INDUSTRIAL BENZENE EMISSIONS IN HOUSTON: LEGAL BARRIERS TO REDUCING A PUBLIC HEALTH THREAT

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DEDICATION

For my parents, without whom I would not be where I am today. Thank you for your constant love and support.

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PREFACE

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Decades of research show that environmental exposure to the chemical benzene is associated with severe carcinogenic, hematoxic and genotoxic effects on the human body. As such, the Environmental Protection Agency (EPA) has designated the chemical as a Hazardous Air Pollutant and prescribed benzene air concentration guidelines that provide cities with an ideal ambient level to protect human health. However, in Houston, Texas, a city home to the top industrial benzene emitters in the US who undoubtedly contribute greatly to the potentially unsafe levels of ambient benzene, regulations beyond the EPA's unenforceable guidelines are critical to protecting public health. Despite this, the EPA has failed to establish National Ambient Air Quality Standards (NAAQS) for benzene. States are thus left to regulate air benzene levels on their own; in the case of Texas, the Texas Commission on Environmental Quality (TCEQ) and state legislature have failed to proactively develop legally enforceable policies to reduce major source benzene emissions. This inaction continues to exacerbate a public health problem, which may only be solved through a legal framework that restricts preventable benzene emissions to protect human health and holds industrial companies accountable for violations of such regulations and

standards. This analysis explores legal barriers that the City of Houston and other relevant agencies currently face in their attempt to demand and bring about such change.

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INTRODUCTION

In as early as 1948 a report, produced and claimed by the American Petroleum Institute (API) to summarize the "best available information on the properties, characteristics and toxicology of benzene", concluded "it is generally considered that the only absolutely safe concentration for benzene is zero" (API, 1948). In 1958, a memo prepared by ESSO's (now ExxonMobil) Medical Research Division stated that "the only level [of benzene] which can be considered absolutely safe for prolonged exposure is zero" and "wherever possible, vapor inhalation should be prevented altogether" (ESSO, 1958). How, when big industry, the producers and emitters of benzene themselves, have acknowledged the toxic effects of benzene exposure, is the general population, six decades later, still subject to chronic involuntary inhalation of industrial source emissions?

This question is particularly valid in Houston, a city home to the top industrial benzene emitters in the US who undoubtedly contribute greatly to the potentially unsafe levels of ambient benzene and thus help create a significant threat to public health. Even with decades of research providing evidence for the positive association of benzene with carcinogenic, hematoxic and genotoxic effects, the Environmental Protection Agency (EPA) has failed to designate the chemical as a criteria air pollutant and thus has not established National Ambient Air Quality Standards (NAAQS) for benzene. States are thus left to regulate air benzene levels on their own; in the case of Texas, the Texas Commission on Environmental Quality (TCEQ) and state legislature have failed to proactively develop legally enforceable regulations to reduce major source benzene emissions. This inaction continues to exacerbate a public health problem, which may only be solved through a legal framework that restricts preventable benzene emissions to protect human health and holds industrial companies accountable for violations of such regulations and standards.

BACKGROUND AND SIGNIFICANCE

Characteristics of Benzene

Michael Faraday first isolated the chemical benzene in 1825 from the liquid product of compressed oil gas (ATSDR, 2007a). Since then, the properties of benzene have been thoroughly explored and are now well understood. It is characterized as a colorless, highly flammable liquid at room temperature that can both dissolve in water and evaporate quickly into air (CDC, 2005). Benzene has a sweet odor and when incorporated into ambient air, can be detected by most individuals at the ASTDR-designated odor threshold of 1.5 parts per million (ppm) or $5 mg/m^3$ (EPA, 2000).

Benzene is a product of both natural processes and human activities. Natural sources of the chemical include gas emissions from volcanoes and forest fires. It is also a natural constituent of crude oil and tobacco (ACS, 2006). As such, though gasoline and cigarette smoke are man-made, these products include natural sources of benzene. In addition, benzene can be present at very low levels in foods such as eggs, beef, various fruits and vegetables and dairy products (Johnson et al., 2007).

The industrial sector is a major source of benzene as a result of oil refining processes and commercial production activities. Benzene is recovered from petroleum, coal and natural gas condensates (Krewski et al, 2000). In 2004 a total of 2,528 facilities either produced or processed benzene (ASTDR, 2007b). Approximately 98% of the benzene produced in the United States is generated by the petrochemical and petroleum refining industries (OSHA, 1987). The US produced 2.3 million gallons of benzene in 2004 (CEN, 2005). As such, it ranks in the top 20 in production volume of all chemicals produced in the US (ASTDR, 2007b).

The high demand and output of benzene production by industrial sources is a direct result of its wide use in chemical manufacturing. Benzene is used as an industrial solvent and as an important starter chemical in the production of drugs, synthetic rubbers, dyes, paints and pesticides (City of Houston, 2007a). It is also used as an intermediary to make other chemicals, namely the benzene derivatives ethylbenzene (an intermediate of styrene, which is used to make Styrofoam® and other plastics), cumene (for resins and acetone) and cyclohexane (for nylon) that account for 55%, 24% and 12% of the annual benzene production volume, respectively (ASTDR, 2007b). Furthermore, benzene is used as a gasoline additive because of its antiknock characteristics and performance as an octane enhancer (Krewski et al., 2000).

Environmental Contamination and Exposure

Benzene can enter the environment in many different ways at any point of its production, storage and transport process. Leakages from underground gasoline storage tanks, seepage from landfill leachate and hazardous waste sites and oil spills can contaminate underground well water supplies, surface water and soil (ASTDR, 2007b). Benzene from surface water evaporates quickly in to air; conversely, the chemical degrades much slower when incorporated into underground water or soil (NH Department of Environmental Services, 2005).

Benzene contaminates ambient air from a variety of sources. One significant contributor to benzene air pollution is cigarette smoke. The amount of benzene found in a cigarette depends on the type and brand, but generally ranges from 12 to 48mg per cigarette; benzene from cigarette smoke is thus considered to be the primary source of benzene in indoor air (Krewski et al., 2000). In addition, automobiles, SUVs and trucks emit large amounts of benzene into the air due to auto exhaust and gasoline vapor emissions (City of Houston, 2007a). As such, ambient air in urban areas with heavy traffic and areas around gasoline fueling stations contain higher levels of benzene than rural locales (CDC, 2005). Other minor sources of benzene air contamination include tire fires, wood burning and vapors and/or gases from products that contain benzene, such as glues, paints, furniture, wax and detergents (ASTDR, 2007a).

The main point source of benzene emissions is attributed to industrial processes such as petrochemical manufacturing and petroleum refining (Carletti, 2002). Benzene enters the atmosphere as it escapes from industrial facilities through flares, tanks, transport pipes, coke ovens, cooling towers, valves and stacks (City of Houston, 2007a). In addition, benzene can enter the environment as a result of industrial discharge and disposal of products containing benzene and leaks from old or faulty equipment (ASTDR, 2007a). Consequently, air surrounding industrial sites contains higher levels of benzene than background air concentrations (ASTDR, 2007a).

Exposure to benzene occurs through three routes: oral ingestion, dermal absorption and inhalation (NIOSH, 2003). Oral ingestion of benzene may result from drinking contaminated tap water or eating foods prepared with such water (ASTDR, 2007b).

However, water and dietary related sources of benzene are insignificant and account for only an estimated 1% of the total benzene absorbed by the general population (Carletti et al., 2002). Dermal absorption of benzene can occur when handling products or water containing benzene.

Inhalation is the primary route of exposure for the general population and accounts for over 99% of the human body's daily intake of benzene (ASTDR, 2007b). Individuals are exposed to benzene when breathing in industrial emissions, gasoline vapors, auto exhaust and first and second-hand smoke. Benzene is both quickly and efficiently absorbed by humans following inhalation (Krewski et al., 2000). Accordingly, individuals living in urban areas and/or near industrial facilities inhale and accumulate more benzene in their bodies than people living in rural communities or cities with smaller industrial sectors.

Benzene in Houston

Major Source Impact

Although emissions from vehicle exhaust and gasoline vapor contribute to benzene concentrations in outdoor ambient air, this analysis focuses on reducing industrial point source benzene emissions for several reasons. Firstly, vehicular benzene emissions in Houston over the last decade have decreased by 70% and will be further reduced by 45% over the next seven years due to federal regulations related to benzene content levels in gasoline and fuel efficiency standards (City of Houston, 2008a). As a result, it is estimated that in three years the total output of all vehicular-related benzene emissions combined will be less than the total output of benzene emissions by industrial facilities located in greater Houston (City of Houston, 2008a).

Furthermore, Houston is home to some of the largest refining and chemical manufacturing facilities in the US. Lyondell-Citgo Refining LP, located in east Harris County, is the single largest emitter of benzene of all refineries in the US (White, 2008). In fact, three of the top five emitters of benzene in the US are located in greater Houston, including Lyondell-Citgo, BP Texas City Refinery and Sweeny Refinery Complex (Table 1).

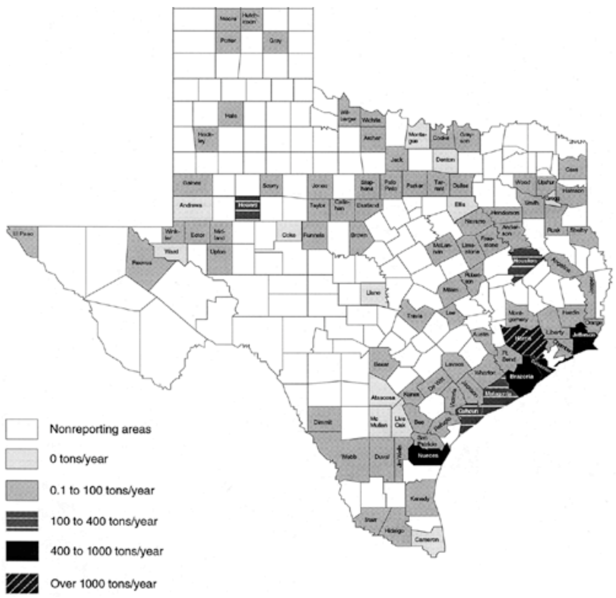
Table 1: Houston-based Refineries Among Top 5 US Volume Emitters of Benzene in 2005

Rank	Facility	City	County	Annual total air emissions, benzene pounds
1	Lyondell-Citgo Refining LP	Houston	Harris	124,242
2	BP Texas City Refinery	Texas City	Galveston	111,038
4	Sweeny Refinery Complex	Old Ocean	Brazoria	77,814

(Data from City of Houston, 2007b)

Additionally, there are over 400 chemical manufacturing facilities in Houston including the largest and second largest petrochemical complex in the US and world, respectively. (Sexton et al., 2007; Hauser, 2006). These industrial facilities contribute greatly to the high levels of benzene in the air; according to the Toxics Release Inventory (TRI), Texas as a state emitted 2,681,263 pounds of benzene air emissions in 2004, more than 2 million pounds over the second highest ranking city (Los Angeles), which accounted for 39.8% of the total reported industrial source benzene emissions in the US (TRI, 2006). Moreover, Houston's industry plays the leading causative role of point source benzene emissions in Texas (Figure 1).

Figure 1: Annual Benzene Point Source Emissions in Texas



(Pendleton, 1995; Data based on TNRCC point source database derived from 1980, 1985, 1988, 1990, and 1992 emissions inventory)

Lastly, industrial point sources are the largest individual sources of benzene in the Houston area (City of Houston, 2007a). Their contribution to benzene air pollution is clearly evident when comparing Houston benzene air concentration levels with other high-traffic urban areas (Table 2).

Table 2: A Comparison of the 2007 Annual Average Maximum Benzene Concentration

City	Benzene level
Houston	5.81ppb
Los Angeles	1.25ppb
Chicago	0.83ppb

(AirData, 2008)

Moreover, industrial air toxic emissions are found to be severely underreported and underestimated, which makes it difficult to assess the actual extent of point source impact on ambient benzene levels. For instance, results from a 2004 study indicate that company data provided to the TRI underreported national industrial benzene emissions by 248% in 2001 (EIP-GHASP, 2004). In addition, recent research shows that actual hazardous air pollutant emissions from petroleum refining and chemical manufacturing plants can be 100 times greater than estimated based on EPA emission factors (City of Houston, 2008b). Since the petrochemical manufacturing and petroleum refining industries are known to be significant and underestimated contributors to Houston's benzene air pollution, point source reduction efforts can have a large impact on overall air concentration of benzene.

Current Benzene Air Concentration Levels

According to the Texas Commission on Environmental Quality (TCEQ), Houston's air is monitored hourly by 141 TCEQ, private and industrial owned air pollution monitoring and sampling instruments (TCEQ, 2005). However, reliable estimates of benzene air concentration levels are difficult to determine because active monitors are spread unevenly throughout the region, various organizations utilize different measurement models and actual monitored concentrations are often underestimated. For example, EPA (2007) has found evidence that the National Air Toxics Assessment (NATA) may underestimate benzene air concentrations by 50%. Furthermore, benzene is not measured by all monitoring locations and inconsistently measured across time; Sexton et al. (2007) note that benzene was measured at 15 public sites in 1999 and 16 in 2004.

EPA's monitoring network reports hourly and daily data to AirData, which provides yearly summaries of benzene concentration levels from each site that actively monitored benzene in the particular year being assessed. In 2008, 29 sites monitored benzene in greater Houston and reported an annual average maximum ambient benzene concentration of

4.11ppb (AirData, 2008). County annual average maximum concentration levels for Harris, Galveston and Brazoria were 8.30, 1.53 and 2.58ppb, respectively (AirData, 2008). The daily maximum averages can very depending on the season, wind patterns and placement of monitoring equipment.

Public Health Significance

Benzene is a known toxic and poses a significant threat to public health. The acute and chronic effects of benzene differ and depend on the length, route and amount of exposure. Though the exact mechanisms of benzene toxicity are still not known, research suggests that not benzene itself, but its metabolites that are formed by the liver and settle in bone marrow, adipose and central and peripheral nervous system tissue are the actual toxicants (EPA, 1998). Several animal and human epidemiological studies have consequently shown benzene to induce bone-marrow damage, developmental effects, immune suppression and cancer (Zeise et al., 2000).

Acute and Chronic Health Effects

The effects of acute benzene exposure (where acute denotes exposure for 14 days or less) depend primarily on the dose of inhalation. For instance, 5-10 minutes of exposure to 10,000-20,000ppm benzene in air is known to cause death due to cardiovascular effects such as ventricular fibrillation, respiratory arrest or cardiac collapse or neurological effects such as vascular congestion of the brain or central nervous system depression (Krewski et al., 2000; ASTDR, 2007b). High levels of acute exposure can also cause chromosomal aberrations, narcosis, tremors and severe hematological effects such as decreased red and white blood cell count and interference with blood platelet formation (Krewski et al., 2000; EPA, 2000).

In addition, effects can occur at acute exposure to lower levels of benzene inhalation (700-3,000ppm) such as heightened cardiac sensitivity to epinephrine-induced arrhythmias, irritation to the eyes and mucous membranes, acute hemorrhagic pneumonitis, respiratory tract inflammation, pulmonary hemorrhages, renal congestion, and cerebral edema (OEHHA-CA, 1999). According to the ASTDR (2007c), recovery from moderate exposure to benzene may take 1 to 4 weeks; during this time, affected individuals can still experience breathlessness, impaired gait, cardiac distress and/or may also exhibit yellow coloration of the skin. Other less severe symptoms including headache, lightheadedness, dizziness, confusion, nausea, impaired gait, and blurred vision may also develop from low level short-term exposure (NIOSH, 2003).

In addition to prolonging short-term exposure effects, chronic exposure to benzene has the ability to induce many different more severe conditions stemming from its hematoxic, genotoxic and immunotoxic qualties. Long-term low-level exposure effects can be divided into non-cancerous and cancerous implications. Health effects of primary concern relate to complications within the hematopoietic system.

The most severe and common non-cancerous effects of chronic exposure to benzene stem from bone marrow depression. Inhalation exposure to benzene can result in clinical pancytopenia. Lan et al. (2004) found a significant decrease in blood cells and platelets among individuals exposed to less than 1ppm for an average of 6.1 years. If an exposure of 1ppm or greater continues for several years, aplastic anemia can develop (ASTDR, 2007b). As aplastic anemia progresses, bone marrow failure can lead to acute myelogenous leukemia (Askoy, 1989). In addition to the reduction of blood cells, chronic exposure to benzene can also lead to decreased lymphocytes. Several studies provide evidence that inhalation of benzene concentrations as low as 0.25ppm to 8ppm results in significant reductions in lymphocyte counts, leaving the body susceptible to opportunistic infections (Qu et al., 2002; Rothman et al., 1996). Myelodysplastic syndrome is another potential health effect and known precursor to leukemia (Hayes et al., 1997).

Benzene has been classified as a Class A human carcinogen by the EPA, known human carcinogen by the National Toxicology Program (NTP) and Group 1 carcinogen by the International Agency for Research on Cancer based on animal and human benzene exposure studies (ACS, 2006). There are two main types of cancer associated with benzene exposure. Firstly, benzene has been consistently shown to cause leukemia, particularly acute myelogenous leukemia. The strongest evidence for benzene's leukemogenicity comes from the Pliofilm cohort study that concluded a 3-fold risk of myeloid leukemia in individuals exposed to 1-5ppm at an 8-hour time weighted average (TWA) over 40 years and the US National Cancer Institute (NCI) and Chinese Academy of Preventative Medicine (CAPM) joint study that found a positive correlation between a range of exposure levels and increased risk for all types of leukemia (Johnson et al., 2006; ASTDR, 2007b). Research also suggests a causal link between chronic benzene exposure and Non-Hodgkin's Lymphoma. In one an analysis of the NCI-CAMP cohort study, Hayes et al. (1997) determined a significantly elevated relative risk (RR = 4.2) for Non-Hodgkin's Lymphoma among workers exposed to benzene for more than ten years.

Established Risk Levels

As a result of scientific evidence linking benzene to toxic effects on the human body, regulatory organizations such as the EPA and TCEQ have established inhalation risk values that serve as suggestive guidelines to protect human health. The EPA's Integrated Risk Information System (IRIS) provides a reference concentration (RfC) for chronic 8-hour TWA inhalation exposure of 0.03mg/m^3 or 0.009ppm based on findings from the Rothman et al. (1996) analysis of the Chinese worker cohort data that showed decreases in lymphocytes at exposure concentrations of 8ppm (IRIS, 2003). The RfC only accounts for non-cancerous effects and indicates the amount of benzene below which long-term exposure is not anticipated to result in any negative health consequences among the general population.

IRIS publishes the individual lifetime excess risk of cancer due to chronic exposure to one unit of benzene, known as the air unit risk, as a range rather than a single number to account for variability (Morello-Frosch et al., 2000). The carcinogenic risk range for an individual exposed to 1mg/m^3 of benzene is 2.2×10^{-6} to 7.8×10^{-6}, based on Crump's 1994 analysis of the Pliofilm cohort (IRIS, 2003). IRIS also publishes benzene concentrations associated with incremental excess lifetime cancer risk based on the Clean Air Act mandate which stipulates exposures to toxics in ambient air be limited to a range of 1 cancer case per 10,000 people to 1 cancer case per 1 million people with the goal of ambient concentrations reaching the most protective end of that range (City of Houston, 2008c). Ideally, the air concentration of benzene should remain below 0.13mg/m^3 or 0.041ppm to reach most protective risk of 1 cancer case per million people due to chronic exposure (Table 3).

Table 3: Benzene Toxicity Ranges Based on the Clean Air Act

EPA Clean Air Act risk range		Benzene (mg/m^3) – Most protective end	Benzene (mg/m^3) – Least protective end
Least health protective end of risk range	1 cancer case per 10,000 people	13.0	45.0

Intermediate risk range	1 cancer case per 100,000 people	1.3	4.5
Most health protective end of risk range	1 cancer case per 1,000,000 people	0.13*	0.45

(Data from IRIS, 2003)

The EPA Office of Air Quality and Planning Standards (OAQPS) publishes one toxicity value consistent with the Clean Air Act's most protective (0.13mg/m^3) end of the toxicity range (City of Houston, 2008c).

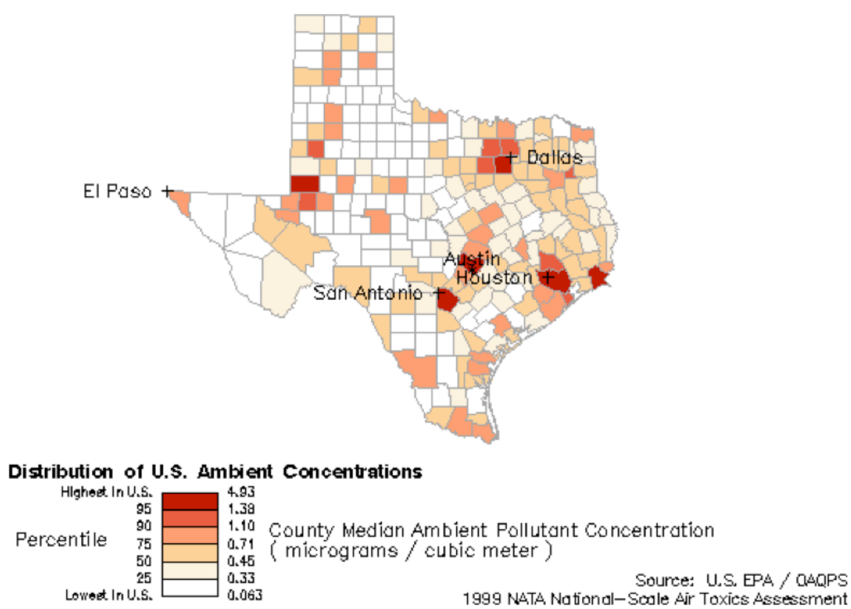
The TCEQ publishes its own version of ambient benzene concentration guideline known as the Effects Screening Level (ESL), which is based on current animal and human epidemiological data. This value reflects a carcinogenic effects level of benzene as a result of long-term exposure. The TCEQ ESL for benzene is consistent with the least protective end of the Clean Air Act intermediate health risk range, that is 4.5mg/m^3 of benzene for 1 cancer case per 100,000 people (TCEQ, 2008a).

Implications for Houston

Though the EPA and TCEQ have established inhalation risk values for chronic benzene exposure, these numbers are not legally enforceable and serve merely as guidelines, for example to conduct health risk analyses, allocate industrial flexible permits or determine benzene hotspots. As such, no legal framework is in place to regulate ambient benzene concentrations creating a significant public health threat for the residents of Houston. For instance, even though the TCEQ ESL is over 30 times less health protective than the EPA Clean Air Act risk goal, ambient concentrations of benzene in greater Houston routinely surpass this level, putting over 5 million Houstonians at excess risk for developing numerous hematological, neurological and genetic defects as well as several types of cancer. In 2007, three TCEQ air monitors located at Cesar Chavez, Milby Park and Clinton Drive exceeded the ESL 34%, 23% and 37% of the time, respectively, and the EPA 1 in a million cancer risk level almost 100% of the time (White, 2008). Furthermore, Sexton et al. (2007) found airborne levels of benzene in greater Houston corresponding with 1 excess cancer risk per 10,000 people. In 2008, EPA air monitors noted maximum ambient concentrations of benzene up to 91.04ppb (AirData, 2008).

In Houston, a city home to numerous facilities ranking among the top benzene emitters in the US, industrial emissions are the largest point source contributors to ambient benzene concentrations in Houston, the impact of which is reflected in the benzene air levels in greater Houston as compared to other cities in Texas (Figure 2).

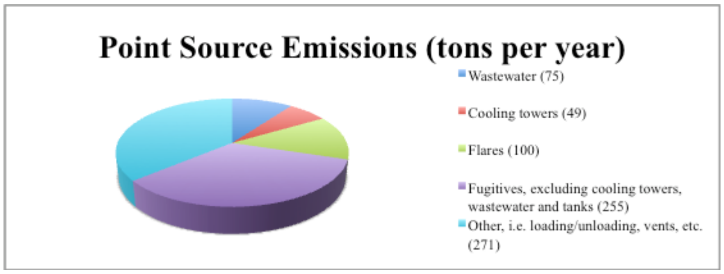
Figure 2: 1999 Estimated County Median Ambient Benzene Air Concentrations for Texas



(EPA NATA, 2006)

Moreover, the largest emitters of benzene are concentrated in east and southeast Houston; Harris, Galveston and Brazoria counties account for approximately 99% of Houston's point source emissions (EPA, 2008a). In fact, the Houston-Galveston-Brazoria area alone reported 750 tons of industrial benzene emissions in 2004 (Figure 3).

Figure 3: 2004 Houston-Galveston-Brazoria Area Point Source Types and Emission Amounts



(Data from City of Houston, 2007a)

The air pollution contributions of these industrial emissions lead to higher benzene air concentration levels in areas surrounding the manufacturing and refining facilities, creating a disproportionate health risk for some of Houston's most vulnerable populations. For instance, some of the highest uninsured rates for health coverage in Harris county occur in East Houston, an area with an average family income 30% lower than the city of Houston (Institute for Health Policy UTSPH, 2006).

In addition, due to wind patterns, underreporting, different emission factors and assessment models and lack of regulatory agency enforcement and oversight, the true magnitude of industrial benzene emissions is clearly underestimated. Consequently, industrial source emissions will continue to contribute significantly to ambient benzene concentrations in absence of a regulatory framework to reduce these releases. Reducing industrial benzene emissions can have far reaching impact on the ambient air concentration in Houston. These reductions would further be reflected in decreases of benzene-induced negative health consequences for the residents of Houston; for instance, one case study found that the health benefits from an average reduction in benzene concentrations by 1mg/m^3 would result in 9 avoided leukemia cases (EPA, 2008b). The reduction of industrial source emissions, the primary point source contributor to benzene in Houston's air, will play a key role in the move towards achieving the EPA Clean Air Act toxicity risk goal.

SPECIFIC AIMS

Under Mayor Bill White, Houston is making a push towards instituting industrial benzene emissions reduction policies. Numerous studies have been undertaken within the past few years to assess the extent of industrial emissions impact on benzene in Houston and the health consequences of current ambient levels. However, even with this current movement and available scientific evidence linking benzene to cancer, among many other non-cancerous health effects, the city faces barriers to developing regulations that will reduce industrial source benzene emissions.

The current federal and state regulatory and legal frameworks as well as legal precedents affect several issues critical to reducing benzene emissions. This analysis aims to identify these elements that may hinder the City of Houston from establishing enforceable benzene emissions standards to reduce the overall ambient benzene concentration. The study is intended to recognize and analyze what legal bases industry and business can and have used to argue against the development of benzene reduction policies.

APPROACH

This study will primarily utilize literature search to identify legally based roadblocks to benzene emissions reduction policies. United States government publications, including the Federal Register and Texas Administrative Code will be examined to identify existing benzene-related laws and regulations. Academic Universe, LexisNexis and Texas Courts Online will be used to identify relevant benzene litigation and established case law at the federal, state and local level. The Houston Chronicle database, Medline Ovid and PubMed will also be used to discover any arguments and/or issues related to air toxics regulation. The keywords used in the literature search will be benzene, air toxics, emissions, policy and industry. Lastly, the EPA, TCEQ and Right-to-Know Network websites will be utilized to assess the degree of emissions disclosure among the Greater Houston industry.

The findings from this literature search will be used to identify potential barriers that the City of Houston currently does or could face in its attempt to legally mandate the reduction of industrial major source benzene emissions. The criteria used to assess if an element is in fact a legitimate barrier will be the presence of a legal basis, such as a supporting regulation, law and/or judicial precedent, associated with the constraint. Prospective barriers without legal justification will not be included in this analysis.

FINDINGS

A major source polluter in Texas must obtain an air permit that legalizes its emissions and consequently serves as the basic regulatory mechanism for industrial benzene emissions. As such, the first barrier identified in this study is Texas's air permitting process, which is structured in a way that prevents effective emissions regulation. The permitting process is supported by Chapter 30 of the Texas Administrative Code (TAC); statues included in this code allow the industry to write their own permits, restrict public participation in the permitting process and enable permits to essentially self-renew, which makes it difficult to both tighten emissions limitations and challenge a permit renewal once a permit has been initially granted (30 TAC). The permitting process is supported by the TCEQ and prevents the City of Houston from challenging industrial benzene polluters because TCEQ-authorized air permits sanction such pollution.

The second barrier recognized deals with jurisdictional barriers that the city faces in its attempt to reduce major source benzene emissions. There are multiple legal bases that support jurisdictional roadblocks for the city. Firstly, the EPA's policy of no benzene air quality standards does not allow the city to legally protect its citizens' public health because there are not legally enforceable standards that can be used to hold industrial emitters accountable for their contribution to ambient benzene (EPA, 2008c). Secondly, the Clean Air Act (CAA) grants emissions regulation authority to state, not the city; as such, the TCEQ carries out statues stipulated in the CAA. The City of Houston is not delegated any power to regulate and/or enforce emissions limitations in the Greater Houston region that are outside of corporate city limits, where the majority of benzene-emitting facilities are located. Lastly, the Texas CAA restricts the city's regulatory authority even within Houston city limits (Texas HSC §382). Consequently, the city's limited jurisdiction prevents it from having the legal power to mandate any preventative mechanisms, such as more stringent control technology than currently utilized.

Finally, the city faces the difficult barrier of proving causation between benzene exposure and specific adverse health outcomes that would necessitate benzene air quality standards and consequent emissions reform to protect public health. Houston's ambient air is polluted with a unique mix of petrochemical and refinery emissions, which can make it difficult to assess the impact of benzene on human health separate from the impact of cumulative causation. This barrier is legally supported by the Data Quality Act (DQA), which gives industrial emitters the legal authority to question regulatory science and minimize the impact of academic science in the regulatory process (OMB, 2002). In addition, the judicial precedents set by *Daubert* and *Havner* provide corporate polluters the legal means to challenge causation in the courtrooms and may prevent potential regulatory influence in favor of emissions reductions as a result of successful litigation against major source emitters (*Daubert v. Merrell Dow Pharmaceuticals, Inc.,* 1993; *Merrell Dow Pharmaceuticals, Inc. v. Havner*, 1997).

DISCUSSION

TCEQ's Air Permitting Program

Title V of the 1990 Federal Clean Air Act Amendments stipulates the foundation of statutory requirements for air pollution permitting in the US. Under Section 501 of the title, any major source, which is defined as "any stationary source or group of stationary sources…that emits or has the potential to emit, in the aggregate, 10 tons per year or more of any hazardous air pollutant or 25 tons per year or more of any combination of hazardous air pollutants" is required to obtain a Federal Operating Permit (FOP) in order to legally emit air pollution (CAA §501). The FOP in and of itself alone does not determine any emissions limitations for the particular source it belongs to, rather it codifies and lists all applicable pollution permits, control requirements and exemptions that the facility or group of facilities is supposed to adhere to. As such, the FOP serves as a legally enforceable document that can be used to cite and punish specific violations of any regulation incorporated into the permit.

United States Code (U.S.C.) stipulates that the EPA promulgate permitting authority to an EPA-designated “state air pollution control agency”, referred to as the “Administrator” throughout the CAA (42 U.S.C. §7661). In the case of Texas, the Administrator refers to the TCEQ, which is the environmental regulatory agency for the state. Furthermore, the Code of Federal Regulations (C.F.R.) specifies that this Administrator is required to provide the EPA with a “complete program description describing how the State intends to carry out its [FOP] responsibilities” (40 C.F.R. §70.4). As such, the TCEQ has developed and codified its air-permitting program in Title 30 of the Texas Administrative Code (TAC).

The permit types of primary concern for major industrial sources are New Source Review, Standard and Flexible Permits and Permits by Rule. As previously mentioned, the FOP codifies the individual permits governing a major source’s emissions limitations; this permit category concerns only permits for existing facilities. Title 30 of the TAC also mandates that “any person who plans to construct any new facility or to engage in the modification of any existing facility which may emit air contaminants into the air of this state” must either obtain a new permit or amend an existing permit, known as a Preconstruction Permit (30 TAC §116.110). The aforementioned permit types can thus fall into the Preconstruction or FOP category, depending on why a major source is seeking a permit (i.e. to construct or modify a facility or renew/amend an existing permit).

Although there are numerous concerns with the fundamental concepts of the permits themselves that contribute to the unnecessarily high air toxics concentration levels in Houston, for instance the ability of a source to set a flexible limit on a group of hazardous air pollutants rather than specific limitations for each chemical, the permitting process itself serves as a barrier to potential industrial benzene emissions reductions. The administrative process to create, grant and renew air permits in Texas tie the hands of the City and other concerned parties in the struggle to reduce emissions while the so called protective mechanisms set up to ensure that environmental health and human safety are acknowledged in the permitting process lack any real world application.

Granting Industry-created Permits

The first issue rising from the permitting process relates to the statues governing how a new permit application is created. The TAC stipulates that each permit applicant submit a PI-1 General Application Form, which includes an extensive list of detailed requirements. For example, the applicant must define the proposed or estimated emissions and "how significant emissions will be measured (stack sampling, ambient monitoring, continuous emissions monitoring, leak detection and repair program for fugitive emissions, etc.) to demonstrate initial and ongoing compliance with permit limitations" (30 TAC §116.111). The applicant must also describe the location of each emission point and develop a "process flow diagram" that can be used to verify why and how hazardous chemicals are used and the reason for their emission (TCEQ, 2008b). Also of particular importance is the applicant's responsibility to demonstrate that the facility will use the "best available control technology (BACT) with consideration given to the technical practicability and the economic reasonableness of reducing or eliminating emissions from the facility" (30 TAC §116.111). The applicant must ultimately ensure that its facilities operations and emissions are consistent with the "protection of public health and welfare" (30 TAC §116.111).

Though the previously mentioned requirements and many other permit application rules seem to provide procedures to protect the environment and ultimately human health, there are several significant flaws. Firstly, a major problem is the entity *writing* the permit, that is, the applicant itself. This means that the petroleum refiners and petrochemical manufacturers are writing their own permits and essentially regulating their own emissions limitations and measurement procedures, a power legally vested to the industry by the TAC. To prevent any abuse of this power, the accuracy of each application of course must be "certified by a responsible official" (30 TAC §122.132). However, this responsible official or authorized representative can be an approved technical consultant that is hired by the applicant to represent the respective company (TCEQ, 2008b).

The application must ultimately go through a technical review by the TCEQ, yet the scrutiny applied during this review is questionable. For instance, as previously mentioned, the applicant must provide the TCEQ with a description and flow chart of their emissions points and production processes to help the application reviewer understand where and why the emissions are being created. However, the application form itself states "permit reviewers know only what you [the applicant] tell them about your process or business. It is important that the information you provide is complete and accurate" (TCEQ, 2008b). In addition, Texas Code requires that BACT standards are utilized to reduce pollution; however, the ambiguous language of the statute allows for the consideration of "economic reasonableness" when choosing which BACT guidelines to adhere to. This way, major source emitters can pick and choose which BACT to employ, regardless of improved BACTs and newer Maximum Achievable Control Technology (MACT) available for the respective industry.

Furthermore, one comparative study showed that of 14 industrial states (including AZ, CA, LA, NJ and NY), Texas had the second fastest air permit application processing time (6 - 9 months), despite the fact that in 2003, only nine application reviewers assessed 6,596 New Source Review permits (O'Brien, 2005). Only Arizona has a faster processing time and only by one month; on the other hand California, historically recognized as the US leader in strict environmental regulation, has the longest review period of 21-28 months (O'Brien, 2005). In fact, the TCEQ itself has noted that since the majority of applications are not commented on and/or contested, they never even reach the three person commission for final review and approval (O'Brien, 2005). These circumstances reflect both the degree of reliance the TCEQ places on the industry and industry-hired consultant to disclose all possible sources and amount of emissions that are expected and dictate their own level of best pollution control standards and acceptance of this information as truth. Consequently, the policy allowing applicants to write their own permits prevents concerned parties, such as the City, from challenging benzene emissions estimates and control strategy compliance when the TCEQ basically authorizes the industry to operate at its own discretion.

(Lack of) Public Notice

In order to protect public interest, before an air permit is granted, the TCEQ does require major source applicants to publish a "notice of receipt of application and intent to obtain permit" within 30 days of an application declared administratively complete, so as to allow public comment in response to potential permit authorizations (30 TAC §39.411). This mechanism is important to ensure that affected individuals are afforded the chance to raise any concerns with the potential impact of industrial emissions on public health and welfare.

However, the regulations governing this public comment opportunity are insufficient and may restrict individuals from taking full advantage of the opportunity to challenge benzene emitters.

Firstly, one public notice can be published in a “newspaper of general circulation in the municipality in which the facility is located or is proposed to be located or in the municipality nearest to the location or proposed location of the facility” (30 TAC §39.603). The Greater Houston area boasts over 34 local general circulation newspapers, aside from the major newspaper, the Houston Chronicle (www.hcnonline.com). This means that an applicant can publish notice in one of the smaller general circulations, reducing the audience the notice will reach. Moreover, it is common sense that air pollution does not respect city borders; even if a facility’s emissions are pushed into Houston due to wind patterns, but the facility is outside city limits, the applicant can publish notice in the municipality it is located in. Next, a sign must be placed at the site or proposed site itself (30 TAC §39.604). Though this is a sound rule, it can be assumed most individuals do not inspect industrial sites on a daily basis and will consequently never physically see such a sign. The chief clerk must also send out a written mail notice (30 TAC §39.602). However, only the applicant, persons on a mailing list, any other person the executive director or chief clerk may elect to include and persons who have already filed public comment are required to be notified of an application via mail (30 TAC §39.413). This means that individuals must register to get on one of two narrow mailing lists, that is either the permanent mailing list for a specific applicant or single county, if they would like to be notified (TCEQ, 2006). Moreover, the City of Houston is not automatically included on this list.

The public comment period compounds the shortfalls of the public notice requirements. This period ends exactly 30 days after publication of the notice (30 TAC §55.21). As such, a person or group must gather and present all relevant concerns, arguments and supporting data within 30 days of the published notice, which may not provide sufficient time if the potential impacts and grievances are far reaching and complex. Additionally, even if public comment is presented, the applicant is not obligated by any statutory requirement to respond to the comment or question, rendering the comment unacknowledged, unless the Commission itself decides further investigation is necessary (Vickery, 2009).

Self-renewing Permits

After a permit is approved, the TCEQ does not have the legal authority to require additional controls to reduce emissions, decrease emissions limitations or alter the permit in any manner (Vickery, 2009). The only time when additional restrictions can be imposed on a permit is during an application for permit renewal. However, permit renewals are only required every 15 years after the date of permit issuance for facilities permitted before December 1, 1991 and every ten years after the date of issuance for facilities permitted on or after December 1, 1991 (30 TAC §116.315). As such, benzene-emitting sites can operate using 10 to 15 year old emission control technology, without the threat of interference from the TCEQ, which ensures that unhealthy levels of emissions can continue to pollute ambient air, even in light of newer and more health-protective control technology. Furthermore, once a permit has been initially granted, it is virtually impossible for the TCEQ to deny a renewal.

Firstly, the majority of permit renewals are not subject to public notice; the primary reason for renewal notice is when and applicant requests a "change in character of emissions or release of an air contaminant not previously authorized under the permit" (30 TAC §39.402). Since TAC does not allow for the TCEQ to "impose requirements more stringent than those of the existing permit" or to reduce emissions limitations during a renewal, most facilities, especially older ones, will not need to increase their emissions limitations because they were already set so high in their initial permit (Vickery, 2009). For instance, Houston Refining, LP has applied for and received approval of 17 changes to its flexible permit since first granted in 1999; however, only one of the 17 alterations was subject to public notice (White, 2008). This policy prevents concerned individuals from submitting their questions, comments and criticisms to the TCEQ thus minimizing the chance of any necessary investigations.

Next, if an applicant provides documentation showing that their "facility is being operated in accordance with all requirements and conditions of the existing permit", the TCEQ must renew their permit without restrictions (30 TAC §116.311). This is especially problematic, as the industry is known to severely underreport their pollutant emissions (EIP-GHASP, 2004; City of Houston, 2008b). For instance, in 2008 two TCEQ investigators discovered that an east Houston industrial facility permitted to release 25 tons of VOCs per year in reality emitted an estimated 386 tons; however, the company reported releasing only 4.7 tons of VOCs for that same year (TCEQ, 2008c).

In 2001, the TCEQ spent approximately $2 million dollars to develop a compliance rating system and legally enforceable rules that would allow the Commission to consider a company's compliance history when reviewing a permit renewal application (O'Brien, 2005; 30 TAC §60.1). The compliance history itself includes many components, notably any notice of violations, legal proceedings and participation in voluntary emissions reduction strategies (30 TAC §60.1). The compliance history rating system is an important safeguard that ideally can be used to impose provisions and more stringent limitations on those facilities that do not abide by the regulations listed on their permit(s). However, the regulations governing the formulation and use of the rating system are deeply flawed.

The compliance rating is based on one large and complex formula that takes into account many components, for example, the number of major and minor violations, the number of enforcement orders and the number of chronic excessive emissions events. Each of these numbers are then multiplied by respective set numbers. Next, the total number is divided by the number of investigations conducted during the compliance period, plus one (30 TAC §60.2). The resulting number is the site's rating, with a lower number indicating higher compliance. The denominator, the number of investigations, presents an obstacle to developing an accurate compliance rating because the more investigations a site incurs, the higher its compliance rating will be (i.e. 100/2 = 50, 100/4 = 25, where the lower number is the higher rating). As such, though a facility may be cited for X number of violations or legal enforcement, the resulting X number of investigations can ensure that the score remains low.

A compliance rating falls into one of three categories: "(1) a high performer, which has an above-average compliance record; (2) an average performer, which generally complies with environmental regulations; or (3) a poor performer, which performs below average”, where a poor performer has a score of 45 or above (30 TAC §60.2). Renewal applicants categorized as poor compliers can be subject to “additional oversight necessary to improve environmental compliance”, such as additional control technology implementation or emissions restrictions (30 TAC §60.3). However, the inefficient rating system formula ensures that most facilities will never be categorized as poor performers. For instance, the TCEQ notes that of the approximately 150,000 currently permitted sites in Texas, only 1,022 or 0.006% are rated in the poor category (Vickery, 2009). Moreover, only 12 facilities in the Houston area were responsible for 5.5 million pounds or 80% of the entire region’s excessive emissions in 2003 (Capiello, 2004). However, none of these facilities are ranked as poor compliers. As such, the largest air polluters are able to regularly amend and renew their permits because the statute only provides for enforcement against those facilities with a poor compliance rating.

Contesting a Permit Renewal

During the 30-day public comment period, individuals, specifically the Commission, executive director, the applicant, a legislator or an “affected person” have the opportunity to contest a permit renewal application (30 TAC §55.21). This legal provision is an important mechanism in the permit renewal process that can help protect public and environmental health. However, a TAC statute provides that the executive director has the ultimate say to decide if a hearing is necessary and warranted, depending on his or her assessment of the evidence presented by the contester against the applicant and if the contester will in fact be personally impacted by the permit decision (30 TAC §55.27). Moreover, a permit renewal that does not seek an increase in allowable emissions cannot be subject to a contested case searing (30 TAC §55.27).

These stipulations vest authorization power in one person's hands and place restrictions on which permits can be contested and thus may greatly diminish the impact that potential case hearings can have on keeping industrial benzene emitters in check by ensuring companies prove they are in compliance with their current permit and that the permit's regulations do not pose a threat to human health. For instance, between 2001 and 2003, approximately 7% of 8,970 challengeable permit applications received hearing requests; however, the TCEQ granted case hearings for only 6% of the total requests (O'Brien, 2005). More recently, in 2008 the City of Houston filed a hearing request to challenge the renewal of Houston Refining, LP's flexible permit. Though the City cited evidence that the applicant, the largest benzene-emitting refinery in the nation, poses potential excessive carcinogenic risks to the public, the TCEQ's executive director did not grant a case hearing (Vickery, 2009).

Furthermore, even if a case hearing is granted and consequently referred to the State Office of Administrative Hearings (SOAH), the TCEQ retains legal authority to take action on any permit (30 TAC §122.110). This ensures that the independent assessment by the state administrative judge(s) can go without any real impact on the renewal decision. For example, in 2007 the El Paso based smelter operator American Smelting and Recycling Co (ASARCO, LLC) requested a permit renewal after it had not been in operation for 8 years due to bankruptcy brought on by $25 billion dollars worth of environmental and asbestos claims, including the mandated Superfund cleanup of more than 1,000 El Paso homes that the smelter had contaminated (Loftis, 2009). After two SOAH judges heard the case against ASARCO, LLC's permit application, they recommended that the TCEQ deny the permit renewal. However, the TCEQ disregarded the judges' counsel and went on to approve the renewal request. As such, what should be a safeguard against the TCEQ's authority to grant any and all permits as it sees fit, the hearing essentially lacks any real enforcement power.

Jurisdictional Issues

The TCEQ grants major source air permits that function to regulate benzene emissions throughout the state of Texas. However, shortcomings of the permitting process and inefficient TCEQ oversight of compliance and enforcement fail to maximize a permit's potential regulatory authority and consequently the potential emissions reductions a permit can legally mandate. As such, ambient air concentration levels of benzene in the Greater Houston area continue to pose additional health risks to individuals throughout the region. The City of Houston has acknowledged this problem and is attempting to address it; however, several policies legally constrain the city from regulating industrial emissions within Greater Houston.

No Policy is a Policy

The first issue of importance with perhaps the greatest impact on benzene emissions reduction goals in Houston is the absence of national or state level benzene air standards. The CAA stipulates that the EPA must establish NAAQS for pollutants "considered harmful to public health and the environment" (EPA, 2008c). NAAQS are legally enforceable maximum air concentration level for pollutants, which can have a substantial impact on the regulation of benzene emissions in area like Greater Houston, due to the large number of petrochemical and refining facilities that contribute to ambient benzene. However, even though the EPA has classified benzene as a Class A human carcinogen, it has failed to establish NAAQS for the air toxic. Moreover, though the EPA has developed cancerous and non-cancerous health risk threshold guidelines for benzene air levels, these levels are not legally enforceable. The TCEQ has adopted its own ESL guidelines that are even more liberal than the EPA's 1 in 1 million health risk suggestion and are also not legally enforceable.

As such, the City of Houston does not have a federal or state-level legal point of reference to use in order to hold industrial facilities accountable for their contribution to the high levels of ambient benzene in Houston's air. For instance, the TCEQ's Air Pollutant Watch List (APLW) identifies areas of particular concern known as "toxic hotspots" where the level of an air toxic has routinely exceeded its respective ESLs (TCEQ, 2009). These areas can remain on the APWL for an indefinite amount of time and the City of Houston or the relevant municipality where the site lies lack regulatory power to protect the public health of city residents by imposing additional emissions restrictions on major sources creating the hotspot. Since the City of Houston does not have the authority to establish ambient air quality standards, NAAQS for benzene could ultimately necessitate and provide the city with legal basis for tighter major source benzene emissions limitations and more protective control technology, especially in industrial complexes that lie within APWL areas.

CAA Delegated Authority

The CAA serves as the pollution prevention framework for the US and provides statutory protections for public and environmental health. Such protections are regulated by each “single state agency designated by the governor of that state as the official air pollution control agency for purposes of [the CAA]” (CAA §302). As such, these state agencies are given the authority to carry out provisions of the CAA, such as the power to regulate emissions, grant permits, enforce policies, penalize CAA violators and establish state-level ambient air quality standards. In Texas, these powers are delegated to the TCEQ which is the state’s highest authority on air pollution control and prevention.

As the TCEQ continues to support a flawed permitting system, has failed to proactively restrict major source benzene emissions and penalize permit violators and has not established any legally enforceable ambient air quality standards for benzene, the City of Houston is left to protect its residents with what available regulatory power and legal ordinances it has available. However, the chief problem with this situation is that the worst industrial benzene emitters are outside of Houston’s city limits. The 10-county Greater Houston region encompasses over 10,062 square miles and 5,628,101 inhabitants, while Houston’s corporate city limits and thus jurisdiction only extends 579 square miles, encompassing 2,144,491 inhabitants residing in areas within Harris, Brazoria and Fort Bend Counties (US Census Bureau, 2006). However, according to the TRI (2004) only one of the top ten benzene-emitting facilities within the 10-county region lies within Houston’s city limits (Table 4).

Table 4: Top Ten Benzene-emitting Facilities in Greater Houston

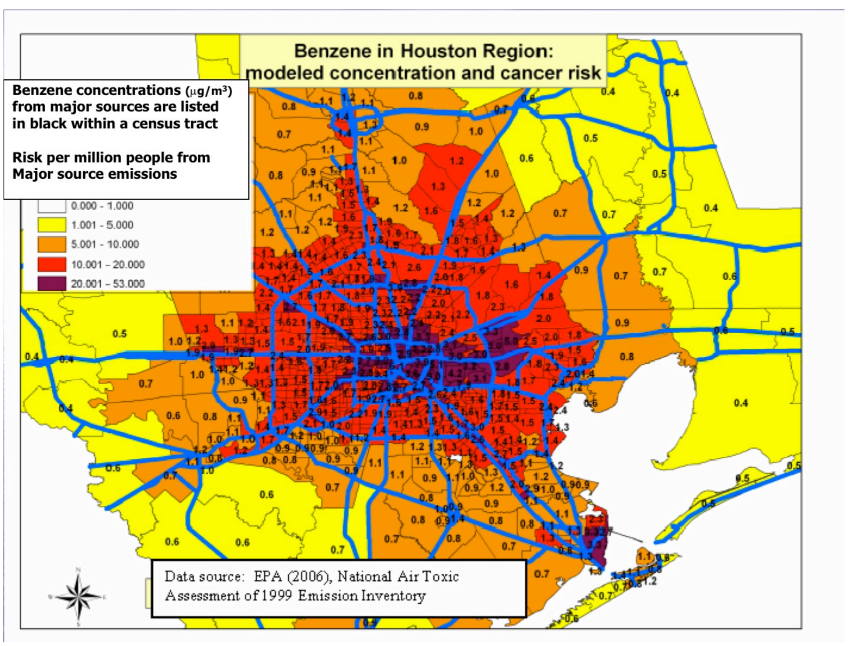
Facility	**City/County**	**Total benzene emissions (Annual tons per year)**
BP Products North America Texas City	Texas City/Galveston	86.675
Equistar Chemicals LP, Channelview Complex	Channelview/Harris	51.5511

ExxonMobil Chemical Baytown Chemical Plant	Baytown/Harris	49.5266
Lyondell Houston Refining LP	Houston/Harris	41.7735
ExxonMobil Chemical Baytown Olefins Plant	Baytown/Harris	41.5693
Shell Oil Deer Park	Deer Park/Harris	34.2546
Dow Texas Operations Freeport	Freeport/Brazoria	31.8008
Equistar Chemicals Chocolate Bayou Complex	Liverpool/Brazoria	29.0378
Lyondell Chemical Channelview	Channelview/Harris	28.947
ExxonMobil Baytown Facility	Baytown/Harris	26.105

(Data from City of Houston, 2007a)

Moreover, Harris County bears a disproportionate burden as 7 of the top 10 emitters lie within this county, adjacent to Houston's city limits. In fact, according to the EPA, some of the highest additional cancer risk levels from ambient benzene inhalation in the Greater Houston region occur within Houston city limits rather than areas surrounding some of the largest benzene emitting facilities due to Gulf Coast wind patterns that push polluted air into the city (Figure 4).

Figure 4: Greater Houston Region Modeled Benzene Concentration and Cancer Risk



(City of Houston, 2007b)

Since the city's jurisdiction does not cover areas where most of the large emitters lie, the City of Houston lacks legal authority to regulate Greater Houston's major source benzene emissions even though the toxic from these facilities pollutes air within the city's limits and poses adverse health risks to Houstonians. Furthermore, jurisdictional constraints prevent the city from bringing available legal action against these emitters. For instance, a current Houston neighborhood nuisance ordinance stipulates that "whatever renders the ground, the water, the air, or food a hazard to human health" is a nuisance, including any offensive matter, gases or odors that are "likely to become hazardous to health or a source of discomfort to persons living or passing in the vicinity" (Houston Code of Ordinances §10-451). This ordinance can provide the city with authority to file charges against industrial benzene polluters; however, as most of the major sources lie outside Houston, the city's jurisdictional limits prevent it from using the nuisance ordinance to reduce benzene emissions.

Texas CAA: Further Jurisdictional Restraints

The Federal CAA does provide authority to "a city, county, or other local government health authority, or, in the case of any city, county, or other local government in which there is an agency other than the health authority charged with responsibility for enforcing ordinances or laws relating to the prevention and control of air pollution, such other agency" to regulate and prevent air pollution within the respective municipality (CAA §302). In addition, the Texas CAA recognizes this authority and clearly states that a "municipality has the powers and rights to (1) abate a nuisance; and (2) enact and enforce an ordinance for the control and abatement of air pollution" (Texas HSC §382.113). As such, the City of Houston should at least be able to regulate major source benzene emissions within city limits. However, the Texas CAA adds one key inhibitive provision to municipal authority; section 382.113 goes on to stipulate that any "ordinance enacted by a municipality must be consistent with [the Texas CAA] and the commission's rules and orders". This restriction essentially strips the City of Houston's legal regulatory authority to enact an ordinance that could reduce benzene emissions within city limits. For instance, the TCEQ can "establish the level of quality to be maintained in the state's air" and "control the quality of the state's air" (Texas HSC §382.011). Since the TCEQ has failed to establish state-level benzene air standards, the Texas CAA statute prevents the City of Houston from establishing local standards because such an ordinance would be inconsistent with the TCEQ's current no air standards policy.

In addition, the Texas CAA also prohibits the city from making a "condition or act approved or authorized under [the Texas CAA] or the commission's rules or orders" unlawful (Texas HSC §382.113). As such, the city is legally restricted from going against any TCEQ rule and may not hold industrial facilities within the city limits accountable for environmental pollution if the pollution is legally sanctioned by the TCEQ. Consequently, even if all of the major industrial benzene emitters were located within the city limits, the Texas CAA greatly limits the city's jurisdictional authority to protect public and environmental health through benzene emissions reduction policies. For example, in 2007 the City of Houston developed a benzene air pollution reduction plan, which provided top emitters with strategies to reduce emissions over the next 5 years (City of Houston, 2007a). However, the plan was voluntary and with out legally binding implications, because such a policy would not be consistent with the Texas CAA and was not adopted by any facility (City of Houston, 2008a). According to the Texas CAA, ultimately only the TCEQ, short of approved state legislation, has the power to legally mandate emissions reform. This jurisdictional restriction thus prevents the City of Houston from enacting any enforceable benzene emission reduction plans.

Proving Causation

Since the city does not have the authority to regulate ambient air standards for benzene and the TCEQ and EPA have failed to do so, the most critical activity to further progress in benzene reduction goals would be to establish definitive causation between low level population exposure to the toxic and related negative health consequences. Peer-reviewed science plays an important role in environmental regulation. In Houston, proving causation can be especially difficult where there is already a high level and unique mixture of industrial toxic emissions. As such, Houston-specific studies that link individual benzene exposure to cancerous and non-cancerous adverse health effects are needed to serve as a potential catalyst for tighter emissions controls and industrial oversight as demonstrated causation would pressure the state to step in and institute legally enforceable ambient air standards to protect human health.

As previously mentioned, decades of animal and human epidemiological studies have cited strong evidence that benzene is a human carcinogen (Fraser et al., 2006). Regardless, since a 1987 analysis of the Pliofilm cohort found an excessive cancer risk associated with 8-hour TWA exposure to benzene at 1ppm (which forced OSHA to adopt its current maximum exposure standard), the industry has and continues to fund its own research in an attempt to challenge and discredit well-conducted and controlled studies to prevent further regulation

(Rinsky et al., 1987). For instance, several studies funded by the oil industry after the adoption of the OSHA standard indicate that there is no to marginal excessive cancer risk when exposed to benzene and that this associated risk does not necessarily demonstrate causation (Gettleman et al., 2005; Fraser et al., 2006). More recently, the NCI/CAPM studies conducted in China have confirmed excessive cancer risks associated with low levels of benzene exposure and further established negative hematopoietic effects at exposure to levels lower than 1ppm; in reaction, five major oil companies (BP, ChevronTexaco, ConocoPhillips, ExxonMobil and Shell) have undertaken a $27 million dollar study to "respond to allegations from [the] nationwide study of benzene exposed workers" (Lan et al., 2004; Capiello, 2005).

Giving Industry Legal Authority to Question Science

Until recently, attempts by industrial companies to raise uncertainties in toxics exposure-outcome research have been just that, attempts, regardless of success or failure. However, proving causation has now become an even more daunting task and barrier to emissions reform since the US legislature enacted the DQA. This statute was attached as a short two-paragraph provision to the Treasury and General Government Appropriations Act, Fiscal Year 2001 (Government Printing Office, 2001). Officially titled "Guidelines for Ensuring and Maximizing the Quality, Objectivity, Utility and Integrity of Information Disseminated by Federal Agencies", this act can essentially serve industrial interests and lengthen the already slow process of developing environmental regulations (OMB, 2002).

According to Office and Management and Budget, the legally enforceable guidelines were created in light of the fact that the "internet enables agencies to communicate information quickly and easily to a wide audience" which can ultimately "increase the potential harm that can result from the dissemination of information that does not meet basic information quality guidelines" (OMB, 2002). Under the statute, each federal regulatory agency is required to develop agency-specific information quality guidelines to ensure information they disseminate can hold up against the DQA standards and must also establish "administrative mechanisms allowing affected person to seek and obtain correction of information" that the respective agency disseminates (OMB, 2002). Accordingly, the EPA has published its agency standards in compliance with the DQA; however, the provisions of the act enable the industry to attack academic and regulatory science while promoting its own research.

Firstly, quality refers to "objectivity" that is "whether the disseminated information is being presented in an accurate, clear, completely and unbiased manner", "integrity" that refers to the "protection of information from unauthorized access or revision" and "utility" which refers to the "usefulness of the information to the intended users" (EPA, 2002). Any "communication or representation of knowledge such as facts or data, in any medium or form" that the EPA disseminates must hold up against the quality guidelines (EPA, 20002). As such, if an oil company or petrochemical manufacturer has an issue with EPA-disseminated research, the company is legally entitled to request that the information be corrected (RFC) or removed from the EPA website based on a complaint related to any of the three quality components. For instance, in 2007 the National Association of Manufacturers (NAM) submitted an RFC in response to the EPA's risk analysis of ground ozone that was to be used in developing more stringent NAAQS for the pollutant, citing that the risk assessment was not presented in an objective manner (NAM, 2007). In 2005, the Texas City-based Sterling Chemicals filed a RFC in reference to an excessive chemical release violation published on the EPA'S Enforcement and Compliance History website, claiming that there was no evidence for violation of the CAA and that the published data was "misleading" and "biased" (Sterling Chemicals, 2005). Even if such petitions do not hold up, the EPA is required to respond to each claim and subsequent related claim until the matter is resolved, which can clog up the regulatory agenda and delay public health protections.

Next, "influential" information must be held to higher standards than the basic quality requirements, where influential refers to scientific, financial or statistical information, which the EPA can "reasonably determine that the dissemination of…will have or does have a clear and substantial impact on important public policies or private sector decisions" (EPA, 2002). For instance, the agency ensures this higher standard by requiring all science it disseminates be held to a stringent reproducibility standard; this entails a "higher degree" of transparency about the data and methods of the research that will allow a third party to ascertain the same results upon study duplication. Influential research must also only include data that is collected by "accepted methods" (EPA, 2002). Though these concepts are important factors in scientific research, the industry can use the legally mandated standards in situations where the information can have a potentially negative impact on company interests. For example, in 2004 Dow Chemicals challenged the EPA's use of its computer model used to estimate potential groundwater flow to determine contaminant fate; citing that the information was influential in light of a pending 3000 plaintiff class action lawsuit for alleged damages from the environmental contamination, Dow Chemicals claimed that the model was not accurate and should be held to a higher standard (Dow Chemicals, 2004).

If the EPA funds, for instance through a specific grant, research, but does not disseminate it, the research is not subject to the Office of Management and Budget (OMB) guidelines. However, even though the EPA sponsors the research, the researchers must explicitly state that the information being offered "is someone's opinions rather than fact or the EPA's views" (EPA, 2002). Moreover, if the EPA does in fact decide to disseminate the research on its own website, the research becomes subject to the OMB guidelines. In addition, even though the OMB and EPA formally recognize that data and analysis that undergo "formal, independent and external peer review", are presumably objective, the DQA assumes that this objectivity is "rebuttable" and thus allows anyone to challenge even the most extensively peer-reviewed research that the EPA chooses to disseminate.

Lastly, all of the aforementioned guidelines apply to only federal agency disseminated research. This means that the quality, reproducibility and related standards do not apply to research that is produced and disseminated by industrial companies. Moreover, federal agencies cannot legally challenge industry-sponsored research. As such, corporations can not only challenge EPA disseminated research but at the same time can continue to publish their own lower quality risk assessment analyses that can be used to further fuel uncertainties regarding the effects of toxic chemicals, such as benzene, on human health. The DQA will exacerbate the difficulties of proving causation and can essentially allow the industry to influence how quickly information reaches the public, which can hinder the regulatory process.

Judicial Precedents Working for Industry

In response to lax state control regulations and minimal oversight of major source benzene emissions, individual citizens are forced to take on industrial emitters in the courtroom. Unfortunately, such litigation most commonly occurs after a person's health has been already been adversely affected by benzene exposure. On the other hand, toxic tort litigation can play an important role in the policy formation process; through successful litigation, industrial companies can be held publicly accountable for their emissions and environmental violations and risk assessments upheld by the judicial system can make a positive impact on ambient air regulation efforts. However, the *Daubert Standard* set by Merrell Dow Chemical's 1993 litigation victory provides the industry with legal authority to challenge science in the courtroom (*Daubert v. Merrell Dow Pharmaceuticals, Inc.,* 1993). Moreover, the Texas Supreme Court established *Havner*, a strict extension of *Daubert*, which further helps discredit studies evidencing causation and thus successful toxic litigation against industrial polluters (*Merrell Dow Pharmaceuticals, Inc. v. Havner*, 1997).

Since 1923, courts have based the admissibility of expert scientific testimony on *Frye*, which holds that a scientific principle or discovery must "be sufficiently established to have gained general acceptance in the particular field in which it belongs" to provide evidential force (*Frye v. United States*, 1923). This standard prevents the courtroom from being filled with pseudoscience, but still allows a jury to hear and determine if evidence based on generally accepted principles support or do not support a plaintiff's claims. However, in *Daubert v. Merrell Dow Pharmaceuticals, Inc.* (1993), the Ninth Circuit court declared that the 1975 Federal Rules of Evidence (FRE), particularly Rule 702, superseded the *Frye* test of admissibility and granted summary judgment in favor of the defendant; in this case, the defendant claimed that *Bendectin*, an anti-nausea medication for pregnant women, had caused birth defects in her child, just as it had in a number of other children whose mothers had taken the drug. Nevertheless, the judges found that the in vitro and in vivo animal studies and chemical structure analyses, which the plaintiff's expert opinion provided the basis for, were not admissible to signal causation as the findings did not come from epidemiological evidence and thus did not satisfy Rule 702 and its translated standards (*Daubert v. Merrell Dow Pharmacueticals, Inc.,* 1993). This judicial precedent is now known as the *Daubert* Standard and governs the admissibility of science in the courtroom.

Daubert provides a checklist for judges to determine if expert testimony is both relevant, that is will "substantially assist the fact-finder [jury]" and reliable (FRE 702). The reliability of expert opinion is assessed according to 4 key indicators, as identified in amendments to Rule 702. These factors are: (1) whether the expert's technique or theory can be or has been objectively challenged; (2) whether the technique or theory has been subject to peer review and publication; (3) if there is known or potential rate of error of the technique or theory; and (4) whether the technique or theory has been generally accepted in the scientific community" (FRE 702). Although important, these standards demand exact science for each specific piece of evidence and do not allow for the holistic assessment of the entire body of research and evidence. Conversely, science as a field is and can not be exact; researchers, especially those studying the effects of toxic chemicals, must base their conclusions on extrapolations from animal studies and if possible, natural human studies, to develop a dose-response curve that can only suggest the likelihood of increased health risk from exposure to any given substance. In addition, the general acceptance of scientific techniques is always changing; for instance, the scientific community now generally accepts deductions from live animal studies, which were inadmissible in the *Daubert* case, as legitimate sources of data. Moreover, in depth peer review is a lengthy process; theories based on valid scientific methods can take years to be affirmed throughout the scientific community.

Of even greater importance, Daubert states that the trial judge enjoys the "responsibility of acting as gatekeeper to exclude unreliable expert testimony" (FRE 702). This means that the judge, a single person, retains the power to decide if highly technical scientific data relevant to human health holds up against his or her own interpretation of the *Daubert* Standard. In fact, in his dissent, Chief Justice Rehnquist noted that Daubert should not give judges "authority to become amateur scientists in order to perform that role [of gatekeeper]" (*Daubert v. Merrell Dow Pharmacueticals, Inc.,* 1993). This is not to say that a judge is incapable of determining legitimate expert opinion free of his or her own bias; however, the 7th amendment protects individuals from such executive decisions by providing for a trial by jury. In civil toxics litigation, the plaintiff's entire defense generally rests on the evidence of expert testimony to demonstrate a casual association between an exposure and outcome. If the judge is allowed to throw out such evidence, the jury, who can pool their knowledge and debate the weight of any evidence, will never even see the case because the judge will have no choice but to declare no-evidence summary judgment in favor of the defendant. *Daubert* inherently questions the ability of a jury to assess scientific testimony but supports the trial judge's ability to do this on his or her own.

It is worth acknowledging that *Daubert* motions can be filed be either party, the plaintiff or defendant. However, in civil litigation, the accuser bears the responsibility of proof to demonstrate that the accused is guilty of inducing harm. As such, it is usually the plaintiff that requires expert opinion to support his or her case. Consequently, it is the industrial companies that can benefit from *Daubert* to question the admissibility of a plaintiff's expert testimony. Moreover, *Daubert* provides a jury cannot be expected to assess the "validity of dramatically opposed testimony" in regards to highly technical or scientific matters (FRE 702). Accordingly, defendants, such as those in the oil industry which are well known to fund and produce research in response to studies that link benzene to adverse human health effects, can submit their own expert opinion to contradict the plaintiff's; in such a case, *Daubert* stipulates that both parties' opinion be tossed prior to trial, which can leave the plaintiff without the evidence necessary for trial by jury.

The Texas justice system has developed its own extended version of *Daubert* based on standards established in *Merrell Dow Pharmaceuticals, Inc. v. Havner* (1997). In this case, the Nueces County District Court had originally judged in favor of the plaintiffs, who sought damages from Dow Pharmaceuticals, Inc. due to the teratogenic effects of Bendectin on their child. On a subsequent appeal, the Texas Supreme Court reversed the ruling in favor of Dow citing that the epidemiological evidence offered was "legally insufficient to establish that the child's defect was caused by exposure to the drug" (*Merrell Dow Pharmaceuticals, Inc. v. Havner*, 1997). As such, *Havner* instituted legal sufficiency requisites for the admissibility of epidemiological evidence, based on considerations beyond those in the *Daubert* test.

According to precedent set in *Havner*, epidemiological studies that hold up against Daubert must further satisfy significance requirements to prove causation. Firstly, the evidence must not only show a doubled risk (RR=2.0) of outcome following exposure to the toxic, but the cited risk must also be demonstrated with a 95% confidence interval and the confidence boundaries may not include 1. The judges noted even if a study shows a relative risk of 2.3 but with a confidence interval at 95% the boundaries range from 0.8-3.1, the results are not statistically significant (*Merrell Dow Pharmaceuticals, Inc. v. Havner*, 1997). This is clearly in alignment with general scientific knowledge; however, in the legal setting, particularly with toxic exposure litigation dealing with benzene, this rule may discredit sound evidence. For instance, current ambient air guidelines for benzene carcinogenicity are based on extrapolations from available studies, most of which look at high-level exposure. As such, dose-response curves are not exact and do not provide definitive cutoffs signifying when a person will get cancer, especially as the long-term effects of chronic low-level exposure are not known. Moreover, there is no known threshold limit for cancer, let alone benzene carcinogenicity.

Next, *Havner* demands that the plaintiff must prove that he or she is “similar to those in the studies”, including that the “exposure or dose levels were comparable to or greater than those in the studies” and the “timing of the onset of injury was consistent with that experienced by those in the study” (*Merrell Dow Pharmaceuticals, Inc. v. Havner*, 1997). This is especially problematic with major source benzene exposure in Houston. First, the ambient air monitoring of benzene is inconsistent, different sampling methods are used and depending on the monitors’ locations they can deliver estimates from the actual levels in the air. In addition, it is difficult to extrapolate the amount of individual exposure to benzene from ambient air concentrations for many reasons, for instance the amount of time one spends indoors versus outdoors and the proximity to and location (downwind versus upwind) from emissions. Moreover, estimating the impact of fugitive emissions events on a person's overall exposure and the impact of this event on triggering a health outcome can be complex, if not impossible. For instance, in *Frias v. Atlantic Richfield Co., Lyondell Petrochemical Co. and Lyondell-Citgo Refining Co.* (2003), the judges did not question that studies prove occupational exposure to benzene could and may have caused the plaintiff's aplastic anemia. However, the Houston Court of Appeals cited that "indefinite terms [such] as 'consistently', 'regular' and 'occasional' exposure to levels of benzene up to 1000ppm left out exact frequency measurements, such as "hourly", "daily" and "weekly" and thus did not fulfill the legal sufficiency standard of plaintiff comparability to the studies.

Lastly, the precedent also dictates that even when the former standards are met, "epidemiological studies only show an association" and do not necessary indicate causation or legal sufficiency (*Merrell Dow Pharmaceuticals, Inc. v. Havner*, 1997). The plaintiff must provide proof beyond general causation (where a "substance is capable of causing a particular injury or condition in the general population") and evidence specific causation that the substance actually did in fact cause the specific outcome. This means that if there are other plausible causes of a condition, the plaintiff "must offer evidence excluding those causes with reasonable certainty" (*Merrell Dow Pharmaceuticals, Inc. v. Havner*, 1997). This stipulation makes it harder to prove causation and easier for the industry to question expert testimony. As most diseases, benzene-induced health outcomes such as leukemia, non-Hodgkin's lymphoma and aplastic anemia can be caused by factors other than benzene exposure, including basic genetic susceptibility. For instance, *Austin et al. v. Kerr-McGee Refining Corp. et al.* (2000), the Texakarna Appellate Court judged in favor of the defendant, citing that though the deceased's exposure to radiation was at best "insignificant", the plaintiff failed to exclude this as a cause in this specific case of chronic myelogenous leukemia with reasonable certainty. As such, the many layers of *Daubert* and *Havner* further impede individuals from establishing causation and inhibit the potential effect of successful benzene litigation on the regulatory process.

LIMITATION AND STRENGTHS

The primary limitation of this study that it only identifies barriers to reducing major source benzene emissions in Houston that have a legal basis which can be used to support anti-regulation efforts. The regulatory process is lengthy and dependent upon many interrelated factors. The analysis does not consider barriers without legal foundation. For example, there have been numerous attempts to legislatively challenge current TCEQ practices; however, the impact of industry's influence in the Texas legislature may potentially function as a barrier to passing pro-environmental legislation. The 80th Legislature of Texas was a Republican majority, the party which during the 2006 election cycle collected 78.48% of the total political contributions from the oil and gas, chemical and related manufacturing and smelting and refining industries (National Institute on Money in State Politics, 2006). In 2007, only two of the over twenty air quality bills related to creating improvements in the state's air permitting and toxic hotspots programs, monitoring, compliance and enforcement were passed by 80th Texas Legislature (Blackburn, 2007). Likewise, the study does not consider economic constraints that the TCEQ faces in its attempt to monitor and enforce emissions regulations, which are vital to ensuring permit compliance. The TCEQ's poor oversight may be due primarily to inefficient funding; as such, if this is the case, then an increase in funding could result in greater industry accountability and thus an overall reduction in benzene emissions. The issues related to emissions regulation are complex and multilayered; this study only considers barriers with legal reference points.

In addition, the analysis focuses on how the identified legal statues, regulations and judicial precedents function to work against reducing major source emissions. Some of the legal components identified may potentially be useful tools for the City of Houston to use against the industry in its movement for tighter emissions control. For instance, in 2008 the city filed a petition to the EPA under the DQA to challenge the current EPA emissions factors that the petrochemical and refining facilities use to calculate their emissions estimates of hazardous air pollutants (City of Houston, 2008b). Since the emissions factors are supported and published by the EPA, the city was able to legally challenge the data used to calculate emissions, citing recent reports that have shown actual emissions from petrochemical and refining industries may be 100 times greater that estimates based on the current factors (City of Houston, 2008b).

The study's key strength is that it identifies barriers that stem from readily identifiable statues, regulations and judicial precedents; they are not theoretical or subjective barriers. The City of Houston can thus challenge such elements through legislation or the justice system to make progress in its industrial benzene emissions reduction goals, for example, as it has done through it's petition to the EPA under the DQA. If the City of

Houston can prove that a specific legal barrier contradicts the CAA's mission to protect public health, it can successfully force the TCEQ to reconsider the relevant regulation and/or practice.

PUBLIC HEALTH IMPLICATIONS

Benzene is a known and recognized carcinogen. It can also induce a range of adverse non-cancerous effects on the human body, such as genetic, developmental and hematopic implications. The Greater Houston region is home to many of the US's largest oil refineries and chemical manufacturing plants; these facilities contribute to some of the largest benzene emissions in the entire country, in one concentrated region. Numerous other toxic chemicals are released by these same facilities, compounding the potential for additional health risk posed by benzene and its interaction with multiple exposures.

In the past, many environmental policies have developed in the aftermath of disastrous pollution events, such as the first Clean Air Acts after the 1952 London smog episode and the Superfund program after the severe toxic effects of the Love Canal had already occurred. Currently, there is strong evidence that benzene is a real threat to human health, even at low exposure levels. As such, it is important that this science translates into action before a disaster forces it to. Policy makers must proactively develop an improved regulatory framework to reduce benzene emissions to improve the quality of Houston's air and life of its citizens by decreasing the potential for negative health impacts related to benzene exposure. Increased oversight and more stringent emissions controls can reduce the risk for large fugitive emissions events, which could otherwise result in death or other serious effects if enough benzene is emitted. The public health implications of decreased benzene emissions can only help, not hurt, human and environmental health in Houston.

CONCLUSIONS

The City of Houston faces many barriers to improve air quality through major source benzene emissions reduction strategies. The constraints identified in this study provide both the TCEQ and industry legal bases to prevent benzene emissions reform and subsequently prevent the City of Houston from bringing legal action against the largest benzene emitters. The primary constraints stem from state-level restrictions that prohibit the city from regulating emissions and enacting and enforcing laws both within Houston's city limits and throughout the Greater Houston region. As such, it is important that scientific evidence can show a direct link between benzene and its specific health consequences.

Consequently, one of the most effective methods to reaching reduction goals may come out of high profile class action lawsuits against specific companies whose benzene emissions can clearly be linked to an affected community's health grievances. For instance, in 2007, the Corpus Christi Citgo Refinery was found guilty on 2 counts of violating the CAA when a random inspection proved that the refinery was operating 2 major tanks without proper benzene pollution control devices (Canales et al., 2007). This class action was brought on by years of community complaints of benzene odor and negative health consequences (Citizens for Environmental Justice). In such cases, where there are hundreds, if not thousands of complaints and often plaintiffs, it is harder for industry to discredit the legitimate health effects of benzene and prove cause for *Daubert* or other legal loopholes. As a result, successful class action suits can serve as a catalyst for the process of "regulation by information”, which has been successful in the past and provided the EPA with evidenced reasoning to regulate air standards for pollutants such as ozone and particulate matter. Unfortunately, the Corpus Christi case was unique for its region; in Houston, it is difficult to pinpoint one facility that is responsible for a neighborhood or community’s health concerns, because Houston is home to such a concentrated industrial sector.

It is important that current, peer-reviewed science translates into action in the form of preventative health protective policies, as required by the *Precautionary Principle* in environmental policy making (Science and Environmental Health Network). If benzene air standards are adopted, they can have a significant impact on major source emissions in Houston, especially on those facilities located within benzene APWL areas. However, current policies and legal standards are working to support the industry’s anti-regulatory efforts and the city faces a difficult path to prove regulatory necessity of reducing major source benzene emissions in the Greater Houston region to protect public health.

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