IEc

Section 812 Benzene Case Study: An Urban-Scale HAP Benefits Analysis

EPA/SAB HAP Benefits Analysis Workshop

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Principal
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Outline

- Purpose/Scope
- Overview of Case Study Approach
- Main Results
- Sensitivity Analysis / Uncertainty
- Individual Risk Analyses for Highly Exposed Populations
- Strengths/Limitations

Purpose and Scope

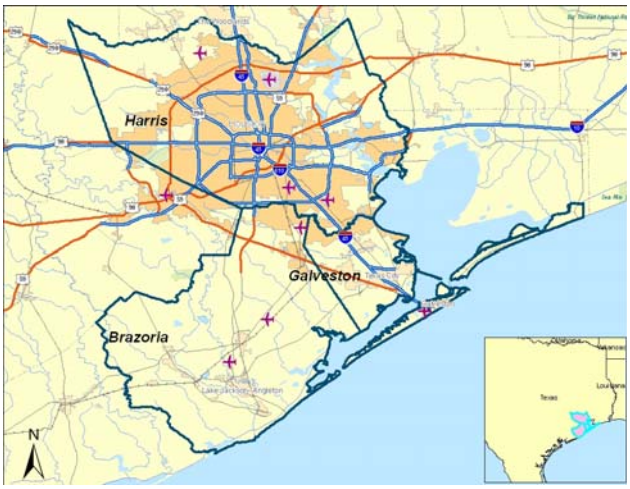
Purpose:

- To generate example Clean Air Act Amendments (CAAA) benefit results for a HAP in an urban setting
- To consider the value of this exercise more broadly for HAP benefits characterization

Scope:

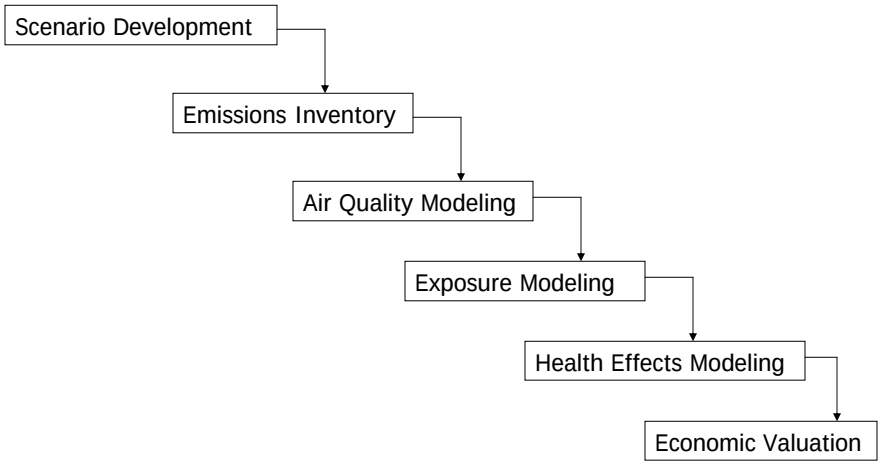
- Conducted a local-scale study of benzene in Houston
- Estimated benefits of reductions in benzene resulting from CAAA provisions from 1990 to 2020
- Three target years (2000, 2010, 2020)

Study Area



Source: "Section 812 Clean Air Act Cost-Benefit Study Air Toxics Case Study: Benzene Emissions Reduction in Houston – Draft Report." E.H. Pechan & Associates, February 2006.

Analytical Approach



Scenario Development

- Without-CAAA Scenario: Freeze regulations at 1990 levels
- With-CAAA Scenario: Include all current and anticipated regulations affecting benzene emissions
  - Title I (through SIP requirements, e.g., vehicle I/M programs)
  - Title II
    - Tailpipe Standards (Tier 1 & 2, Heavy Duty Engine/Diesel rule)
    - Evaporative Emissions Standards (Stage II and Onboard Vapor Recovery, Evaporative Test Procedure)
    - Fuel Regs (RFG Phase II, Summertime Volatility Requirements, Sulfur limits)
  - Title III
    - Identify MACT rules affecting benzene, such as:
      - 7 year MACT - Oil and Natural Gas Production
      - 4 year MACTs - Petroleum Refineries, Gasoline Distribution
      - 2 year MACT – Hazardous Organic NESHAP
  - 2007 Mobile Source Air Toxics (MSAT) rule not included

Emissions Estimation

- Point and Non-Point Sources
  - 1990: NEI for HAPs
  - Without-CAAA: Grow emissions from 1990 NEI for HAPs
  - With-CAAA: 2002 NEI used for 2000 and as base for emissions growth in 2010 and 2020
  - NP includes aircraft, locomotives, commercial marine vessels
- On-Road Sources
  - Generated seasonal hourly link-level (i.e., roadway segment) emissions data
  - VMT estimates from HGAC and TTI for 2005
  - Emissions factors from MOBILE 6.2
- Non-Road Sources (sources in NONROAD model only)
  - Product of benzene speciation factors and VOC emissions estimates
  - Speciation factors and fuel data inputs – EPA's NMIM
  - VOC emissions for EPA's 2004 NONROAD model

Air Quality and Exposure Modeling

- For ambient concentrations, used American Meteorological Society/U.S. EPA Regulatory Model (AERMOD).
  - Modeled at block group level
  - Meteorological data: 1990 (base year) and 2000 (all else).
  - County level emissions data (nonroad, nonpoint) spatially allocated to census tracts.
  - Used county-specific 1999 NATA background levels
  - Calculated annual average concentrations plus hourly averages for use in HAPEM6.
- Generated exposure point concentrations using EPA's Hazardous Air Pollution Exposure Model (HAPEM), Version 6
  - Separate distributions by age (0-1; 2-4; 5-15; 16-17; 18-64; >=65).
  - Accounts for exposure gradients near major roadways.
  - Exposure concentrations at the census tract level.

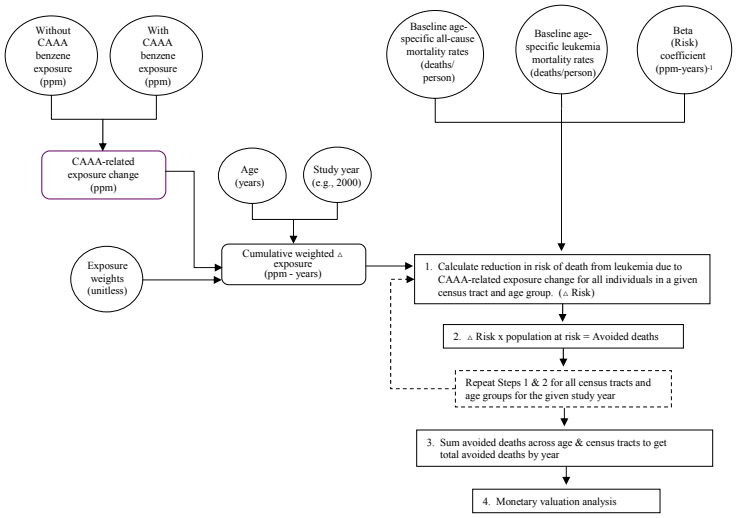
Key Health Endpoints

- Benzene literature review completed in July 2005
- Key benzene health endpoints identified
  - Cancer
    - All leukemias – most data rich endpoint
    - Epidemiologic Data – Pliofilm cohort study (Crump et al., 1994),
    - Linear Dose-Response (D-R) Relationship
  - Non-Cancer
    - Subclinical effects (e.g., changes in white blood cell counts) found at occupational levels. Limited data for ambient levels
    - Effects evaluated using the benzene Reference Concentration (RfC)

Approach to Estimating Avoided Cancer Cases

- Used Life-table approach to estimate avoided fatal and non-fatal leukemias
  - Patterned after NRC's BEIR IV report on radon exposure (1988)
  - Allows for estimation of benefits to age-specific cohorts
  - Allows us to model "cessation lag" effects on benefits directly by using cumulative weighted exposure estimates
  - Generates estimate of benefits expected in each year, not a rolled-up estimate to be spread across future years
  - Model was run with both leukemia mortality and incidence data. The difference between leukemia incidence and leukemia mortality results provide estimate of non-fatal cases.

Overview of Health Benefits Model



Note: This flowchart assumes the model is being run with leukemia mortality data. The model can also be run with leukemia incidence data. The difference between the model results for these two runs represents an estimate of avoided non-fatal cases of leukemia.

Benefits Valuation

- Fatal cancers: value of statistical life (VSL) from Viscusi and Aldy (2003) (starting at $6.8 million for 1990 income levels) plus $150,000 per case for pre-mortality morbidity from EPA's Cost of Illness Handbook (All 2006$).
- Non-fatal cancers: used range of values from WTP for chronic bronchitis to WTP for non-fatal lymphoma as endpoints ($0.41 – 4.3 million 2006$).
- Income growth incorporated for VSL, assuming an elasticity value of 0.4.
- Benefits discounted using 5% rate (3% and 7% used as a sensitivity analysis) per current guidance.

Results – Health Benefits

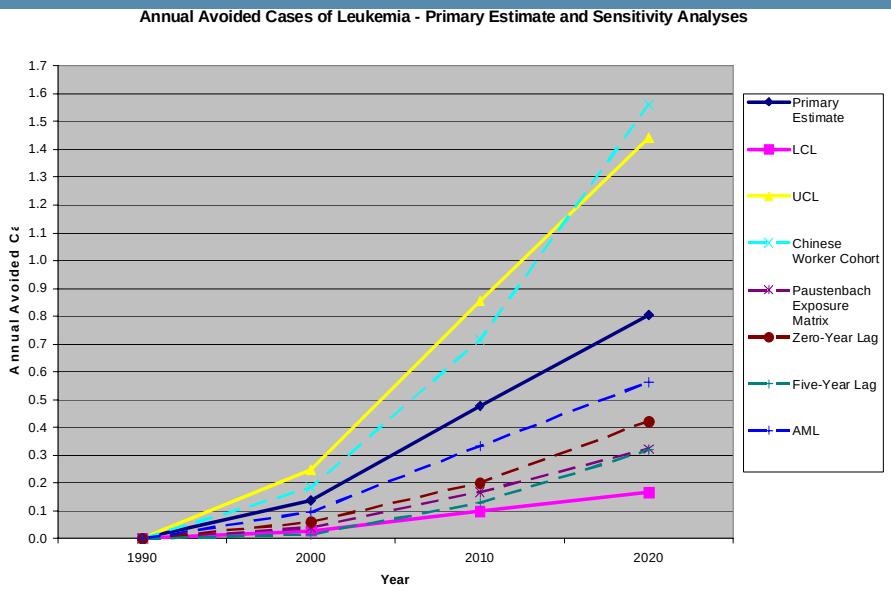
STUDY YEAR	ANNUAL AVOIDED CASES OF LEUKEMIA		
	AVOIDED FATAL CASES	AVOIDED NON-FATAL CASES	TOTAL AVOIDED CASES
1990	0	0	**0**
2000	0.1	0.1	**0.2**
2010	0.3	0.2	**0.5**
2020	0.4	0.4	**0.8**
Cumulative Cases Occurring Within the Study Period	**7**	**6**	**13**
Additional Cumulative Cases Occurring After 2020*	**3**	**3**	**6**
Total Cumulative Cases	**10**	**9**	**19**
*Note: These avoided cases are due to changes in benzene exposure that occurred within the study period.			

- Majority of benefits occur in Harris county (~85%) with remainder spread equally between Brazoria and Galveston counties.
- No differences found in the number of individuals experiencing benzene concentrations above the RfC under the *With-CAAA* and *Without-CAAA* scenarios (proposed approach in the original analytic plan)

Results – Monetary Benefits

STUDY YEAR	TOTAL BENEFITS (1990 NPV, MILLIONS OF 2006$, 5% DR)		
	BENEFITS FROM FATAL CASES OF LEUKEMIA	BENEFITS FROM NON-FATAL CASES OF LEUKEMIA	TOTAL BENEFITS
1990	$0	$0	**$0**
2000	$0.36	$0.02 – 0.18	**$0.4 - 0.5**
2010	$0.80	$0.04 – 0.40	**$0.84 - 1.2**
2020	0.92	$0.04 – 0.45	**$0.96 - 1.4**
Cumulative Cases Occurring Within the Study Period	**$20**	**$1.0 - 10**	**$21 - 30**
Additional Cumulative Cases Occurring After 2020*	**$3**	**$0.15 - 1.5**	**$3.1 - 4.5**
Total Cumulative Cases	**$23**	**$1.2 - 12**	**$24 - 35**
*Note: These avoided cases are due to changes in benzene exposure that occurred within the study period.			

Results – Sensitivity Analyses



Uncertainties

- Model sensitive to inputs – results range can vary by plus 66 percent to minus 81 percent
- Only quantified leukemia – potentially other health endpoints related to benzene (cancer and non-cancer)
- Use of occupational cohort study
  - Only included certain age groups
  - Potential for "healthy worker effect"
- Shape of dose-response function at low exposures uncertain (Supralinear? Threshold?)

Highly Exposed Subpopulations

CAAA-RELATED LEUKEMIA RISK REDUCTIONS IN 2020 FOR INDIVIDUALS LIVING IN CENSUS TRACTS WITH HIGH AMBIENT BENZENE CONCENTRATIONS

COUNTY	CENSUS TRACT	MEDIAN WITHOUT-CAAA RISK	MEDIAN WITH-CAAA RISK	PERCENT REDUCTION IN RISK	POPULATION OF CENSUS TRACT
Brazoria	6643	2×10^{-4}	3×10^{-6}	98	5,452
Brazoria	6638	3×10^{-5}	6×10^{-6}	77	4,470
Galveston	7222	1×10^{-4}	7×10^{-6}	95	3,487
Galveston	7224	5×10^{-5}	8×10^{-6}	82	1,108
Harris	1000	1×10^{-4}	1×10^{-5}	92	6,678
Harris	2523	3×10^{-5}	7×10^{-6}	72	12,686

Note: These risk values were calculated using the 7.8 × 10-6 per $\mu g/m^3$ benzene inhalation unit risk (IUR) from the range of IURs reported on IRIS.

- **Attached Garages** - Additional health benefits may accrue to individuals living in homes with attached garages. Inclusion of CAAA-related benzene reductions in the garages of these homes could increase benefits by up to 63 percent over our primary estimate.

Science Advisory Board Review – May 2008 – Major Comments

- Overall value of case study: "of high quality… a reasonably comprehensive estimate of the primary health benefits"
  - Not optimistic that the approach can be repeated on national scale or be extended to many of the other air toxics due to insufficient epidemiological data
  - Council encourages EPA to consider alternative approaches (e.g., a reduced-form re-analysis using NATA concentration data and a more integrated multi-pollutant approach)
  - Health benefits are likely to be underestimated (doesn't include all health end points, benefits would extend beyond 2020 and study doesn't include MSAT rule)
- Emissions: urge greater attention to discrepancies between emission inventories and monitored concentrations
- Air quality modeling: concerns about estimates for background concentrations and calm periods
- Life-table approach: support using a linear exposure-response function for primary analysis; suggest considering evidence on non-Hodgkins Lymphoma, being clearer on latency v. cessation lag, and considering alternative exposure-response functions
- Valuation: suggest more work on transferring benefits to value non-fatal leukemias and encourage EPA to review cancer premium issue
- Individual Risk / Highly Exposed Populations: discuss indoor air exposure to provide overall public health context

Strengths of Risk Model

- Dynamic modeling of population risk changes
- Finer resolution than NATA-scale analyses
- Integrates lagged effects
- Uses central estimate of cancer potency, appropriate for regulatory analysis
- Adaptable for alternative D-R models and exposure measures
- Could be adapted to measure lost life expectancy
- Computationally efficient – analyze 700+ census tracts in minutes
- Best for urban-scale analysis

Limitations of Risk Model

- Data and resource intensive, particularly for emissions and AQM/exposure
- Universe of HAPs to model is limited
- Use with other HAPs may require estimation of central estimate dose-response function as many available toxicity values are based on upper bound estimates of potency
- Best if augmented by high-exposure analyses
- Not yet demonstrated for non-cancer analysis
- Non-cancer health effects may be difficult to value economically (if not clinically significant)

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Background/Timeline

- Prior attempts to estimate air toxics benefits in 812 analyses had been only partially successful
- **2001** - the Science Advisory Board (SAB) recommends performing a metropolitan scale case study on benzene
- **2003** – Analytical blueprint published for the 812 second prospective, including plan for case study
- **2003** – SAB reviews analytical blueprint and provides comments
- **Spring 2008** – EPA, IEc, and Pechan complete draft case study
- **May 2008** – SAB reviews case study report and provides comments
- **Fall 2008** – Revised version of case study report
- **March 2009** – Draft Final Version