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Environmental Health Insights

Supplementary Issue: Ambient Air Quality (A)

Houston's Novel Strategy to Control Hazardous Air Pollutants: A Case Study in Policy Innovation and Political Stalemate

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ABSTRACT: Although ambient concentrations have declined steadily over the past 30 years, Houston has recorded some of the highest levels of hazardous air pollutants in the United States. Nevertheless, federal and state regulatory efforts historically have emphasized compliance with the National Ambient Air Quality Standard for ozone, treating "air toxics" in Houston as a residual problem to be solved through application of technology-based standards. Between 2004 and 2009, Mayor Bill White and his administration challenged the well-established hierarchy of air quality management spelled out in the Clean Air Act, whereby federal and state authorities are assigned primacy over local municipalities for the purpose of designing and implementing air pollution control strategies. The White Administration believed that existing regulations were not sufficient to protect the health of Houstonians and took a diversity of both collaborative and combative policy actions to mitigate air toxic emissions from stationary sources. Opposition was substantial from a local coalition of entrenched interests satisfied with the status quo, which hindered the city's attempts to take unilateral policy actions. In the short term, the White Administration successfully raised the profile of the air toxics issue, pushed federal and state regulators to pay more attention, and induced a few polluting facilities to reduce emissions. But since White left office in 2010, air quality management in Houston has returned to the way it was before, and today there is scant evidence that his policies have had any lasting impact.

KEYWORDS: air toxics, control strategy, hazardous air pollution, Houston policy, Houston air pollution

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Introduction

The overarching legal framework for managing air quality in the U.S. was established by the Clean Air Act (CAA) of 1970[1] and modified by subsequent major amendments in 1977[2] and 1990.[3] The CAA creates a complicated set of relationships and responsibilities among federal, state, and local governments as part of a complex regulatory system, which authorizes setting of standards and objectives, design and implementation of control strategies, assessment of status, and measurement of progress.[4–6] The federal government, coordinated by the U.S. Environmental Protection Agency (EPA), is given the preeminent role in managing the nation's air quality to ensure appropriate national equivalence in air quality standards and commonality in approaches to pollution mitigation so that all Americans are assured a basic level of environmental protection.[6] Setting priorities and taking preventative and/or remedial action is accomplished primarily by statutory or agency fiat.[6] Although state and local governments have some authority within their jurisdictional domains for implementing and enforcing federally mandated rules and

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regulations, the EPA is empowered to oversee these activities and, in certain circumstances, to impose federal sanctions and federally devised pollution control plans on areas and localities deemed to be delinquent.[6]

Among the Act's primary goals are mitigation of harmful ambient concentrations of six "criteria" pollutants (ozone, particulate matter, lead, carbon monoxide, sulfur dioxide, and nitrogen dioxide) and limiting sources of exposure and associated risks from hazardous air pollutants (HAPs), also referred to as "air toxics," including chemicals like benzene, toluene, ethylbenzene, and xylenes. To protect public health and welfare, the EPA is authorized by the CAA to set health-based National Ambient Air Quality Standards (NAAQSs) for criteria pollutants and to set emission standards for a diversity of mobile and stationary sources to limit criteria pollutants, their precursors, and HAPs. The EPA is further directed by the statute to promulgate supplementary emission standards for HAPs that continue to pose significant "residual risk" after the first cycle of emission standards has been put into effect.[1–6]

Because of the specific and detailed requirements for regulation of criteria pollutants, historically the bulk of federal and state management actions and resources have been devoted to this small subset of air pollutants, and resultant controls have been aimed at reducing widespread ambient pollution rather than focusing on specific localized areas of elevated pollutant concentrations or "hot spots" (eg, areas adjacent to busy roadways, communities directly downwind of industrial plants).[6] There is growing concern, however, that this emphasis on criteria pollutants and area-wide ambient controls may not be justified on the basis of actual risks to human and ecological health, and that the risks of untested and unregulated HAPs may be greater than those from HAPs that are currently regulated.[6]The evidence indicates that most residents of U.S. cities, and particularly those residing in poor neighborhoods near pollution sources, are exposed to concentrations of HAPs likely to increase lifetime risk of both cancer and non-cancer health effects.[6–16]

The EPA administers development of state implementation plans (SIPs) that lay out how each individual state, in conjunction with national control programs, will achieve mandated standards for both NAAQS pollutants and HAPs. The SIPs must be prepared and submitted for EPA approval in accordance with explicit instructions set forth in the CAA.[1–6] The SIP provides the fundamental connection between (a) state rules and regulations, (b) EPA oversight of state actions, and (c) federal enforcement activity, and it sets forth state and local obligations for meeting HAP-related expectations, goals, and standards.[1–6] Subject to approval from EPA, a state may be allowed to take responsibility for CAA compliance within its legal jurisdiction, using the EPA-sanctioned SIP as a blueprint for enforcement.[1–6] The CAA explicitly acknowledges that, where appropriate, states should take the lead in air quality management because they have unique knowledge and insight about provincial pollution sources, pathways, and problems.[6] But while the importance of state policies and procedures for environmental protection is widely recognized,[6,12,17,18] relatively little attention has been paid to the role of local government,[19–24] particularly the role of municipalities in controlling HAPs.[25–30] This despite the fact that municipal governments are closest to HAP-related problems, their causes, and practical solutions, and have a special understanding and empathy for affected populations. Furthermore, most people view their local government as the first line of defense against air pollution, and the level of government most likely to appreciate and respond to their concerns.[19–24]

Although the 1990 CAA Amendments[3] expressly allow for local governments to address HAPs within certain restrictions and with EPA approval, few have done so. A primary reason is because the role of cities and municipalities is embedded deeply within the CAA legal labyrinth, and their ability to act is nested, and thereby constrained, under the oversight of both federal and state authorities. In the State of Texas, for example, the Texas Commission on Environmental Quality (TCEQ) has not delegated its authority for HAP control to local governments. Thus, few Texas cities have struck out on their own to address HAPs, despite language in the Texas CAA[31] that allows municipalities to undertake control actions as long as they do not conflict with state laws or regulations. A major exception is the City of Houston (Houston), which from 2004 to 2009, on its own initiative and sometimes in conflict with federal and state regulators, undertook a mix of cooperative and confrontational policy actions aimed at reducing HAP-related health risks for residents of the city, which targeted the energy sector, including oil refineries and petrochemical plants – one of the area's largest employers.[28–30] The subsequent discussion examines the political and regulatory context within which the City of Houston initiated its own HAP controls, reviews the nature and timing of city-initiated policy activities, explores reasons why Houston decided to take the actions it did, and considers whether the city's policies were successful in achieving desired ends.

Setting the Stage: Realities and Perceptions of Air Quality in Houston

Houston is the county seat of Harris County, located near the Gulf Coast in southeast Texas. With a population of more than 2.1 million, up more than 7% over the past decade, Houston is the largest city in Texas and the fourth largest in the U.S. The 10-county Houston metropolitan area consists of more than 600 square miles, and has a population of approximately 6 million. It contains numerous and diverse sources of HAPs, including the largest petrochemical complex in the country, two of the four largest petroleum refineries in the U.S., more than 400 chemical manufacturing facilities, and the Port of Houston, one of the largest in the world. Houstonians drive more than 140 million miles each day and tailpipe emissions from cars, trucks, and buses add to air pollution over the city. Air pollution levels are also affected by aggregate emissions

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from many small operations, such as dry cleaners, gas stations, restaurants, and printing operations, which are geographically dispersed throughout Greater Houston.[32]

In the Houston Metro Area, there are more than 140 air pollution monitors of different kinds measuring a variety of NAAQS pollutants and HAPs. Owned and operated by TCEQ, local governments, or private industry, these monitors operate at dozens of locations and measure ambient concentrations of more than 140 different chemical substances (although only about 40 are HAPs). According to the TCEQ[33] and the Houston Regional Monitoring (HRM) Corporation,[34] Houston has more air pollution monitors than any city in the U.S. and possibly the world. Monitoring data indicate that Houston meets all NAAQSs except for ozone, and that despite increases in population, manufacturing, and vehicle miles traveled, ambient concentrations of most NAAQS pollutants and HAPs have decreased since the 1990s.[33–39] The 20-year time trend from 1988 to 2008 for annual average concentrations of benzene, toluene, ethylbenzene and xylenes (BTEX) is shown in Figure 1.[34] From 1990 to 2013, network-wide annual average values for benzene (2.7 ppb in 1990 versus 0.48 ppb in 2013) and 1,3-butadiene (0.8 ppb in 1990 versus 0.15 ppb in 2013) have decreased significantly, a trend also observed at most, but not all, individual monitoring sites.[37]

Yet despite historical gains, Houston is currently ranked by the American Lung Association as the 6th most polluted city in the nation for ozone and the 30th most polluted city for annual average particle concentrations.[40] And, notwithstanding the apparent downward trajectory in ambient levels of many HAPs, there is evidence that Houstonians are still exposed to airborne concentrations that may cause adverse health effects, especially in sensitive and vulnerable populations.[11–14] Based on ambient air measurements in Houston, 10 HAPs, including benzene, 1,3-butadiene, and formaldehyde, have been identified as "definite health risks" and nine more, including vinyl chloride and carbon tetrachloride, have been labeled "probable health risks."[11] As shown in Table 1,[41] annual average and maximum-24-hour-average concentrations of benzene and 1,3-butadiene are substantially higher in Houston than those in similar cities, while formaldehyde levels are at or near the top.[14,41] The cumulative cancer risks from exposure to multiple HAPs are unevenly distributed across Greater Houston and tend to fall disproportionately on residents who are poor and Hispanic; many of whom live along Houston's heavily industrialized ship channel.[13]

Although all stakeholders and interested parties were looking at essentially the same monitoring data, two competing narratives emerged between 2004 and 2009 to describe air quality in Houston.[30] We term the dominant narrative the "Glass Half-Full" scenario for its sanguine outlook, optimistic projections, and contentment with the status quo.[33–39] Proponents of this scenario included the Greater Houston Partnership (Houston's version of the Chamber of Commerce), the region's petrochemical and manufacturing firms, the Houston-Galveston Area Council (regional coalition of city and county officials), state legislators, the TCEQ, and EPA Region VI (headquartered in Dallas).[30] We label the alternate narrative the "Glass Half-Empty" scenario for its doubtful outlook, pessimistic projections, and dissatisfaction with the status quo.[11,13,14,28,32,40–46] Major advocates for this perspective were local and national environmental advocacy groups, Houston's major newspaper (The Houston Chronicle), local academics (from Baylor University, Rice University, the University of Texas Medical Branch, and the University of Texas Health Science Center), and the City of Houston.[30] Illustrative quotes from believers in each world view are presented in Table 2.

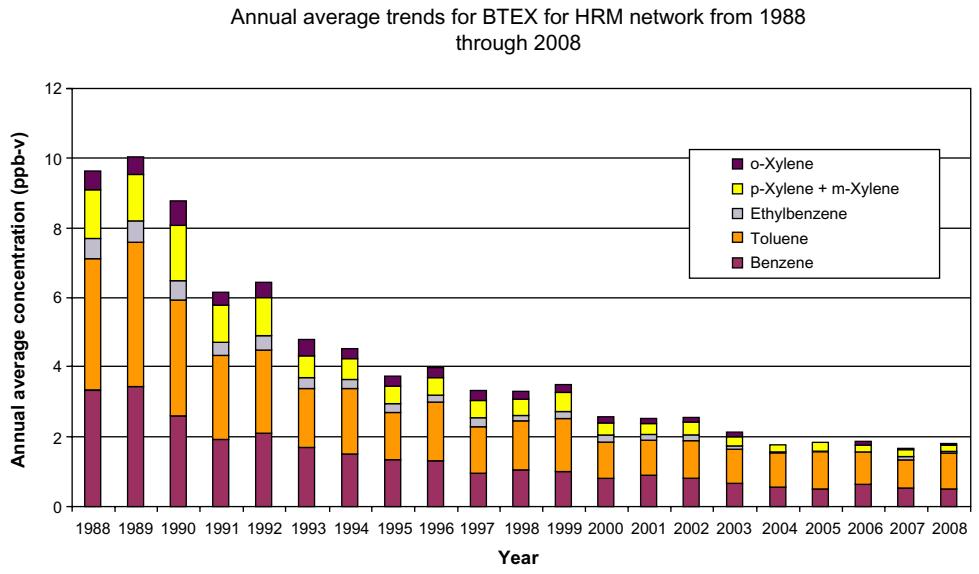


Figure 1. Time trends from 1988 to 2008 for annual average ambient concentrations of benzene, toluene, ethylbenzene, and xylenes (BTEX) for multiple monitoring sites in the HRM network.[34]

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Table 1. Comparison of measured ambient concentrations (ppb) from the single-highest-monitoring station at four U.S. cities for 2004.[41]

	BENZENE (ppb)		1,3-BUTADIENE (ppb)		FORMALDEHYDE (ppb)	
	ANN AVG	MAX 24-HR	ANN AVG	MAX 24-HR	ANN AVG	MAX 24-HR
Chicago	0.5	2.7	0.08	0.5	2.0	8.1
Los Angeles	0.9	2.9	0.2	0.5	7.2	15.5
St. Louis	0.5	1.1	0.07	0.3	4.2	35.6
Houston	1.7	73.5	4.0	37.4	7.9	20.1

Abbreviations: ppb, parts per billion; ann avg, annual average; max 24-hr, maximum 24-hour average.

Adherents of the Glass Half-Full scenario argued that, overall, Houston's air was comparatively good, certainly no worse than other major U.S. cities and better than most. They regarded HAPs as an important but minor aspect of both ozone reduction and general air quality improvement. Their emphasis was on a backward look at how bad Houston's air quality had been 20 years ago juxtaposed against how much better it was now. They accentuated the steady downward trend in ambient pollutant concentrations and lauded the achievement of decreased NAAQS pollutants and HAPs virtually across the board. Proponents highlighted the extensive federal and state regulations already in place, and suggested that HAPs were a residual problem, which would be solved over time by existing policies. In their view, the status quo was good and getting better, steady progress was achieving adequate air quality for Houstonians, and current air pollution control strategies would ensure continued improvement in the future.[30]

Supporters of the Glass Half-Empty scenario, on the other hand, while agreeing that Houston's air had gotten cleaner over time, disputed that it was good enough or that it was improving fast enough. They believed that HAP monitoring was too limited to identify toxic hot spots, concentrations at some monitoring stations still presented unacceptable health risks, and Houstonians at greatest comparative risk were likely to be poor and non-white. Advocates viewed

Table 2. Representative quotes on the state of air quality in Houston from advocates of the "Glass Half-Full" and "Glass Half-Empty" scenarios, respectively.

GLASS HALF-FULL NARRATIVE – AIR QUALITY IN HOUSTON IS GOOD AND GETTING BETTER; REGULATIONS CURRENTLY IN PLACE ENSURE CONTINUED IMPROVEMENT; IT IS UNNECESSARY AND COUNTERPRODUCTIVE FOR HOUSTON TO TAKE INDEPENDENT ACTION ON HAZARDOUS AIR POLLUTANTS	
Houston Regional Monitoring (HRM) Corporation[34]	"Houston's air meets five of six NAAQS [except ozone]." And it "compares favourably with many other large cities … Through concerted effort and investment, Houston has achieved an 87 percent reduction in the ambient concentrations of key Volatile Organic Compounds (Benzene, Toluene, Ethylbenzene and Xylenes) in the past 27 years… [industry] invested between $4 and $6 billion by 2013 to make further improvements in air quality."
Texas Commission on Environmental Quality (TCEQ)[33]	"Even with all of its challenges, the Houston region has made significant improvements in air quality over the last two decades…three [of 109 hazardous air pollutants] were shown to exceed the state's health-effects screening levels. Agency toxicologists have determined that these measurements are not an immediate health threat…no studies have shown evidence of elevated levels of cancer or specific types of respiratory disease in Houston, compared to other areas…Cancer cluster studies conducted by the state health department did not find elevated cancer rates in east Houston."
GLASS HALF-EMPTY NARRATIVE – HOUSTON AIR QUALITY IS NOT HEALTHY ENOUGH AND IS NOT GETTING BETTER FAST ENOUGH; EXISTING REGULATIONS ARE INSUFFICIENT AND INADEQUATE; IT IS IMPERATIVE THAT HOUSTON TAKE INDEPENDENT ACTION TO CONTROL HAZARDOUS AIR POLLUTANTS	
T.O. McGarity and K. Sokol, Center for Progressive Reform, Washington, DC[44]	"…exposure of residents living near polluting facilities in Houston…to hazardous air pollutants such as benzene and 1,3-butadiene is an 'unnatural disaster' that has resulted from the powerful influence that the oil and chemical industries have traditionally exercised over the state's legislature and pollution control agency… Like phantoms, [toxic hot spots] come and go…Tracking the hot spots as they move is also difficult, but doable with adequate resources and will. As it stands now, both are in short supply."
Consortium of Environmental Advocacy Groups: Galveston-Houston Association for Smog Prevention; Industry Professionals for Clean Air; Environmental Defense Fund; Environmental Integrity Project[45]	"As the petrochemical capital of the United States, the Houston area is at the center of a toxics storm. Recent studies…have documented dangerous levels of toxic air pollution in parts of the city…Texas regulators and politicians, however, have been unable or unwilling to place adequate limits on industrial toxic air emissions to protect the health of Texans."

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HAPs as at least as important from a public health perspective as ozone and other NAAQS pollutants, and they did not trust that current regulatory approaches were sufficient to rectify the problem, now or in the future. Their position was that the goal of decreasing HAP exposures for at-risk Houston residents was too important to be lost in the self-congratulatory and, in their minds, self-serving rhetoric associated with the Glass Half-Full stance.[30]

Policy Activities: What Actions Did Houston Take?

The fundamental disagreement about the status of Houston's air quality turned into open political and regulatory conflict during the three terms that Bill White served as mayor from 2004 to 2010. Throughout the White Administration, the city took a series of unilateral actions aimed at tightening controls on HAP emissions, with special emphasis on benzene. These actions were generally supported by environmental advocates and many local academics, and opposed, to one degree or another, by the Greater Houston Partnership, individual petrochemical and manufacturing firms, the Houston-Galveston Area Council, state legislators, the TCEQ, and EPA Region VI.[28–30]

Bill White, a moderate Democrat, is a lawyer, businessman, and politician who served as U.S. Deputy Secretary of Energy in the Clinton Administration from 1993 to 1995. He was elected to three two-year terms as Mayor of Houston, taking office in January 2004 and leaving in January 2010 because of term limits. White was a popular mayor, winning his first term with 63% of the vote, his second with 91%, and his third with 86%.[47] A reformed smoker and bicycling enthusiast, White adopted "clean air" as one of the major themes of his administration, with particular emphasis on limiting exposure to HAPs. He explained his commitment to air quality improvement this way:

"Clean air is a moral and ethical issue, because no one should have the right to make risky chemical alterations to air which they don't own and others must breathe. But cleaning our air is also important to our ability to attract new jobs, preserve the value of all our homes, and protect the respiratory health of the young people who we want to make Houston their home. We have made great progress on the State Implementation Plan to decrease ozone, but we cannot ignore air toxics. And we must create a level playing field for those responsible firms investing billions to reduce emissions, so an entire industry will not be tarnished by those who cut corners."[29]

Soon after taking office, the White Administration moved to enhance the city's regulatory reach by withdrawing from its contract with TCEQ, which provided state funding for Houston's monitoring and investigative work in return for the city waiving its right to undertake independent enforcement action against companies that violated air pollution rules and regulations. The city reacquired local enforcement authority in 2004 and began operating its own air pollution control program, with reduced funding, in 2005. Houston's stated purpose for not renewing the contract was to acquire leverage in future emission-reduction negotiations and to serve as a warning and deterrent to local polluters. In short order, the city used its newly regained enforcement authority to initiate regulatory action against a chemical firm, which had a long history of violations and was thought to be the source of elevated HAPs at one particularly problematic monitoring station. The company soon agreed, through a court-enforced consent decree, to reduce its emissions significantly and install a state-of-the-art fence-line monitoring system. In the context of the prevailing Glass Half-Full consensus, the city's action was considered both aggressive and unorthodox; establishing an antagonistic and confrontational tenor for Mayor White's efforts to improve Houston's air quality.[29,30]

At about this same time, two publications focused attention on potential health problems associated with local HAP exposures. The 2005 TCEQ annual technical report revealed that over the previous three years historically high concentrations of benzene and 1,3-butadiene had been recorded at three monitors east of the city's central business district.[48] Contemporaneously, the *Houston Chronicle* published a five-part series on elevated HAP levels in four East Houston communities, titled "In Harm's Way,"[43] which stirred public debate about the magnitude and extent of HAP-related problems.[28–30] Given the city's reclaimed enforcement authority and demonstrated willingness to use it, along with growing public concern about healthful air quality, the stage was set for conflict between the Glass Half-Full and Glass Half-Empty coalitions over the appropriateness and justification for unilateral actions by the City of Houston to curb HAP emissions.[30]

From 2004 through 2009, the White Administration undertook an array of diverse, independent policy actions aimed at limiting exposures to HAPs. As discussed by Bruhl et al.[29] the different policy tools employed can be grouped chronologically and thematically into three phases. Phase 1, from January 2004 to August 2005, was a period of expanding local enforcement capabilities, which has been described above. Phase 2, from September 2005 to July 2006, was a time of moving beyond enforcement activity and entailed (a) commissioning scientific reports to rank Houston's air pollution-related health risks and compare measured ambient concentrations with other similar cities and (b) enhancing the city's ability to monitor, investigate, and interpret air quality data. Phase 3, from August 2006 to August 2008, involved developing alternate compliance and enforcement strategies, including: writing citations under the authority of the municipal code; initiating a voluntary benzene reduction plan in collaboration with local industry; using a municipal ordinance to require polluters to register with the city and pay a fee; proposing a municipal nuisance ordinance that would have allowed the city to bring suit against polluters outside the city limits; working with EPA to conduct a joint investigation of Houston's air toxics problem; issuing a Benzene Action

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Plan that suggested specific actions by federal, state, and local government as well as private industry to reduce benzene emissions; petitioning EPA under the Data Quality Act to update EPA's emission factors, equations, and estimates for HAP emissions from petroleum refineries and chemical manufacturing plants; and challenging TCEQ facility-emission permit renewals in court.[28–30]

Bruhl et al.[29] have pointed out that the variety of policy instruments used by the city can be classified into three major categories: regulatory, evidentiary, or persuasive tools. Regulatory tools impose formal limits on activities deemed socially undesirable and are the most coercive and antagonistic. Evidentiary tools rely on scientific and technical information to promote desired policy goals and are less coercive and antagonistic than regulations. Persuasive tools are the least coercive and antagonistic because they use approaches like moral suasion and public appeals to encourage voluntary cooperation and compliance. A summary of the policy actions undertaken by the City of Houston to control HAPs, including the phase in which they occurred and the type of policy tool employed, is provided in Table 3 based on the work by Bruhl et al.[29]

Understanding Causes: Why Did Houston Act Unilaterally?

The events and associated conflict that occurred during White's three terms raise a key question. Why did the City of Houston independently take an activist role in controlling emissions of HAPs, thereby provoking a protracted clash with local industry as well as federal and state regulators? Or posed in a different way, why did the city act unilaterally to disrupt a longstanding, comfortable consensus among elected officials, regulators, and industry leaders, while at the same time challenging a key premise of the U.S. air quality management system that puts cities in a subordinate role to federal and state authority? In addition to the obvious strength of the opposition and the inherent problems involved with antagonizing them, the city's decision is all the more remarkable given the substantial transaction and opportunity costs associated with an extended political and legal battle in which they were a decided underdog. Any search for answers must begin by examining the motivations of the principal decision maker, Bill White.

As mayor, Bill White was the initiator, driving force, champion, and leader of Houston's efforts to exert local control over HAPs.[29,30] Without him, there would have been no systematic attempt to disrupt the status quo, and the city would not have injected itself into a controversy over municipal regulatory authority. Although he was certainly aware of the costs, Bill White made a considered and public decision that HAPs would be one of the major themes of his administration.[29,30] The question is why? Throughout the six years of his administration and in subsequent interviews, Bill White has consistently portrayed his decision as "the right thing to do" because Houstonians were (and still are) being "poisoned" by both regulated and unregulated air pollutants. He has always framed the issue in terms of "quality of life for the future," and spoken about the "moral and ethical" dimensions of ensuring healthful air quality. At the same time, he regularly pointed out the potential economic gains in terms of jobs and property values of cleaning Houston's air.[29,30] But Bill White is more than just a humanitarian, he is also a good politician, which means he almost certainly took account of the political pros and cons of the HAP issue before deciding to take the plunge.

From virtually the beginning of his administration, it was rumored that Bill White would eventually run for either the U.S. Senate or the Governor's Office. As a Democrat in a heavily Republican state, he had to know it would be difficult for him to win state-wide office. It is possible that he thought Houston's intervention to control HAPs was not only ethically justified and morally correct, but also politically expedient; reasoning that it might help him with independent voters from across the state who cared about the environment. Moreover, Republicans already had plenty of other reasons to vote against him anyway. So he could have rationalized that being seen as a moderate Democrat leading the fight against industrial air pollution had only potential political benefit with virtually no political downside. In 2010, after leaving the Mayor's office, Bill White won the Democratic primary for Governor of Texas but subsequently lost handily in the general election to the state's longest-serving incumbent, Republican Rick Perry.

Table 3. Summary of policies undertaken by the City of Houston to control HAPs during the White Administration from 2004 to 2009, adapted from Bruhl et al.[29]

	PHASE 1 (JAN 2004 – AUG 2005) EXPANDING LOCAL ENFORCEMENT CAPABILITIES	PHASE 2 (SEPT 2005 – JULY 2006) MOVING BEYOND ENFORCEMENT AUTHORITY	PHASE 3 (AUG 2006 – AUG 2008) ALTERNATIVE ENFORCEMENT AND COMPLIANCE STRATEGIES
Primary Policy Approaches	*Regulatory* – gaining enforcement authority and using it to negotiate emission reduction agreements	*Evidentiary* – enhancing monitoring and investigative capacity; priority setting	*Persuasive followed by Regulatory* – appealing for voluntary cooperation, then invoking the municipal code and intervening to strengthen emission permits
Secondary Policy Approaches	*Persuasive and Evidentiary* – disclosing information to the public and media; moral suasion	*Persuasive* – disclosing information to the public and media	*Evidentiary* – enhancing monitoring and data collection; data used as evidence for enforcement

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Whether or not elected officials are likely to get involved with a particular issue typically depends on three factors: salience – how much voters care about the issue; complexity – how difficult it is for voters to understand, and politicians to master, the necessary technical essentials; and conflict – how much political risk there is from discord among opposing interest groups.[49–51] Politicians are more apt to get involved with issues that are important to voters, relatively easy to understand, and do not involve entrenched conflict between rival interest groups (which implies that taking a position will automatically alienate one side or the other). Based on these criteria, Bill White would not have been predicted to make the HAP issue a centerpiece of his administration because it had comparatively low salience for voters (at least in Houston), was reasonably complicated in terms of understanding the relationship between industrial processes, emissions, ambient concentrations, exposures, and related health effects, and involved deep-rooted conflict between opposing interest groups (eg, business interests vs environmental advocates) that had strongly held and conflicting points of view. Although not definitive, the available evidence suggests that Bill White likely took action because he meant what he said; "that it was the right thing to do." But it is also probable that he made a political calculation; assessing that it might help him with independent (undecided) voters while not necessarily making him any less attractive to Republican voters who probably weren't going to support him anyway.

Political scientists have a variety of theories and models to help them understand the workings of the policy-making process and to explain how it produces the policies it does.[49–51] Elite theory, for example, accentuates the role of economic or political elites (eg, business leaders), who may hold values and policy preferences that are substantially different from those of the general public. Group theory treats the policy process as a continuous struggle among organized interest groups, such as business associations and environmental advocacy organizations. Institutional theory stresses the formal and legal features of government institutions, focusing on their organizational structure, legal powers, and procedural rules. Rational choice theory seeks to explain public policies in terms of individual policy actors (eg, regulators, interest group leaders, elected officials), who try to maximize their self-interest in the course of the policy-making process. Depending on the situation and circumstances, each of these perspectives can be useful in explaining certain characteristics of environmental policy and politics; however, no single theory or model is entirely satisfactory by itself because each tends to highlight specific policy-making attributes at the expense of other relevant factors.[49–51]

One model that seems especially relevant to the Houston case is the "three streams" model offered by Kingdon[49] to explain how issues enter or leave the public policy agenda. Kingdon proposed that three interdependent "streams" of activities (problem, policy, and politics streams) flow continuously through the political system. The "problem stream" refers to data about environmental conditions and trends, while the "policy stream" denotes ideas and proposals about mitigating environmental problems. The "politics stream" signifies the political climate and/or public mood at a particular time and place regarding the state of the environment and public health. When these streams converge, often with the assistance of "policy entrepreneurs," it creates windows of opportunity for policy development as issues gain prominence and get on the policy agenda. The policy agenda is defined by Kingdon to mean "the list of subjects or problems to which government officials, and people outside of government closely associated with those officials, are paying some serious attention to at any given time."[49] Environmental policy entrepreneurs are leaders, either inside or outside of government, who devote themselves to advancing a particular issue, and who act when they see a viable opening or focusing event, such as a hazardous waste spill or severe air pollution episode, to bring the three streams together and enhance public awareness and support for development of suitable environmental policies.[49,51]

The Kingdon model appears to fit the facts in Houston quite well. Bill White acted as a policy entrepreneur, who used his mayoral election and ongoing popularity as a platform from which to advocate for HAP regulation. Early on he exploited a fortuitous focusing event, the *Houston Chronicle* series on elevated HAP levels in Houston neighborhoods[43] ("In Harm's Way"), to engage public and political support for local HAP control. His actions served to foster convergence of the problem stream (ie, TCEQ report on unexpectedly high levels at some monitoring sites,[35] report of the Mayor's Task Force on HAP-related health risks,[32] report by Rice University comparing Houston HAP concentrations with other similar cities[41]), the policy stream (ie, the city implemented or attempted to implement a diversity of evidentiary, persuasive, and regulatory policies to control HAPs[28–30]), and the politics stream (ie, White's electoral popularity with Houston voters,[47] the possibility he would run for state-wide office, dueling narratives concerning HAPs in Houston[28–30,32–46]). Through Bill White's pioneering and persistent efforts, HAPs remained front and center on the Houston policy agenda throughout his six-year tenure as mayor.

Gauging Success and Impact: Did Houston's Actions Matter?

In the end, of course, the central question is whether the city's policies were successful in reducing HAP concentrations for residents of Houston? But answering this question is problematic because it necessarily involves a counterfactual contention about what might have happened had Houston not intervened. As noted earlier, measured HAP concentrations have been steadily declining since about 1990, and this trend has continued since the mayor left office in 2010. As shown in Tables 4 and 5, levels of both benzene and 1,3-butadiene have mostly decreased at the five monitoring stations with highest

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Table 4. Annual average benzene concentrations (ppb) at the five highest Houston Metro Area monitoring sites from 2006 to 2013.[37]

MONITORING STATION	2006	2007	2008	2009	2010	2011	2012	2013
Lynchburg Ferry	2.38[a]	1.51	1.10	0.90	0.83	0.67	0.94	0.74
Haden Road	0.61	0.49	0.40	0.33	0.30	0.28	0.34	0.37
Cesar Chavez	0.47	0.49	0.43	0.34	0.29	0.27	0.31	0.36
Clinton Drive	0.53	0.56	0.41	0.32	0.38	0.30	0.33	0.34
Deer Park	0.51	0.47	0.39	0.32	0.29	0.28	0.32	0.32

Note: [a]The TCEQ has declared that the safe concentration of benzene in air, referred to as the annual AMCV, is 1.4 ppb.[52]

levels in the Houston Metro Area. In recent years, however, there have been increases at some monitoring stations and concentrations overall seem to be leveling off. It is important to note that all measured concentrations of benzene and 1,3-butadience are well below the values (1.4 ppb for benzene and 9.1 ppb for 1,3-butadiene) designated by TCEQ as safe annual average concentrations (referred to as annual Air Monitoring Comparison Values or AMCV). In fact, TCEQ recently proposed to remove benzene from the Texas City Air Pollutant Watch List (APWL) because "air monitoring has shown sufficient improvement over the last three years."[36] Benzene was previously removed from the Lynchburg Ferry APWL in 2010 after a clear trend of benzene reductions was observed.[36] According to TCEQ, from 2000 to 2012, more than 90% of benzene monitors in the Houston area showed a decrease in annual average concentrations and, in 2012, all monitors had annual average benzene concentrations below the state's AMCV.[36]

Monitoring data demonstrate that HAP concentrations in Houston, including benzene and 1,3-butadiene, were decreasing before the mayor took office and continued declining throughout his six-year term; a waning trend that has generally persisted since he left office. It is virtually impossible, therefore, to discern a distinctive effect of Houston's policies or to apportion a specific fraction of the observed decrease directly to any actions, either individually or collectively, taken by the city. But the city's efforts did produce tangible policy outcomes, including: focusing attention on the heretofore backburner issue of HAPs by challenging the conventional wisdom and provoking the consensus Glass-Half Full coalition to re-examine and defend their view that ozone compliance is the holy grail of Houston air quality while HAPs are only a peripheral and manageable residual issue; commissioning scientific reports that documented the magnitude and extend of Houston's HAP problem; recovering the city's right to take independent enforcement action against polluters; prodding the TCEQ to negotiate a Voluntary Emissions Reduction Agreement with a major polluter; increasing the monitoring, investigative, and interpretive capacity of the city's air quality staff; writing pollution citations using the authority of the municipal code; developing a cooperative Voluntary Benzene Reduction Plan for Greater Houston; amending a city ordinance to broaden the scope of HAP emitters required to register with the city and pay a fee (later overturned by the courts); proposing a municipal nuisance ordinance to address HAP emissions outside the city limits (stymied by political resistance from area mayors and state legislators); issuing a Benzene Action Plan that recommended actions by major stakeholders to reduce benzene levels; spurring TCEQ and EPA to devote additional time and resources to HAPs in Houston; and petitioning the EPA under the Data Quality Act to update its emission factors, equations, and estimates for HAP emissions from petroleum refineries and chemical manufacturing plants. While all these policy actions stimulated debate, and in some cases remedial action, they also generated significant opposition. Disagreements continue about their contribution, if any, to observed HAP reductions in Houston.[28–30]

The split between the Glass Half-Full and Glass Half-Empty narratives endures with regard to the import of Houston's unilateral policies. As summarized in Table 6,[29] the former mayor, his staff, and environmental advocates tend to believe that the city's actions made a significant and lasting impact, while industry observers see any effects as transitory, with little or no lasting benefit.[29] In truth, there are few, if any,

Table 5. Annual average 1,3-butadiene concentrations (ppb) at the five highest Houston Metro Area monitoring sites from 2006 to 2013.[37]

MONITORING STATION	2006	2007	2008	2009	2010	2011	2012	2013
Milby Park	1.30[a]	1.03	0.91	0.51	0.59	0.49	0.47	0.84
Channelview	0.37	0.27	0.27	0.24	0.27	0.24	0.31	0.29
Cesar Chavez	0.25	0.24	0.27	0.18	0.15	0.14	0.16	0.18
Clinton Drive	0.29	0.23	0.26	0.19	0.16	0.18	0.15	0.13
Haden Road	0.20	0.18	0.14	0.15	0.16	0.14	0.18	0.13

Note: [a]The TCEQ has declared that the safe concentration of 1,3-butadiene in air, referred to as the annual AMCV, is 9.1 ppb.[52]

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Table 6. Representative quotes on the import of Houston's unilateral policy activities aimed at reducing ambient concentrations of HAPs, adapted from Bruhl et al.[29]

GLASS HALF-FULL NARRATIVE – AIR QUALITY IN HOUSTON IS GOOD AND GETTING BETTER; REGULATIONS CURRENTLY IN PLACE ENSURE CONTINUED IMPROVEMENT; IT IS UNNECESSARY AND COUNTERPRODUCTIVE FOR HOUSTON TO TAKE INDEPENDENT ACTION ON HAZARDOUS AIR POLLUTANTS	
Industry Scientist	"As a far-reaching, sustainable impact of the White Administration on those issues, I can't think of one. Industry folks aren't talking about responding to these issues anymore. When they talk about previous efforts, they say we did that a few years ago but now that administration is gone. I guess there was an impact that was concurrent with the duration of the Administration."
Texas Commission on Environmental Quality Manager	"Obviously the city's efforts had some effect on TCEQ. Without a doubt, there were actions taken. It is not a bad thing to have a mayor or county judge or someone focused on air quality. That is only good for Houston and the region. If you have a mayor focused on something, you're going to get additional state attention."
GLASS HALF-EMPTY NARRATIVE – HOUSTON AIR QUALITY IS NOT HEALTHY ENOUGH AND IS NOT GETTING BETTER FAST ENOUGH; EXISTING REGULATIONS ARE INSUFFICIENT AND INADEQUATE; IT IS IMPERATIVE THAT HOUSTON TAKE INDEPENDENT ACTION TO CONTROL HAZARDOUS AIR POLLUTANTS	
Former Mayor of Houston	"Ultimately determinations of success are driven by what we can measure. There was more than 50% reduction in 1,3-butadiene due to [the Voluntary Emissions Reductions Agreement with a major HAP-emitter]. That agreement changed the monitoring culture and has been held up as a model. Benzene levels have gone down. I think the visibility given to benzene has resulted in more TCEQ regulatory activity and industry compliance."
City of Houston, Air Quality Staff Manager	"The attention to toxics and the need to reduce toxics was not on anybody's radar screen before. The White Administration had made great strides in addressing and reducing air toxics concentrations in Houston, but more importantly, it was able to successfully lay the legal and policy framework necessary to facilitate continued reductions in air toxics."
Environmental Advocate	"The consent decrees that EPA settled with a number of industries – that's one thing. Without increased visibility the city gave to the issue, we wouldn't have seen some of the actions we did … The biggest thing Mayor White did was say the word [air toxics] over and over again. He made it an issue and he kept the spotlight on it. He told people that it was a problem and that we had to do something about it."

vestiges remaining of the White Administration's six-year effort to implement municipality-based HAP controls. The new mayor, Annise Parker, took office in January 2010 and is currently completing her third term. She has not picked up on the previous Administration's efforts, remaining largely silent on the HAP issue and apparently joining the Glass Half-Full coalition. The whole issue of HAPs is once again out of the public eye as political pressure has subsided and media attention has shifted to other environmental issues, such as ozone compliance, energy policy, and climate change. Recently, the business community released a statement, saying of Houston's air quality:

"It's getting better. Air quality in the greater Houston area has improved significantly since 1987 and continues to improve…Greater Houston's air quality currently meets five of six [NAAQS] standards – all except ozone. In 2013, there were only two days when the 1-hour ozone standard was exceeded at one or more monitoring stations. In 1987, there were 66 days when the standard was exceeded."[37]

Similarly, the TCEQ recently released a statement on "air quality successes," stating that:

"The HGB [Houston-Galveston-Brazoria] area had the third largest decrease [nationally] in eight-hour ozone design values from 2000 to 2012…Texas has one of the most extensive, aggressive air monitoring programs in the nation…As of July 2012, there are more stationary monitors that measure volatile organic compounds (like benzene) in the state of Texas than in any other state…From 2000 to 2012, over 90 percent of the benzene monitors … in the Houston Region showed a decrease in annual average concentrations. In 2012, all monitors in the Houston Region had annual average benzene concentrations below the state's safe level."[36]

The situation today is much the same as it was in 2003 before Bill White took office. A coalition of elected officials, regulators, and business leaders from regulated industry is proclaiming improvements in Houston's air quality and projecting further advancements in the future. The spotlight is once again on NAAQS pollutants and meeting compliance requirements stipulated in the SIP. The only dissenters still concerned about unhealthful levels of HAPs are environmental advocacy groups, including environmental justice organizations, and a few academics.[11,28–30,40,44–46] All of which brings to mind the old adage – "The more things change, the more things stay the same."

Summary and Conclusions

The National Research Council (NRC)[6] has made it clear that health risks from exposure to HAPs are a continuing concern and that most Americans are exposed to levels that may increase risks of both cancer and non-cancer health effects. The NRC notes that the problem may be even worse than it seems because "…these estimates do not consider the risks associated with exposures to numerous poorly characterized HAPs, or to the large number of chemicals that are not

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[formally] identified as HAPs but that might pose a health hazard. Although some monitoring data suggest that concentrations of commonly measured HAPs are declining and the implementation of maximum achievable control technology (MACT) and other regulations are expected to substantially reduce toxic emissions, significant residual risk is predicted to remain."[6] Moreover, not enough has been done to identify and remediate toxic hot spots, where ambient HAP concentrations are substantially higher than indicated by air pollution monitors located in adjacent or surrounding areas.[6] The enormity of the problem is illustrated by the fact that only 188 compounds have been officially designated by EPA as HAPs, yet there are roughly 70,000 chemicals in commerce and approximately 300 new ones are introduced each year.[6]

As in most states and cities, air quality management programs in Texas and Houston have traditionally concentrated primarily on achieving the NAAQS for ozone through enactment of the complex and legally binding SIP. This has meant that unless HAPs were also volatile organic compounds that contributed to photochemical ozone formation, they did not receive substantial regulatory attention and scrutiny beyond the technology-based standards spelled out in the CAA.[6,11,13,28–30,42–46] The NRC has recognized this disconnect and opines that "A major challenge for the nation's AQM [Air Quality Management] system over the coming decades will be the development of a research and regulatory infrastructure capable of protecting human health and welfare from the increasing number of potentially toxic pollutants in the atmosphere in an effective and timely manner while not unnecessarily impeding economic activity and technological progress."[6]

When he took office, Mayor Bill White made a public commitment to bring the previously undeclared and underpublicized HAP problem in Houston to center stage. In doing so, his administration's innovative policy initiatives challenged the conventional wisdom and jeopardized a comfortable coalition of business leaders, politicians, and regulators who shared the opinion that, if there was a HAP problem in Houston (a contention that was in dispute), it was being addressed adequately within the framework of existing air quality regulations and programs. The White Administration initiated a diverse array of inventive policies, including regulatory, evidentiary, and persuasive interventions that sparked controversy and engendered opposition from the business community, local and state politicians, TCEQ, and EPA Region VI. For six years, the City of Houston stood alone in its quest to exert local control over HAPs, remaining steadfast in the face of significant resistance and criticism. Although the city had some success (eg, heightened media attention and public awareness, reclaiming the city's enforcement authority, pushing TCEQ to take action on HAP emissions), there was also disappointment (eg, Houston's amended ordinance requiring more polluters to register with the city and pay a fee was overturned in court, a proposed ordinance to address HAP emissions outside the city limits was blocked by political resistance from local mayors and state legislators). As of 2014, HAPs have fallen out of the headlines, faded from public consciousness, and dropped from the public policy agenda. There is scant evidence today that the White Administration's efforts had any lasting effect on air quality management in Houston.

So how should we view this saga? Is it a cautionary tale about a mayor's reach exceeding his grasp; of an elected official who squandered his chance to build a legacy of enduring accomplishments by spending his political capital on a relatively minor and, ultimately, unwinnable issue? Or is it a profile in courage and policy innovation, featuring a big-city mayor who tried to do the right thing for the right reasons even if it was politically risky and mathematically improbable? Like the answer to many questions, where you stand on this issue probably depends on where you sit. For those who subscribe to the Glass Half-Full narrative on Houston air pollution there is little doubt that it is the former, while those who see the Glass Half-Empty are convinced it is the latter. In the end, whether the outcome justified the effort requires a subjective judgment concerning pivotal issues like opportunity costs and cost–benefit ratios.

One lasting legacy of the White Administration's efforts is the indirect effect it had on environmental policymaking at the federal level, which benefits other municipalities facing similar HAP issues. Houston set in motion fundamental changes in the way EPA conducts HAP analyses by (1) a formal petition challenging compliance under-reporting and (2) a legal request to revise HAP risk calculations. In 2014, EPA conducted public hearings (in Houston) on a new federal rule[53] incorporating many of the provisions requested by the city.

The good news is that air quality in Houston is better today than it was 10 years ago and much better than it was 30 years ago. The bad news is that it's still not good enough and is not improving fast enough, especially for sensitive and vulnerable populations living in close proximity to major emission sources. The White Administration tried hardily to focus attention and resources on HAPs, and for a time they were successful. But once Bill White left office, the spotlight shifted and the city returned to old familiar ways of thinking and acting about air pollution. The take-home message from the Houston experience is perhaps best summarized by modifying a well-known axiom – "you can't fight city hall (in the long run), even if you are city hall (in the short run)."

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Author Contributions

Conceived and designed the experiments: KS, SHL. Analyzed the data: KS, SHL. Wrote the first draft of the manuscript: KS. Contributed to the writing of the manuscript: KS,

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SHL. Agree with manuscript results and conclusions: KS, SHL. Jointly developed the structure and arguments for the paper: KS, SHL. Made critical revisions and approved final version: KS, SHL. All authors reviewed and approved of the final manuscript.

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