THE CONTROL OF AIR TOXICS:

TOXICOLOGY MOTIVATION AND HOUSTON IMPLICATIONS

EXECUTIVE SUMMARY

Introduction

Houston's poor air quality has marred the reputation of the city. As a giant in the petrochemical industry, a major port, and a large metropolitan center, Houston has numerous sources of air pollution and the impact on human health in the area cannot be ignored. Investigations reported in the Houston Chronicle have focused attention on the levels of hazardous air pollutants (HAPs or air toxics) in neighborhoods near industrial facilities [1]. The series triggered action on many fronts, including additional air quality monitoring, analysis of existing datasets, and intensified health monitoring and assessment. The Houston Endowment also took notice and funded this study to compile the underlying toxicology of HAPs and to determine how regulation of HAPs is conducted in other jurisdictions. This is a summary of the findings. The full report contains the data supporting the conclusions drawn and recommendations offered.

Background

In an effort to combat air pollution nationwide, in 1970 Congress established the United States Environmental Protection Agency (US EPA) and passed the Clean Air Act and its amendments so that the agency could develop, implement, and enforce controls on various kinds of air pollution.

The Clean Air Act established National Ambient Air Quality Standards for six criteria air pollutants that have widespread sources and are found in relatively large quantities in the lower atmosphere. Separately, the Clean Air Act promulgated regulation of hazardous air pollutants (HAPs) which are present in ambient air in much lower concentrations. HAPs, however, have a larger amount of uncertainty about the type and degree of risk they pose. Current federal regulation of HAPs has aimed at controlling the emission of these air toxics through the use of technology. Maximum achievable control technology (MACT) standards have been set for a number of different stationary emission sources as a result of 1990 amendments to the Clean Air Act. Technology alone, however, does not ensure that ambient concentrations of HAPs remain below the levels of concern for the health effects of the various pollutants.

Scope

Monitoring of ambient levels of HAPs in the Houston area has been conducted for a number of years. For the four HAPs investigated in this study, benzene and 1,3-butadiene are monitored at 14 locations in Harris County, formaldehyde is measured at three locations, and diesel particulate matter is not routinely monitored.

Data gathered over the last few decades suggest that the ambient levels of HAPs in Houston have decreased as a result of the implementation of various control strategies. Increased monitoring has also uncovered previously unrecognized "hot spots" where localized concentrations are much higher than area average concentrations. Monitoring has found that concentrations of many pollutants are still substantially higher than the levels measured in other cities across the United States (Tables 1 and 2) - high enough to warrant concern about the health implications for Houstonians. This environmental health risk deserves urgent attention.

Table 1: *A comparison of the 2004 annual average concentration of three hazardous air pollutants at the single highest monitoring location in four US cities [2].*

	Benzene	1,3-Butadiene	Formaldehyde
Chicago	0.5 ppb	0.08 ppb	2.0 ppb
Los Angeles	0.9 ppb	0.2 ppb	7.2 ppb
St. Louis	0.5 ppb	0.07 ppb	4.4 ppb
Houston	1.7 ppb	4.0 ppb	7.9 ppb

Table 2: *A comparison of the maximum 24-hour average concentration during 2004 of three hazardous air pollutants as observed in four US cities [2].*

	Benzene	1,3-Butadiene	Formaldehyde
Chicago	2.7 ppb	0.5 ppb	8.1 ppb
Los Angeles	2.9 ppb	0.5 ppb	15.5 ppb
St. Louis	1.1 ppb	0.3 ppb	33.0 ppb
Houston	73.5 ppb	37.4 ppb	20.1 ppb

Table 1 shows that measured annual average concentrations of these three HAPs are significantly higher in Houston than in the other major US cities. In the case of 1,3-butadiene, the observed annual average concentration is about twenty times higher than that observed in the Los Angeles area, which is the closest competitor. Table 2 shows that the comparison is even more dramatic on a 24-hour average basis showing that over short periods, the air quality in Houston is dramatically worse than other cities. Because the measured concentrations are significantly higher on both long and short time scales, reductions in average HAPs concentrations and in peak concentrations during extreme events must be made.

Toxicity and Concentrations

Detailed toxicology data are needed for each compound because each HAP has a unique dose-response relationship in the human population. For example, air toxics differ in their metabolic pathways and the toxicity of metabolites, and an individual's sensitivity to them also varies. Ongoing scientific research has provided much of the needed information on the toxicology of HAPs and organizations including the US EPA, the California Environmental Protection Agency, and the Agency for Toxic Substances and Disease Registry have reviewed the body of data and included it in their risk assessments. The epidemiological studies on which the risk assessments are based for benzene, 1,3-butadiene, and diesel particulate matter were mainly investigations of cancer incidence in healthy adult worker populations, primarily male. Most states refer to these risk assessments or occupational standards when setting exposure levels, and they sometimes include a safety factor to better protect particularly susceptible populations.

This study evaluated the existing toxicology and risk assessments in order to provide relevant data for four HAPs of particular concern in the region: benzene, 1,3-butadiene, formaldehyde, and diesel particulate matter (PM). These four pollutants were identified by the Mayor's Task Force on the Health Effects of Air Pollution as being definite risk pollutants, which means that there is “compelling and convincing evidence of significant risk to the general population or vulnerable subgroups at current ambient concentrations” [3].

The four pollutants chosen are representative of the types of HAPs emitted from both industrial facilities (point sources) and vehicles (mobile sources - cars, trucks, trains, ships). The key health impact of primary concern for benzene and 1,3-butadiene is cancer, although the type of cancer induced and toxicological mechanisms are different. The key health impact of formaldehyde is not cancer but rather irritation and damage to the respiratory system. Diesel PM can cause damage to both the respiratory and cardiovascular systems, including the induction of cancer, and acts differently from the other three as it is a particle pollutant.

Also included in the discussion are census tract maps of Harris Country illustrating the estimated concentrations of each pollutant studied. These maps contain data from the US EPA's National Scale Air Toxics Assessment (NATA) [4] and are modeling calculations made using emission estimates from point and mobile sources. Various factors such as emission rates, locations of emission sources, and weather patterns affect the predicted concentrations. While each of these factors can introduce uncertainty into the model results, the NATA concentrations are useful to show the countywide distribution of HAPs, since monitoring is conducted at only a limited number of locations, many of them in eastern Harris County. The maximum 2004 annual average concentrations listed in Table 1 are in general agreement with the maximum annual average concentrations predicted by NATA.

Benzene

Benzene is a product of the petrochemical industry and is also emitted in motor vehicle exhaust. Benzene exposure has been shown to lead to an increased risk of leukemia (carcinogenic effect) as well as to non-carcinogenic effects, including decreased blood cell counts. The US EPA risk assessment has been identified as the most appropriate basis for determining protective levels. Using their estimate of the cancer risk for benzene exposure, an estimated one excess cancer death per million people would result from lifetime exposure to annual average concentrations between 0.04 and 0.14 parts per billion (ppb). Protecting against carcinogenicity to this level also serves to protect people from the identified non-carcinogenic effects of the chemical.

1,3-butadiene

Like benzene, 1,3-butadiene is a product of petrochemical manufacturing and is also present in motor vehicle exhaust. Exposure has been shown to lead to an increased risk of cancer as well as to non-carcinogenic effects. For 1,3-butadiene the carcinogenic effect is considered to be the most pressing environmental health concern. Using the data given in the US EPA risk assessment, identified as the most appropriate basis for determining protective levels, a cancer risk of one excess death per million people would result from lifetime exposure to an annual average ambient concentration of 0.013 ppb of 1,3-butadiene. Again, protecting against carcinogenicity to this level would protect people from identified non-carcinogenic effects.

Formaldehyde

Formaldehyde is emitted directly from various sources and is also formed through atmospheric chemical reactions. Exposure has been shown to cause sensory irritation of the eyes and respiratory tract. Inhalation exposures to formaldehyde in laboratory animals cause degenerative effects and nasal tumors in rats. Similar risks are anticipated in humans. The current US EPA risk assessment for formaldehyde is considered outdated and is expected to be revised in the light of new data using a mechanistic modeling approach. The new model, developed by the Chemical Industry Institute for Toxicology Centers for Health Research, suggests that the risk of cancer is lower than was previously thought. The authors of this study recommend that a level low enough to avoid sensory irritation be used, because protecting to this level will also protect people against the carcinogenic effects of this chemical.

Since formaldehyde is acutely irritating, a 24-hour averaged ambient standard of 10 ppb is recommended. This level is ten times lower than the lowest levels recognized to cause regenerative proliferation in target tissues and at least eight times lower than the threshold for eye, nose, or throat irritation. Occupational, indoor, and in-vehicle concentrations of formaldehyde are often much higher than ambient concentrations. Efforts should therefore be directed at controlling formaldehyde exposure in these environments.

Diesel Particulate Matter

Diesel PM toxicity acts by a variety of pathways and mechanisms that reflect the oxidative, mutagenic, and toxic properties of the particles' chemical components. Sources of these particles are widespread, including vehicles, engines, and generators. To date the best estimates of the cancer risk posed by diesel PM lie within a range between those offered by the California Office of Environmental Health Hazard Assessment and by the International Programme on Chemical Safety. Using these estimates of the cancer risk for diesel PM, one excess cancer death per million people would result from lifetime exposure to annual average concentrations between 0.003 and 0.029 micrograms per cubic meter ($\mu g/m^3$). In other words, for every 1 $\mu g/m^3$ of lifetime exposure to diesel PM, the estimated range of excess cancer deaths would be 3.4 to 30 for every 100,000 people. Protecting against carcinogenicity to the recommended level also protects people against the identified non-carcinogenic effects of diesel PM.

Unlike the other three HAPs studied, diesel particulates are not routinely monitored at local air quality monitoring sites. Recent air pollution research studies in Houston have quantified diesel PM concentrations between 1.6 and 3.7 $\mu g/m^3$ [5]. These values are significantly lower than the maximum concentrations predicted by the NATA model, which predicts diesel PM levels in excess of 20 $\mu g/m^3$ in some parts of Harris County. Since measurements were conducted in only a few locations, it is possible that ambient measurements did not sample the maximum values predicted by the NATA model [5]. While this discrepancy does suggest some uncertainty in the NATA estimates, measured diesel PM levels in the area nevertheless indicate that action must be taken to reduce observed concentrations.

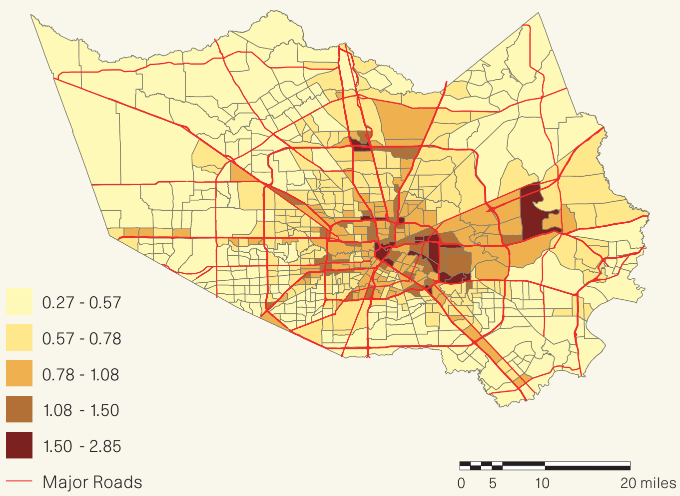

Figure 1: Benzene concentrations (ppb)

Benzene concentrations (ppb) across Harris County census tracts. Data from the US EPA's 1999 NATA [4].

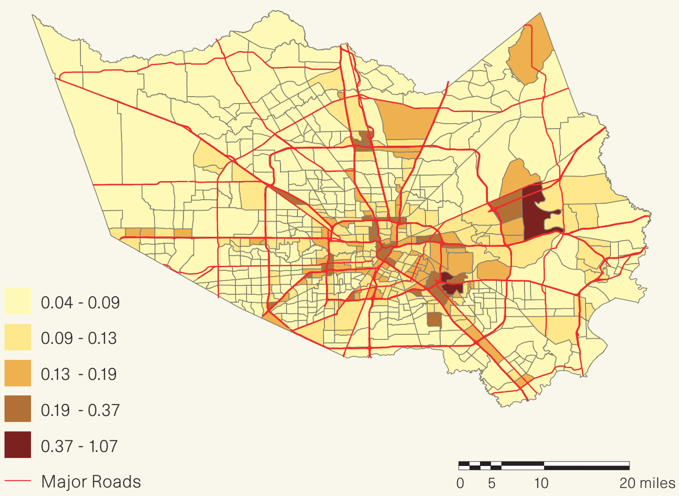

Figure 2: Concentrations of 1,3-butadiene (ppb)

Concentrations of 1,3-butadiene (ppb) across Harris County census tracts. Data from the US EPA's 1999 NATA [4].

Summary of Toxicity

Based on the toxicological information and the concentrations seen in the Houston area for the selected four air pollutants, it is clear that large portions of the city have ambient air concentrations posing a risk higher than one excess cancer death in every 100,000 people (Table 3). Observed concentrations of 1,3-butadiene and diesel PM approach a level indicating risk greater than one excess cancer death per 10,000 people. Furthermore, since these risk levels are calculated for individual compounds, the cumulative risks from several pollutants present simultaneously are even greater and emphasize the need for action.

Table 3: *Four levels of excess cancer risks associated with lifetime exposure to three of the air toxics discussed. The recommended ambient air standards are independently summarized in Tables 4 and 5.*

Increased Cancer Risk	Benzene	1,3-Butadiene	Diesel PM
1 in 1,000,000	0.04 - 0.14 ppb	0.013 ppb	0.003 - 0.03 µg/m^3
1 in 100,000	0.41 - 1.41 ppb	0.133 ppb	0.03 - 0.29 µg/m^3
1 in 10,000	4.1 - 14.1 ppb	1.33 ppb	0.33 - 2.94 µg/m^3
1 in 1,000	41.0 - 141 ppb	13.3 ppb	3.33 - 29.4 µg/m^3

Formaldehyde: The proposed ambient standard for formaldehyde will protect against sensory irritation because protecting to this level will also be protective for carcinogenicity.

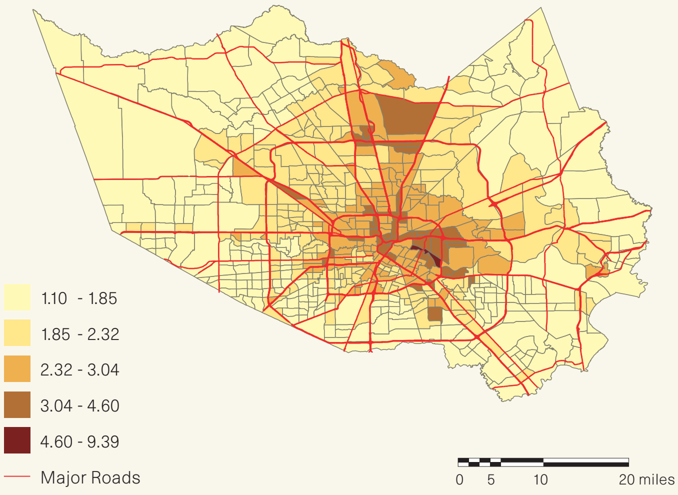

Figure 3: Formaldehyde concentrations (ppb)

Formaldehyde concentrations (ppb) across Harris County census tracts. Data from the US EPA's 1999 NATA [4].

State Approaches to Regulating HAPs

Through the Clean Air Act Amendments, Congress has charged the US EPA with creating regulations to address the residual risk that remains from HAPs exposures after the adoption and implementation of maximum achievable control technology (MACT) standards. These regulations have yet to be established, now more than ten years after the establishment of MACT standards. In the interim, states have taken the initiative to try to address the residual risk posed by HAPs by developing regulations beyond the MACT standards set by federal regulation.

No matter what methods a state decides to use in regulating air toxics, the fundamental question involved is common to all regulating bodies: What is an acceptable ambient concentration of these HAPs? The US EPA has chosen a benchmark of reducing the excess cancer risk to less than one in a million. As any future federal legislation is likely to use this benchmark, many states have chosen it as their goal. The exact benchmark concentrations vary slightly among states that have made this their goal, reflecting variation in the risk assessments consulted and the year of implementation. The underlying toxicological data, however, are essentially the same.

Currently, the only effort to address HAPs in Texas beyond the requirements of federal regulation has been in the establishment by the Texas Commission on Environmental Quality (TCEQ) of Effects Screening Levels (ESLs). ESLs are non-binding target concentrations used in issuing permits for new facilities. When a permit application for a new emission source is reviewed, the permitted

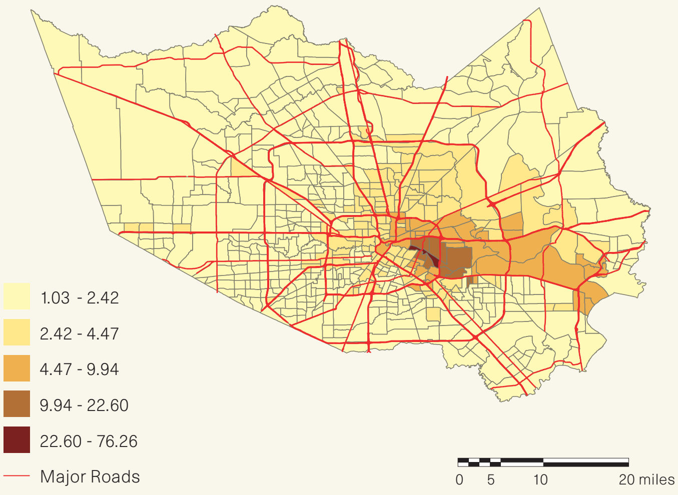

Figure 4: Concentrations of diesel particulate matter (µg/m^3)

Concentrations of diesel particulate matter (µg/m^3) across Harris County census tracts. Data from the US EPA's 1999 NATA [4].

emissions of pollutants are calculated without consideration of other existing sources or of background pollutant levels. If the expected ambient contribution from the new facility exceeds the established ESLs, additional emissions controls may or may not be required before an operating permit is issued. It is important to note that the Texas ESLs are established at a screening level equivalent to a health impact of one excess cancer death in 100,000 people Also, ESLs do not govern the surrounding ambient air concentrations and do not take into account the residual or pre-existing risks due to the ambient concentration of HAPs.

Most of the states examined in this report attempt to control emissions of HAPs through the permitting process. This method caps the emissions from a single source or complex, effectively ignoring the residual or pre-existing risk and other sources in the area. As a result, any approach focusing solely on the permitting process does not limit ambient air concentrations. Several states, including Massachusetts, Michigan, New Jersey, North Carolina, and Oregon, have chosen to cap the incremental contribution of a permitted source to the ambient air at a risk level associated with a one in a million excess cancer risk. The California Hot Spots program however, addresses the ambient concentration of HAPs by focusing on reducing emissions in areas where ambient concentrations are high regardless of type of source and whether or not permitted point sources are operating within permit guidelines.

How effective the established emission limits are at controlling the release of HAPs into the air is largely dependent on the type and rigor of the enforcement approach adopted by each state. Some states place the burden of compliance on the sources by requiring that they monitor emissions and report their data. Others place the burden on the state to identify and address problems. Based on the examination of regulations in other states, the approach we favor as the best for Texas is a hybrid model that places responsibility for compliance reporting directly on the regulated entities and allows the state the flexibility to address hot spots. We recommend further investigation into how such an approach could be implemented.

Recommendations

We strongly recommend immediate action to lower the ambient concentrations of the four HAPs studied in this report. From a health perspective, we recommend that a goal of one excess cancer death in a million people be the target throughout the state. The recommendation to protect to this level is based on a concern for human health and is based on widely accepted risk assessments and health effects data.

Unresolved implementation issues are associated with attaining an air quality standard representing a one in a million cancer risk. The ESL approach used by the TCEQ is not adequate to address this problem. The ESL approach is deficient because it is permit-specific rather than comprehensive, and as practiced, it is not enforceable. We feel that relying solely on ESLs applied to individual permit actions will never lead to attainment of the one in a million health-based risk level throughout the community. To the extent that the ESL approach is maintained by the TCEQ, we strongly urge that the screening levels for air toxics be based on a risk of one excess cancer death in one million,

Table 4: *Proposed Ambient Standard Goals*

	Benzene	1,3-Butadiene	Formaldehyde	Diesel PM
Proposed Ambient Standard Goal	0.14 ppb	0.013 ppb	10 ppb*	0.03 μg/m^3

**24-hour average standard based on acute irritation.*

Other standards are proposed as annual averages.

Table 5: *Proposed Interim Ambient Standards*

	Benzene	1,3-Butadiene	Formaldehyde	Diesel PM
Proposed Interim Ambient Standard	1.4 ppb	0.13 ppb	10 ppb*	0.29 μg/m^3

**24-hour average standard based on acute irritation.*

Other standards are proposed as annual averages.

rather than the current levels, which are based on a risk level of one excess cancer death in 100,000.

We recommend that as an ultimate goal, enforceable ambient air quality standards be adopted that protect human health to a level where the excess risk of cancer from exposure to individual HAPs does not exceed one in one million. Table 4 shows the ambient levels required to achieve a risk level of one in a million for the four air toxics studied.

We recommend that these levels be attained throughout the state of Texas. However, recognizing that there are areas within the Houston region where the current ambient air quality is associated with an excess cancer risk approaching one in 10,000, we recommend urgent action be taken to reduce HAPs concentrations to an interim goal consistent with no greater than a one in 100,000 excess cancer risk. In Table 5, interim ambient standards required for a risk of one in 100,000 are set out.

In reviewing ambient data relative to these standards, certain "hot spots" can be identified where, to achieve this interim ambient standard, benzene levels will have to be reduced by up to 40%, formaldehyde levels by up to 50%, and 1,3-butadiene levels by up to 95% from measured 2004 levels. In addition, diesel PM will have to be reduced by up to 90% from the measured 1998 levels. Adoption of these interim standards is essential to make immediate progress in protecting public health.

It is important to note that risk assessment is an ongoing process. New information about toxicological mechanisms, individual susceptibility, multi-pollutant exposure, and other factors continually refines our understanding. Reducing ambient air toxics levels as suggested in this study will not lead to zero risk from exposure to HAPs, but rather to a risk of one excess cancer death in a million people for each individual compound.

Next Steps

An investigation into how such standards would be implemented should be undertaken. Such an effort might emphasize:

- the feasibility and effectiveness of focusing on hot spots rather than on widespread implementation
- using a command-and-control approach for point sources rather than devoting resources to inspection, maintenance, and emission standards for vehicles
- denying operation and building permits or implementing an emissions offset program
- providing various economic incentives to reduce emissions.

In determining an appropriate implementation plan, attention should be drawn to strategies that other states and countries are using. One strategy to reduce ambient concentrations of HAPs is anti-idling regulations which have been adopted in California, Connecticut, and Massachusetts. Such a strategy, and others like it, can be recommended for rapid implementation and can make an immediate difference to ambient air quality, but they are only part of an overall solution.

A growing trend internationally is to require producers of new chemicals to conduct scientific studies regarding the toxicity of their chemicals. This information makes regulations easier to establish as chemicals come onto the market and alleviates some of the burden on regulating bodies. The US EPA, as well as the states, can capitalize on this information in the future.

From a community health perspective, the effects of air pollution on vulnerable populations may be compounded by socioeconomic inequities, racial and demographic differences, and disparities in access to health care and use of health services. Although occupational and housing patterns explain much of the variation in proximity to pollution, there is persistent inequity in potential exposure across population groups. Modifiers of the health effects of air pollution include income, race, ethnicity, age, proximity to traffic, and residential patterns. These factors need to be considered in determining an implementation strategy to ensure that everyone shares a similar risk. These factors underscore that for immediate improvements in health, initial implementation steps should focus on the most heavily impacted populations.

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