy car use in cities and suburbs results in high levels of pollution and congestion, but when services, activities, and homes are concentrated in the city and within walking or biking distance or easily accessed by public transportation, those problems can be alleviated. By targeting sources of air pollution, water contamination and causes of sick building syndrome, we can begin to rebuild healthier and less environmentally harmful cities.

[58] Alexander Garvin, "Greening Cities: A Public Real Approach," In *Growing Greener Cities: Urban Sustainability in the Twenty-First Century,* Ed. Eugenie L. Birch and Susan M. Wachter (Philadelphia: University of Pennsylvania Press, 2008), 71.

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