IMPERVIOUS SURFACES: THE HEAT ISLAND EFFECT

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Impervious surfaces are manmade surfaces that allow little to no water infiltration. The most common types of impervious surfaces include sidewalks, roads, and roofs. Furthermore, the most common materials for impervious surfaces are concrete, asphalt, brick and stone. The amount of impermeable, paved areas has been increasing rapidly since the end of World War II because of urban and suburban sprawl and the intensification of heat islands coincide with urban and suburban development (Gartland 8). Impervious surfaces, although very useful in our everyday lives, cause multiple detrimental effects on the environment. One major type of pollution impervious surfaces cause is thermal pollution.

Impervious surfaces cause thermal pollution and thermal shock to the surrounding ecosystem through stormwater runoff that is at an unusually high temperature. This effect is called the heat island effect, which occurs because impervious surfaces rapidly heat up when exposed to sunlight, and retain much more heat than soil or vegetation. Stormwater runoff over the heated impervious surfaces absorbs heat from the surfaces, which results in an increase in water temperature that the surrounding ecosystem that is not accustomed to, and thereby causing thermal pollution to that ecosystem.

“The term "heat island" describes built up areas that are hotter than nearby rural areas.” (Heat Island Effect 2013) Heat islands are formed in paved over areas (Lee and French 2009) because there is displacement of trees and vegetation, which minimizes evapotranspiration, or the “natural cooling effects of shading and evaporation of water from soil and leaves” (EPA 2003). Therefore, heat islands are most common in dense urban areas because there is more impervious coverage in urban areas than there is in rural areas (Nowak and Greenfield 2012).

In addition to less tree coverage, urban areas also produce more “waste heat from vehicles, factories, and air conditioners may add warmth to the air, further increasing temperatures” (EPA 2003). To understand how hot impervious surfaces can become, for example, “on a hot, sunny summer day, the sun can heat dry, exposed urban surfaces, like roofs and pavement, to temperatures 50 to 90°F (27 to 50°C) hotter than the air, while shaded or moist surfaces—often in more rural surroundings—remain close to air temperatures” (Urban Heat Island Basics, Reducing Urban Heat Islands: Compendium of Strategies). Furthermore, during the day, the difference in temperature between urban areas and rural areas tends to be about 18-27°F, and during the night, the difference is about 9-18°F (Urban Heat Island Basics, Reducing Urban Heat Islands: Compendium of Strategies). Therefore, “the heat island effect is strongest during calm, clear weather "(Gartland 8) and during the summer because the Earth is tilted more towards the sun, and is exposed to more solar energy than during other seasons during the year.

Impervious surfaces heat up more than soil and vegetation because they are impermeable, so they do not allow for any water infiltration, and stormwater tends to be cooler than the air temperature since it is coming from the clouds that are at higher altitudes. Plants produce evapotranspiration, which is the releasing of water that cools down the air (Urban Heat Island Basics, Reducing Urban Heat Islands: Compendium of Strategies). Additionally, "darker surfaces tend to have lower solar reflectance values than lighter surfaces" and therefore, absorb more heat from solar energy (Urban Heat Island Basics, Reducing Urban Heat Islands: Compendium of Strategies). Since asphalt, for example, is black; it absorbs a lot more heat than green leaves. The result of these heat islands is thermal pollution in the ecosystems surrounding the paved areas.

Thermal pollution is the degradation of water quality due to the significantly different temperature of the water than the usual water temperature in the ecosystem. In the case of the heat island effect, the water that is introduced to the ecosystem is much warmer than it is usually and has more heat than the ecosystem can tolerate. For example, "a sudden thunderstorm striking a parking lot that has been sitting in hot sunshine (where surface temperatures of 120°F are not unheard of) can easily yield a 10°F increase in rainfall temperature" (Frazer 2005). The water quantity is also an important contributor to thermal pollution. " Stormwater runs off these urban areas at higher rates and volumes" (Energy Independence and Security Act) because in many scenarios, the "heated water isn't coming off just one parking lot or one street, but more likely several, all adding heated water to a stream or river" (Energy Independence and Security Act) (Frazer 2005). The percent of rainfall that runs off into nearby streams can be from "from thirty to forty percent" and in dense urban areas it can be "more than fifty percent" (Frazer 2005). The largest impact of the heat island effect and thermal pollution is thermal shock in organisms.

Thermal shock occurs in organisms when the water temperature around them has changed significantly enough to cause them harm. The temperature changes under which thermal shock do not have to necessarily be drastically different than the usual temperature of the water. For example, "only small changes in temperature (typically 1 or 2 degrees Centigrade) are needed to have considerable environmental impact" (Thermal Pollution of Water) Warmer water disrupts animals' bodily functions such as "growth, reproduction, and food supply" (Thermal

Pollution of Water) including “ decreased egg survival, retarded growth of fry and smolt, increased susceptibility to disease, and decreased ability of young fish to compete for food and to avoid predation. Especially affected are species that require cold water throughout most stages of their lives, such as trout and salmon.” (Frazer 2005) Additionally, migratory fish affected by thermal shock might not be able to migrate to waters where the temperature is better suited for them, and this can result in death (Thermal Pollution of Water).

The heat island effect also impacts humans and their health because hot temperature events can increase people’s chances of having heat strokes and physiological disruptions that can cause organ damage, and in severe cases, death (EPA 2003). Moreover, the heat island effect from impervious surfaces also has adverse economic effects because since impervious surfaces retain heat, the surroundings areas require a lot of energy in order to cool them. A larger use of energy results in a larger cost to insulate the surrounding areas from that heat, and “for every 1°F (0.6°C) increase in summertime temperature, peak utility loads in medium and large cities increase by an estimated 1.5 – 2.0 percent” (EPA 2003).

One of biggest issues besides pollution with impervious surface is that there are not any federal policies in the United States about impervious surfaces because it’s non-point source pollution. Thermal pollution from impervious surfaces is nonpoint source pollution because warm storm-water runoff does not come from one particular source. The warm stormwater runoff is a result of the water flowing over many different surface areas, and therefore, it can be difficult to pinpoint where the warm stormwater runoff is coming from. However, there are local and state policies that regard impervious surfaces, for example, Maryland has a 10 percent rule about impervious surface cover, especially for intensely developed areas (IDAs). Maryland has a “Critical Area Criteria” that requires “any development within the IDA be accompanied by urban “best management practices (BMPs)” to help mitigate potential water quality impacts associated with stormwater runoff. The Critical Area Criteria further specifies, “that these practices should be capable of removing pollutant loads generated from the development site to a level at least 10% below the load generated at the site prior to development” (Maryland State 2003).

Despite the lack of federal regulations of impervious surfaces, there are some ways to mitigate the heat island effect and the thermal pollution caused by the heat island effect. One solution is installing cooling roofs or green roofs instead of traditional roofs. A “‘cool roof’ describes roofing materials that have a high solar reflectance" (EPA 2003) and "are able to keep roofs between 50 to 60 degrees Fahrenheit cooler than traditional roofs" (Green Roof vs. Cool Roof 2013) and a green roof is a roof that has vegetation growing on it. There are two types of green roofs, which are intensive green roofs and extensive green roofs. Intensive green roofs are roofs with trees and shrubs that usually add "80-150 pounds per square foot of load to the building," and require complex irrigation and drainage system, and are often accessible to the public, whereas extensive green roofs are grasses and short vegetation that require only simple irrigation and drainage systems, and are not usually accessible to the public (EPA 2003). Both cool roofs and green roofs help alleviate the heat island effect, and therefore, decrease the amount of thermal pollution because vegetation naturally does not absorb as much heat as impervious surfaces so any runoff that does occur is not as increased in temperature as it would be running off an impervious surface. Green roofs also help insulate buildings during the cold season (Green Roof vs. Cool Roof 2013) and prevents the amount of stormwater runoff overall, because the vegetation absorbs the rainfall.

Other solutions to help mitigate thermal pollution from the heat island effect are planting more trees, change building designs and promote porous alternatives for surfaces. Planting trees increases evapotranspiration, which cools the air and therefore, the surrounding area and increases the amount of shade on impervious surfaces from sunlight. Changing building designs to promote LEED certifications for buildings (Gartland 168) would allow for less impervious surfaces to be used and allow for an increase in shade over impervious surfaces. For example, the NASA sustainability base in Moffett Field, California utilizes the "the exoskeleton approach" because it "provides a framework for daylighting and shading strategies" (NASA Sustainability Base / William McDonough + Partners and AECOM 2012). Lastly, using porous concrete or asphalt would increase water infiltration to groundwater and uses water infiltration as a natural cooling agent of the concrete or asphalt surfaces.

A reduction in impervious surfaces would be beneficial to society, the economy, and the earth. Reducing the amount of impervious surfaces would decrease the amount of heat islands in urban and suburban areas that cause thermal pollution in the surrounding ecosystems. Decreasing heat islands would lower not only the air temperature in that can affect human health, and create more energy costs, but it would also the amount of stormwater runoff and lower stormwater runoff temperatures that affect the plants and animals in the surrounding ecosystems. The thermal pollution prevention solutions such as alternative surfaces and designs for development also have secondary positive effects. For example, green roofs not only decrease the amount and temperature of stormwater runoff, but they can also naturally filter the rainwater and insulate building in the cold winter months to keep heat in. Impervious surfaces have become integrated with our everyday lives, but due their detrimental effects, it is time to rethink their place in our world.

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