THE IMPACT OF ENVIRONMENTAL HAZARDS IN TEXAS

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FULL REPORT

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DEFINITIONS

Key terms will be defined as the following:

- Natural disaster: a widespread event that affects large portions of the population and geographic area.
- Environmental Hazard: “a substance, state or event which has the potential to threaten the surrounding natural environment and/or adversely affect human's health” (Al-Sharqi, 2017).
- Anthropogenic activity: any activities by humans, including industrial development, waste disposal, and environmental disturbances.
- Health: “a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity”(World Health Organization, 2020).
- Mitigation: the ability to deter, prevent, or prepare for natural disasters.
- Resilience: the ability to return to or positively exceed normalcy after a hazard or disaster.
- Hotspot: concentrated areas of impact.
- Cost: any loss due to a natural disaster; this can be fatalities, lost property, degraded mental health, or other shadow values.
- “100-year flood”: describes the likelihood that a flood of a specified magnitude has a 1% chance of happening in any given year (United States Geological Survey).
- Environmental carcinogen: cancer-causing compounds found in nature, naturally or man-made, that humans are exposed to.
- Haboob: massive dust storms occur when storms sweep past a dry landscape, picking up dust and traveling with it.
- Ozone: made up of both a natural and a man-made product that appears in the Earth's stratosphere and troposphere.
- Particle pollution: a combination of solid and liquid droplets floating in the air.
- Superfund sites: places with harmful wastes that were managed improperly or abandoned.
- Corrosion: when metal is dissolved because of a chemical reaction.

INTRODUCTION

Environmental hazards are an increasingly common threat across the state of Texas and the United States. An environmental hazard[1] is defined as "a substance, state or event which has the potential to threaten the surrounding natural environment and/or adversely affect human's health" (Al-Sharqi, 2017). The United States experiences a wide variety of environmental hazards and natural disasters, including tornadoes, hurricanes, droughts, wildfires, landslides, and sinkholes, among others. Other forms of natural disasters are associated with anthropogenic activity, such as air pollution, fracking externalities, and oil spills. Anthropogenic activity is defined as any activities by humans that has an impact on the natural environment, including industrial development, waste disposal, and other environmental disturbances. These hazards and disasters have taken a tremendous toll on the communities they impact, both in terms of damage to property and loss of life.

The purpose of this report is to identify the set of environmental hazards that impact the health and well-being of Texans. We utilize the definition of health provided by the World Health Organization, defining it as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (World Health Organization, 2020). By this definition, a health impact may be physical, psychological, emotional, or social. Previous literature has substantiated the claim that environmental hazards create unique health challenges for those who experience them, ranging from disease and illness to psychological, social, and emotional stress (Grineski et al., 2013; Peek, 2009). In this report, we specifically explore three hazards that are of concern to Texans—water quality, air quality, and flooding— and identify their impacts on the health and wellbeing of our communities.

Texas consistently experiences a wide variety of environmental hazards and natural disasters. These include hurricanes, wildfires, tornadoes, dust storms, hail, drought, and flooding, as well as hazards related to human activity, such as erosion, exposure to hazardous chemicals, and potential issues from unconventional oil and gas extraction methods such as fracking. While environmental hazards and natural disasters pose a threat to all environments, we will demonstrate that Texas is uniquely more vulnerable than other states. Texas leads the nation in both the number

[1] In this document, the terms hazard and disaster are used interchangeably.

and the scope of natural disasters; it has experienced every major type of natural disaster, and at least one major disaster is declared every year (NASA, 2017).

From 2010 to 2019, the United States endured 119 natural disasters that individually caused greater than $1 billion in damages. These disasters collectively resulted in $807.3B in damages and over 5,000 casualties (National Oceanic and Atmospheric Administration, 2020). This number accounts for a substantial portion of the 273 billion-dollar disasters that have been recorded since 1980, as the trends show an increase in both the frequency of which major disasters occur and the degree of damage they cause (U.S. Global Change Research Program, 2017). A similar trend is observed in Texas, where the frequency and severity of disasters have increased significantly (National Oceanic and Atmospheric Administration, 2020). The National Oceanic and Atmospheric Administration (NOAA) specifically tracks billion-dollar disasters to demonstrate the frequency and strength of high-damage hazards. This monitoring is important because the increasing frequency of large-scale disasters, which causes enormously costly property damage and may lead to considerable losses of life, creates conditions of uncertainty and stress for communities who experience them, leading to negative outcomes in health and well-being.

Health impacts related to human exposure to environmental hazards may be felt directly, in the form of injury or loss of life, or indirectly, due to the emotional and psychological stress experienced by communities vulnerable to these disasters. The communities most frequently impacted by environmental hazards may face considerable stress from the threat of property damage, loss, and fiscal uncertainty in the aftermath of a hazard, and communities that consistently experience hazards report higher levels of stress and lower levels of emotional well-being than do communities in less vulnerable circumstances (Peek, 2009). Compounding this issue is that the communities commonly most affected by natural disasters and hazards are also often less affluent, increasing the impact that financial insecurity following a hazard may have on their health (Peek, 2009).

In recent decades, scholars have begun to investigate the linkage between environmental quality and human health. In this report, we utilize the definition of health provided by the World Health Organization as an all-encompassing indicator of human physical and emotional wellbeing to investigate how exposure to hazards may impact health. Poor physical and mental health is directly correlated with poorer air and water quality as well as with other hazards that result in property damage. The three primary hazards explored in this report—flooding, water quality, and air quality—significantly impact the health and wellbeing of Texans, making it critical that these hazards be defined and evaluated for their implications.

Environmentalists use the term “100-year flood” to describe the likelihood that a flood of a specified magnitude has a 1% chance of happening in any given year (United States Geological Survey). This term is reserved for describing floods with a degree of severity that poses a significant threat to life and property. Central Texas is one of the most flood-prone regions of the United States and has experienced six 100-year floods in the last ten years (Earl & Vaughan, 2015). An analysis of Texas’ identified flood plains indicates that population growth within the flood plains of central Texas is higher than population growth in areas not located on floodplains, increasing the numbers of people potentially vulnerable to catastrophic flooding (Maciag, 2018).

Lake Travis, located in Travis County in Central Texas, is ranked in the top 10% of flood-prone regions by the Federal Emergency Management Agency (FEMA). Lake Travis’ highest recorded flood reached 710 feet above sea level, with nine other floods coming within mere feet of the record. While the most obvious impact of flooding is in loss of human life, other outcomes may hamper health and wellbeing, such as exposure to mold due to inadequate recovery measures, inability to access medical affected medical facilities, and increased vulnerability to waterborne diseases such as Legionnaire disease (Prudent et al., 2016).

Texas cities experienced increasingly poor water quality following the landfall of Hurricane Harvey on August 25, 2017. Samples taken of the water following the storm showed an increase in polycyclic aromatic hydrocarbons (PAHs), an environmental carcinogen that is also linked to autoimmune illnesses and diseases of the skin and liver (Horney et al., 2018). Another study found higher concentrations of bacteria and organic carbon, alongside other hazardous pollutants, immediately following the storm. These toxins in the water can cause long-term health concerns for residential populations, and especially children, who are more likely to ingest a higher concentration of toxins for their size. Over 900,000 Texans experienced impacts to their water quality and access after Harvey, ranging from mild reductions in water quantity to boil-water notices in approximately 200 counties and full water outages in the most heavily impacted areas (Palin et al., 2018).

In recent years, air quality-related disasters and incidents have been tied to incidents involving chemical manufacturing plants in the Houston area (Collier, 2019). On November 27, 2019, multiple explosions and a fire at the Port Neches chemical plant, owned by Houston-based corporation Texas Petroleum Chemicals, led to the release of large amounts of known carcinogens into the air, including butadiene (Collier, 2019). An incident report by the Texas Commission on Environmental Quality and subsequent media coverage estimates that approximately 500 pounds of particulate matter and 1000 pounds of butadiene were released into the air as a result of the plant explosions (Collier, 2020). The explosions caused mandatory evacuations within a four-mile radius of the incident area. The plant had been fined multiple times previously by TCEQ for avoidable air pollution incidents (Collier, 2019). Air quality concerns were reported in the days after the incident, particularly for exposures of butadiene, which is associated with cardiovascular disease and cancer with long-term exposure (KBMT, 2019).

Texas also experiences tornadoes, many of which occur in the northern portion of the state in Tornado Alley. In October 2019, ten tornadoes of varying intensities were confirmed in and around North Dallas on a single Sunday, causing $2 billion in damages and becoming the costliest tornado outbreak in state history (Holcombe & Maxouris, 2019). The strongest tornado occurred near Richardson and was rated an EF-3, meaning severe damage, with maximum wind speeds of 140 miles per hour and a path length of 15.75 miles (NBC, 2019).

Other hazards experienced by Texans include fracking-related earthquakes and severe dust storms. The increased use of fracking in the past decade has caused the frequency of earthquakes in the state to increase six-fold; many of these earthquakes are felt in Central and West Texas, where fracking is used across the Barnett Shale (Magnani et al., 2017). North Texas experiences massive dust storms known as haboobs, which occur when storms sweep past a dry landscape, picking up dust and traveling with it.

The costs incurred by these disasters push Texas to the top of the list in disaster-related spending (Weiss et al., 2013). Some risk factors that contribute to the high frequency of disasters in Texas are man-made, while other risk factors are a product of the state's geological makeup and geographic location. The combination of increased urbanization (especially in coastal regions), increased frequency and strength of storms, and the geological makeup of the state of Texas creates a region prone to severe disasters and natural hazards. The hazards discussed in this report have been selected for their impacts on Texans' well-being, as well as their geographical areas of impact, severity, and frequency.

Given the large geographical area of the state, Texas has several regions, each of which experiences different varieties of natural disasters. Most of these hazards will be intensified by climate change; temperatures have risen between one-half and one degree Fahrenheit statewide in the last century and are expected to continue to rise, leading to more frequent and more severe disasters (United States Environmental Protection Agency, 2016c). Texas has already begun to witness the impacts of rising global temperatures alongside the rest of the United States, as storms have increased in frequency and devastation across the state, often resulting in significant property damage and loss of life (U.S. Global Change Research Program, 2017). This trend will continue without adequate attention paid to the root causes of hazards and planning policies that engage multiple sectors of the economy, government bodies, and individuals (Basher, 2008).

Due to the interconnectedness of the global ecosystem, policymakers require information transparency and interdependencies within virtually all sectors and agencies to create a comprehensive disaster resilience plan (Scalingi, 2007). A deeper understanding of these ecological structures strengthens the understanding of natural hazards, thus leading to a more holistic comprehension of vulnerability and plans to prevent catastrophes. There are many communities in Texas that are particularly vulnerable to the effects of environmental hazards. Vulnerability is a function of the social exposure of a community—that is, the degree to which people and property are exposed to a potential hazard—and the incidence of hazards (Dixon & Moore, 2012).

The purpose of this project is threefold: first, we conduct a review of current scholarly literature surrounding natural hazards in Texas. Second, we conduct a case study of natural hazards, specifically related to flooding, air quality, and water quality. Finally, we analyze data related to historical and current perceptions of natural hazards and policy preferences. We conclude with some comments on the future of hazards in Texas and potential ways to address them.

LITERATURE REVIEW

This report focuses on three distinct aspects of environmental quality—flooding, water quality, and air quality. This section will examine and summarize current literature documenting historical information, trends, patterns, and sources that will aid this report in defining the effects of environmental hazards on health, property, policy, and mitigation strategies.

It is paramount that researchers and policy makers understand the impact of disasters on the physical and social environment to guide and implement effective mitigation strategies and improve community resilience. The effect from disasters can be felt throughout other geographic and demographic areas and contribute to various disparities between communities based on social class, wealth, race, citizenship, and other forms of social stratification. Studies show that mitigation and resilience play a vital role in community development and health. Understanding the geographic and demographic impact trends, patterns, and available data will help to expand upon gaps and reiterate well-reasoned strategies regarding mitigation and resilience.

Flooding

Researchers have examined the impact of flooding on various aspects of social life for decades. Studies suggest that flooding impacts the physical and mental health of communities, that nuances are overlooked due to data aggregations, and that current floodplain mapping creates inequities in the distribution of resources. The widespread nature of flooding impacts long and short-term strategies for mitigation and resilience. The studies analyzed for this literature review use surveys and statistical models to build conclusions. Data sources include the National Climatic Data Center (NCDC), FEMA, National Flood Insurance Program (NFIP), NOAA, and peer-reviewed research from academic institutions.

Understanding flooding impact allows proper allocation of resources and an increased capacity to recover. Flooding is the leading hazard in Texas and comprises some of the most significant natural disasters in the United States (Czajkowski et al., 2013). Floods occur in coastal areas, rivers, basins, watersheds, and low-lying areas with high-intensity rainfall. From 1997 to 2001 there were 423 reported floods throughout Texas, in both coastal and non-coastal areas (Zahran et al., 2008). The literature also suggests that areas with higher impact, greater exposure, and higher socioeconomic standing are more likely to receive government aid and allocated resources . These areas have the greatest number of studies and research, which leads to aggregated and potentially skewed data, as other impacted 'outside' areas may go ignored.

Socio-Economic Impact

While flooding in Texas affects communities across the socioeconomic spectrum, those with less wealth disproportionately experience the impacts of flooding events (CITE). This disparity may be due to geography, demographics (i.e., gender, ethnicity, race, and ideology), and economic status.

Studies show that areas with high percentages of socially vulnerable populations experience significantly more casualties during flood events (Paul et al., 2018). Social stratification is linked to resource access; these resources are needed to provide assistance after a disaster, maintain strong infrastructure, and provide education, healthcare, and opportunities. Because of this, disadvantaged populations have greater health disparities following a disaster and can experience increased difficulties in recovering from a flood or other disaster (Cite). Additionally, disadvantaged populations also face longer-term impacts from prolonged difficulty or challenges in recovery.

Mental and Physical Health

In addition to the socioeconomic effects flooding events have on disadvantaged communities, the mental and physical health of affected individuals may suffer. These impacts include loss of property, psychological impacts, fatalities, or other physical injuries. Notable trends from the literature suggest that most flood fatalities in Texas are due to motor-related incidents or heat-related deaths and occur along transportation routes, that urban locations are more likely to flood due to a lack of impermeable surfaces and increased water retention, and that spring and summer are the deadliest seasons, with May experiencing the most flood-related fatalities (Paul et al., 2018; Sharif, Jackson, et al., 2010; Sharif, Sparks, et al., 2010).

There is a linkage between human health and the maintenance of property as having an adequate place to live creates stability, shelter, and safety. The loss of property after a flooding event or other hazard may affect an individual's ability to regain stability and a sense of safety. According to a report from the National Flood Insurance Program, from 1999-2009 40% of flood damage claims were outside the 100-year floodplain; the majority of these were structural losses (Brody et al., 2013). Structural losses may displace individuals from their homes or create unsafe living conditions after the hazard has subsided. This impacts economic viability (evacuation, rebuilding, ability to work, etc.), increases the risk to personal health (mold, exposure to the elements, fatalities, etc.), and can increase stresses on the mental health of affected individuals. Post-traumatic stress disorder (PTSD) may occur in acute or delayed-onset forms following property loss, making it an important area of study within the literature (Baddam John et al., 2007).

Geographic Implications

Texas is large and geographically diverse, and this affects the degree to which communities are impacted by flooding events. Like other states, those that live on floodplains are routinely affected by flooding. However, there is wide variation in the size of these areas, and those living in floodplains may experience the impacts of flooding differently due to the wide variety of geological formations and soil compositions found across the state. Floodplains, with their defined boundaries, provide useful tools to analyze flood impacts and prepare for them, but it is important to remember that affected areas extend beyond the floodplain and real-world impacts are felt by all individuals. As a result, mitigation strategies and efforts to build resilience to flooding must also extend beyond the floodplain.

Floodplains allow federal agencies, like FEMA, to pre-allocate funds to heavily impacted areas. Texas is one of eleven states that make up the Southern Floodplain (Czajkowski et al., 2013). Texas' location in these floodplains makes flooding a leading cause for loss, property, and fatalities (Paul et al., 2018; Sharif et al., 2015). For example, the Flash Flood Alley is the largest in-state floodplain. Located in Central and North Texas, the alley accounts for 43% of in-state flood fatalities and is considered a hot spot due to its low lying, in-land position along several rivers and basins (Paul et al., 2018).

As the literature shows, floodplain boundaries are useful, but they are not sufficient to represent the true scale of costs and impact. The concept of risk aggregation within floodplains provides a false sense of impact uniformity and risk. Currently, over 50% of losses occur outside floodplain boundaries, and when data is normalized and restructured to reduce data redundancy and improve data integrity, the risk of impact is as high and sometimes higher, than in other Texas floodplains (Brody et al., 2013; Sharif et al., 2015; Sharif, Hassan, et al., 2010). This means that impact data is missing key components regarding nature, scale, development, and location when analyzing exposure, risk, and mitigation.

Mitigation and Resilience

The creation of effective strategies for mitigation and resilience is contingent on an understanding of hazard impacts on affected areas. Current literature shows that effective mitigation and resilience strategies depend on the organizational capacity of governments and communities, as well as their geophysical, and socioeconomic characteristics (Brody et al., 2010). Mitigation largely falls to local governments and decision-makers due to its highly specific nature (Brody et al., 2010).

It is necessary to build a strong local organizational force with the capacity, resources, and expertise to form effective mitigation strategies. These organizations must have sufficient resources and the ability to both adapt to evolving situations and to facilitate collaboration between leading entities working to implement strategies (Brody et al., 2010). Improving hydrometeorological forecasting, creating education programs aimed at increasing awareness of risk and precautions, and local mitigation action can reduce negative flood impacts (Sharif, Hassan, et al., 2010).

Because mitigation strategies rely on accurate data, the misrepresentation or misunderstanding of floodplain boundaries can result in inaccurately predicted response needs (Sharif, Sparks, et al., 2010). Effective implementation helps reduce property damage and human fatalities. Therefore, before creating mitigation strategies, decision-makers must first understand the demographic and geographic components of an area. Studies show that location affects human responses and perceptions to risk (Quinn et al., 2018). By understanding how individuals relate to their location, both within and outside of floodplains, decision-makers can increase risk preparedness and reduce the risk of long-term negative impacts (de Vries, 2019). This understanding can contribute to the creation of data on human attachments to locations, their willingness to evacuate, and their desire and ability to build resilience against future hazards.

Water Quality

Water quality is measured by gauging the presence of a multitude of components from a water sample. This review focuses specifically on components of water quality that have the potential to affect human health. The United States Geological Survey (USGS) defines water quality as “a measure of the sustainability of water for a particular use based on selected physical, chemical, and biological characteristics” (United States Geological Survey, 2020). Anthropogenic activity, such as dumping, agriculture, natural gas extraction, and landfills may impact the quality of the water supply; without these activities, water quality would be defined solely by environmental influences (Carr & Neary, 2008). However, naturally occurring substances may be found in water that can negatively affect human health, including mercury, lead, cadmium, organic toxins, and radioactive contaminants (Carr & Neary, 2008). Understanding how both natural and anthropogenic events affect water quality is crucial to recognizing their effects on human health.

Historical Background

Water quality came into the national spotlight when The Federal Water Pollution Control Act (FWPCA) was passed in 1948. FWPCA was the first federal law that addressed the issue of water pollution directly; prior to 1948, the issue of water pollution appeared inconsistently throughout environmental legislation. The Refuse Act, which appeared in the Rivers and Harbors Appropriations Act of 1899 (33 U.S.C. 403), is considered the first piece of legislation that attempted to regulate water pollution. The law’s primary focus was to limit the dumping of waste that had hindered navigation, but because it addressed waste in waterways, the Refuse Act is credited as one of the first notable attempts at controlling water pollution (Copeland, 2008).

After the passage of the Refuse Act, efforts to curb water pollution were overshadowed by World War II, and excessive dumping continued. By 1945, records show that more than 3,500 communities dumped 2.5 billion tons of waste into waterways daily (Copeland, 2008). In response, legislators passed The Federal Water Pollution Control Act in 1948, becoming the first national legislation to regulate water pollution. However, inconsistencies in the legislation and challenges to its implementation were identified, leading to the amendment of the FWPCA in 1972. These amendments became what is now known as The Clean Water Act of 1972 (CWA) (United States Environmental Protection Agency, 2020b). Today, the CWA is the central federal law that limits water pollution and establishes nationwide water quality standards. Like other environmental laws, the federal government establishes the standards to be followed, and the states carry out enforcement.

The CWA consists of two distinct sections. The first offers financial assistance from the government for the building of sewage treatment plants within municipalities, and the second set regulatory standards for industrial and municipal waste that affect water sources (Congressional Research Service, 2020). The Clean Water act had two primary goals: first, to reach a benchmark of zero pollutants being discharged into waters by 1985, and second, to improve water quality enough by mid-1983 that waters would be “fishable” and “swimmable” (Congressional Research Service, 2020). The act made it unlawful to dump waste into water sources unless accompanied by a permit, and if a permit was not present the polluter would face criminal prosecution.

After its initial passage in 1972, the CWA was amended several times. One of the most notable amendments was added when it was discovered that large amounts of water pollution occurred outside of point source pollution, which had been the initial focus of CWA legislation. Point source pollution is pollution that has a single identifiable source, such as a pipe or smokestack (National Oceanic and Atmospheric Administration, 2013). It became clear that the CWA needed to be amended to include other types of pollution, leading to the 1987 amendments; these amendments were the first to address nonpoint source pollution, or pollution that is naturally occurring, such as runoff from storms, snow, and urban areas (Copeland, 2008). The 1987 amendments also called on individual states to create plans for the management of nonpoint source pollution and urged them to establish mechanisms to protect groundwater resources from contamination.

The most recent amendment to The Clean Water Act was the Water Resources Reform and Development Act of 2014 (WRRDA) (H.R. 3038). WRRDA authorized the Army Corps of Engineers to work on several projects, especially on rivers and harbors, to improve and restore structures and safety mechanisms that were damaged by natural disasters such as hurricanes and flooding (Congressional Budget Office, 2014). Legislation for assistance in the creation of levee systems was also included for state and local governments.

Anthropogenic Events

While several events were responsible for spurring the amendment of the Federal Water Pollution Control Act, the primary factor was an incident along the Cuyahoga River. The section of the Cuyahoga spanning from Akron to Cleveland, Ohio, was one of the most polluted waterways in the US at the time (United States Environmental Protection Agency, 2020b). Several fires occurred in the river before the most infamous fire in 1952, which caused more than $1 million in damages to surrounding infrastructure. The damages created by pollution in the Cuyahoga River captured the attention of the public and garnered support for the water pollution restrictions put in place by the Clean Water Act.

Since the Cuyahoga River incident, several events across the US have affected water quality, and in turn, the health of the American people. One of the most prominent recent water quality crises, which was covered extensively by the media, has been the water crisis in Flint, Michigan. The breakdown of the city's water infrastructure had lasting effects on the health of its citizens. After exposure to the water, Flint residents experienced skin rashes, hair loss, increased blood lead levels, and an outbreak of Legionnaires disease (Pauli, 2020). Eventually, the city switched back to getting its water supply from Lake Huron, but the community is still feeling the ill effects of the water crisis today. Water quality in Texas may potentially worsen from runoff created from fracking and natural gas production. Because the sector is relatively new, there are questions about the effects that fracking activity has on human health, as side effects could take years to present. Potential risks include water and air contamination, elevated noise pollution, occupational hazards, and community stress for rural communities that are not equipped to handle the population boom that comes with drilling crews and fracking-related businesses moving into small towns (McDermott-Levy et al., 2013). There is also concern that the rules and regulations set in place by the CWA, designed to protect the environment, will be violated, resulting in further damages for the surrounding community (McDermott-Levy et al., 2013).

During a public hearing that was held by the Secretary of Energy Advisory Board (SEAB) Natural Gas Subcommittee regarding Marcellus Shale Drilling in Pennsylvania, 67.2% of those who were not in favor of drilling cited health concerns as their reasoning (Goldstein et al., 2012). It is not currently known whether chemicals found in fracking runoff, such as arsenic, bromine, and radioactive compounds, have the potential to combine with already-present chemicals that exist in our bodies (Goldstein et al., 2012). If ingested, these chemicals may cause long-lasting disruptions to the human endocrine system (Finkel & Law, 2011).

Fracking activity may also potentially threaten aquifers. There have been several instances where methane has migrated from sites of natural gas drilling into drinking aquifers. In private drinking-water wells, researchers found the methane levels to be 17 times higher when there was a drilling site within 1 kilometer of the aquifer (Osborn et al., 2011). The buildup of methane in aquifers poses potential health risks, including the potential for explosion and asphyxiation.

Several studies have attempted to understand the health effects of fracking on communities located near production sites. In Texas's Permian Basin, where oil and gas is the major industrial sector and development continues to rapidly expand, researchers collected and analyzed samples from several wells in three different counties within the region. The samples were studied at four different points in time to see the effects on groundwater as oil and gas production increased. They found increases in several chemicals and metals that have the potential to harm human health if consumed such as organic carbon, ethanol, and bromide (Hildenbrand et al., 2016).

The difficulty of drawing conclusions on the health-related risks of fracking is illustrated by another study in this area. This study examined how fracking in surrounding areas was affecting newborns and found statistically significant correlations between mothers living close to well sites and the increased frequency of congenital heart defects in their babies (Raimi, 2018). However, researchers also found that there was a decrease in the frequency of preterm births—a positive health outcome—for babies born to mothers living near well sites (Raimi, 2018). This discrepancy in results highlights the need for further examination of the topic.

Runoff from pesticides is another concern for water quality, particularly in areas that participate heavily in agriculture activities. This topic has been studied to a greater extent in the developing world, where it is seen as a larger issue than it is in developed nations. A research study conducted in Sri Lanka indicated that the restricted use of pesticides cut deaths caused by pesticides by 50%, without negatively affecting agriculture outputs (Dawson et al., 2010). The study conducted by PLOS Medicine used rats to test the effects of ingesting pesticides on health. Pesticides that were deemed lethal by the study contrasted with the World Health Organization's toxicity classifications for pesticides associated with agriculture uses. The study concluded that regulations based upon toxicity regulations for humans would significantly reduce the deaths caused by pesticides globally (Dawson et al., 2010).

Naturally Occurring Events

Naturally occurring environmental events may also harm human health. An article published in GeoHealth in 2019 examined several state phenomena in 2012 and reported on two water quality case studies with the potential to cause negative health impacts. The first case study evaluated harmful algal blooms that were becoming increasingly frequent in Florida. These algal blooms are caused by higher temperatures at the surface of the sea and increased acidity in the water, which are both attributed to climate change. The increased frequency of algal blooms poses risks to respiratory, digestive, and neurological health. Depending on the species, compounds released by the algae may be toxic or non-toxic; a human's health would be impacted if these compounds accumulated in fish or shellfish and then were ingested by humans (Fleming et al., 2011; Kirkpatrick et al., 2010).

The authors also studied West Nile Virus (WNV) in Texas, a mosquito-borne virus that first appeared in the United States in 1999 and peaked in cases in 2003. If an individual contracts WNV, they can experience a myriad of symptoms including headache, body aches, joint pains, vomiting, diarrhea, or rash (Limaye et al., 2018). The risk of contracting West Nile Virus is contingent on genetic variables and the conditions of the surrounding environment. Environmental conditions are cited as the catalyst for the outbreak in Texas in 2012, as the state was experiencing a drought that caused increased temperatures and led to stagnant pools of water statewide that attracted mosquito carriers (Duggal et al., 2013; Poh et al., 2019). In total, 48 states reported cases of WNV, but Texas reported the highest number of infections and deaths from the outbreak, specifically in the Dallas-Fort Worth area (Yango et al., 2014).

A 2012 study done on primary schools and preschools in south-central Kansas found that about one-third of the water consumed by children age six and under in the region had some form of lead contamination. The drinking water contamination exposed the children to a multitude of health risks including attention deficits, slowed growth, and reading disabilities (Massey et al., 2012). More long-term health problems can include hearing loss, tooth decay, spontaneous abortions, cardiovascular disease, anemia, hypertension, and kidney disease (Bogden et al., 1997; Lanphear et al., 2005).

In summary, an examination of the literature demonstrates that both naturally occurring and anthropogenic events may potentially cause adverse effects on water quality. These impacts can be short-term or long-term, depending on the types of areas, people, and property they affect. These effects are increasingly salient because of their potential impacts on human physical and mental health, which is expanded on in the next section.

Health Impacts

Water pollution also poses a significant risk to human health. A study published in the Journal of Economic Literature assessing health and human capital found that their results applied to developed countries but recognized that higher levels of pollution are typically found in developing countries. While this study primarily focuses on the effects of air pollution on health and human capital, it draws on a previous study that looks at the effects of water pollution on these factors. The study was conducted in China by Ebenstein (2012), who explored how the country's rapid industrialization impacted its water quality. Ebenstein gathered water pollution data from China's national water monitoring system and mortality records from select cities. He found that for each unit of reduction in water quality (on a scale of six), the likelihood that a person developed digestive system cancer increased by almost 10%. Ebenstein also explores the economic consequences of pollution, arguing that if wastewater were cleaned enough to avoid even one death from water pollution, it would save $30,000 per case of digestive system cancer.

In addition to the visible physical effects, water pollution may have on humans, there are also psychological impacts that often go unnoticed. A study published by the US National Science Foundation concluded that the majority of mental illness connected to water is related to water insecurity, which is defined as "the inability to access and benefit from affordable, adequate, reliable, and safe water" (Jepson et al., 2017; Wutich et al., 2020). These negative mental and emotional health outcomes include emotional distress, perceived stress, depressive symptoms, anxiety symptoms, somatic symptoms, and a reduced quality of life (Jepson et al., 2017). Mental health is measured on a continuum ranging from no symptoms to moderate degrees of impairment, to having a identified disorder (Frank et al., 1991). Water insecurity may affect mental health by causing material deprivation, shame of social failure, worry about threats to health, loss of connections, frustration around lost opportunities, interpersonal conflict, and institutional injustice (Wutich et al., 2020).

One study looking at the mental health aspects of water quality predicted that the residents of Flint, Michigan will experience post-traumatic stress disorder (PTSD) for those affected by the city's water crisis. Researchers looked for a relationship between perceptions of tap water quality and symptoms of post-traumatic stress disorder and found a positive correlation (Kruger et al., 2017). This is outlined in more detail below.

Monitoring the mental health outcomes that come from water insecurity can provide valuable feedback on intervention strategies to determine if they are working as intended (Bisung & Elliott, 2017). This feedback may potentially lead to improvements in the effectiveness and efficiency of current water interventions. While the connection between water quality and mental health requires further research and has yet to be confirmed empirically, tracking mental health outcomes provides insight until research measures are taken.

There are several avenues through which states can procure funding for the mitigation of water pollution issues. In 1956, federal legislation was passed that awarded grants for the planning, design, and construction of municipal sewage treatment facilities. These grants are based on population size, estimated need, and ability to carry out changes proposed. Similarly, the World Health Organization (WHO) implemented a water quality and health strategy plan that spanned from 2013-2020. The goal of the plan was to manage the safety of the water supply for drinking, food production, or any other aspect that has the potential to impact human health (World Health Organization, 2020). The plan was intended not only to promote wellbeing, but to encourage socioeconomic development as well, which in turn promotes positive human health outcomes.

Air Quality

Air pollution is caused by the release of harmful pollutants, such as greenhouse gases, smog and soot, pollen, mold, and chemicals such as mercury, lead, dioxins, and benzene, into the air

(Mackenzie, 2016). In 2013, 5.5 million premature deaths worldwide were attributed to air pollution (World Bank, 2016). In addition to reducing the quality of life and expected lifespan, air pollution may also decrease the industrial competitiveness of cities, because of its ability to restrict plant growth in concentrated areas as well as reduce agriculture productivity (Avnery et al., 2011). According to the World Bank, air pollution deaths cost the world economy $225 billion. The impact of pollution is felt across age and demographic groups; it is not only a risk for young children and the elderly, but may also affect working-class men and women, creating losses in labor and income (World Bank, 2016).

Hazardous chemicals in the air can have both acute and chronic effects on human health and may impact a number of different organs and systems within the body. Effects can range from minor upper respiratory irritation to chronic bronchitis. Exposure to air pollution, whether in the long or short-term, has also been linked to a shorter life expectancy, premature mortality, and increased hospital admissions (Brunekreef & Holgate, 2002). Some pollutants are released naturally into the air, via fires or volcanos, while others are emitted from human activities such as the chemicals released from industrial facilities and the burning of fossil fuels (Kampa & Castanas, 2008).

In 1955, the United States passed the Clean Air Act to protect human health and the environment from emissions that pollute the air we breathe. The Act requires the Environmental Protection Agency (EPA) to create national minimum health-based standards for air quality and sets deadlines for state and local government compliance. It also requires the EPA to set national emission standards for industrial sources that contribute to pollution, such as motor vehicles and power plants. The Clean Air Act requires preventative actions to be taken in areas with higher air quality and also implements emission controls and cap-and-trade programs (Congressional Research Service, 2020).

Measurement

The level of pollutants in the air is measured by a numerical value where higher values indicate poor air quality, and the lower values represent better air quality. One source of air quality measurement comes from the Air Quality Index (AQI). The AQI is split into different levels of concern; the value assigned indicates the level of risk and potential effects air quality may have on the population or specific population subgroups. A value of 100 or below is typically seen as adequate, meaning the air quality is either good or moderate. An AQI value between 101 and 150 is seen as unhealthy for people in population groups more sensitive to air pollution. A value between 151 and 200 is seen as unhealthy, meaning that members of the public are prone to negative health effects in such conditions, and individuals in more sensitive population groups may experience more serious issues. If the value is between 201 and 300 the air quality is seen as a health alert and places everyone at risk of negative health effects. A value higher than 301 then becomes a health warning of emergency conditions, meaning that everyone in such an area can be affected by the air quality (United States Environmental Protection Agency & Information Division, 2009).

Under the Clean Air Act, states must submit a State Implementation Plan to the EPA. The plans are a way for the EPA to reaffirm that the states meet the statutory requirements in place from the Act (Congressional Research Service, 2020). A State Implementation Plan is an enforceable document that dictates how the states will comply with the requirements of the Clean Air Act. The Texas State Implementation Plan highlights seven areas of Texas—El Paso, San Antonio, Austin, Dallas-Fort Worth, Houston, Corpus Christi, and Victoria—and details plans for the protection and promotion of air quality in each area.

By understanding the source of air pollution, decision-makers can implement preventative measures that reduce the impact pollutants have on human health, particularly when pollutants are emitted as a result of anthropogenic activity. Texas is the leading crude oil and natural gas producer in the nation, responsible for 41% of the nation's crude oil production and 25% of its sold natural gas in 2019 (United States Energy Information Administration, 2020). Texas is home to 30 petroleum refineries that collectively contribute to 31% of the nation's crude oil refining capacity.

The state also leads in energy consumption, half of which is consumed by the state's industrial sector (United States Energy Information Administration, 2020). A report created by the Clean Air Task Force states that the oil and gas industry will deposit upwards of 9 million tons of methane and other pollutants like benzene, ozone, and smog into the air each year (Clean Air Task Force, 2020). Ozone smog is of particular concern to children, the elderly, and people with existing respiratory conditions. When inhaled, it can weaken lung function, cause asthma attacks, and exacerbate diseases like bronchitis and emphysema, and in more severe cases may lead to premature death (Clean Air Task Force et al., 2016; United States Energy Information Administration, 2020). Furthermore, Texas is home to three cities with 25,000 or more asthma attacks, more than any other state included (Clean Air Task Force et al., 2016).

Texas was ranked first in the nation in 2017 for total carbon dioxide emissions at 707.0 million metric tons. The second-ranked state, California, emitted only half of that number at 359 million metric tons. Carbon dioxide is emitted into the atmosphere through the burning of fossil fuels like coal, natural gas and oil, as well as through solid waste, trees and other biological materials, and certain chemical reactions, like the manufacturing of cement (United States Environmental Protection Agency, 2020c).

The largest environmental risk for premature death is air pollution (Environmental Defense Fund, 2020). Air pollution increases the risk of non-communicable diseases and exacerbates existing conditions like asthma, making it responsible for millions of premature deaths around the world each year (Pimpin et al., 2018; Ritchie & Roser, 2017). With both human and natural emissions contributing to reductions in air quality, monitoring the level of air pollutants proves daunting. Air pollution has both short-term and long-term health effects, leading to public concern about air quality and the measures that can be taken to control air pollution in the future.

Common Airborne Pollutants

The Environmental Protection Agency has set National Ambient Air Quality Standards for six pollutants: carbon monoxide, lead, nitrogen dioxide, ozone, particle pollution, and sulfur dioxide. Carbon monoxide, a colorless and odorless gas emitted by vehicles or machinery or formed from an incomplete ignition of fossil fuels, is harmful when inhaled in large amounts (Graber et al., 2007). Prolonged exposure to carbon monoxide leads to a buildup in the bloodstream, causing carbon monoxide poisoning. This level of exposure can occur during routine domestic, occupational, and recreational activities, or in the aftermath of large-scale disasters like hurricanes, floods, and winter storms (Hampson et al., 2009). With Texas's coastal regions regularly experiencing storms and hurricanes, carbon monoxide exposure poses a potentially significant public health problem.

Lead is a naturally occurring element that can be released into the environment by way of industrial sources, contaminated sites, metals processing, iron and steel foundries, copper smelters, commercial and institutional boilers, glass manufacturers, and cement manufacturers. Children and adults, including pregnant women, are all susceptible to lead exposure, which can cause issues within kidney function, or may impact the nervous system, immune system, reproductive and developmental systems, and cardiovascular system (United States Environmental Protection Agency, 2017a). Children exposed to lead are at risk of neurological and nervous system effects which can have long-term impacts on health and well-being.

Nitrogen dioxide is a chemical compound of a group of nitrogen oxides, which are highly reactive gases. Nitrogen dioxide is emitted into the air by way of cars, trucks, buses, power plants, and off-road equipment. High exposure to nitrogen dioxide can irritate airways, increasing susceptibility to respiratory diseases, especially asthma. Population groups potentially more susceptible to nitrogen dioxide exposure include children, the elderly, and anyone with asthma (United States Environmental Protection Agency & Information Division, 2009).

Ozone is made up of both a natural and a man-made product that appears in the Earth's stratosphere and troposphere. The effects of ozone on Earth are dependent on the location of the gas (United States Environmental Protection Agency, 2020d). Good ozone is found in the stratosphere, the upper level of the atmosphere, as a natural product that protects the Earth from harmful UV rays produced by the sun. However, ozone found lower, in the troposphere, can be potentially harmful to humans when pollutants react chemically to sunlight (United States Environmental Protection Agency & Information Division, 2009).

Particle pollution, sometimes referred to as particulate matter (PM), is a combination of both solid and liquid droplets floating in the air. Particle pollution takes many forms, including acids, inorganic compounds, organic chemicals, soot, metals, soil/dust particles, and biological materials (United States Environmental Protection Agency & Information Division, 2009). Particles can be grouped into two specific categories, coarse particles, and fine particles. Coarse particles are generally any particles larger than 2.5 µm in diameter but not larger than 10 µm diameters. Large coarse particles are those larger than 10 µm in diameter. Fine particles are generally particles equal to or smaller than 2.5 diameters. Nanoparticles and ultrafine particles are particles with a diameter of less than 0.1 μm (United States Environmental Protection Agency, 2017b; Wilson & Suh, 1997). In outdoor settings particle pollution can come from construction sites, unpaved roads, fires, or reactions to other chemicals within the air like sulfur dioxides and nitrogen oxides. The health effects of exposure to particulate matter include cardiovascular symptoms like a heart attack or stroke, respiratory effects, and, in some more extreme cases, premature death. Children and older adults over age 65 are more likely to experience the effects of particle pollution. Children who spend more time outside are at higher risk, as are adults with pre-existing respiratory and cardiovascular conditions.

Similar to nitrogen dioxide, sulfur dioxide is a component used as an indicator for a larger group of sulfur oxides. The emission of sulfur dioxide into the air comes through the burning of fossil fuels, power plants, industrial sites, volcanos, locomotives or ships, and any other heavy equipment that burns a high amount of sulfur. Health effects associated with exposure to sulfur dioxide are respiratory effects such as asthma; when individuals are subjected to prolonged exposure, sulfur dioxide may enter the lungs and contribute to lasting negative health outcomes (United States Environmental Protection Agency, 2019).

In Texas, ozone is the pollutant that is of most concern (U.S. Government Accountability Office, 2009). A study conducted by researchers at the Massachusetts Institute of Technology examined the total number of early deaths per year and the mortality rate from ozone exposure as a result of emissions from six sectors. The sectors evaluated were electric power generation, industry, commercial/residential activities, road transport, marine transport, and rail transport (Caiazzo et al., 2013). The study found that more than 20 percent of the ozone-related mortalities from all sectors occurred in the state of Texas and that the primary sectors responsible were road transportation and industrial emissions.

Impact and Health Effects

Air pollution may negatively impact human health by elevating the risk of non-communicable diseases such as cardiovascular disease, respiratory disease, and lung cancer, or by exacerbating existing conditions like asthma (Pimpin et al., 2018). When high levels of pollutants like sulfur dioxide and nitrogen oxide are present, individuals may experience problems with the respiratory system and show signs of nose and throat irritation, and people with pre-existing respiratory conditions like asthma often experience signs of bronchoconstriction and dyspnea, or the narrowing of the airway and shortness of breath (Wald & Balmes, 1987). Lung inflammation can be caused by inhaled particulate matter and ozone pollution (Ghio & Huang, 2004; Uysal & Schapira, 2003).

Prolonged exposure to ozone pollution, as well as heavy metals, can reduce lung function and has also been linked to asthma, emphysema, and lung cancer. Studies on the cardiovascular system show that carbon monoxide enters the bloodstream and reduces its ability to transfer oxygen, obstructing the function of organs that consume high amounts of oxygen, including the brain and the heart (Badman & Jaffe, 1996).

Decreased lung function due to pollutant exposure may also lead to changes in blood clotting. Obstruction of the blood vessels can cause tachycardia, lead to increased blood pressure, cause individuals to become anemic, or lead to angina or myocardial infarction, more commonly known as heart attacks (Ghio & Huang, 2004). Heavy metals in the air have been shown to affect the nervous system and exposure can cause neurotoxicity, the symptoms of which include memory infraction, sleep disorders, blurred vision, slurred speech, hand trembles, tiredness, and increased agitation or anger (Ratnaike, 2003).

Memory function is one of the leading effects of lead poisoning, while mercury exposure has been linked to neurological cancer (Lasley & Gilbert, 2000). Liver cancer is the third leading cause of death in the world. The state of Texas has recorded the highest incidence of liver cancer in the United States (Cicalese et al., 2017).

According to a study of air quality by the American Lung Association in 2019, the city of Houston has the 9th worst ozone pollution in the United States. Sixty percent of Houston’s ozone pollution stems from the vehicle exhaust of over five million registered cars. However, during the COVID-19 pandemic, Houston issued stay-at-home measures that led to decreased traffic on city roads, leading to a decrease in ozone pollution of 13 percent compared to the same time a year ago (Rogalski, 2020). A survey done by the Kinder Institute in 2020 indicates that Houston-area residents want to see more done to control the area’s air pollution, with 63% of respondents answering that control of air pollution was “fair” or “poor” (West, 2020). With reductions in pollution due to decreased vehicle operation during the COVID-19 pandemic showing the industrial city what pollution reduction looks like, there is increased attention to the city's air pollution problem.

Literature Review Summary

The available literature focuses on socioeconomic status, overall health, location, and strategic impact. Each of these impacts is studied in concentrated areas of high risk, high impact, and high social standing. While useful in building mitigation strategies and allocating resources, aggregating data omits nuances in the population that still face one or more areas of impact.

Flooding, water quality, and air quality have wide-ranging socioeconomic impacts on populations, mitigation, and resilience. Hotspots allow for effective resource allocation of federal aid in the case of hazards and disasters, but it is important to remember that impact data transverses time and location. Environmental hazards can be naturally occurring or man-made, and government intervention is often needed to rectify the damages incurred as well as set standards to mitigate the severity of future disasters.

Further research done in these arenas must expand to consider the impact outside of mainstream studies to create a fully realized impact analysis. The research that is to be done in coming years will allow us to generate a deeper understanding of the specific impacts that these hazards have on human health. However, current data is invaluable for building current mitigation strategies and bolstering resilience for those negatively affected by flooding, water quality, and air quality.

CASE STUDIES

The linkage between environmental hazards and health impacts in Texas is visible and demonstrable, but measures can be taken to mitigate impact. We draw on evidence from three case studies to illustrate how three hazards of interest —flooding, water quality, and air quality—can cause undesirable health outcomes. We have selected events that occurred outside of Texas and impacted the health of residents, and examine actions taken in response to prepare for the possibility of similar hazards occurring in Texas.

Flooding

Like other climatic disasters, floods are often uncontrollable and difficult to endure. Floods are devastating both during and after they occur, and consequences can be especially grave, as residents are forced to rebuild and restore destroyed structures, and eliminate scattered waste and debris for years, leading to negative health and wellness impacts.

Of particular concern is industrial waste containing toxic substances which, if left in the open or poorly isolated, can prove dangerous to humans. There are 41 Superfund sites in the Texas coastal area, 13 of which are located near Houston and seven in Houston itself, that becomes especially dangerous during floods. (CNBC, 2017). Various wastes located at these sites can enter floods and groundwater (Bubenik, 2018). Floods often release toxic elements from existing hazardous waste dumps and expose communities to secondary exposure to dangerous substances (CNBC, 2017).

Residents near Superfund sites may feel worried or anxious because there is little assurance that Superfund contaminants will be reliably protected from flooding events. Carcinogenic or otherwise toxic chemicals such as creosote, dioxin, polyvinyl chloride (PVC), and other substances that are stored at the Superfund facilities can cause serious harm to residents and their health if exposed (CNBC, 2017). For instance, the level of dioxins in the water near one of the Superfund facilities, which was destroyed by Hurricane Harvey, exceeded 2,000 times the permissible level (Bubenik, 2018).

The flooding caused by Hurricane Katrina is another example of how floods can be dangerous and risky for human health and life. Many residents of New Orleans, Louisiana, were isolated and trapped by Katrina’s floodwaters. The territory of the City of New Orleans was flooded by 80%, and the damages were estimated at about $17 billion (Diaz et al., 2020). Additionally, the floods have seriously damaged the environment of the city and the state as a whole. Consequences of the flooding included the spill of oil and oil products, the spill of chemical and solid waste, damage to landfills, the scattering of debris from houses and structures, and damage to sewerage (Diaz et al., 2020).

In the aftermath of Hurricane Katrina, hazardous industrial chemicals and other waste from Superfund facilities became a dangerous threat to human health for several years. Many factories are located along the Gulf of Mexico coast or tributaries that lead to the Gulf (Fidis, 2005). It is one of the most developed and polluted areas in the country, where toxic substances are regularly stored, produced, and discarded (Reible, 2007).

Industrial and household chemicals, oil, and pesticides were also released in the floods and dispersed throughout the Gulf region. Sources suggest it may take years to identify and to clear up the entire volume of these chemical spills (Reible, 2007). EPA experts found that the floodwaters mixed with wastes from the Superfund facilities high in lead, carcinogenic asbestos, and other toxic substances (Fidis, 2005). Additionally, oil and oil products from industrial enterprises, gasoline from gas tanks of cars, and boats were found in the water, which caused significant damage to all living things in this region (Fidis, 2005).

Experts found particles of mercury, arsenic, and other hazardous chemical elements in floodwaters (Fidis, 2005). The carcinogenic arsenic was found in concentrations 200 times higher than acceptable levels, and benzo (a) pyrene levels were 570 times higher than the permissible limit for human health (Reible, 2007). Experts also found toxic mixtures such as toluene, carbon disulfide, lead, benzene, and barium in floodwaters (Reible, 2007).

Colonias

Colonias, which are self-organized communities or neighborhoods located primarily along the US-Mexico border, may be particularly vulnerable to flooding events. Texas has the largest number of colonia residents, with 500,000 people residing in these communities (Strickland, 2016). Galvin (2018) found that Texas has about 2,300 colonias, and that these communities are home to many low or non-permanent-income residents. While the scale of flooding in colonias is not comparable to that of large cities like Houston or New Orleans because the population density differs significantly, colonias are still vulnerable, particularly because the proximity of colonias to the Gulf of Mexico increases their vulnerability to climatic events that cause floods, like tropical storms and hurricanes.

For example, while communities in Houston may be heavily impacted by flooding, they have developed infrastructure and may quickly recover, and utility companies generally help them restore water, electricity, sewage, and other amenities in a timely manner. In contrast, colonias are located in remote areas far from urban settings, and they lack piped water, sewerage, electricity, roads, and regular garbage collection, exacerbating the situation for residents after hazard events. For instance, the inhabitants of colonias in Hidalgo County, Texas, take out garbage near their colony, aggravating the ecological situation during floods (Strickland, 2016). Some Hidalgo colonias are located on reclaimed agricultural land, making them more prone to flooding, and residents can be exposed to toxic pesticides during floods from previous agricultural activity (Galvin, 2018).

Clow (2018) argues that the main issue for colonia residents is the removal of water from settlements after hurricanes and storms have subsided because there are no drainage systems. For instance, the landscape of the Hidalgo County colonias is flat, and precipitation remains on the surface until it evaporates in the sun, leading to suffering for residents (Tyx, 2016). Moreover, floodwater mixes with wastewater, and the contaminated water may make its way into drinking wells, causing stomach problems in the colonias of Hidalgo and Nueces Counties (Rowles et al., 2020; Tyx, 2016). Standing waters created after flooding events attract insects and parasites, leading to illnesses and skin diseases in the colonias (Tyx, 2016).

The inhabitants of Hidalgo and Nueces county colonias build makeshift wells and septic tanks because of the lack of developed water and sanitation infrastructure. But such improvised structures expose residents to the risk of contracting various diseases. During floods, wastewater rises from septic tanks and is directed to wells and groundwater, creating a public health crisis (Rowles et al., 2020). For example, the number of cases of infectious diseases such as shigellosis, flea typhus, rubella, hepatitis A, rabies in the Hidalgo County colonias is four times higher than in other states (Knab, 2016; Tyx, 2016).

Floods and flood waters can extract pesticides from agricultural fields, sewage from homemade septic tanks, and human waste stored on the colony’s outskirts. All of these materials settle on the ground, in wells, and aquifers, causing harmful bacteria and toxic materials to enter the drinking water. Rowles et al. (2020) argued that wells in colonias might contain dangerous Escherichia coli (E. coli) bacteria, arsenic, mercury, nitrate, boron, and vanadium due to massive flooding.

Food Security

Flooding also poses threats to food security because when agricultural infrastructure, harvested crops, and farmland are flooded, food provisions can be threatened. In 2017, Hurricane Harvey hit Texas, releasing heavy rainfall, and the ensuing flooding wreaked havoc on Texas farmers, ranchers, and agricultural exports. Harvey's floods virtually paralyzed Texan agrarian activities, with more than 60 inches of total rain reported (Perroni, 2017). Flooding damaged many crops, such as soybeans, wheat, and cotton; cotton farmers, in particular, were among the hardest hit agricultural producers as hundreds of tons of cotton were left wet in the fields (Perroni, 2017). Although most of the wheat, maize, and rice crops were harvested in a year, farm infrastructure such as storage bins could be severely damaged by wind and water, resulting in colossal crop losses (Hawkes, 2019). .

Floods also affected livestock farms and pastures. Texas farmers were forced to move livestock to higher lands, but fears persisted about access to food, water, vulnerability to disease, and a predatory environment. During the floods, some farmers could not reach their livestock to move them (Perroni, 2017). The livestock losses included agricultural infrastructure, feed, livestock, and other animals (Corey, 2017).

Floodwaters have also created significant risks to public health and food contamination. Cereals, fresh fruits, and vegetables, chilled and frozen foods that have been exposed to flood waters have deteriorated and become inedible (Perroni, 2017). Food and water can easily be contaminated or spoiled after a power outage, which can be detrimental to public health.

The cost of grain and livestock losses due to flooding was more than $200 million, with $93 million in livestock losses, $100 million in cotton losses, and $8 million in rice and soybean losses (Corey, 2017; Fannin, 2017). Although Texas farmers harvested about 75% of their rice harvest year-round, wind and water destroyed storage tanks and caused further crop losses (Malewitz, 2017). Many industries related to commercial and recreational fisheries also suffered losses related to damaged vessels, industry infrastructure, and gear (Corey, 2017). The oyster industry suffered severely due to productivity losses related to excessive freshwater in local bays (Corey, 2017).

Flooding often occurs in coastal areas of the United States and dramatically affects people's livelihoods. Each time, floods create catastrophic consequences detrimental to both the economy and the environment. Moreover, infrastructure, landfills, and food security are both vulnerable and poorly protected from floods.

Water Quality: Flint, Michigan

Consumption of contaminated water may cause physical and mental harm to exposed populations. To prevent this, it is beneficial to examine a case in which contaminated water was consumed on a large scale and learn from strategies used to address the crisis. This case study will discuss the events of the Flint, Michigan water crisis that began in 2014. The detrimental effects the contaminated water had on Flint's population are reasonably comparable indicators to possible contamination effects fracking activity can have on nearby water supplies.

Background

Flint's water crisis began when officials were exploring the option of switching water providers from the Detroit Water and Sewage Department (DWSD) to save money (Kennedy, 2016). The plan had been for the city to build a pipeline that would connect to the Karegnondi Water Authority (KWA) which was predicted to save the city $200 million over 25 years. Officials opted to go forward with the plan, and services with the DWSD were terminated. Until the new pipeline could be connected to the KWA, the city decided to use the Flint River as an interim water source (Kennedy, 2016).

The water had not been immediately treated until residents complained about the smell and color of the water and when E. coli and coliform bacteria were found in the water (Kennedy, 2016). Flint would later be found to have violated the Safe Drinking Water Act when trihalomethanes were found; these were the result of chlorine added to the water to address the E. coli and coliform, mixing with organic matter found in the water.

High levels of lead were also found in Flint's water (Kennedy, 2016). The Michigan Department of Environmental Quality notified the Environmental Protection Agency (EPA) that no corrosion control treatments were in place at the Flint Water Treatment Plant. Hundreds of Flint homes were tested for lead and found to have high levels of lead contaminants present. An increased percentage of the children of Flint were also found to have elevated blood lead levels. Flint switched back to its initial water supplier, but the damage was done; a state of emergency was declared (Kennedy, 2016).

Lead can get into drinking water from lead pipes, faucets, and fixtures, particularly in cities and homes built before 1986 (United States Environmental Protection Agency, 2020a). The risk comes from the possibility of corrosion, when metal is dissolved as a result of a chemical reaction between the water and plumbing surface. The dangers of corrosion can be mitigated through corrosion control measures, which reduce lead seeping into the water by "pH adjustments and/or promoting the formation of insoluble corrosion scales" on the pipe's walls by adding corrosion inhibitors (Pieper et al., 2018). A common inhibitor is phosphate-based inhibitors containing orthophosphates which bind metals to their structures (United States Environmental Protection Agency, 2016b).

The Flint water treatment plant had neither a corrosion control plan nor the needed corrosion control equipment installed (Masten et al., 2016). Plant personnel were reported to have been left to address the water quality issues and the chemical dosages for treatment through trial and error, leading to increased levels of trihalomethanes (TTHM), which are produced when the disinfectant by-products react with the organic matter found in the water and may be carcinogenic for humans (Centers for Disease Control and Prevention, 2016). The necessary studies that were needed to test the corrosivity of the new water source before switching were not commissioned or completed prior to the switch (Masten et al., 2016).

Contaminated water creates concern that those who use it will suffer negative health effects. In Flint's case, the risk was the possibility of residents developing lead poisoning because of prolonged consumption and exposure. Exposure may result from materials in older homes, toys and jewelry, performing certain jobs, or, in this case, lead pipes (Centers for Disease Control and Prevention, 2020). Typical at-risk populations include children under six years old, children living at or below poverty levels, children of minority groups, pregnant women, and adults who work in industries such as mining, manufacturing, construction, and services that include mechanics, automotive, and electrical maintenance (Centers for Disease Control and Prevention, 2018, 2019b).

The short-term physical effects of lead poisoning include abdominal pain, fatigue, headaches, weakness, among other physical ailments (Centers for Disease Control and Prevention, 2018). Long-term effects, because of prolonged exposure, include high blood pressure, heart disease, kidney failure, forgetfulness, and depression. High concentrations of lead may lead to anemia, kidney and brain damage, or death.

The impact of lead poisoning may vary by age. According to the World Health Organization, there is no known safe level of blood lead concentration as even a low amount can cause negative health effects for children (World Health Organization, 2011). According to the CDC, children may experience physically evident effects such as damage to the brain and nervous system and delayed growth and development, as well as cognitive issues such as learning and behavior problems and issues with hearing and speech (Centers for Disease Control and Prevention, 2019c). Lead also affects the reproductive health of women, and children can be exposed while in the womb. If the mother can carry to term (as miscarriage is also a possible effect), the infant may be born prematurely or underweight (Centers for Disease Control and Prevention, 2019b). The baby's brain, kidney, and nervous system can be affected as well, and as the child grows, learning and behavior problems can begin to present.

Reported Effects on Flint Population

The evident increase in blood lead levels in Flint's children prompted calls for action (Morckel & Terzano, 2019). Children, specifically those six years and under, are one of the groups identified as most vulnerable to lead, because it may impact their development and growth (Centers for Disease Control and Prevention, 2019a). Studies show that children can absorb 4-5 times more ingested lead when compared to adults (World Health Organization, 2011). To address the potential effects of lead on small children, a specialized preschool for exposed children was established (CBC News: The National, 2017). Catching the symptoms and learning to address them as early as possible is beneficial for the child's future success.

For older children that were exposed to lead, there is a concern as to whether the city has the resources necessary to identify and address the effects. Requests for special education services rose and, without the needed resources, there is the risk that the resulting neurological and behavioral issues could overwhelm a school system (Green, 2019). One mother discussed the effects one year of exposure had on her 10-year-old son, describing his behavior as having transitioned from hyperactive to hysterical; she was told by pediatricians that her son's ADHD had been exacerbated (Green, 2019). The number of students who met the requirements for special education services rose 13% from the year prior to the crisis (Green, 2019). Beyond behavioral and developmental challenges, there was also the mental and emotional effect of lead exposure on older children who know and understand what happened, and making educators able to address those effects properly requires extensive resources (CBC News: The National, 2017).

Flint schools were already struggling and losing students to charter schools before the water crisis. With the effects of the water crisis, it seemed as if more students would be enrolled out of the district and into charter schools (Green, 2019). One teacher, whose own children experienced negative health effects from exposure to the contaminated water, discussed how educators were given little training to meet these new challenges. She described the extreme behavioral reactions exhibited by her first-grade students in class and argued that the students' language retention was dramatically reduced. She also commented that her district was pushing resources towards obtaining other materials instead of looking into hiring more teachers, social workers, and special education aides (Green, 2019).

Adults in Flint faced mental health issues because of the crisis. Disasters and crises generally affect a community's ability to address physical and emotional needs through their negative effects on physical and mental health, finances, social attachments and relationships, and political trust (Sobeck et al., 2020). The Flint water crisis increased the rate of mental health issues among Flint adults, especially regarding stress, anxiety, and depression (Cuthbertson et al., 2016). These issues may have been the result of both physical health effects as a result of lead exposure and level of severity as well as worry and concern about their children's blood lead levels and potential health issues (Cuthbertson et al., 2016). There was also the financial stress of paying for water that could not be used safely, and a sense of betrayal, powerlessness, and distrust towards officials (Sobeck et al., 2020).

These mental health issues were correlated with physical ailments, such as stress resulting from the potential of cardiovascular disease, increased blood pressure, and a compromised immune system (Cuthbertson et al., 2016). The use of substances to cope, including "alcohol abuse, illicit drug use, and prescription drug misuse or abuse" may have exacerbated mental health conditions (Cuthbertson et al., 2016). Eating problems were also noted (Sobeck et al., 2020).

The residents of Flint have been permanently impacted by lead exposure from their water. Children have been physically and mentally affected by an event that they had no control over, while their parents are left to not only cope with their ailments but also those of their children. Experiencing a crisis of this magnitude, with permanent effects on an entire community, naturally results in resentment towards those charged with keeping the public safe and healthy, and who failed to mitigate the crisis, leading to a loss of faith in those who hold official positions.

Connection to Potential Local Water Issues

The effects of contaminated water as experienced in Flint provide a reasonable comparison case for possible water quality issues related to fracking and underground injection in Texas. While the method of contamination differs, the health of nearby populations might be similarly affected.

Hydraulic fracturing, otherwise known as fracking, is "an oil and gas well development process" that involves injecting a combination of water, sand, and chemicals under high pressure into the ground through a well (United States Environmental Protection Agency, 2016a). The well reaches 2500-3000 meters, the point at which horizontal drilling can begin (Nacamulli, 2017). Drilling moves horizontally through the layer known as the shale rock formation where a perforated gun creates small inch-long holes. Fracking fluid is later pumped down the well at a high pressure to crack the shale rock. These cracks are where oil and gas escape (Nacamulli, 2017).

Proximity to fracking activity can pollute drinking water reserves, but the manner and the exact point of contamination can vary (Hildenbrand et al., 2016). Toxic compounds can be found in groundwater near areas with high fracking activity. Contamination can also occur as a result of the contaminants being transported via the fractures created by fracking (Hildenbrand et al., 2015). Contaminants can also seep into the water supply from mishandled wastewater or produced water. Thus, pollutants from fracking activity can potentially enter the water supply both underground and above ground if the proper precautions are not in place.

Fracking wastewater must be managed and properly disposed of as it contains some of the fracking solutions and hydrocarbon constituents that oil or gas reservoirs release (Uhlman et al., 2013). If those overseeing the process are not careful, fracking directly into underground water can have detrimental effects on the drinking water of surrounding communities (Nacamulli, 2017). This contamination can be caused by hazardous underground leakage, inadequate treatment of wastewater, and inadequate disposal of the resulting highly toxic wastewater. Improperly handling treatment residuals, pit, and tank runoffs, and leaching and runoff are also possible risks (United States Environmental Protection Agency, 2016a). The EPA (2016a) notes that "Bromide, chloride, and iodide are commonly found in high-TSD hydraulic fracturing wastewater"; bromide and iodide are both of concern because they may react to form disinfection byproducts such as trihalomethanes (TTHM). In Flint, TTHMs became a concern when more chlorine was added to the water, creating potential human carcinogens (Centers for Disease Control and Prevention, 2016).

Flint presented a case in which water contamination, because of prior inaction, resulted in a community suffering permanent effects. Addressing the possibility of such an event could have resulted in a different outcome. Similarly, planning for the potential contamination of Texas drinking water from fracking could prevent the health of Texans from being adversely affected. However, beyond overseeing water quality and planning for emergency scenarios, other environmental factors must be monitored. When considering hazards, air quality is also a health concern for Texans.

Air Quality: Los Angeles

As discussed above, water-related issues, in the form of flooding or pollution can have a negative impact on human health. Similarly, air quality has notable effects on human health. The 2020 State of the Air report estimates that millions of people in the United States are regularly exposed to unhealthy or polluted air. Nearly 45.8% of the people in the United States are living in counties with unhealthy levels of ozone or particulate pollution. The number of those in the United States exposed to air pollutants is also growing as there are now 8.76 million more Americans living in counties with unhealthy air than in 2018. Although the total number of people in unhealthy areas is lower than the 2016 reports found, the amount of air pollution is still concerning (American Lung Association, 2020a). In this case study, we examine the poor air quality of Los Angeles, one of the United States' most polluted cities. An examination of Los Angeles is useful to draw conclusions about air pollution in Texas because the LA region is similar in many aspects to major cities in Texas.

Los Angeles is a major urban-industrial area with high levels of emissions originating from different commercial and residential operations (Buckland et al., 2017). The negative effects of air pollution include, but are not limited to, reduced lung function and asthma (Künzli et al., 2003). Los Angeles, with a total population of more than 18 million, is ranked first for high ozone days among 229 metropolitan areas. Ozone is a toxic oxidant gas that is harmful to humans even at low levels (United States Environmental Protection Agency, 2020d). Cities can have high levels of ozone on different days and even seasons. When a region experiences higher ozone levels, it is seen as a cause of childhood asthma (Becerra et al., 2013). Like Los Angeles, Dallas, Texas is also ranked as a city with high ozone levels, making studying the city important.

In addition to its ozone levels, LA is ranked 6th for 24-hour pollution and 4th for the level of annual particle pollution (American Lung Association, 2020a). Particles are tiny pieces of different solids and liquids that can pollute the air; in high numbers, particles can be detrimental to human health. Studies show that there are numerous contributing factors to air pollution in Los Angeles with potential consequences for human health. We discuss two contributing factors below.

Transportation

Exhaust emissions from trucks and automobiles are the primary reason for air pollution in Los Angeles, though airports and marine port complexes emit pollutants as well (Künzli et al., 2003). The LA area has extremely heavy traffic due to its high population, leading to vehicle exhaust emissions that contribute to its poor air quality. The level of traffic pollution depends on types of vehicles, wind direction, and meteorological factors (Brugge et al., 2007; Zhou & Levy, 2007). Particulates from traffic pollution are associated with coronary heart disease, respiratory problems, greater use of health care, and increased mortality (J. O. Anderson et al., 2012; Ghosh et al., 2016). Many researchers also have analyzed traffic pollution and its negative health effects and found that it causes respiratory diseases and even cancer (Br̊bäck & Forsberg, 2009; Health Effects Institute, 2010; Salam et al., 2008).

In Texas, cities are becoming bigger as they become centers of job opportunity. This often leads to more congested roads. It is expected that by 2050, 74% of the Texas state population will live in metropolitan cities, which will increase congestion and air pollution (Texas Department of Transportation, 2020). For this reason, studying the traffic pollution conditions in LA provides valuable guidance for the future of Texas cities.

One of the main health effects of traffic pollution is childhood asthma. Emerging evidence also suggests that the proximity of residential homes to highways impacts childhood asthma (H. R. Anderson et al., 2013; Brandt et al., 2014). Around 5% of the population living in the Los Angeles area has either childhood or adult asthma (American Lung Association, 2020b). Research also suggests that as the ozone particulates increase, there is a relative increase in presence of autism among those affected (Becerra et al., 2013). High levels of ozone, small particles in the air, and airborne nitrogen gases can also lead to a decrease in the cognitive ability of older adults (Gatto et al., 2014). Nitrogen gases are also harmful to the human respiratory system (United States Environmental Protection Agency, 2016b). Exposure to higher NO_2 levels and other traffic pollutants decreases lung function growth by 10% (Künzli et al., 2003).

To reduce the effects of near-roadway pollution, residential areas should be far from the highways. In the Los Angeles area, residential development is allowed near roadway areas and 92% of residential areas are only 500 feet away from freeways (Gabbe, 2018). Los Angeles permits several thousand new housing units near roadways every year (Barboza & Schleuss, 2017). Moreover, the construction of multi-family housing is also allowed around near-roadway parcels. This increases both the number of people exposed to traffic pollution and the number of vehicles in the near-roadway areas (Gabbe, 2018). On the other hand, cities in California ban new school constructions within 500 feet of a roadway, which can be one way of mitigating negative health effects (California Air Resources Board, 2010, 2017).

Water transportation is also causing air pollution in the California bays (Künzli et al., 2003). The emission from the ships is calculated as 1.2−1.6 million metric tons (Tg) of particle pollution per year and is seen as a significant source of pollution for coastal regions like Los Angeles (Ault et al., 2009). The emissions from the Los Angeles and Long Beach Port significantly increase the air pollution levels in the San Diego area (Ault et al., 2009). The research shows that there is an increase in particles such as soot, metals (i.e., vanadium, iron, and nickel), sulfate, and nitrate during high shipping periods. During regional transport events, there are 2−4 times higher concentrations in the air, which raises negative effects on health and the environment (Ault et al., 2009). The other research also concludes that nitrate and sulfate concentrations increase up to 12.8 and 1.7 μg m^{-3}, respectively, in the basin when ship emissions are included, and ozone may reach as high as 59 ppb (Vutukuru & Dabdub, 2008). These chemicals all impact human health. The results show the importance of regulating ship emissions. As many Texas cities are also port cities, Texas experiences similar pollution challenges and air quality will continue to degrade if not addressed.

Oil and Gas Drillings

Los Angeles also has active oil and gas facilities (ONG) that contribute to air pollution. Although the main ONG drills are in rural regions, there are facilities in highly urban areas like Los Angeles. There are 58,000 wells in California and many of these are located in the Los Angeles area (Czolowski et al., 2017). According to research, 1.7 million residents are living within one mile of an active ONG well in the Los Angeles Basin (Shonkoff & Gautier, 2015). Poorer air quality around ONG wells has adverse health impacts (Garcia-Gonzales, Shamasunder, et al., 2019). According to the US Environmental Protection Agency, there are 187 hazardous air pollutants (HAPs) that are carcinogens or may potentially cause other severe health problems, and several of these are found in high numbers around ONG sites. Gonzales, Shonkoff, et al. (2019) reviewed 37 studies related to this issue and concluded that 61 unique HAP compounds were found in 37 research studies on ONG drills. Moreover, 44 HAPs were mentioned in more than one article (Garcia-Gonzales, Shonkoff, et al., 2019). The results show that there is a high probability of developing serious health problems when living near ONG drills as people will be exposed to many hazardous air pollutants. According to statistics, there are more than 170,000 oil and 80,000 gas wells in the Texas region. In Austin County alone, there are at least 1,800 active oil wells operated by the major companies (Texas Railroad Commissioner, 2019). The high number of active oil wells of Texas makes it comparable to the case of the LA region. The importance of regulating the well locations remains an important issue for Texas cities as well.

Case Study Summary

The case studies evaluated public health challenges and crises from outside of Texas, and the health impacts these crises had on residents. These effects could also be seen in Texas and create similar health outcomes. A key takeaway is the need to prepare in advance for scenarios such as these to mitigate, if not avoid, the level of impact on the public. Examining the actions taken prior and throughout these events presents areas in need of particular focus that could make a difference in the level of impact events such as these would have on Texans' health.

DATA ANALYSIS

In the analysis section, we present various summaries and descriptions of flooding, water quality, and air quality data in Texas and other areas of the nation. The data comes from various sources, including FEMA, Index, the Environmental Protection Agency, the Texas Water Development Board Groundwater Database, the Social Vulnerability Index, Safe Drinking Water Information System, and city public works departments. The purpose of the data analysis section is to provide evidence and empirical documentation about hazards and disasters as well as the levels pollution in Texas.

Flooding

The data used in this analysis comes sources such as Federal Emergency Management Agency (FEMA), Our World in Data, the Centers for Disease Control (CDC), The Kinder Institute at Rice University, and the National Centers for Environmental Information. In conducting this analysis, two important insights that may be useful to consider when exploring how flooding impacts the health of Texans stand out. First, the data demonstrates that flooding in Texas occurs at a high frequency. This is significant, as the frequency of flooding, paired with a broad geographical scope of where flooding occurs, makes flooding a type of natural disaster that can significantly impact the lives of Texans. Second, the research asserts that the impact of flooding has spillover effects on economic infrastructure and health outcomes of Texas residents. As previously stated, we define health as physical, psychological, emotional, or social for our research. Our analysis will examine the impact of flooding on Texans, specifically through death rates, economic ramifications, and health-related outputs.

Frequency and Scope

Texas has experienced 350 FEMA disaster declarations since 1953, with flooding ranking as the second most frequent type of disaster. These disasters include fires, hurricanes, drought, severe storms, and snow, with flooding accounting for 11% of the total number of disasters reported[2]. While at first glance this figure may seem to represent a small proportion of overall Texas disasters, flooding is preceded only by fires which are responsible for 69% of all Texas disasters (as seen in Figure 1).

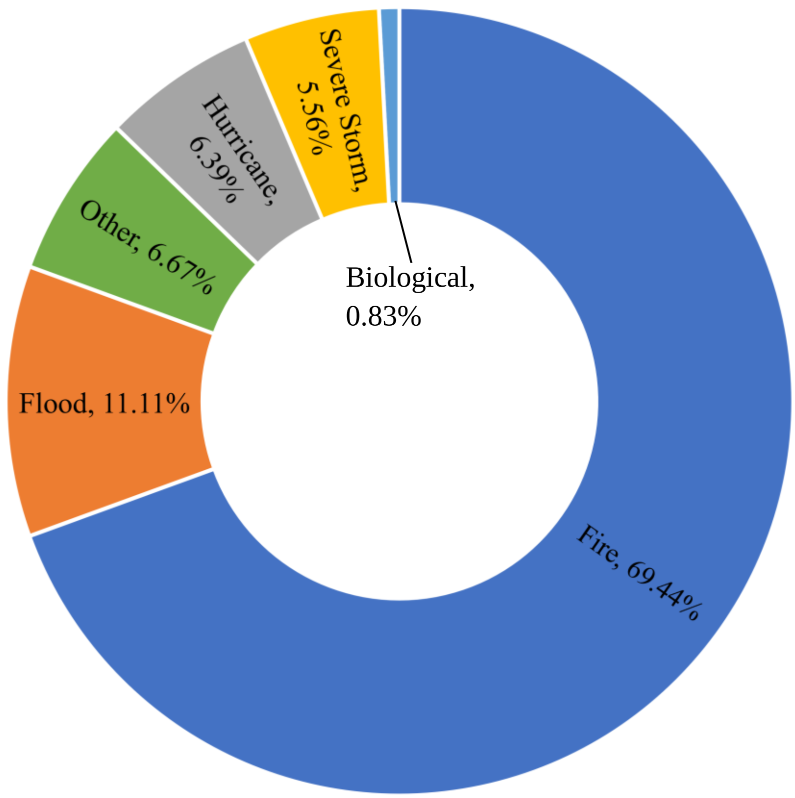


Figure 1: Reported Natural Disasters in the State of Texas

Most flooding incidents are located around coastal areas and river basins with the average flood lasting no longer than a day. For example, Harris County, east Texas's largest county, has coastal surfaces, soils, bayous, and canals; because of these flood-prone areas, Harris County has the highest percentage of declared floods, at 2.19% (FEMA Disaster Declarations Summaries, 2021). In total, there have been 184 reported flooding events in Texas over the past 20 years. The

[2]The 2020-2021 COVID-19 pandemic created a spike in biological disasters that is inconsistent with natural patterns of events.

total number of floods over the past five years is presented in Figure 2 with the frequency by county reported in Figure 3.

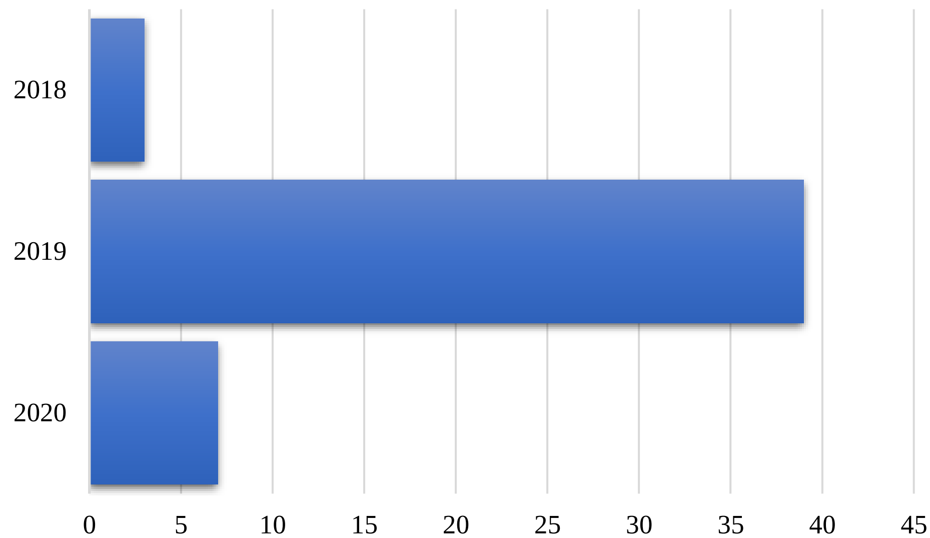


Figure 2: Number of Recent Flooding Events in Texas[3]

[3] FEMA Disaster Declarations Summaries, 2021

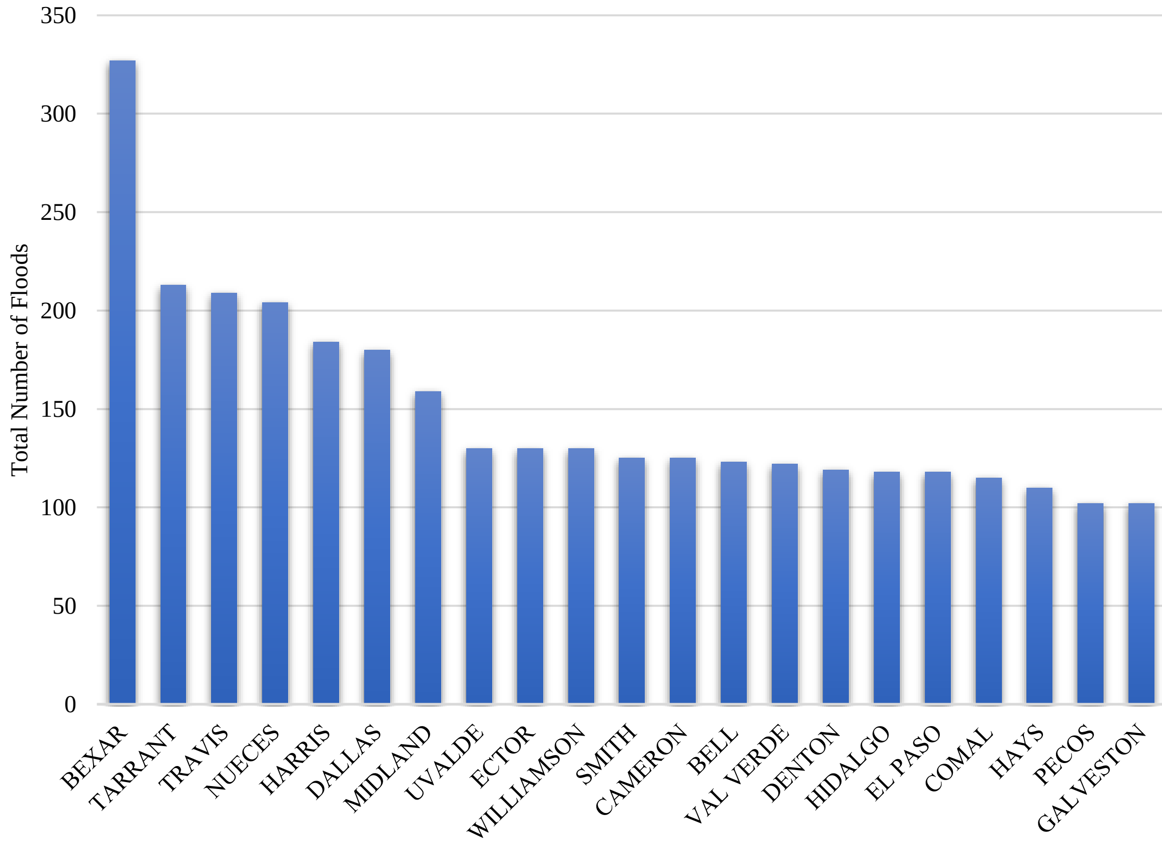


Figure 3: Total Number of Flood Disasters by County, 2000-2020

Impact of Flooding on Texans

All flooding incidents in Texas were categorized as requiring “major disaster management” while incidents with the potential to cause floods—such as hurricanes and severe storms—were determined to require both “major disaster management and emergency management” (FEMA Emergency Management Performance Grants, 2021).

A significant portion of FEMA disaster management relief funding is provided to flood victims (47%), with significant aid also provided to victims of hurricanes (29%) and severe storms (24%) (FEMA Web Disaster Declarations, 2021). The following figures provide further evidence that establishes flood-related disasters as one of the most devastating types of natural disasters.

Health Impacts

A recent study from Rice University expands the sphere of flood-related health risks by asserting that flooding poses seven major negative physical and emotional health impacts as seen in Figure 4. Those who report health impacts from flood list headaches/migraines, problems concentrating, shortness of breath, illness due to storms, injuries due to storms, skin rashes, and mental/emotional changes due to the event as causing particular difficulties following a flood.

Figure 4: Short Term Impacts of Floods on Texans

The Economic Impact of Flooding on Texans

As previously noted, flooding in Texas occurs frequently and can impact a significant portion of the population. This can lead to substantial damage to infrastructure and an enormous economic burden on impacted citizens and societal institutions.

When not handled appropriately, the short-term impact of flooding can have long-term consequences. Floods are one of four major reported incidents that qualify for FEMA's Individuals and Households Program (IHP), which aims to provide "financial and direct services to eligible individuals and households affected by a disaster, who have uninsured or under-insured necessary expenses and serious needs".[4] According to FEMA, 21% of damages covered under housing insurance and protection in Texas are dedicated to flood-related issues. Additionally, the cost of floods amounts to 22% of average payables. Floods and hurricanes are the second most commonly reported incidents, while severe storms are first (FEMA 2017).

Losses associated with damage to private property from flooding total in the billions. For example, between 2000 and 2020, residents of Harris County lost properties totaling more than $17 billion (Figure 5).

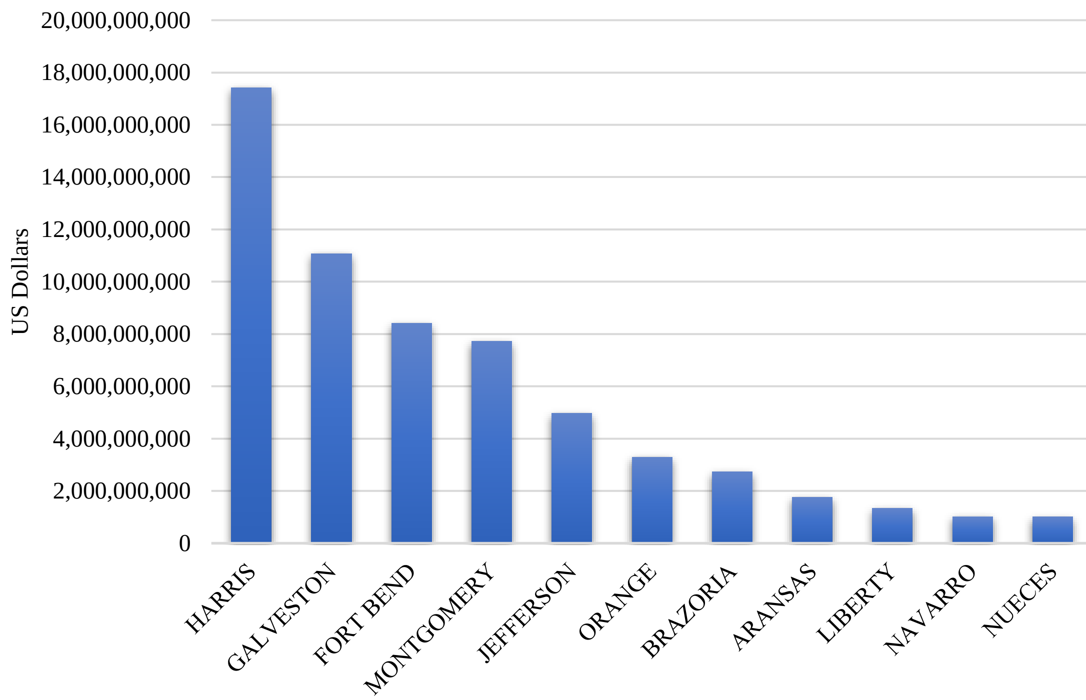


Figure 5: Counties with Over $1 Billion in Losses Due to Flooding Disasters, 2000-2020

For Texas farmers, drought clearly results in the most crop loss in Texas. However, frequent flooding can lead to severe losses amounting to of millions of dollars, as well as the potential inability to harvest. This can be seen in Figure 6.

[4] Taken from FEMA; https://www.fema.gov/assistance/individual/program

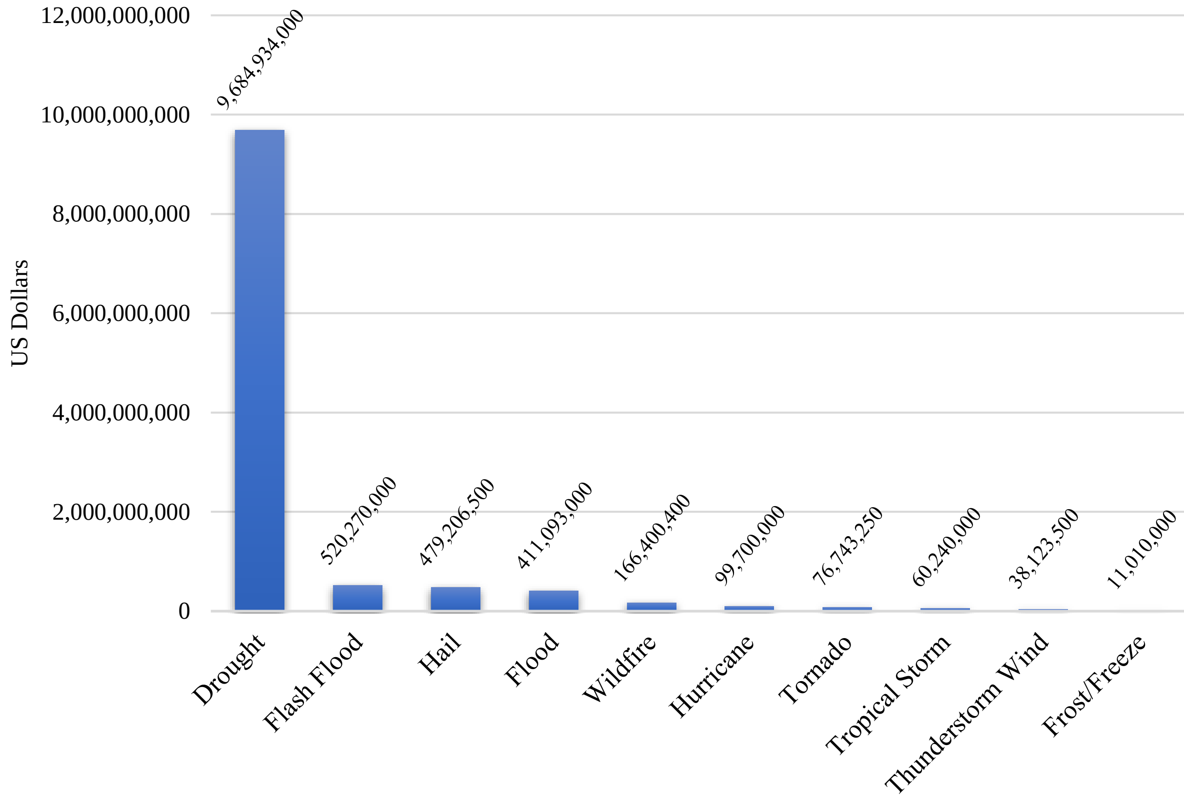


Figure 6: Top Ten Disasters Impacting Crop Losses, 2000-2020

Other commodities are lost to flooding, including cotton, onions, sugarcane, watermelons, sesame, and others, resulting in massive financial losses for affected counties. Figure 7 shows that flooding has caused over $10 million in losses over the past 20 years. Lynn County, a rural and lower-income county[5], faced the highest losses at $250 million.

[5] https://www.census.gov/quickfacts/lynncountytexas

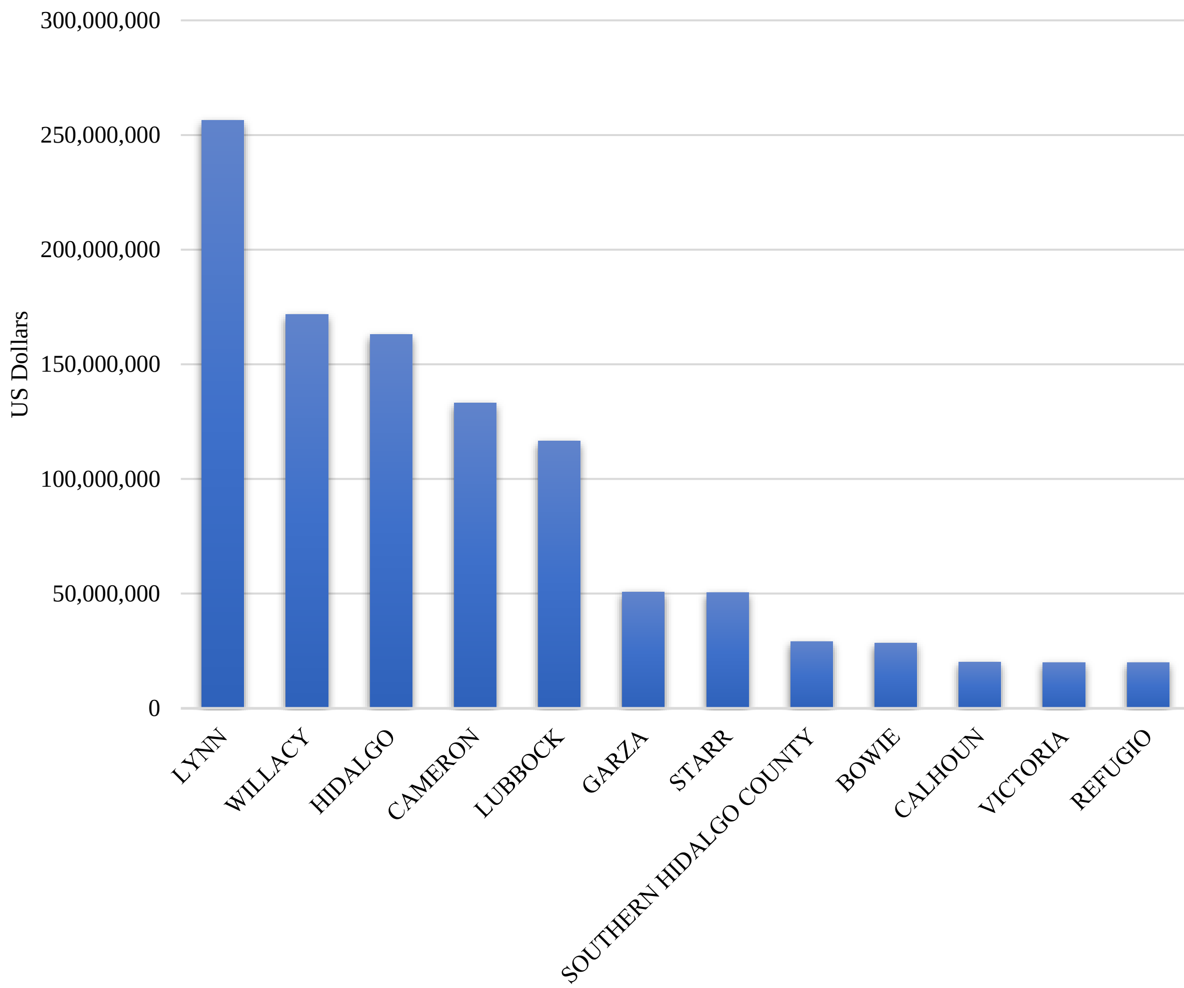


Figure 7: Counties That Lost Commodities Valued Over $10M in Flood Disasters, 2000-2020

In summary, Texas leads the nation in natural disasters, with at least one declared per year (FEMA Disaster Declaration Summaries 2021). Due to the frequency of flooding in Texas, and the economic costs coupled with flooding disasters, flooding has a direct impact on the socio-economic wellbeing of Texans. This means that mitigation, recovery, and policy responses to flooding that buffer the severity of impact are vital to the state. Increasing our understanding of the scope and frequency of flooding in Texas, as well as making accurate predictions of the severity of impending flood-related disasters, can make the response and recovery processes more efficient and effective. This, in turn, will potentially reduce some of the impacts of flooding over time.

Water Quality

This section explores water quality in Texas through several indicators, including: the levels of enterococcus bacteria in recreational waters, levels of dissolved arsenic in major state aquifers, the level of contaminants in public works municipal waters, and the number of water system violations. Data is derived from the Beach Advisory and Closing Online Notification (BEACON) 2.0 system, a database compiled by the Environmental Protection Agency, city public works departments, and the Social Vulnerability Index. Data on arsenic levels in major Texas aquifers is taken from the Texas Water Development Board Groundwater Database.

Enterococcus Levels in Texas' Recreational Waters

The amount of enterococcus bacteria found in recreational waters is an important indicator of water quality. Enterococci are bacteria found in the intestinal tract of some warm-blooded animals, including humans. While not typically harmful on their own, water is monitored for enterococci because high concentrations of the bacteria may indicate contamination by fecal matter from sources such as wastewater treatment plants, septic systems or sewers, and wildlife waste, as well because of beef production (Environmental Protection Agency, 2021). These pathogens can cause illness in those who swim, play or fish in contaminated recreational waters. In some cases, diseases of the eyes, skin, ears, or respiratory tract may occur due to contact with enterococci and similar bacteria; the consumption of shellfish or fish caught in contaminated waters may also cause illness (Environmental Protection Agency, 2013).

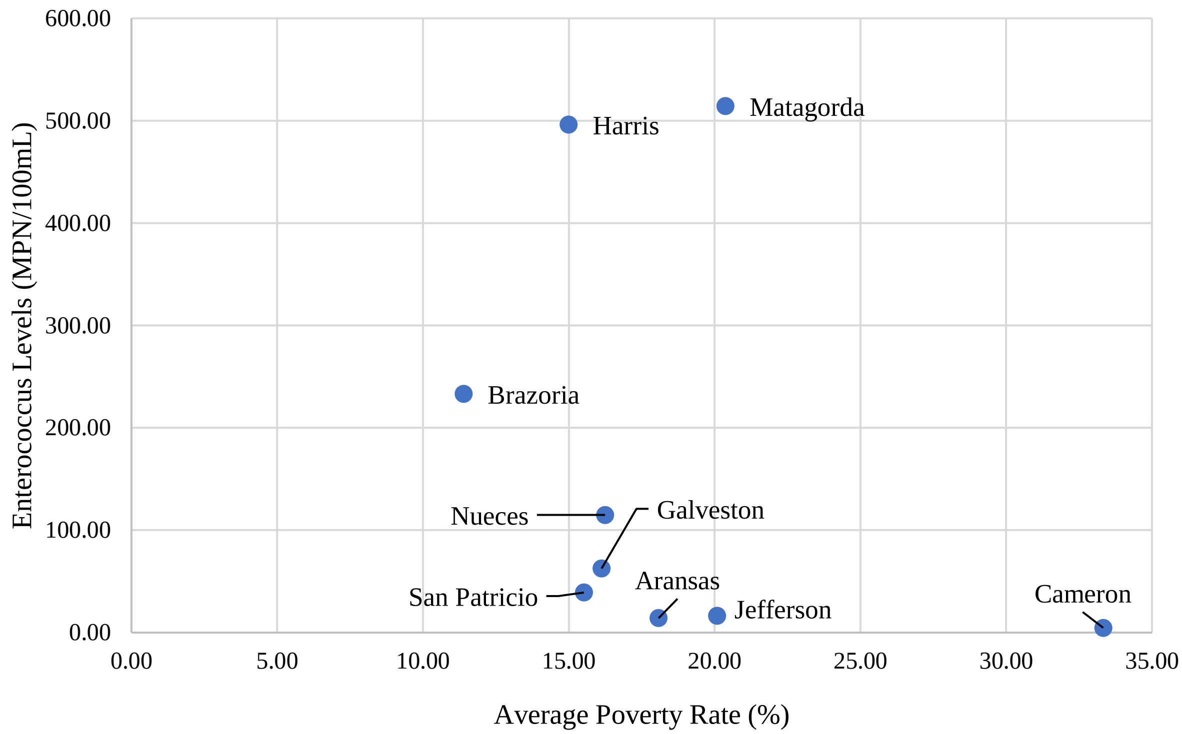


Figure 8: County Enterococcus Levels and 2019 Poverty Rate in Selected Texas Coastal Counties

Figure 8 highlights the relationship in nine Texas counties between the poverty rate and enterococcus bacteria levels in recreational waters. It is important to look at pollution levels across various characteristics in counties as some counties may have additional resources to ensure clean recreational waterways and others may not. All counties shown are included because they are home to recreational beaches along the Gulf of Mexico. As seen in the figure, there is no evidence of a positive relationship between a county's poverty rate and the amount of enterococcus (measured in most probable number per 100 milliliters of water) in its recreational water. This means that, in this sample, Texas coastal counties with higher poverty rates do not experience higher levels of enterococcus in their recreational waters that could potentially sicken those who swim and fish there.

Some counties exhibit unusually high levels of enterococcus in their waters that may be causes of concern: namely, Harris and Matagorda counties. This is particularly concerning in Harris County, home to Houston and a diverse population, some of which may rely on contaminated coastal waters for fishing, tourism, or recreation. This creates the possibility that some who use coastal waters in Harris or Matagorda county may become ill from exposure to enterococcus bacteria.

Arsenic in Texas Aquifers

Arsenic is a known carcinogenic element that can pose harm to humans if ingested, even at low levels. It may leech into aquifers and contaminate drinking water collected from wells, putting humans at risk. Reflecting its high toxicity, the level of arsenic considered safe by the Environmental Protection Agency is only ten micrograms per liter (United States Geological Survey, 2021).

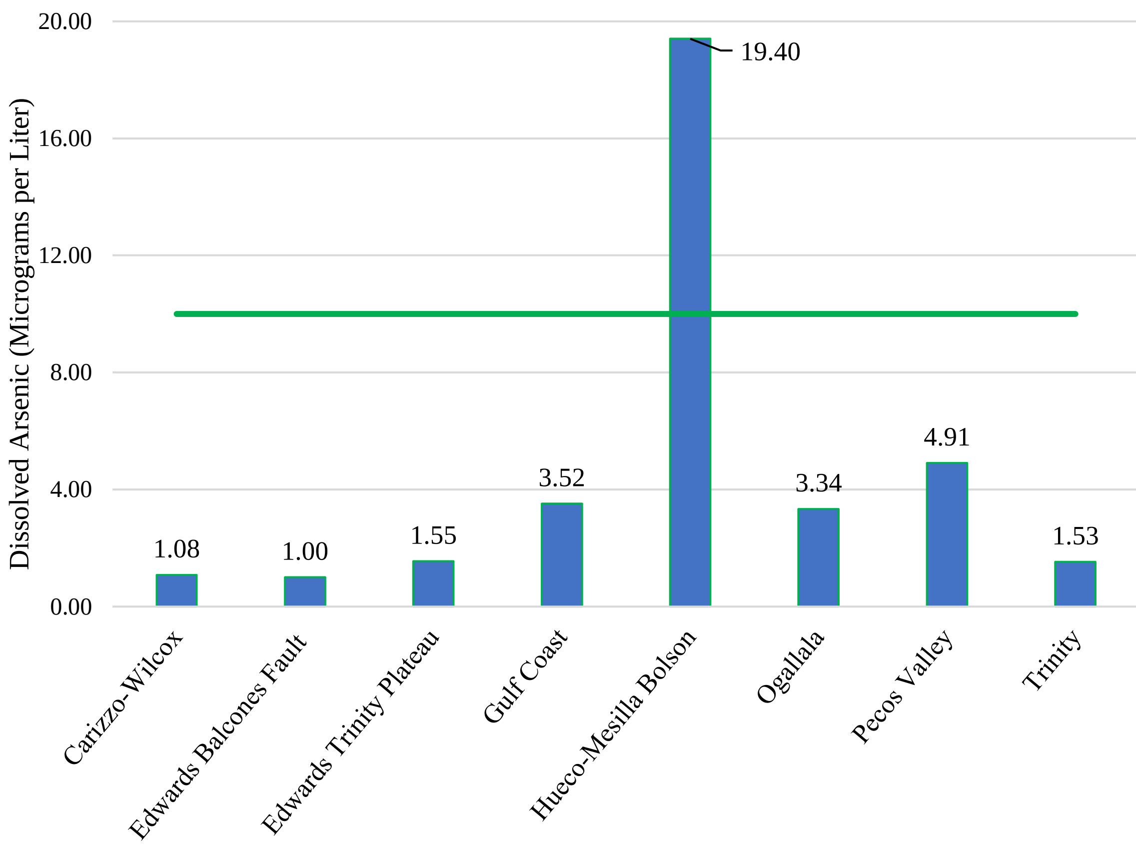


Figure 9: Average Level of Dissolved Arsenic by Major Texas Aquifers, 2018

Figure 9 shows the average level of arsenic (measured in micrograms per liter) across major Texas aquifers in 2018. The safe level, ten micrograms per liter, is indicated by the solid green line. Though most major aquifers show low to moderate levels of arsenic below the accepted safe level, the Hueco-Mesilla Bolson aquifer is particularly contaminated. In that aquifer, the average level of arsenic is nearly double the accepted safe level, indicating that water drawn from this source may be potentially harmful to humans.

This aquifer primarily serves El Paso County, home to El Paso, a large Texas city, increasing the risk that humans will ingest well water drawn from this aquifer with toxic levels of arsenic. The high levels of arsenic may be due to the aquifer's proximity to the Rio Grande River, and thus associated with the river and nearby agricultural activities, including the use of arsenic-based pesticides, or the elevated levels may be due to naturally occurring arsenic from volcanic rocks moving downstream (United States Geological Survey, 2020).

Water Quality in Municipal Public Works Waters

Figures 10 and 11 represent five major cities in Texas (Austin, Dallas, El Paso, Houston, and San Antonio), and the levels of five toxins—arsenic, copper, fluoride, lead, and TTHM—measured in parts per billion reported from the years 2012 and 2019. The data used in this graphic came from each city's public works department.

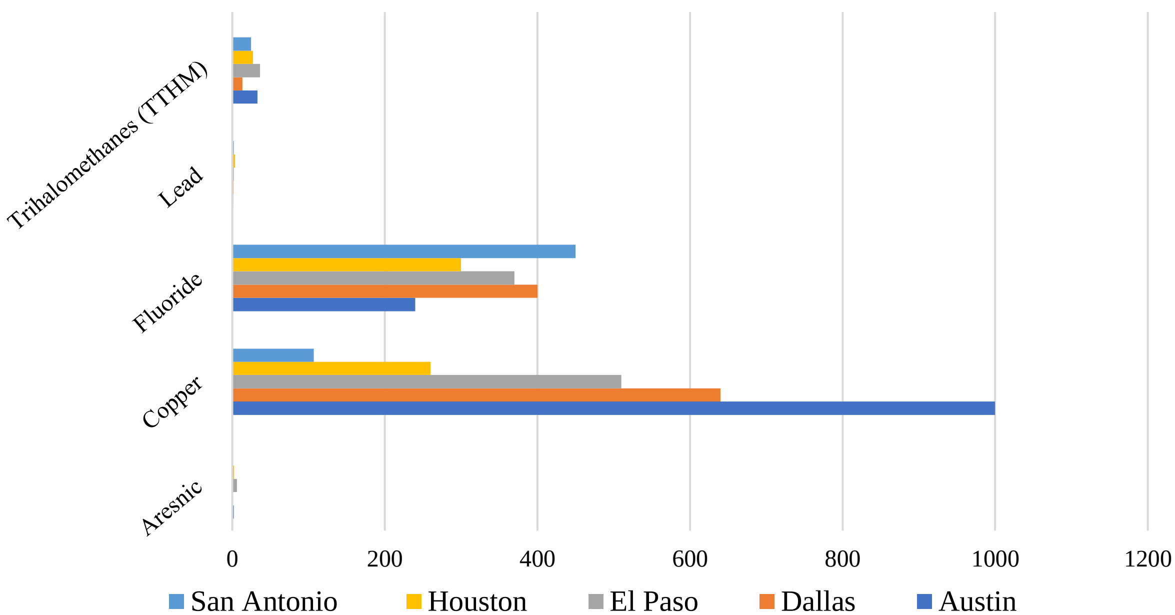


Figure 10: Public Works Water Quality Elements in Four Major Cities, 2012

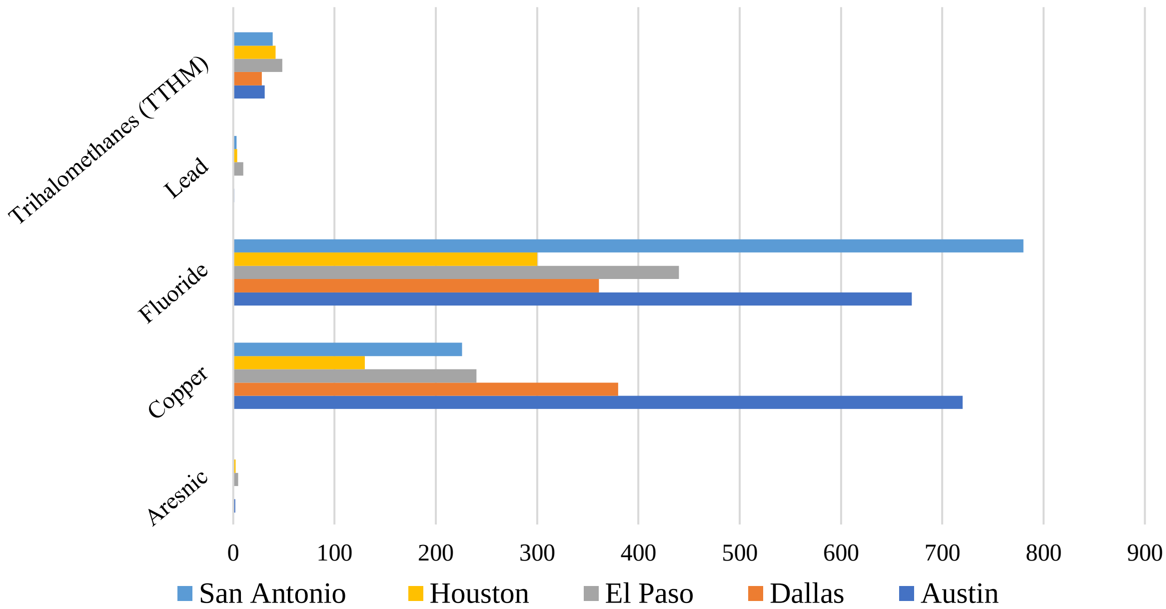


Figure 11: Public Works Water Quality Elements by City, 2019

Individuals who consume water that is polluted above the levels defined by the Safe Water Drinking Act are in danger of potential health risks. As discussed above, arsenic exposure can cause cancer, skin damage, and circulatory problems. High levels of copper and/or lead exposure have the most adverse effects on pregnant women and young children. Fluoride exposure has the potential to harm tooth enamel and cause bone disease and thyroid problems. TTHM consumption above SDWA specified levels can lead to cancer as well as adverse reproductive outcomes.

A potentially significant increase in the element TTHM can be seen between 2012 and 2019 in Dallas, Houston, and San Antonio. This increase may be due to disinfectant by-products reacting with organic matter, which is how TTHM is typically produced. Monitoring TTHM is important because it is potentially carcinogenic (CDC, 2016).

In these years, El Paso saw a significant increase in lead in its drinking water, although levels were still below the limit of fifteen parts per billion as set by the SWDA. However, it is important to monitor for any adverse health effects in the city's residents to determine if they are caused by lead levels. These unfavorable health outcomes could include Legionnaire's disease, cardiovascular disease, hypertension, or kidney disease; some of these outcomes were seen in Flint, Michigan, and in the school children in south-central Kansas after lead exposure.

Air Quality

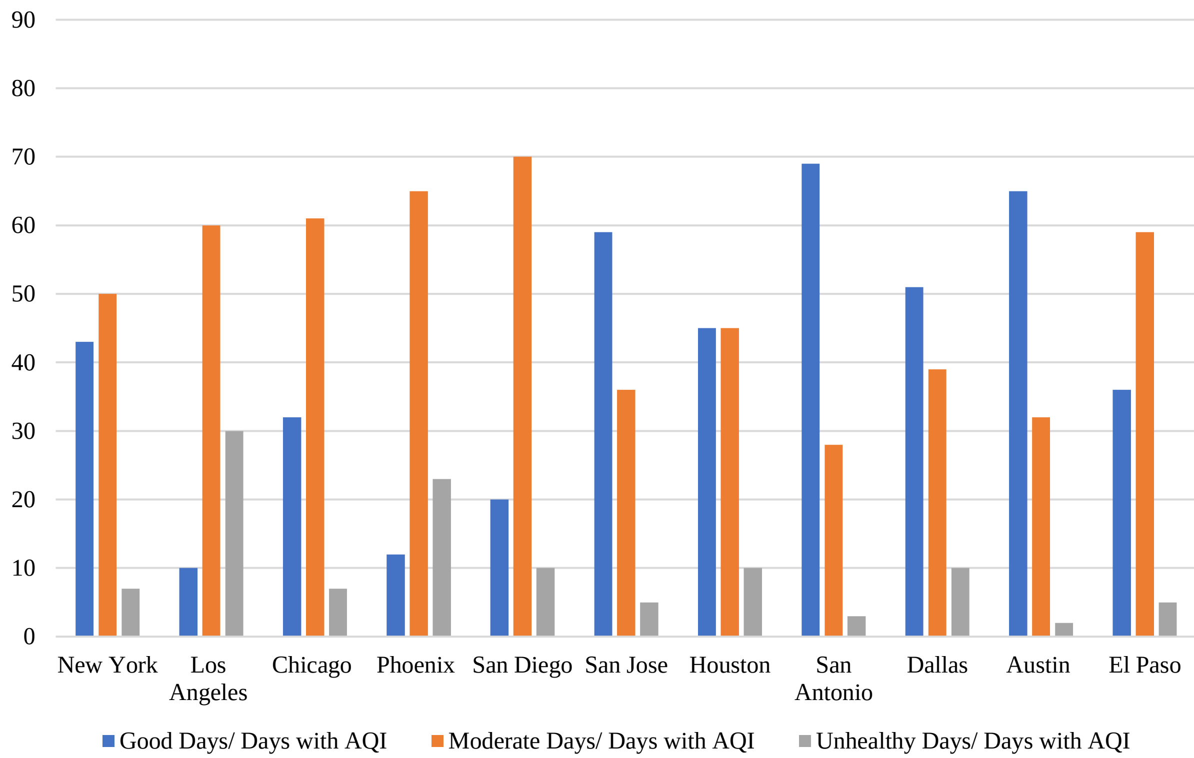
This section describes and analyzes data from the Environmental Protection Agency on air quality trends in Texas as well as other major cities in the United States. The data focuses explicitly on indicators that comprise the Air Quality Index (AQI), such as particulate matter pollutants, ozone, carbon monoxide, sulfur dioxide, and nitrogen oxides. A comprehensive understanding of these air quality indicators allows us to analyze potentially harmful health implications associated with poor air quality. Other sociodemographic indicators were also used, such as the Rural Urban Continuum Code (RUCC) of a county, poverty levels, and unemployment rates to determine how varying populations are affected by AQI.

Air Quality Index (AQI)

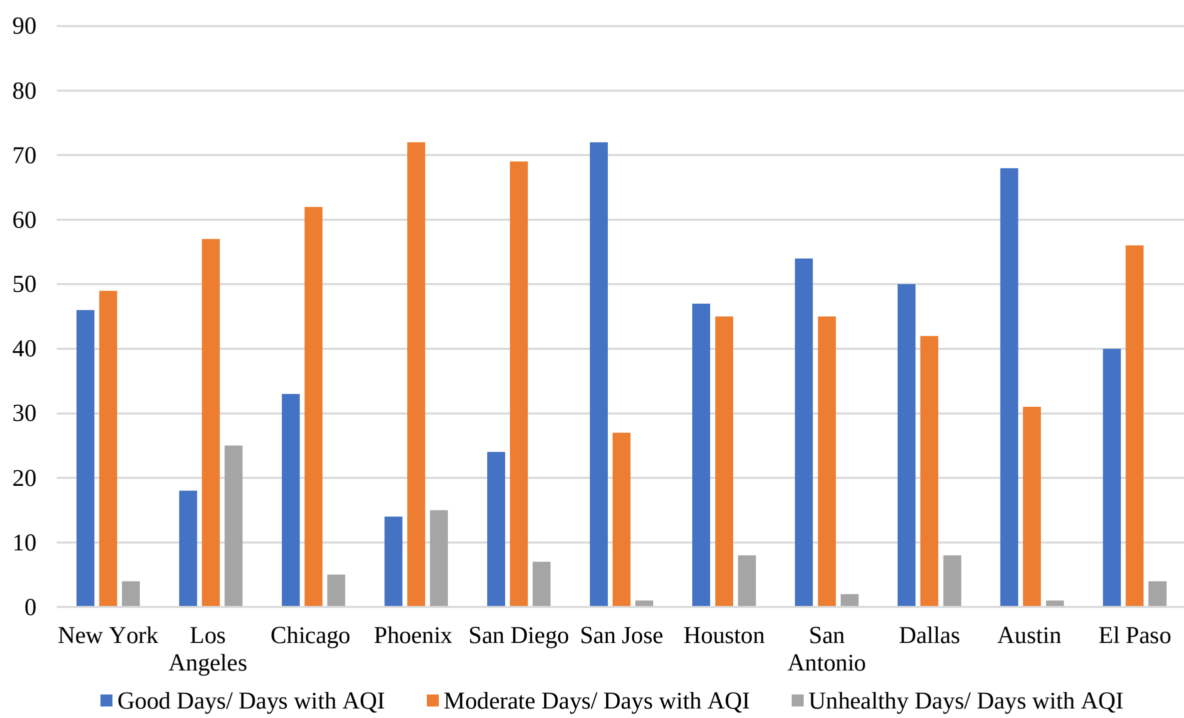
The Environmental Protection Agency provides data regarding the AQI of cities in the US. The data presented here is used to compare the air quality of highly populated cities in the US, specifically Texas cities, from 2018 to 2020. The data includes the number of days that AQI was measured and how many of those days can be considered good, moderate, and unhealthy days. The percentage of the good, moderate, and unhealthy days is calculated by dividing the number of days that AQI was measured by the number of days that fall within the good, moderate, and unhealthy ranges.

Poor air quality can cause breathing problems ranging from minor upper respiratory irritation to chronic bronchitis. Exposure to air pollution can also lead to a shorter life expectancy, premature mortality, and increased hospital admissions. Figure 12 is a set of three images that illustrate the percentage of days in each air quality category in each of the nation's seven most populous cities[6] and the five most populated cities in Texas. Since the AQI is not measured every day in all cities, we present the percentages of days in each air quality category. Cities in other states and Texas are ordered in accordance with the population of each city. The trend shows that Texas cities, in general, have a higher percentage of good days compared to large cities in other states such as Los Angeles, Chicago, Phoenix. These cities outside of Texas also have the highest percentage of unhealthy or dangerous days. The graph shows that, in general, highly populated Texas cities do not have worse air quality than the other major U.S. cities.

[6] Many of these figures capture data in the city metroplex, not just the city listed.


90
80
70
60
50
40
30
20
10
0
New York
Los Angeles
Chicago
Phoenix
San Diego
San Jose
Houston
San Antonio
Dallas
Austin
El Paso
Good Days/ Days with AQI
Moderate Days/ Days with AQI
Unhealthy Days/ Days with AQI

2018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New York
Los Angeles
Chicago
Phoenix
San Diego
San Jose
Houston
San Antonio
Dallas
Austin
El Paso
Good Days/ Days with AQI
Moderate Days/ Days with AQI
Unhealthy Days/ Days with AQI

2019

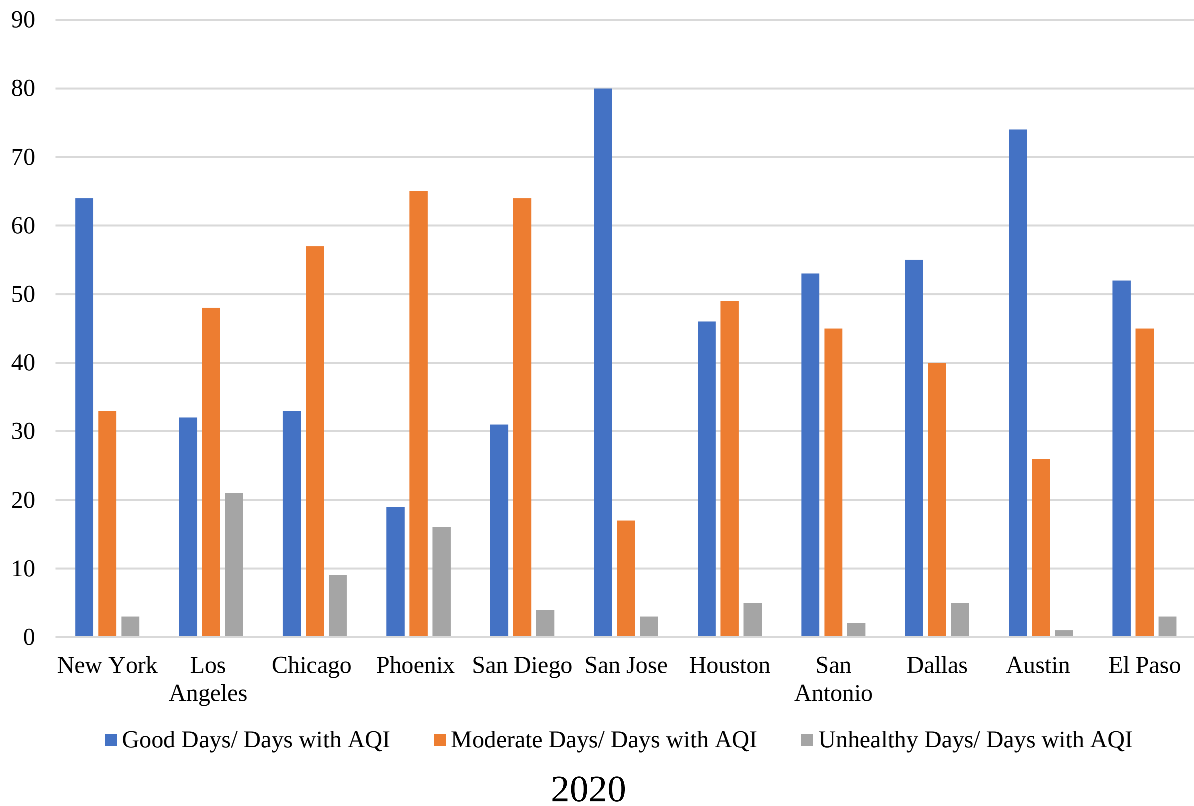
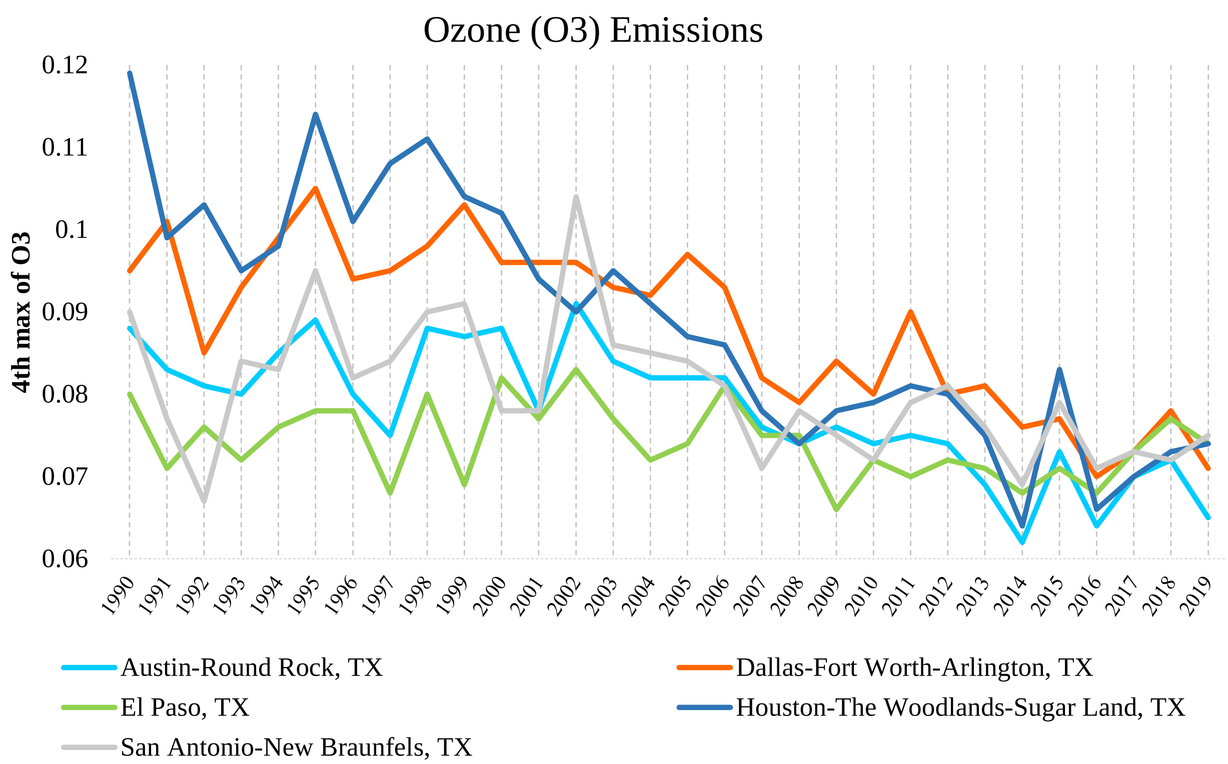
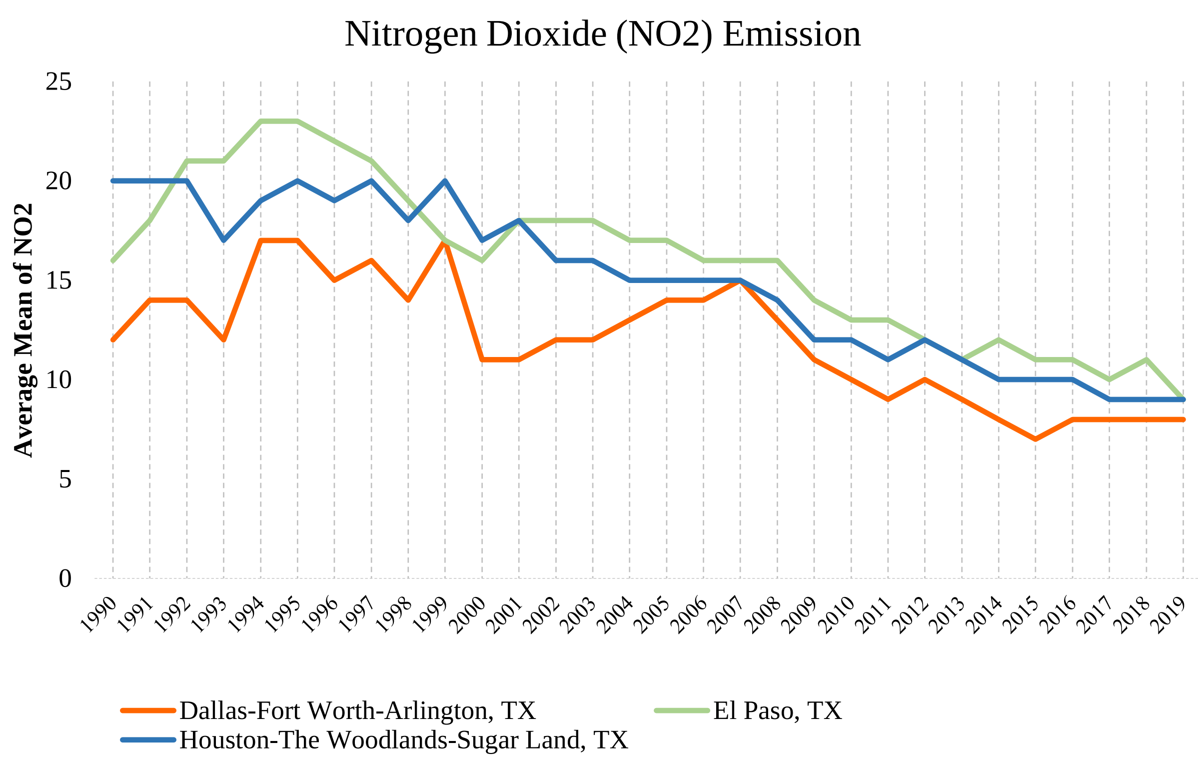


Figure 12 (set of three): The percentage of good, moderate, and unhealthy days in the most populated US and Texas cities from 2018 to 2020

Figure 13 (three images) shows the trend of Ozone, Particulate Matter 2.5, and Nitrogen Dioxide for five major Texas cities, when measured, in the 1990s. The highest Ozone (O3) emission rate was initially found in the Houston area, though the overall level of O3 emissions decreased from 1990 to 2019. In 2019, San Antonio had the highest emission rate, though the differences between these major cities are insignificant. Particulate Matter (PM) 2.5 emission was the highest in the Houston region for all the years, except in 2011 when the El Paso region had a sharp increase in particulate matter emission. Overall, there is a decreasing trend in PM emissions. Nitrogen Dioxide (NO2) emission demonstrates a similar decreasing trend over the years, with the El Paso area having the highest NO2 emissions in 2019.


Ozone (O3) Emissions
4th max of O3
0.12
0.11
0.1
0.09
0.08
0.07
0.06
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
Austin-Round Rock, TX
Dallas-Fort Worth-Arlington, TX
El Paso, TX
Houston-The Woodlands-Sugar Land, TX
San Antonio-New Braunfels, TX


Nitrogen Dioxide (NO2) Emission
Average Mean of NO2
25
20
15
10
5
0
1990 1991 1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013 2014 2015 2016 2017 2018 2019
Dallas-Fort Worth-Arlington, TX
El Paso, TX
Houston-The Woodlands-Sugar Land, TX

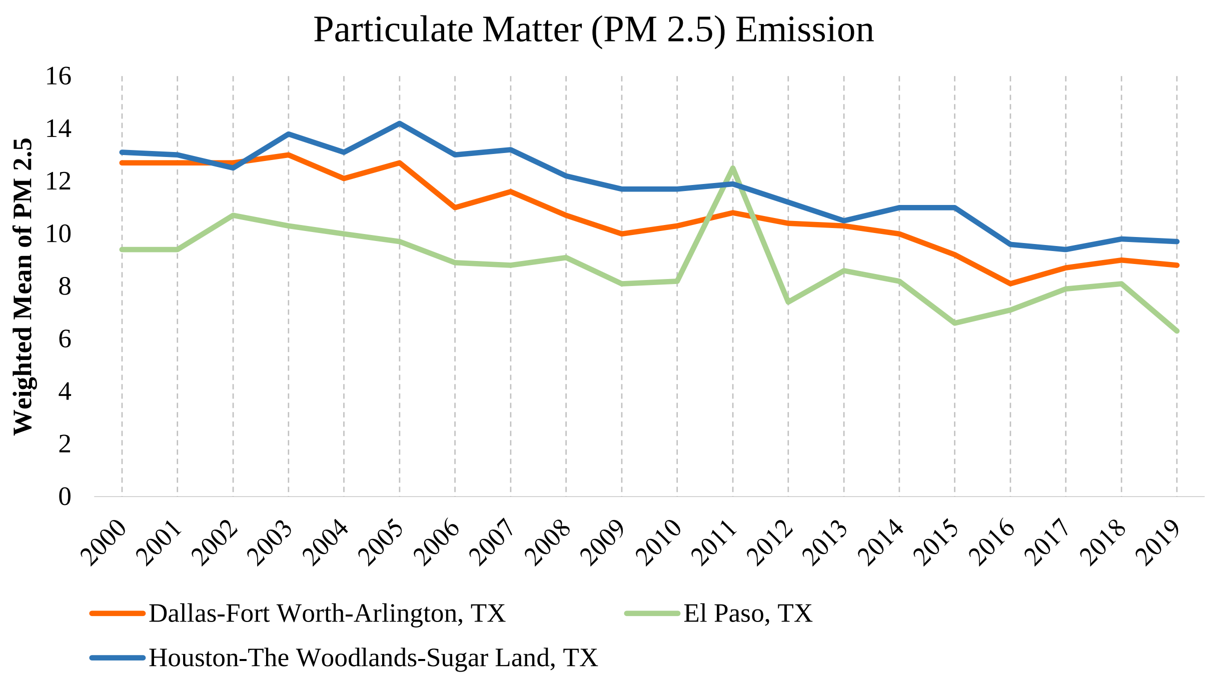


Figure 13: The emission levels of Ozone (O3), Particulate Matter (PM2.5), and Nitrogen Dioxide (NO2) in 5 most populated cities of Texas.

The AirData Air Quality Index Summary Report displays the annual summary of Texas's AQI by county between the years 2000 and 2019. Rather than breaking down the more specific air quality hazards, the AQI is an indicator of the overall air quality seen in Texas counties. Data includes values from 0 to 100 and a rating of good, moderate, unhealthy for sensitive groups, unhealthy, and very unhealthy. The percentage of the good days was calculated by taking the ratio of good days to days with AQI. "Good" days on the AQI are classified as a number ranging from 0 to 50. A number within this range means that the air quality is at a satisfactory level, and there is little to no risk posed from air pollution (AQI Basics).

Figure 14 shows trends of what is classified as "good" AQI Levels of Concern for ten counties in Texas from 2000 to 2019.[7] The graph shows the counties of Bexar, Cameron, Hidalgo, and Webb all had a decreased percentage of good days from 2000 to 2019. These counties,

[7] Figure 14 is divided into two figures for ease of identifying AQI levels. Figure A1 includes all cities in one figure for reference and is located after the Data Descriptions section.

excluding Cameron county, saw at least a 22 percent population increase over the last 19 years. This data shows that most counties in 2004, 2010, and 2016 saw a consecutive upward trend in the number of “good” air quality days. All years that succeeded a Texas legislative session that saw a focus on the Texas Emissions Reduction Plan or TERP (History of LWVTX Action on Air Quality/Climate Change, 2020).

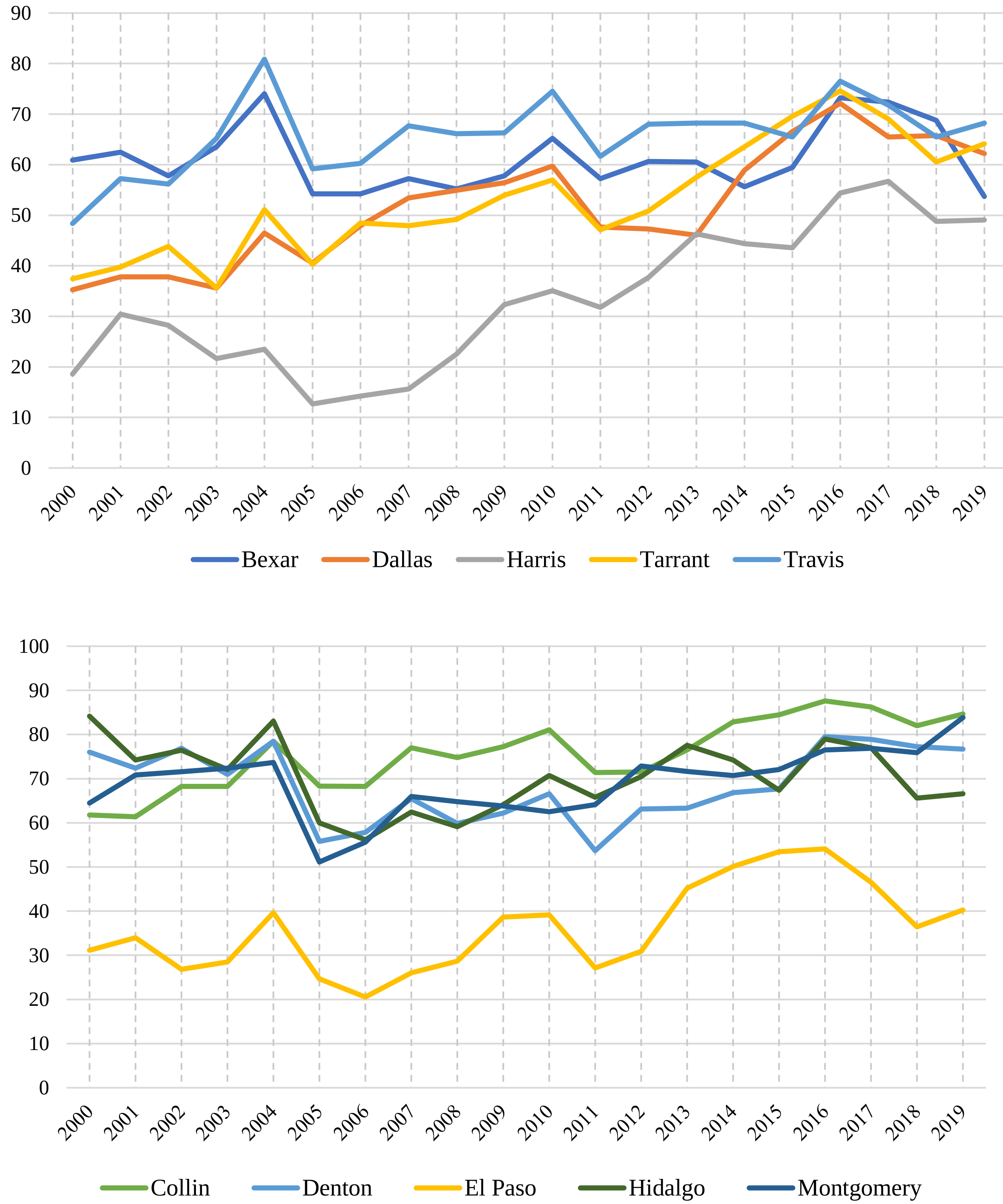


Figure 14: Percentage of Good Days in Ten Populous Texas Counties Over 19 Years

Impacts of Poor Air Quality

Health issues such as asthma, bronchitis, emphysema, lung disease, and shortness of breath can be associated with low air quality. Bexar County, specifically, has seen the highest rate of child hospitalization rates for asthma attacks between the years 2002 and 2013. The hospitalization rates between these years were highest among the Black and Hispanic communities (Bravo, 2016). Texas has a growing population of almost 30 million people, which means an increasing number of factories and cars, potentially worsening air quality for Texans.

Poverty levels in Texas counties range from zero percent (Irion County, King County, and Loving County) to 39.6% (Hudspeth County). Poverty levels are defined in this data as a percentage of families whose income falls below the poverty threshold, which combines household size with annual income. In 2010, these thresholds were $10,800 for a family of one, $14,500 for a family of two, and $18,300 for a family of three. These levels of poverty are seen in urban and rural areas, demonstrating the need to consider how urbanization has also affected air quality. For this research, poverty was categorized into four ranges: 0-10%, 10-20%, 20-30%, and 30-40% (Figure 15) representing the percentage of people in that county who fall under the poverty level. The majority of Texas counties, 158 to be exact, have poverty levels between 10% and 20%, leaving this section with the highest sample size. There are nine counties in Texas with poverty levels above 30%. Rural and Urban Continuum Code (RUCC) is categorized on a range from 1 (predominantly urban) to 4 (predominantly rural). In Texas, 104 counties are classified as a 3, or mostly rural, while 82 counties are categorized as a 1. These two comprise a majority of Texas counties with 19 counties are categorized as a 2, leaving a much smaller sample size for those data. These values are demonstrated in Figure 16.

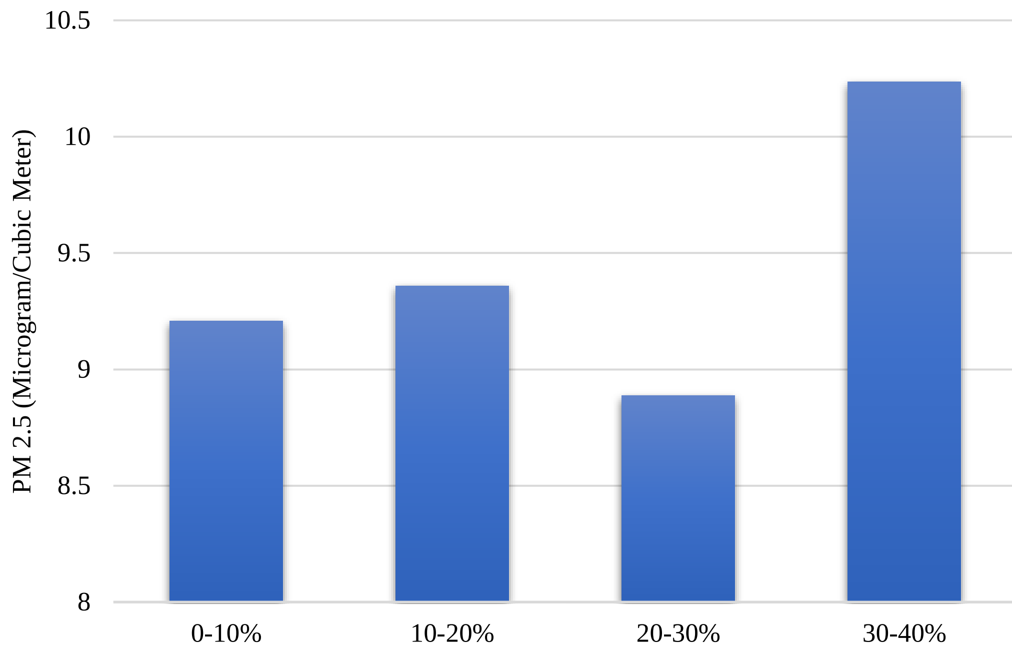


Figure 15: PM 2.5 Concentration by County Poverty Rate in Texas Counties

Impacts of Particulate Matter & the Ozone

As previously discussed in the literature review, PM 2.5 is defined as particulate matter larger than 2.5 µm in diameter but not larger than 10 µm. These are coarse particles that pollute the air and can cause lung and cardiovascular effects when people are overexposed to these particles. Comparing particulate matter to county RUCC demonstrates a slight trend across Texas counties. Significant developments that lead to higher PM concentrations include construction sites, unpaved roads, and reactions with other chemicals in the air. More urbanized regions have more construction and infrastructure, which in turn contributes to increased particle pollution. The case study on air quality previously discussed in this report concluded that urban areas like Los Angeles tend to have poor air quality, which is confirmed through higher levels of particulate matter in urban counties.

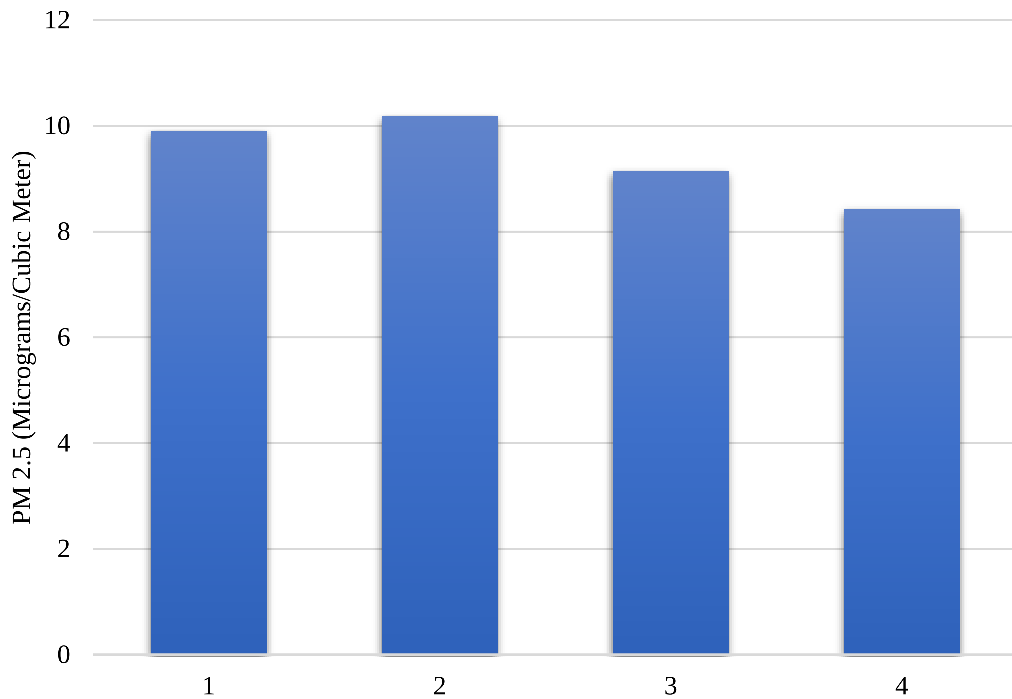


Figure 16: PM 2.5 Concentration by Rural-Urban Continuum Code in Texas Counties

As Texas presents a diverse population, it is beneficial to understand how underserved populations are impacted by air quality. According to the Environmental Quality Index from 2006-2010, regions with higher poverty levels are more likely to have higher amounts of particulate matter. Regions with higher levels of poverty tend to have less infrastructure, such as paved roads and less frequent updates to infrastructure, leading to higher levels of particulate matter as construction weathers over time.

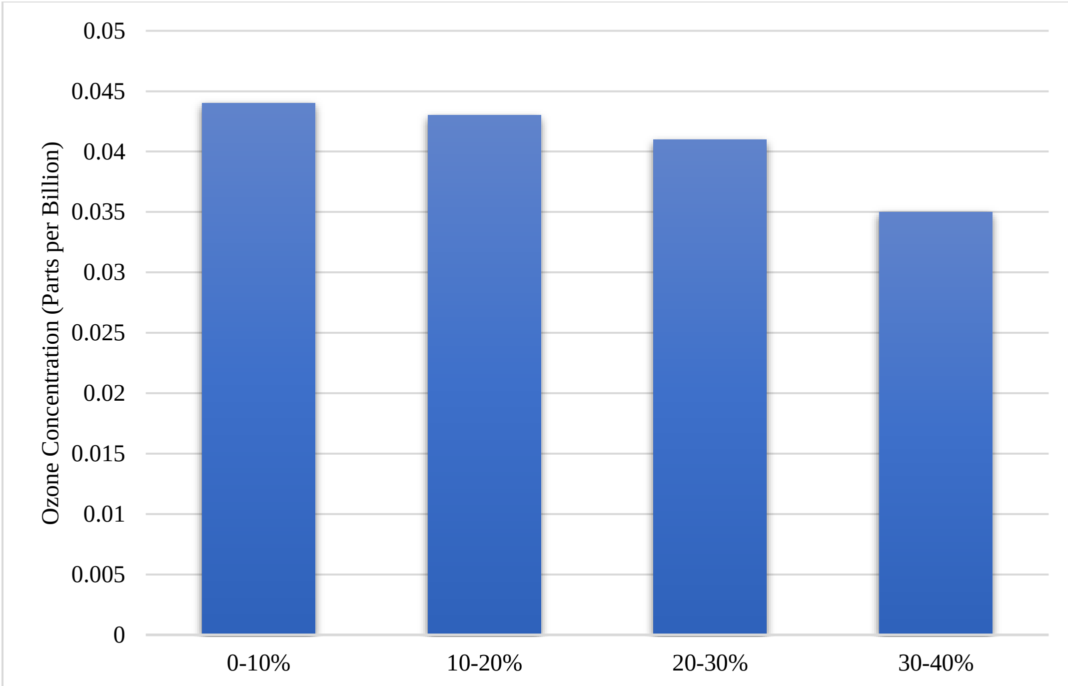


Figure 17: Ozone Levels by County Poverty Rates in Texas

On the other hand, ozone levels tend to decrease as poverty levels increase, as demonstrated in Figure 17. As discussed in the literature review, ozone mortalities in Texas are primarily from emissions in the transportation and industrial sectors. These sectors can bring a significant amount of income to a region, leading to lower poverty levels. For example, counties with prominent oil and gas industries, such as Harris County, Galveston County, and Ector County, all have poverty levels below 15%. Emissions from these industries contain hazardous chemicals such as methane, benzene, ozone, and smog, contributing to poor air quality levels in lower-poverty areas. Similarly, urban areas are significant regions within Texas as corporations and universities tend to reside in larger cities. As people migrate towards urban areas in search of work and education, the likelihood of individuals being exposed to air pollution increases. Furthermore, there are higher populations in urban areas, putting more Texans at risk of health conditions as a consequence of urban development.

Pollution from Superfund Sites

As stated above, Superfund sites are places with harmful wastes that were managed improperly or abandoned. Superfund sites include hazardous landfills, plants, manufacturing, and mining facilities. Superfund facilities pose a particular threat to the environment and people during natural disasters such as hurricanes, tornadoes, and floods (Center for Health, Environment & Justice, 2010). Toxicity from Superfund's can be dispersed over large areas and enter groundwater, rivers, lakes, soil, and air (Center for Health, Environment & Justice, 2010). Superfund sites contain oil, oil products, chemical and non-chemical waste, debris, and other materials that can threaten the environment and humans. Some materials can cause cancer and birth defects in children (Franklin, S., Intern, C., & Intern, C., 2010).

The EPA has identified more than 47,000 Superfund sites across the country that require cleaning and conservation (Franklin, S., Intern, C., & Intern, C., 2010). However, the Superfund program only covers 1,300 properties across the country, all of which are included on the National Priorities List (NPL).

Texas has 55 Superfund sites (National Priorities List, 2021). These facilities are concentrated primarily in Harris County, as seen in Figure 18. Harris County is the most potentially polluted county regarding industrial waste and toxic chemicals in Texas (Franklin, S., Intern, C., & Intern, C., 2010).

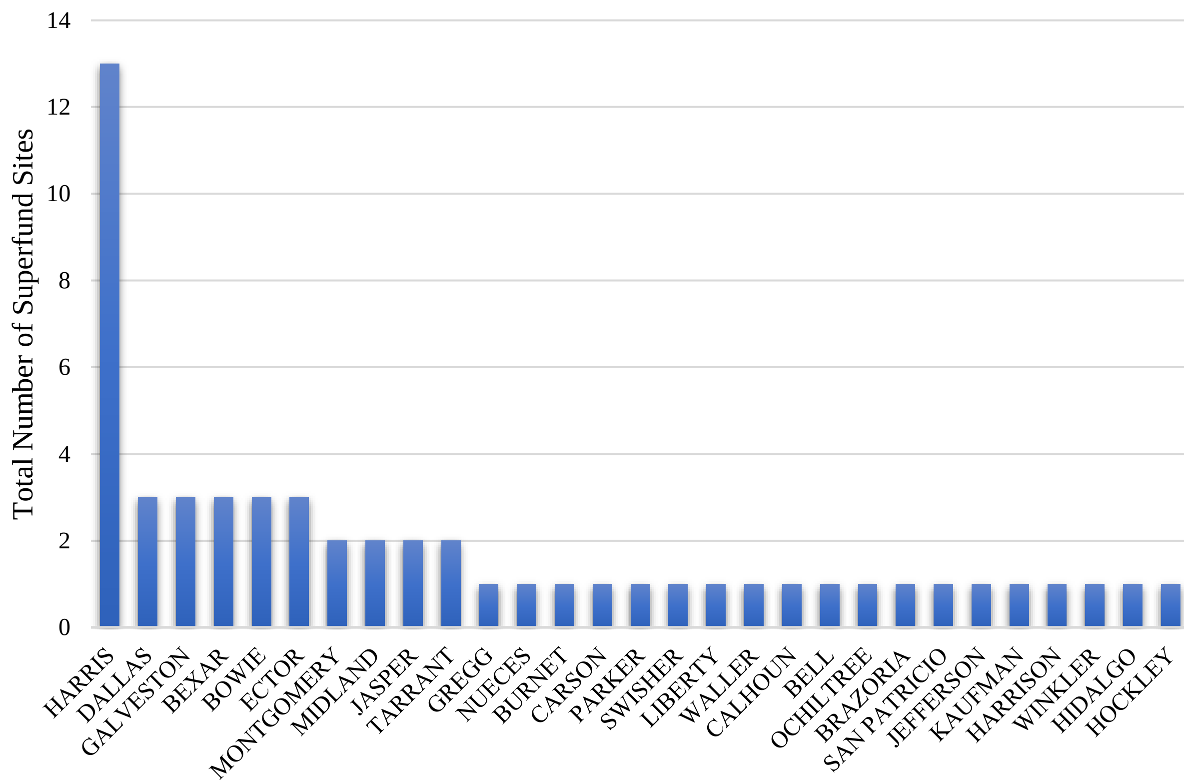


Figure 18: Total Number of Superfund Facilities in Texas, by county

Between 2004 and 2008, 56 superfund facilities in the Gulf of Mexico region were severely damaged by tropical storms and floods, which washed away a substantial amount of chemical and non-chemical materials; 28 of those damaged Superfund sites are in Texas (Franklin, S., Intern, C., & Intern, C., 2010). The areas surrounding the Gulf of Mexico are some of the most industrialized and polluted regions in Texas. There are hundreds of chemical and petrochemical plants, and thousands of industrial enterprises for the production, processing, storage, and release of toxic materials. (Franklin, S., Intern, C., & Intern, C., 2010).

The Toxics Release inventory, managed by the EPA, contains data of toxic chemicals and other carcinogenic materials released from industrial facilities into the environment during manufacturing, processing, and disasters. More than 1,700 industrial enterprises in Texas submit reports on releasing toxic materials into the air, water, or conservation in the ground (Toxics Release Inventory, 2021). These enterprises are not included in the National Priorities List.

This study used data from the EPA to estimate how Texans are at risk of poisoning from toxic materials and industrial waste emitted by industrial facilities. Figure 19 shows that these facilities' chemical emissions peaked in years of hurricanes and tropical storms (2003, 2006, 2008, 2011, 2017, and 2019). While it is difficult to identify if the toxic release made it into the air, water, or soil, these levels of release increase potential health threats to citizens in Texas during an already stressful time.

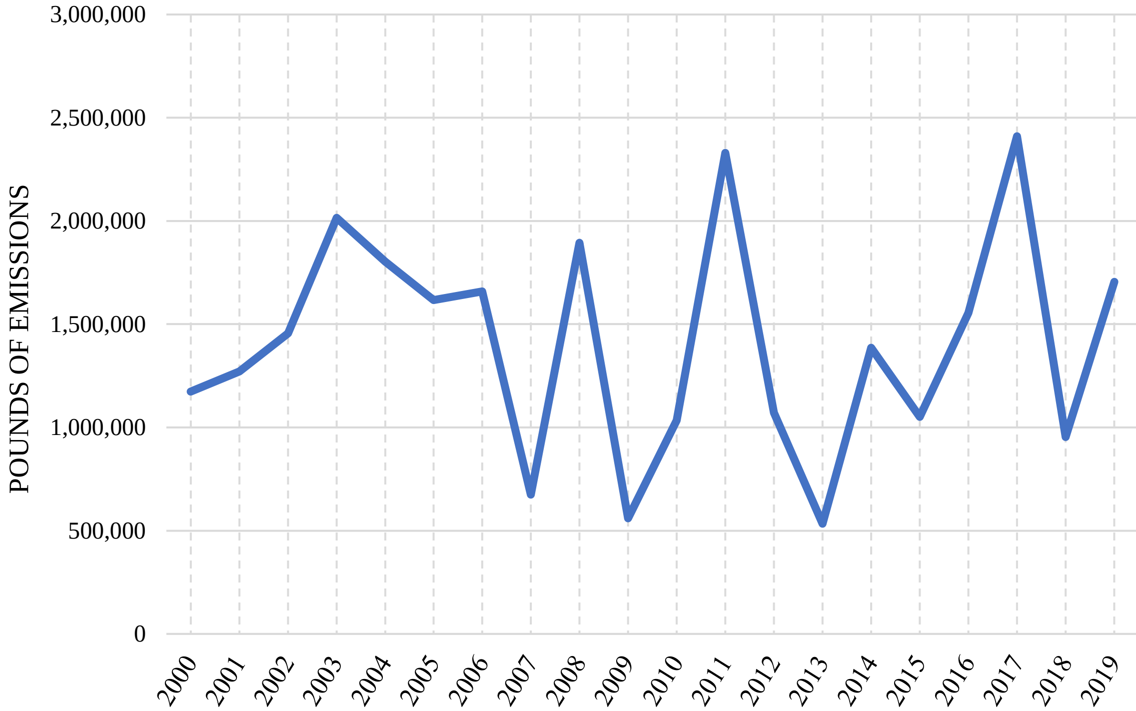


Figure 19: Trends of Toxic Chemical Releases in Texas, 2000-2019

Figure 20 presents the number of industrial facilities releasing chemicals in Texas from 2000-2019. The number of sites steadily increased between 2000 and 2015 and slightly decreased from 2016-2019. As is observed in Figure 21 and Figure 22, it does not appear that an increase or decrease in the number of sites affects the fluctuating amount of chemicals released into the environment.

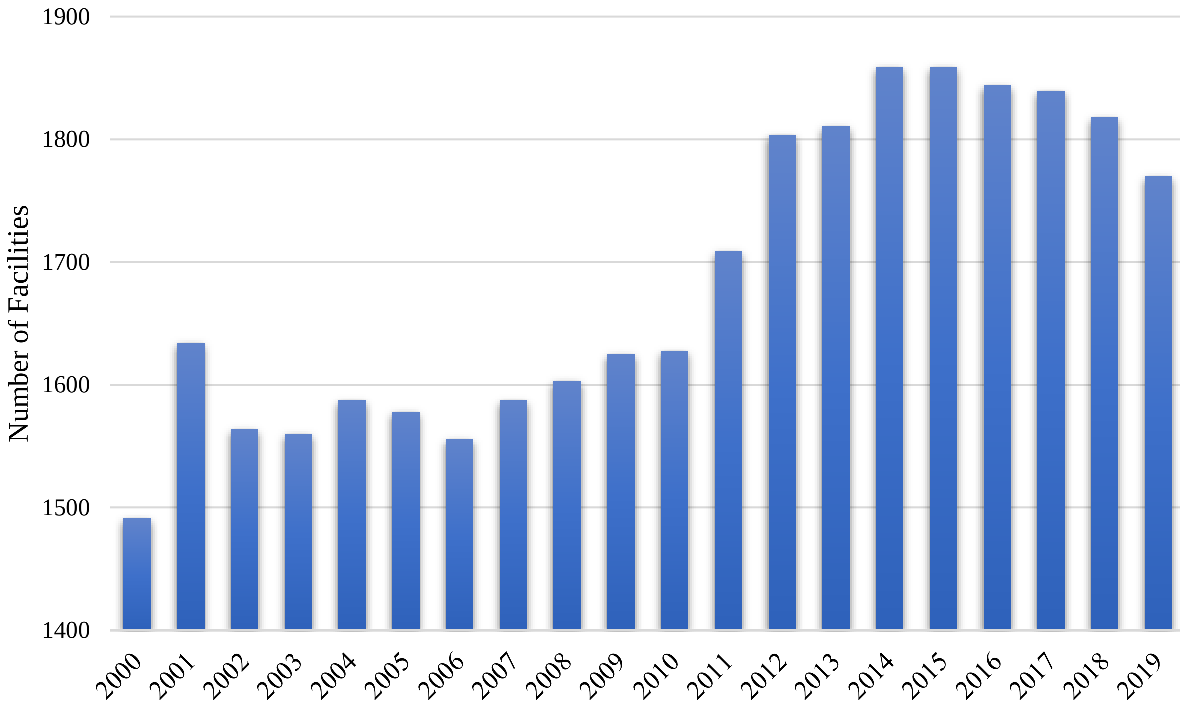


Figure 20: Number of Facilities Releasing Chemicals in Texas, 2000-2019

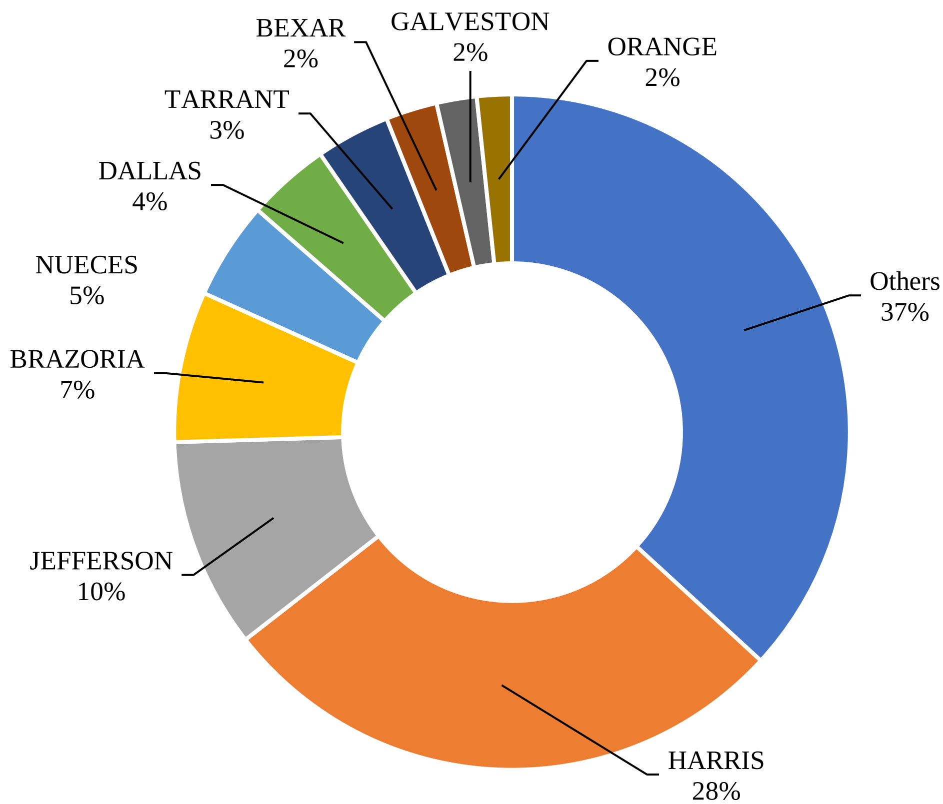


Figure 21: Percent of Chemical Releasing Facilities in Texas, by County

Figure 21 presents counties with the most industrial facilities releasing chemicals into the environment from 2000-2019. Harris and Jefferson counties have the highest number of facilities that release chemicals into the environment. Counties that have less than 40 facilities are included in the “Others” category.

Figure 22 illustrates Texas's top ten counties where industrial facilities emit the most amount of chemicals into the environment between 2000 and 2019. As demonstrated, Harris county experiences the most toxic chemicals released.

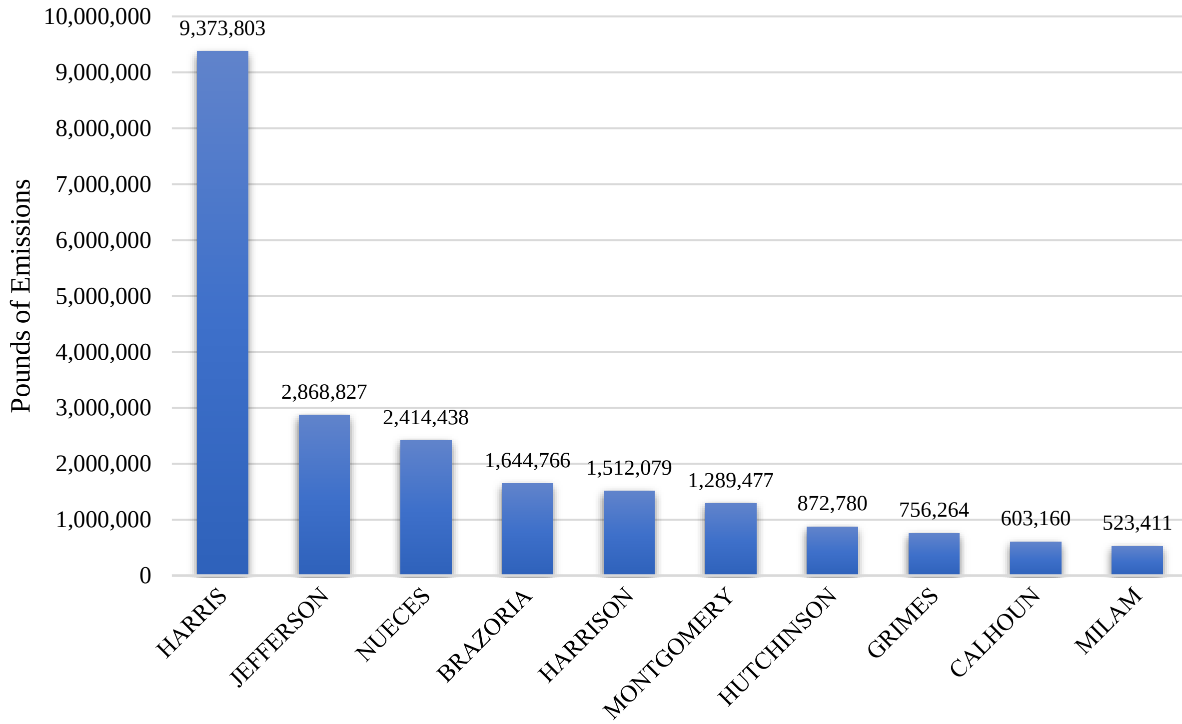


Figure 22: Top Ten Counties Experiencing Chemicals Releases, 2000-2019

Facilities also release carcinogens into the environment during disasters. Figure 23 depicts the counties that experience the most carcinogenic chemical releases during disasters from 2000-2019. Harris county again experiences the most exposure to detrimental chemicals.

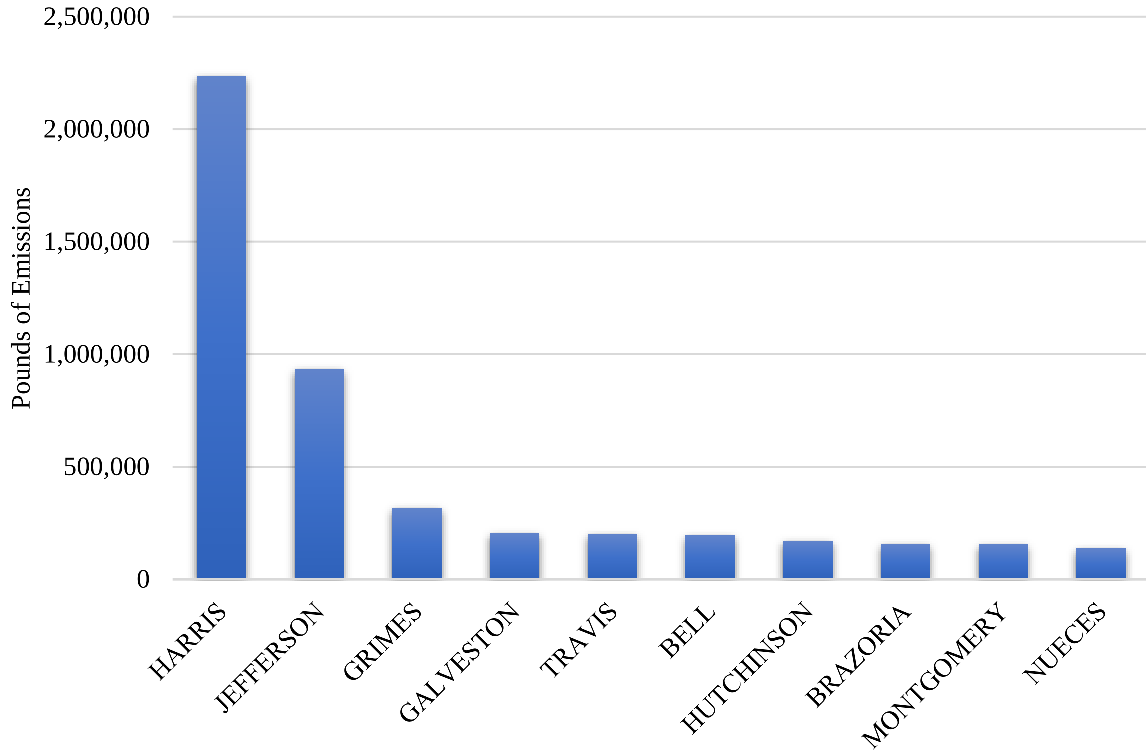


Figure 23: Top Ten Counties Releasing Carcinogenic Compounds, 2000-2019

The industrial facilities in Texas produce, process, and manufacture various chemicals, commodities, and metal and non-metal toxic materials. These consist of carcinogens that can impact people's well-being. As seen in Figure 24, among these harmful materials, nickel and styrene are the most frequently released carcinogens in disasters at the facilities from 2000-2019.

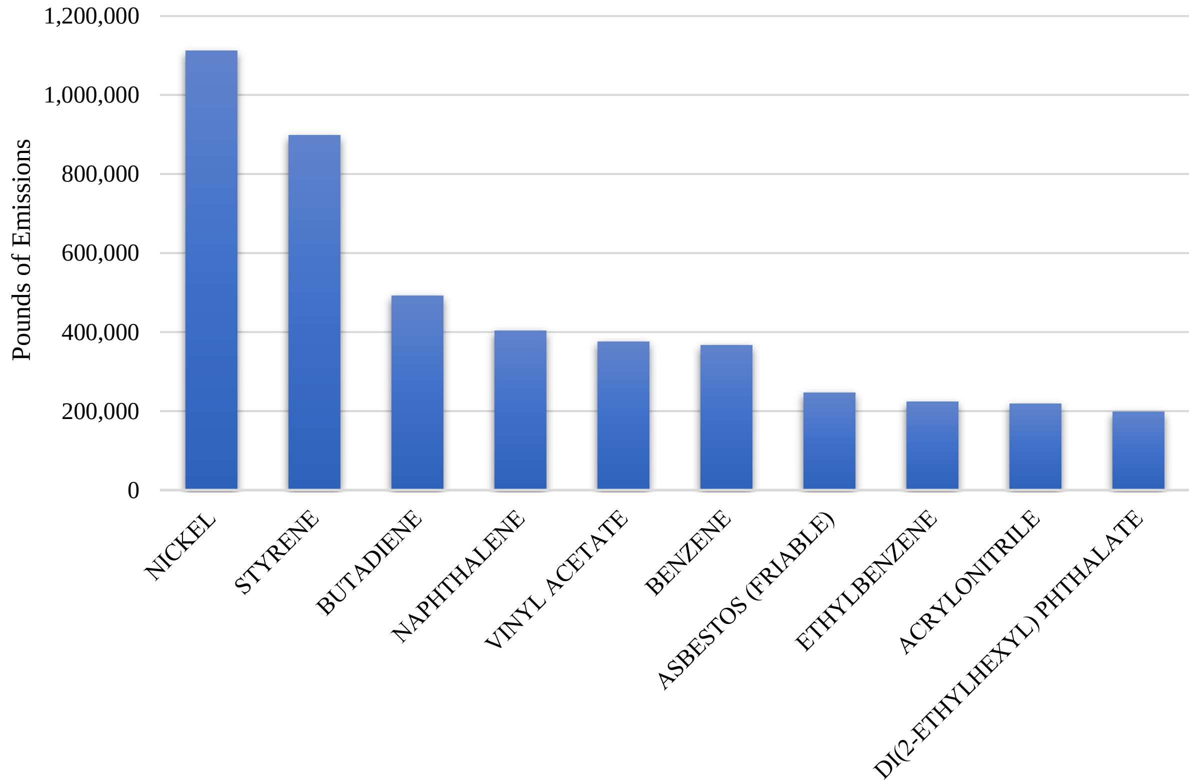


Figure 24: Top Ten Carcinogenic Chemicals Released in Texas, 2000-2019

DISCUSSION AND CONCLUSION

This report set out to identify the effects that flooding, water quality, and air quality have on the health of Texans. To identify health impacts and their connection to these environmental factors, data from varying sources were utilized, such as from the Environmental Protection Agency, FEMA, the National Centers for Environmental Information, among others.

The location of Texas in the coastal region of the Gulf of Mexico acts as a double-edged sword for Texans. On the one hand, it provides a variety of economic and recreational benefits to the state. One the other, it makes the state and its residents vulnerable to frequent natural disasters such as floods and hurricanes. This gulf region is one of the most industrialized and environmentally unfriendly coastal regions in the country. Many industrial enterprises are concentrated in Texas. These facilities produce, process, and emit millions of tons of various chemicals, petrochemicals, oil, and other commodities that affect the environment and health of the states’ residents.

Floods and hurricanes cause significant damage to agriculture and result in great losses to citizens by destroying property and impacting local economies. People with low income living in unsettled and problematic areas disproportionately suffer from such disasters. There are also many landfills and burials of industrial waste which can exacerbate the impact that hazards and disaster have on local communities. Some of these sites, specifically Superfund sites, are under the EPA's control for conservation and clean-up, but the EPA covers only a small proportion of potentially hazardous sites. The contents of numerous Superfund can be carcinogenic, cause skin diseases, and result in birth defects when citizens are exposed. Severe hurricanes and floods can impact the industrial integrity of Superfund sites and industrial facilities and potentially spread hazardous materials into the local environment, harming local residents and economies.

Anthropogenic and environmental factors continue to affect water quality throughout Texas. Keeping specific toxins under the legal limits defined by the SWDA and monitoring contaminant levels going forward is of paramount importance. Our research finds no relationship between county poverty rates and the level of enterococcus found in their recreational waters. However, arsenic contamination may be a significant issue in some areas; levels in the Hueco-Mesilla Bolson aquifer greatly exceed the threshold considered safe for consumption, making water drawn from this aquifer potentially toxic.

The number of water contaminant violations is connected to different social vulnerability indicators affecting Texas populations served by public water systems. Water contaminant violations also relate to poverty and race in that health-based water contaminant violations were reported in considerable numbers for non-white populations and populations considered to be in poverty. While the figures presented here are only introductory, it is important to consider the impact of hazardous materials on all sub-populations in Texas.

Air quality in Texas coincides with industrial emissions, which tend to impact regions with higher levels of urbanization and lower levels of poverty. On the other hand, particulate matter pollutants tend to impact areas with lower levels of infrastructure and higher levels of poverty. This creates an important scenario where all populations are likely to be impacted by poor air quality across all regions of Texas. Maintaining clean air must be an important point of consideration across the state, particularly for at-risk or vulnerable populations.

The AirData Air Quality Index Summary Report displays the annual summary of the Texas Air Quality Index (AQI) values by county between the years 2000 and 2019. The data shows consecutive spikes in 2004, 2010, and 2016. The Environmental Quality Index demonstrates the variance in air quality levels across Texas counties. By comparing air quality indicators to demographics by county, people living in regions with more urbanization and/or higher poverty levels tend to have worse air quality. Furthermore, the comparison of AQI levels in the most populated cities of the USA and Texas shows that, in general, the percentage of good days is relatively higher in Texas state than in the cities of other states. Among the 5 most populated cities in Texas, El Paso has the highest level of Ozone (O3) and Nitrogen Dioxide (NO2) while Houston has the highest Particulate Matter (PM2.5) emission.

In conclusion, the research conducted suggests that natural hazards such as flooding, water quality, and air quality all bring negative health consequences to the people of Texas. Socially vulnerable populations are likely to suffer from the impacts of natural hazards in all regions of the state. In order to improve the quality of life for all Texans, various natural hazards should be thoroughly evaluated and monitored and recommendations that will bring the most positive impacts state-wide should be provided and implemented where possible.

DATA DESCRIPTIONS

Flooding

Disaster Declaration Summaries was collected by FEMA to show locations affected by various disasters throughout the years. https://www.fema.gov/openfema-data-page/disaster-declarations-summaries-v2

Emergency Performance Measurement Grant was collected by FEMA to show the types of preparedness and management undertaken by states using FEMA EPM Grants. https://www.fema.gov/openfema-data-page/emergency-management-performance-grants-v1

FEMA Individuals & Households Flood Damage by State and Disaster was collected by FEMA to show disaster damages and costs by state. https://www.fema.gov/about/openfema/data-sets/individuals-households-program-flood-damage

FEMA Individuals and Households Flood Program Damage (2006-current) was collected by FEMA to measure how much Texas spends on disaster relief. https://www.fema.gov/about/openfema/data-sets/individuals-households-program-flood-damage

FEMA National Flood Insurance Program was collected by FEMA to report the number of claims regarding flood insurance. This includes the number of policyholders and affected residences (per type) that were damaged. https://www.fema.gov/openfema-data-page/fima-nfip-redacted-claims

FEMA Web Disaster Declarations - v1 was collected by FEMA to show disaster declarations per year and state. https://www.fema.gov/openfema-data-page/fema-web-disaster-declarations-v1

FIMA NFIP Redacted Claims - v1 was collected by FEMA to show national flooding insurance claims which include location, costs, risk, year, and buildings claimed. https://www.fema.gov/openfema-data-page/fima-nfip-redacted-claims-v1

Number-of-deaths-from-natural-disasters was collected by Hannah Ritchie and Max Roser of *Our World in Data*. Its focus is to show total deaths per year due to various natural disasters in the US https://ourworldindata.org/natural-disasters

Social Vulnerability Index was collected by the CDC to measure how vulnerable a community will be after a disaster by collecting data regarding unemployment, disability, minority status, and income. https://www.atsdr.cdc.gov/placeandhealth/svi/data_documentation_download.htm

Texas Flood Registry Response (2017-2020) was collected by the Urban Data Platform and Kinder Institute at Rice University. It is collected health and housing information from individuals impacted by floods; it measures the social impact, behaviors, health, and shelter data. https://doi.org/10.25612/837.9MGN8KBMEGA9

U.S. Billion-dollar Weather and Climate Disaster (1980-present) was collected by the National Centers for Environmental Information to help project the cost of damages per Texas zip code due to flooding. https://www.ncdc.noaa.gov/billions/events/TX/1980-2020

Water Quality

State of Texas Arsenic Violations Report

This dataset comes from the EPA's Safe Drinking Water Information System (SDWIS) Federal Reporting Services. The SDWIS provides information on water system characteristics, sampling data, violations, and enforcement. Information is collected through states reporting water information to the EPA as required by the Safe Drinking Water Act. States are required to report basic information, violations, and enforcement information on their water systems. The Arsenic dataset presents violations from 1981 to 2020. Violation types were mostly identified to be health based. Most of the public water systems in this report are community water systems. Others are non-transient non-community systems. The primary source for most of the public water systems are ground water sources with very few being surface water. The number of people served under population served ranges from a minimum of 12 to a max of 196,429. Retrieved from https://ofmpub.epa.gov/apex/sfdw/f?p=108:11::::RP,RIR::

State of Texas Lead and Copper Rule Violations Report

This dataset comes from the EPA's Safe Drinking Water Information System (SDWIS) Federal Reporting Services. The SDWIS provides information on water system characteristics, sampling data, violations, and enforcement. Information is collected through states reporting water information to the EPA as required by the Safe Drinking Water Act. States are required to report basic information, violations, and enforcement information on their water systems. The lead and copper rule controls lead concentrations in water to not exceed the maximum action level. This data set presents violations to this rule from 1992 to 2020. Violation types were mostly non-health based as they mostly pertained to lead consumer notices. The types of water systems included are community systems and non-transient non-community systems. Water sources include ground water and surface water. Most of the systems sourced their water from ground water. The minimum population served by a public water system is 10 and the max is 2,231,840. Retrieved from https://ofmpub.epa.gov/apex/sfdw/f?p=108:11::::RP,RIR::

State of Texas Stage 1 Disinfectants and Disinfection Byproducts Rules Violations Report

This dataset comes from the EPA's Safe Drinking Water Information System (SDWIS) Federal Reporting Services. The SDWIS provides information on water system characteristics, sampling data, violations, and enforcement. Information is collected through states reporting water information to the EPA as required by the Safe Drinking Water Act. States are required to report basic information, violations, and enforcement information on their water systems. Stage 1 Disinfectants and Disinfection Byproducts Rules reduces drinking water exposure to disinfection byproducts and applies to community water systems and non-transient non-community systems. This data set presents violations to the stage 1 rules from 2002 to 2020. Most of the water system types are community water systems. The water is primarily sourced from either groundwater or surface water. All violations are at the maximum contaminant level and identified as health-based risks. The population numbers range 14 at the minimum to 133,052 at the maximum. Retrieved from https://ofmpub.epa.gov/apex/sfdw/f?p=108:11::::RP,RIR::

State of Texas Stage 2 Disinfectants and Disinfection Byproducts Rules Violations Report

This dataset comes from the EPA's Safe Drinking Water Information System (SDWIS) Federal Reporting Services. The SDWIS provides information on water system characteristics, sampling data, violations, and enforcement. Information is collected through states reporting water information to the EPA as required by the Safe Drinking Water Act. States are required to report basic information, violations, and enforcement information on their water systems. Stage 2 Disinfectants and Disinfection Byproducts Rules strengthens compliance monitoring requirements for TTHM and HAA5. It applies to public water systems that present greater risk. The dates of the violations range from 2002 to 2020. Water system types are primarily community water systems. Water is either sourced from groundwater or surface water. The violations in this report are all at the maximum contaminant level and are identified as health-based risks to the population. Population served range from a minimum of 25 people to 325,733. Retrieved from https://ofmpub.epa.gov/apex/sfdw/f?p=108:11::::RP,RIR::

Air Quality

The EPA's Environmental Quality Index data provides data on individual indicators of air, land, and water quality by county from 2006-2010. Socioeconomic demographics are also recorded by county to enable a comprehensive view of environmental justice and its correlations to EQI. Each piece of data collected can be combined to measure the environmental quality of a county, state, or region during this time period. This data was collected by the United States Environmental Protection Agency and can be found on their website and the United States government database.

The AirData Air Quality Index Summary Report displays the annual summary of the Texas Air Quality Index (AQI) values by county between the years 2000 and 2019. The Air Quality Index is a more all-encompassing indicator of the overall air quality seen in Texas counties rather than a breakdown of the more specific air quality hazards. Data shows values from 0 to 100 that show a rating of good, moderate, unhealthy for sensitive groups, unhealthy, and very unhealthy through each given number (Environmental Protection Agency, n.d.).

The datasets are downloaded from Environmental Protection Agency official website. The dataset shows the amount of emission of different air pollutants over the years of 1990-2019. Not all cities have the same air pollutants measured. This dataset was used to evaluate the emission rates of Ozone, Particulate Matter, and Nitrogen Dioxide in 5 major Texas cities. Website: https://www.epa.gov/air-trends/air-quality-cities-and-counties

The datasets are downloaded from Environmental Protection Agency official website. The three datasets were appended, and they show the annual AQI indexes of different cities. The dataset includes the number of the days that AQI was measured and how many of those days can be considered good, moderate, and unhealthy days. The data was used to compare the air quality of highly populated USA and Texas cities over the years of 2018-2020. Website: https://aqs.epa.gov/aqsweb/airdata/download_files.html

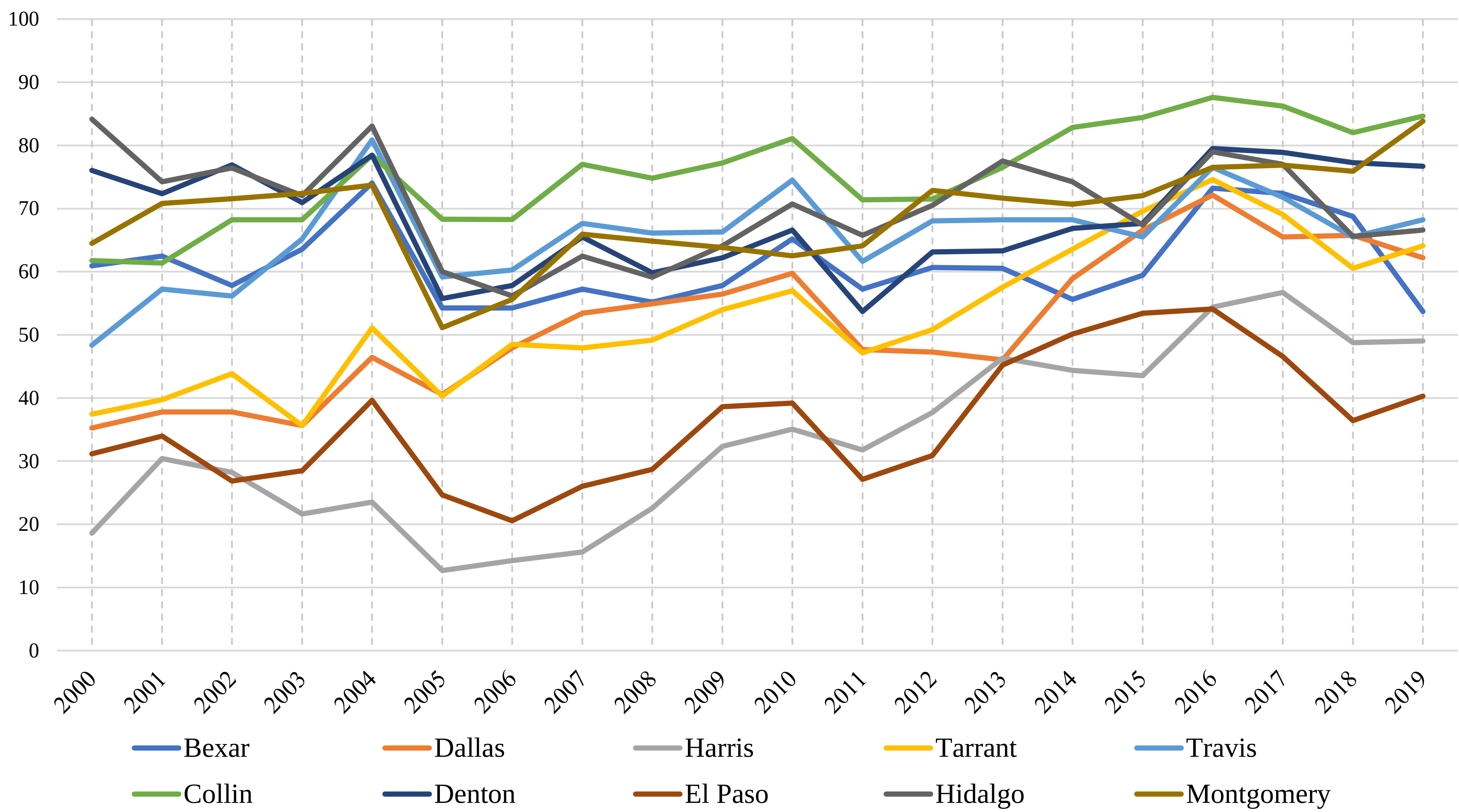


Figure A1:Percent of Good Air Quality in Ten Major TX Counties

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