

Acute and Chronic Health Risks Estimated from Ambient Non-methane Levels in Colorado's Oil and Gas Basins

HEI Workshop: Research Planning to Understand Population-
Level Exposures Related Development of Oil and Natural Gas
from Unconventional Resources.

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72-96 hour samples: Boulder County Public Health.

1-minute samples: Colorado Department of Public Health and Environment provided to the National Center for Atmospheric Research and NSF Front Range Air Pollution and Photochemistry Experiment (FRAPPÉ) campaign which took place in conjunction with the NASA DISCOVER-AQ project.

Continuous air measurements: NASA DISCOVER-AQ project



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Human health risk assessment of air emissions from development of unconventional natural gas resources☆☆☆

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ABSTRACT

Background: Technological advances (e.g. directional drilling, hydraulic fracturing), have led to increases in unconventional natural gas development (NGD), raising questions about health impacts.

Objectives: We estimated health risks for exposures to air emissions from a NGD project in Garfield County, Colorado with the objective of supporting risk prevention recommendations in a health impact assessment (HIA).

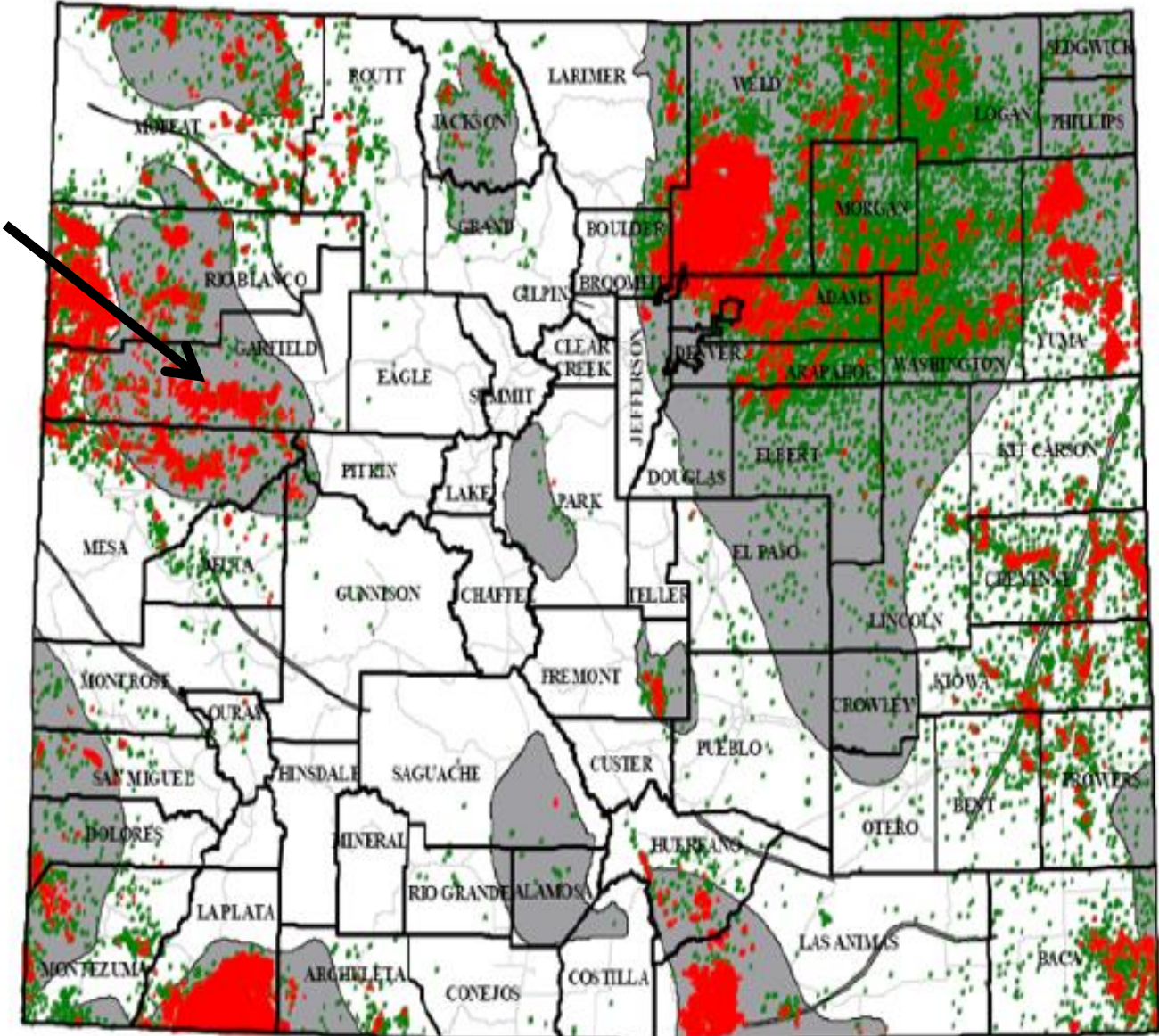
Methods: We used EPA guidance to estimate chronic and subchronic non-cancer hazard indices and cancer risks from exposure to hydrocarbons for two populations: (1) residents living $> \frac{1}{2}$ mile from wells and (2) residents living $\leq \frac{1}{2}$ mile from wells.

Results: Residents living $\leq \frac{1}{2}$ mile from wells are at greater risk for health effects from NGD than are residents living $> \frac{1}{2}$ mile from wells. Subchronic exposures to air pollutants during well completion activities present the greatest potential for health effects. The subchronic non-cancer hazard index (HI) of 5 for residents $\leq \frac{1}{2}$ mile from wells was driven primarily by exposure to trimethylbenzenes, xylenes, and aliphatic hydrocarbons. Chronic HIs were 1 and 0.4, for residents $\leq \frac{1}{2}$ mile from wells and $> \frac{1}{2}$ mile from wells, respectively. Cumulative cancer risks were 10 in a million and 6 in a million for residents living $\leq \frac{1}{2}$ mile and $> \frac{1}{2}$ mile from wells, respectively, with benzene as the major contributor to the risk.

Conclusions: Risk assessment can be used in HIAs to direct health risk prevention strategies. Risk management approaches should focus on reducing exposures to emissions during well completions. These preliminary results indicate that health effects resulting from air emissions during unconventional NGD warrant further study. Prospective studies should focus on health effects associated with air pollution.

Oil and Gas Drilling in Colorado

2012 Risk Assessment



Important Risk Assessment Concepts

- **Definition of the populations at risk:** Populations living near may experience exposures and risks differently than the regional population.
- **Identification of hazard:** concentrations of hazardous air pollutants in samples collected within 500 feet of O&G well site during uncontrolled flowback are significantly higher than in samples collected within 2640 feet (1/2 mile) from 13 O&G well sites in production.
- **Complete exposure pathway:** Inhalation of ambient air is an important exposure pathway for residents living near oil and gas well sites.
- **Potential for non-cancer health effects:** A potential for respiratory, neurological, hematological, and developmental health effects exists for residents living nearest the sites from short-term (20-month) exposures to hazardous air pollutants.
- **Slight elevation in lifetime excess cancer risk** for residents living nearest the sites

Population Size, Growth, and Environmental Justice Near Oil and Gas Wells in Colorado

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S Supporting Information

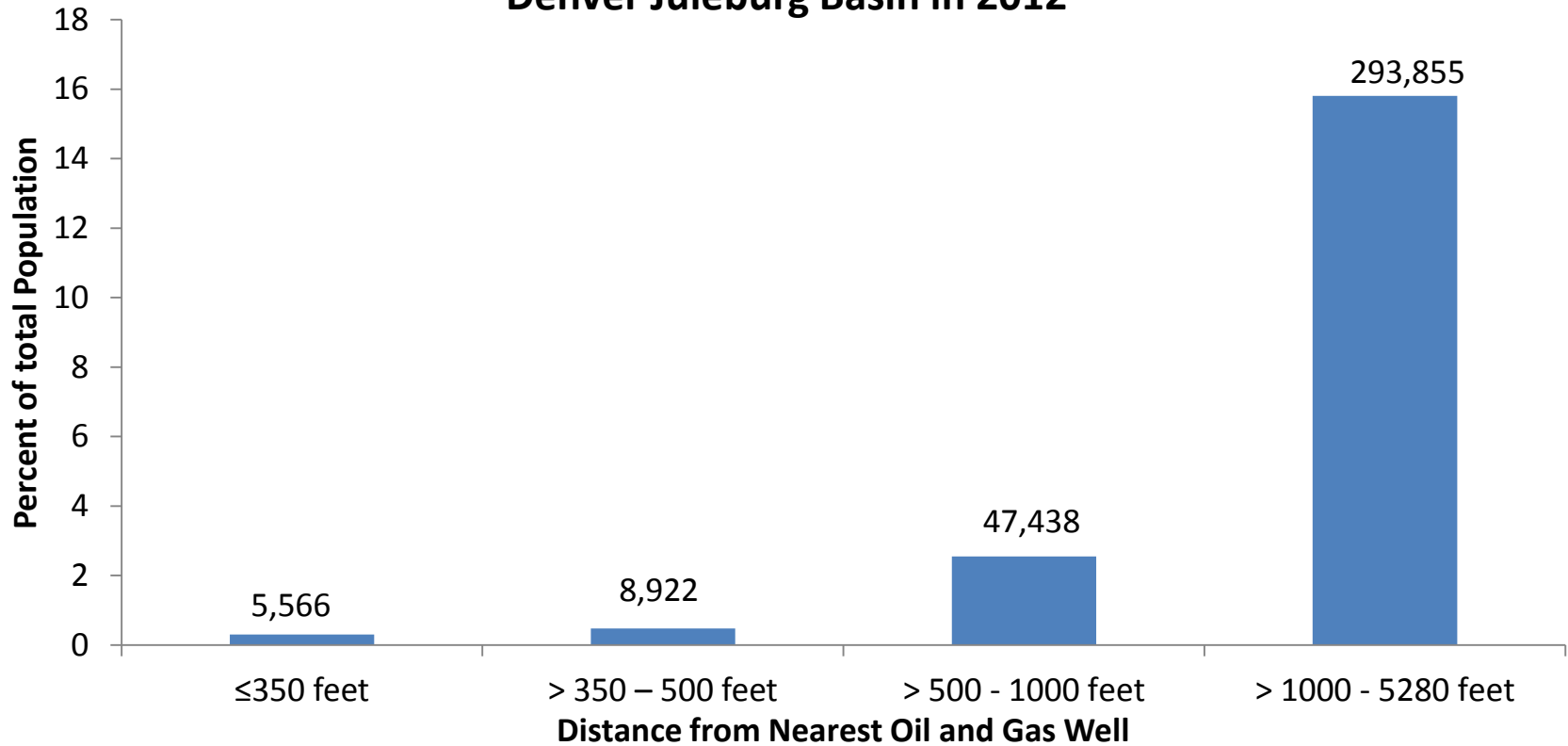
ABSTRACT: We evaluated population size and factors influencing environmental justice near oil and gas (O&G) wells. We mapped nearest O&G well to residential properties to evaluate population size, temporal relationships between housing and O&G development, and 2012 housing market value distributions in three major Colorado O&G basins. We reviewed land use, building, real estate, and state O&G regulations to evaluate distributive and participatory justice. We found that by 2012 at least 378,000 Coloradans lived within 1 mile of an active O&G well, and this population was growing at a faster rate than the overall population. In the Denver Julesburg and San Juan basins, which experienced substantial O&G development prior to 2000, we observed a larger proportion of lower value homes within 500 feet of an O&G well and that most O&G wells predated houses.

In the Piceance Basin, which had not experienced substantial prior O&G development, we observed a larger proportion of high value homes within 500 feet of an O&G well and that most houses predated O&G wells. We observed economic, rural, participatory, and/or distributive injustices that could contribute to health risk vulnerabilities in populations near O&G wells. We encourage policy makers to consider measures to reduce these injustices.

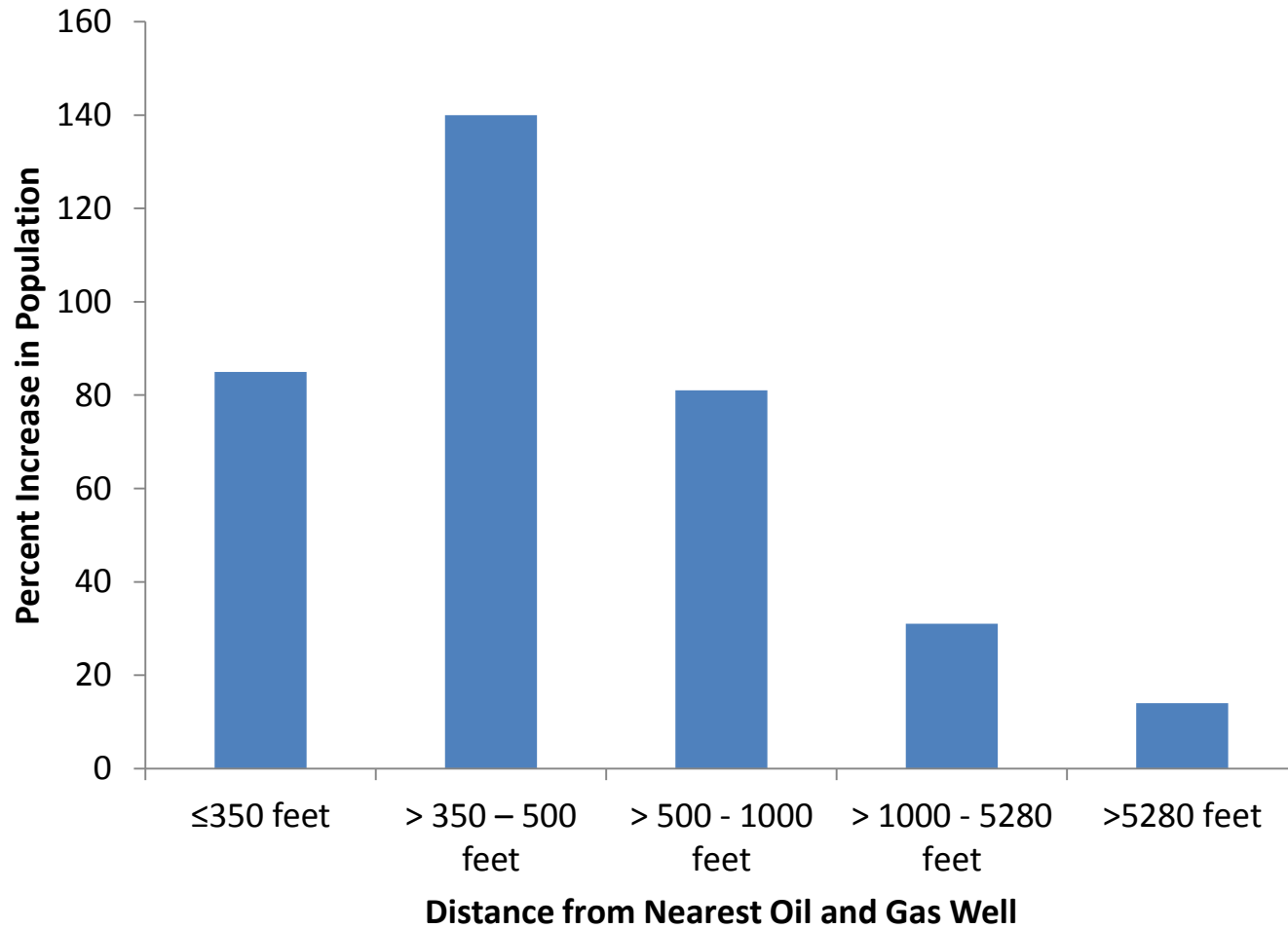


> 378,000 Coloradans living within one mile of an O&G well:
Populations in the Setbacks growing faster than the population outside
the setbacks

**~355,781 People living within 1 mile of an Oil and Gas Well in the
Denver Juleburg Basin in 2012**



Population with 1000 feet of oil and gas wells grew the fastest between 2001 and 2012



Ambient Nonmethane Hydrocarbon Levels Along Colorado's Northern Front Range: Acute and Chronic Health Risks

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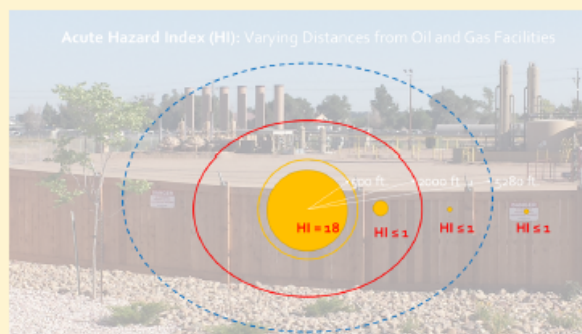
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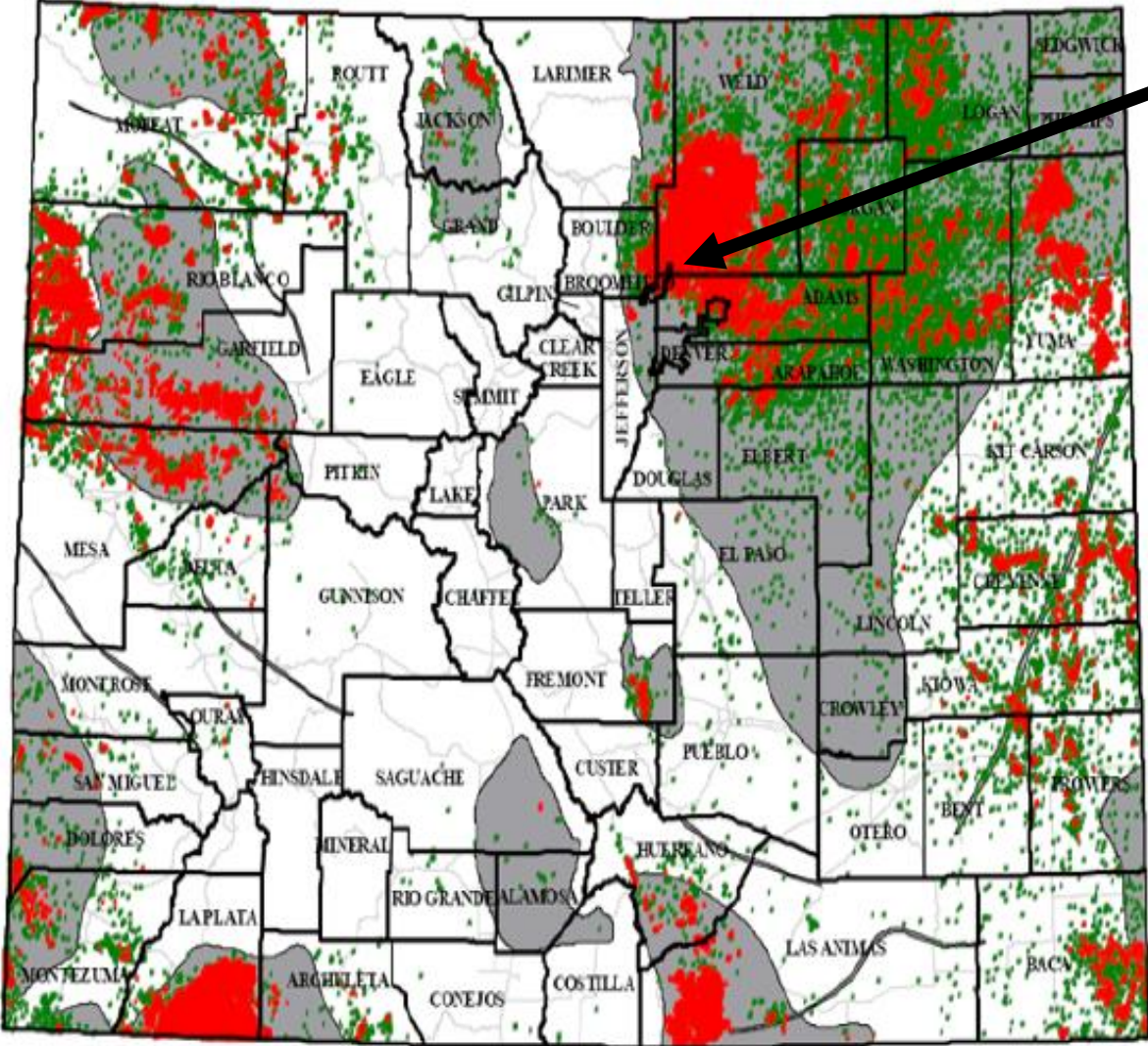
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Supporting Information

ABSTRACT: Oil and gas (O&G) facilities emit air pollutants that are potentially a major health risk for nearby populations. We characterized prenatal through adult health risks for acute (1 h) and chronic (30 year) residential inhalation exposure scenarios to nonmethane hydrocarbons (NMHCs) for these populations. We used ambient air sample results to estimate and compare risks for four residential scenarios. We found that air pollutant concentrations increased with proximity to an O&G facility, as did health risks. Acute hazard indices for neurological (18), hematological (15), and developmental (15) health effects indicate that populations living within 152 m of an O&G facility could experience these health effects from inhalation exposures to benzene and alkanes. Lifetime excess cancer risks exceeded 1 in a million for all scenarios. The cancer risk estimate of 8.3 per 10 000 for populations living within 152 m of an O&G facility exceeded the United States Environmental Protection Agency's 1 in 10 000 upper threshold. These findings indicate that state and federal regulatory policies may not be protective of health for populations residing near O&G facilities. Health risk assessment results can be used for informing policies and studies aimed at reducing and understanding health effects associated with air pollutants emitted from O&G facilities.



Oil and Gas Drilling in Colorado



2018 Risk Assessment



Concentrations of hazardous air pollutants increase with density of oil and gas wells

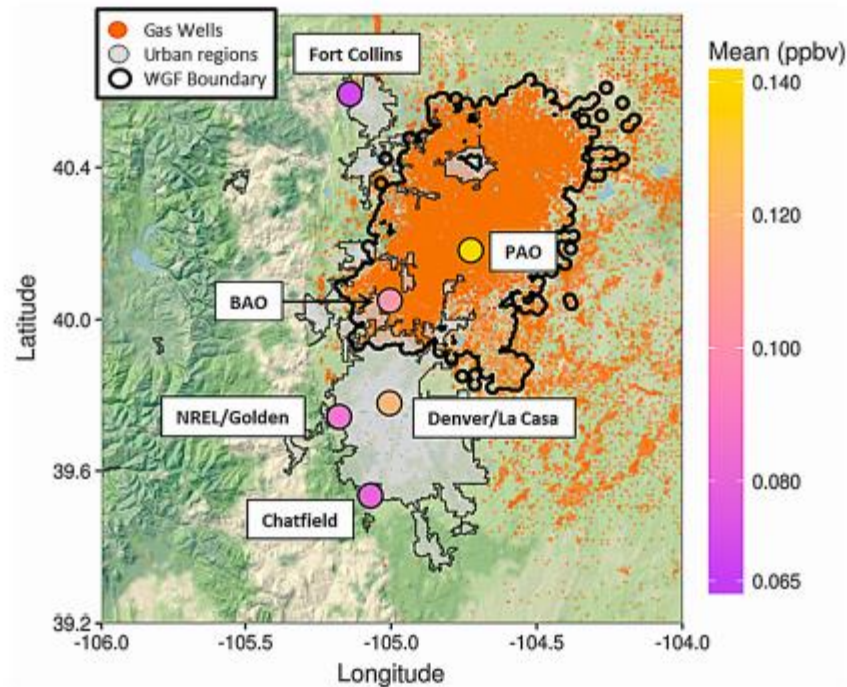
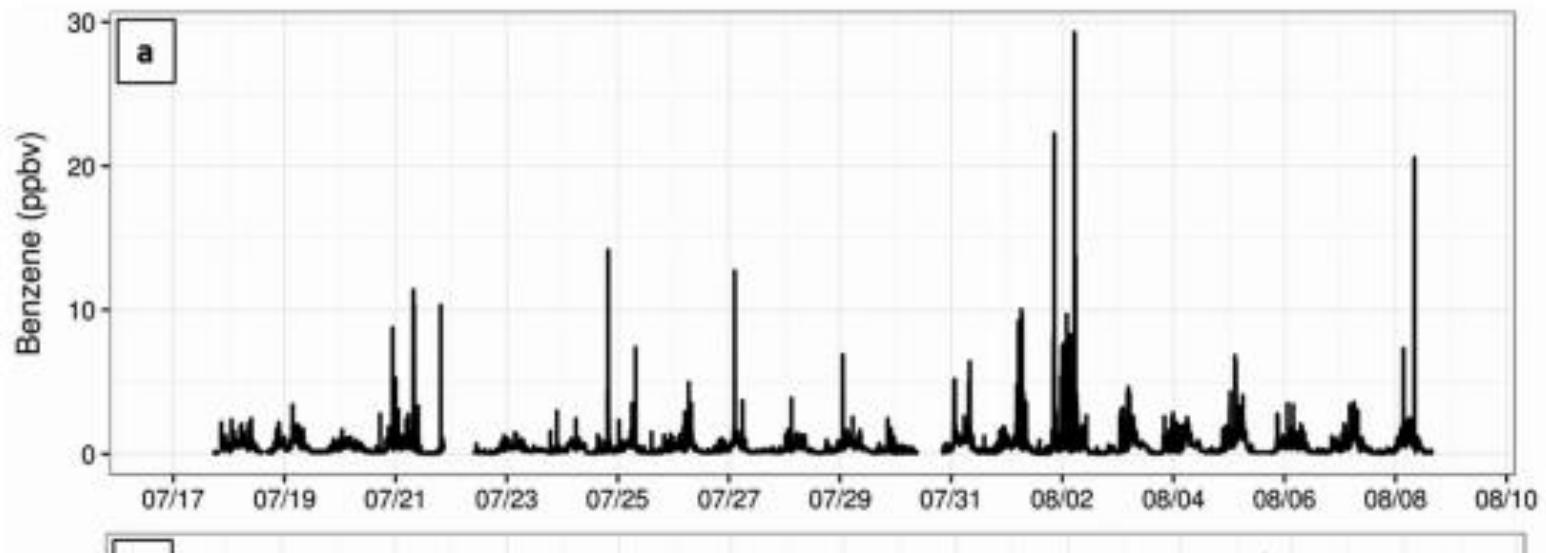


Figure 1. Map of the 2014 DISCOVER-AQ study area. The urban areas are shown in grey (data courtesy of the United States Census Bureau, <http://www.census.gov/geo/maps-data/data/tiger.html>). The boundary of the WGF is shown in black along with the gas wells (brown points) (data courtesy of the Colorado Oil and Gas Conservation Commission, <http://cogc.state.co.us/>). The DISCOVER-AQ ground sites are plotted and colored using the mean benzene volume mixing ratio measured during the aircraft spirals over each site. Benzene statistics were calculated using data from the bottom 1 km agl for each site.

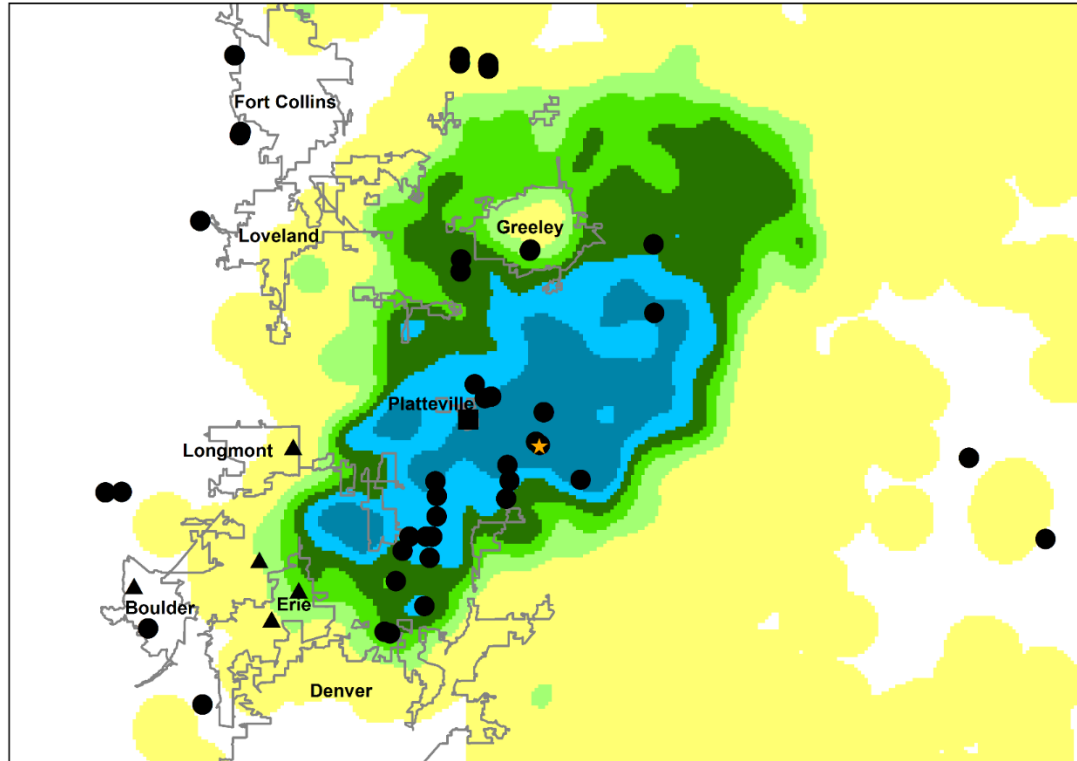
Halliday HS, Thompson AM, Wisthaler A, et al. Atmospheric benzene observations from oil and gas production in the Denver Julesburg basin in July and August 2014. *Journal of Geophysical Research: Atmospheres*. 2016;121(18):11055-11074

Repeated peak exposure potentials at night, before sunrise



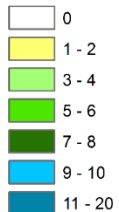
Halliday HS, Thompson AM, Wisthaler A, et al. Atmospheric benzene observations from oil and gas production in the Denver Julesburg basin in July and August 2014. *Journal of Geophysical Research: Atmospheres*. 2016;121(18):11055-11074

Locations where air was sampled at ground level in the summer of 2014.

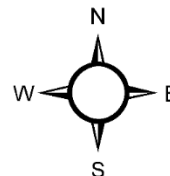
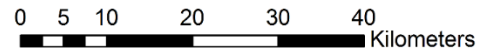


Legend

Wells / Sq Km



- ★ Continuous Monitoring
- ▲ 72-96 Hour Integrated Canisters
- 3 Hour Integrated Canisters
- 1 Minute Grab Canisters
- Cities / Towns



Continuous monitoring and 1-minute grab canister samples: Halliday HS, Thompson AM, Wisthaler A, et al. Atmospheric benzene observations from oil and gas production in the Denver Julesburg basin in July and August 2014. *Journal of Geophysical Research: Atmospheres*. 2016;121(18):11055-11074; Colman, J. J.; Swanson, A. L.; Meinardi, S.; Sive, B. C.; Blake, D. R.; Rowland, F. S., Description of the Analysis of a Wide Range of Volatile Organic Compounds in Whole Air Samples Collected during PEM-Tropics A and B. *Analytical chemistry* **2001**, 73, (15), 3723-3731.

72-96 hour integrated canisters: Helmig, D.; Hannigan, M.; Milford, J.; Gordon, J. *Final Report- Boulder County Oil and Gas Development Air Quality Study*; University of Colorado: 2015.

National Aeronautics and Space Administration (NASA). *Discover-AQ, Colorado 2014*. <http://www-air.larc.nasa.gov/missions/discover-aq/discover-aq.html> (April 2, 2016)

3-hour integrated samples: Colorado Department of Public Health and Environment Air Quality Control Division Technical Services Program. http://apcd.state.co.us/about_us.aspx

Four Exposure scenarios based on distance of sample collection from nearest O&G facility

1. ≤ 152 meters (500 feet):
 1. *29 1-minute canister samples*
2. > 152 meters to 610 meters (>500 feet to 2000 feet):
 - ✓ *50 1-minute canister samples*
 - ✓ *467 1-Hour samples from continuous monitoring over 21-days*
 - ✓ *47 72-96 hour integrated canister samples collected on Western border of O&G area*
 - ✓ *41 3-hour canister samples collected in middle of O&G area*
3. >610 meters to 1600 meters (> 2000 feet to 1-mile)
 - ✓ *6 1-minute canister samples*
4. > 1600 meters (> 1 -mile)
 - ✓ *24 1-minute canister samples*
 - ✓ *12 72-96 hour integrated canister samples collected in Boulder, CO.*

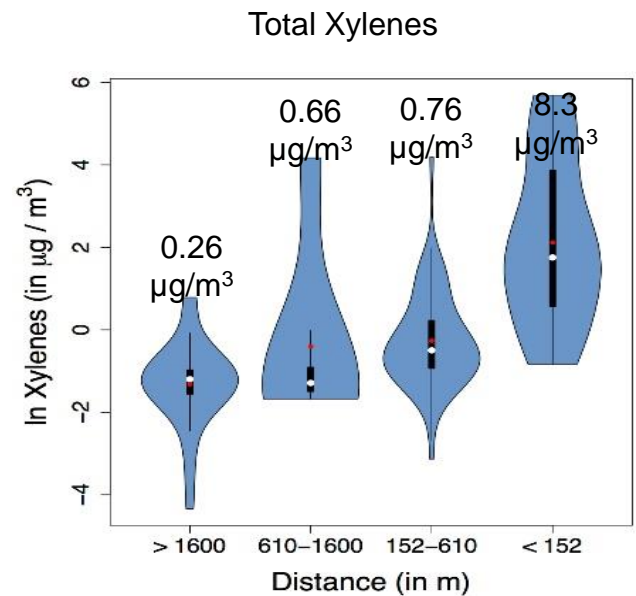
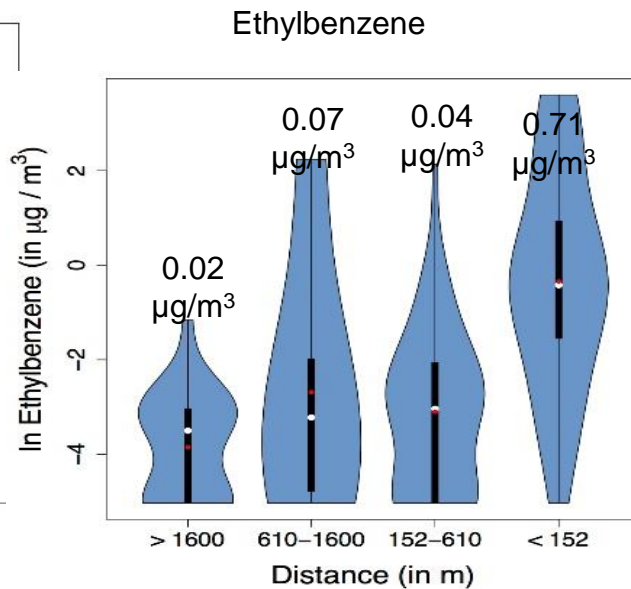
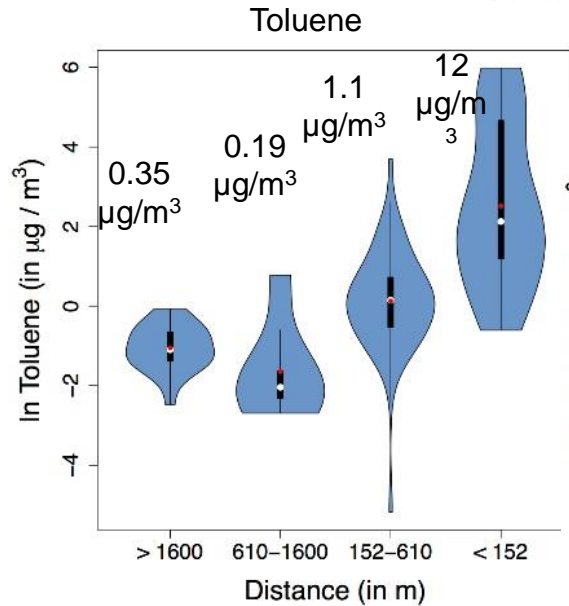
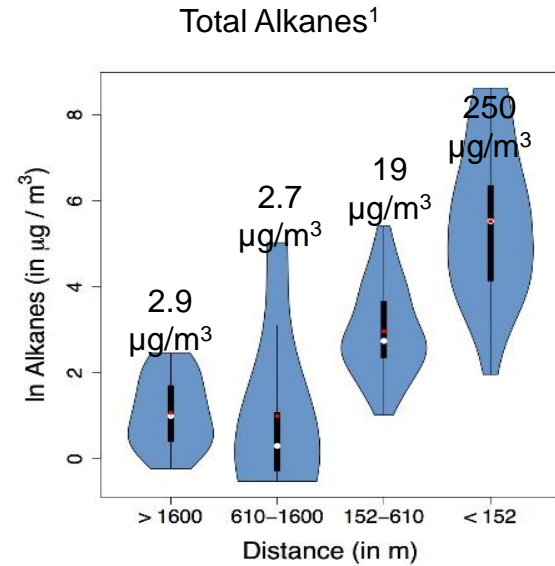
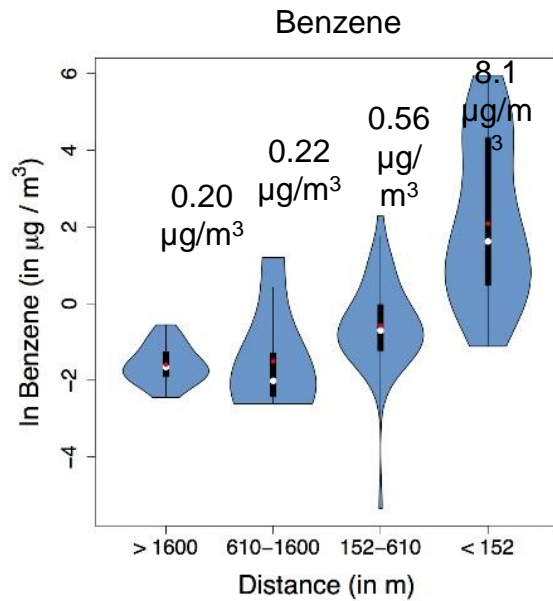
Methods

- Human Health Risk Assessment Guidance from California Office of Environmental Health Hazard Assessment (OEHHA) (California Office of Health Hazard Assessment (OEHHA). *Risk Assessment Guidelines*. In Air Toxics Hot Spots Program, Ed. California Environmental Protection Agency: 2015)
 - ✓ Current toxicity information for benzene
 - ✓ Consideration of lifelong effects resulting from exposures beginning in gestation.
- Assessed health effects for exposure to hydrocarbons associated with petroleum.
 - ✓ Did not assess ozone, particulate matter, or carbonyls

Methods Continued

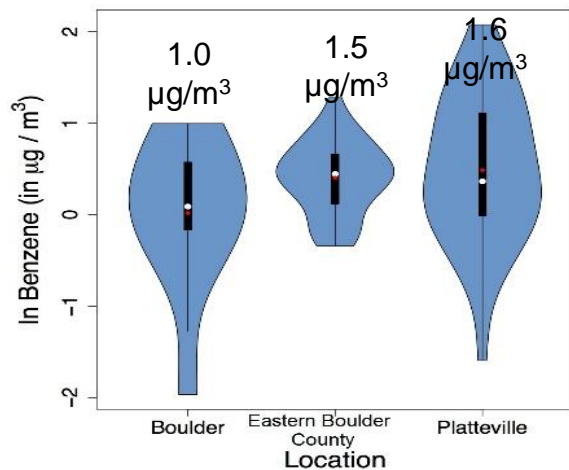
- Used maximum concentration to estimate health hazards from exposure for 1 hour (acute)
- Used time weighted averages for long term chronic and cancer exposures which considered higher nighttime exposures
- For non-cancer health effects: assumed chronic exposures for 24 hours per day, 350 to 365 days per year for more than 7 years.
- For cancer health effects assumed that people spend 72 to 85 percent of their time at home over a 30 year period.

Concentrations of hazardous air pollutants in 1-minute samples collected by University of California, Irvine

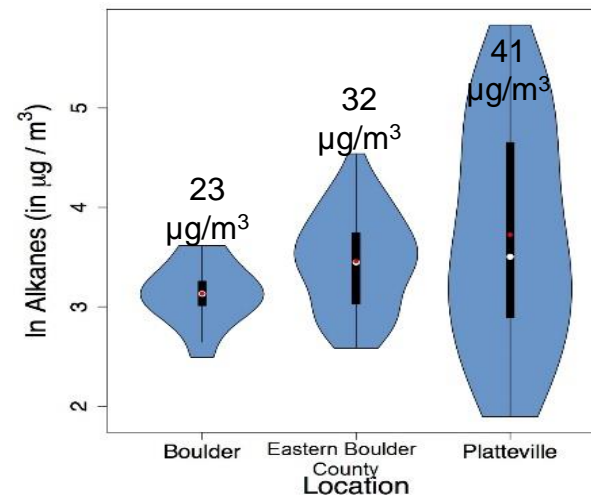


Concentrations of hazardous air pollutants in 3-96 hour integrated canister samples collected by Boulder County Study (INSTAR) and CDPHE

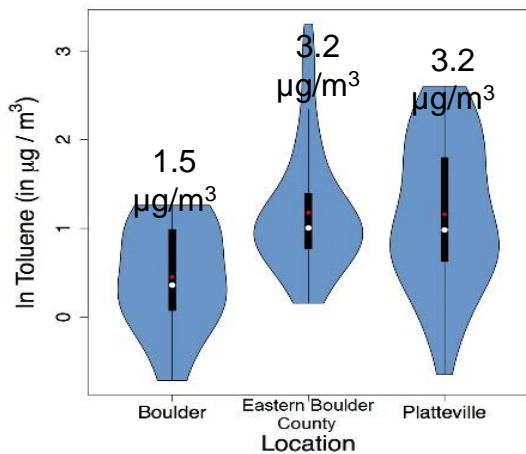
Benzene



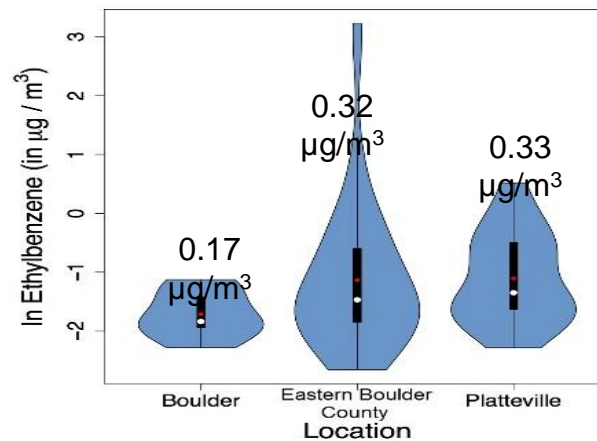
Total Alkanes¹



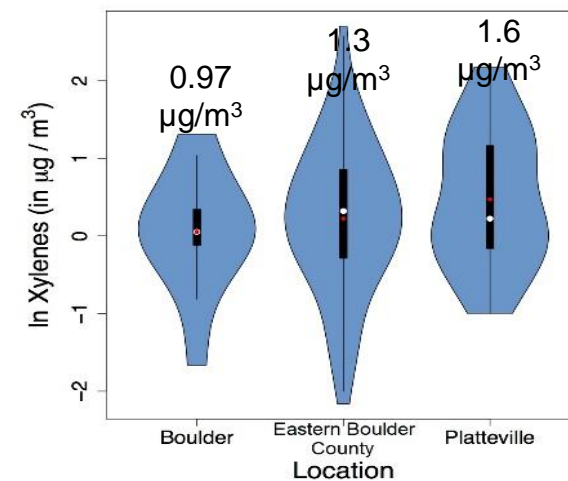
Toluene



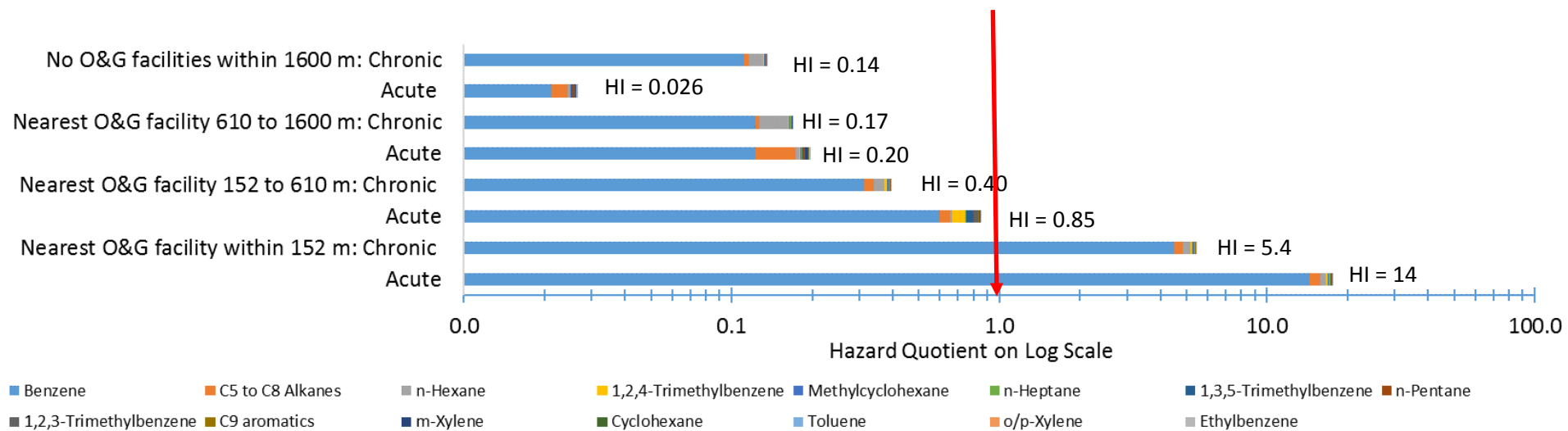
Ethylbenzene



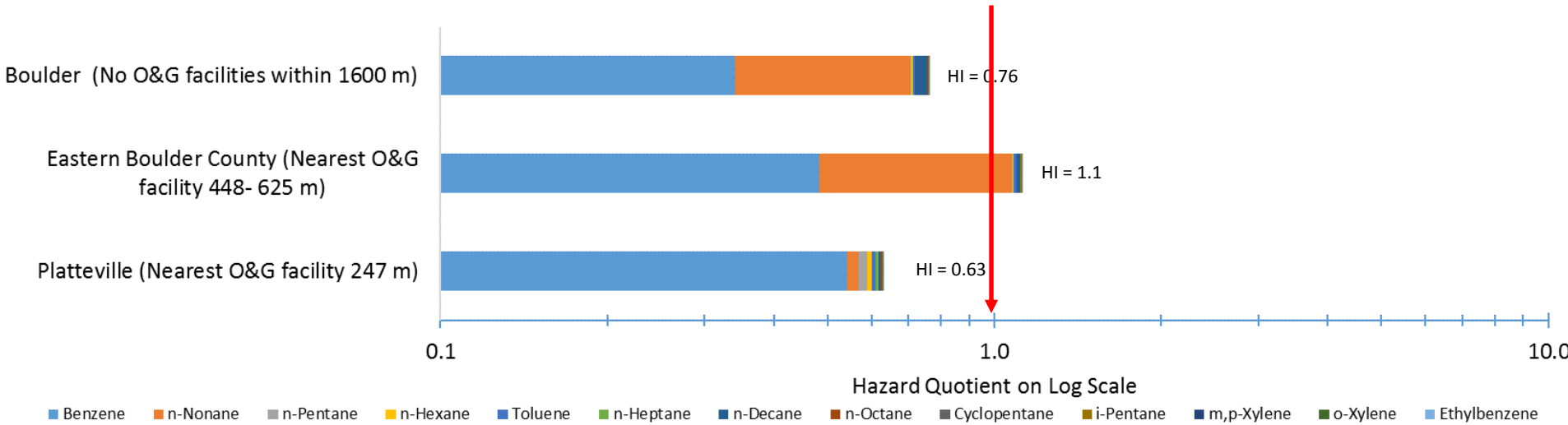
Total Xylenes



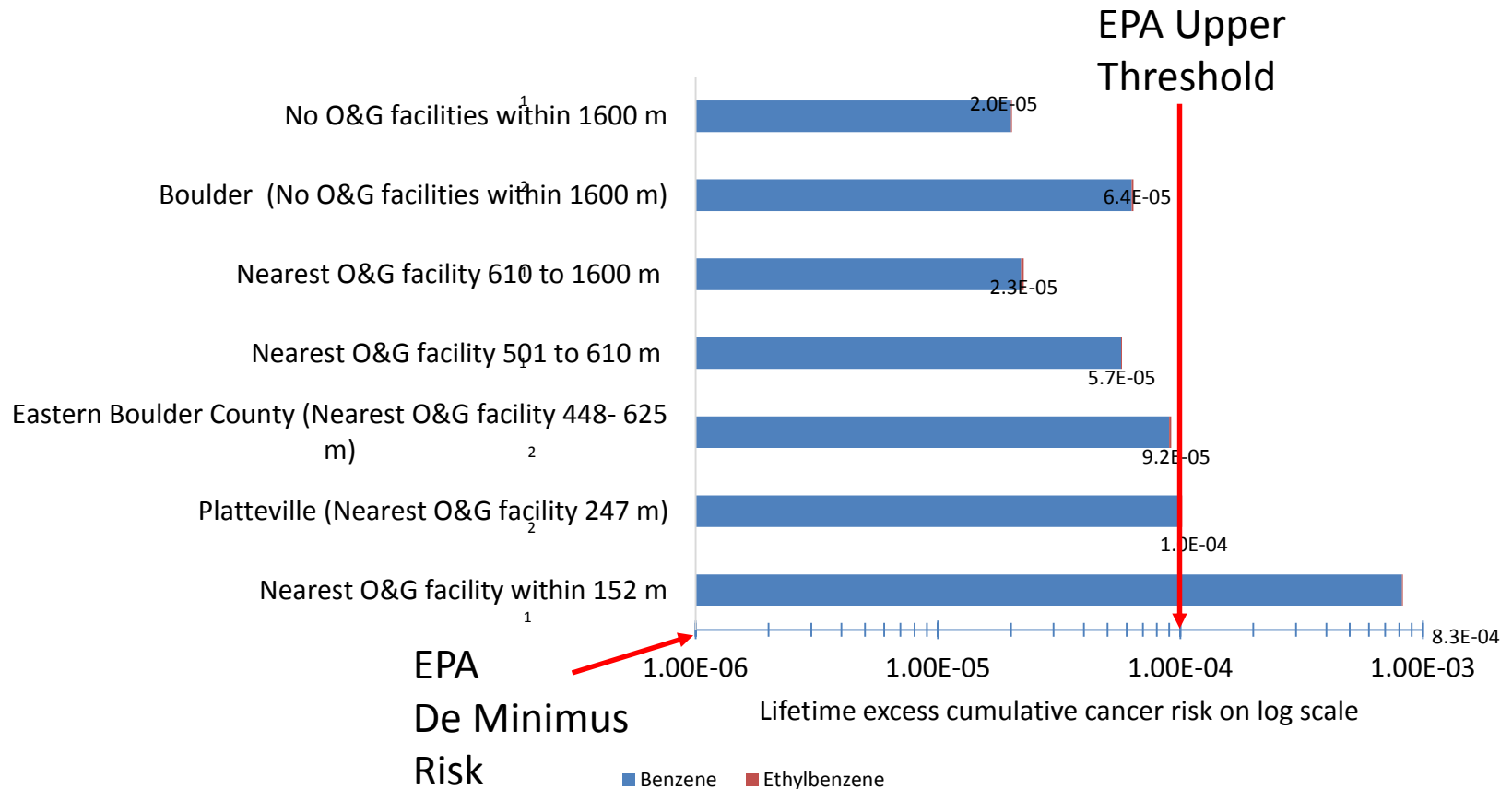
Chronic and acute hazard quotients and hazard indices based on 1-minute and 1-hour sample results



Chronic hazard quotients and hazard indices for residents living in Boulder, Eastern Boulder County, and Platteville based on 3, 72, and 96-hour sample results



Lifetime excess cancer risks (30 year exposure duration)



Strengths

- Realistic residential exposure scenarios
- Incorporated spatial and temporal variability
- Evaluated risks resulting from short exposures to high levels of hazardous air pollutants
- Reference sites (> mile for an O&G site) included those with traffic influences
- Findings consistent with published epidemiological studies and risk assessments.

Data Gaps in the Risk Assessments

- Overall, small number of samples and samples were not collected specifically for risk assessment.
- Lack of toxicity information for several of the hydrocarbons measured.
- Not all hazardous air pollutants that may be associated with O&G development have been measured.
- Ozone, particulate matter, and noise exposures have not included.

Conclusions

- Tens of thousands of people in Colorado live within 500 feet of an oil and gas well site.
- Cancer burden in this population is estimated at 14 additional cancers.
- Risk assessments indicate the potential for neurological, respiratory, hematological, and developmental effects in this population.
- The population living within 500 feet of an oil and gas well site is growing faster than the general population.

Policy Implications

- State regulatory setback distances and municipal building codes
 - ✓ Historical setbacks: 150 and 300 feet
 - ✓ Reverse Setbacks
 - ✓ Setbacks for all types of O&G facilities
- Existing wells
 - ✓ Older and smaller facilities may have leaks and equipment malfunctions
 - ✓ 65% of 145 O&G sites in Boulder had gas leaks – most leaks were from storage tanks, thief hatches, separators, and wellheads
 - ✓ Audio, visual, and olfactory inspections miss most leaks.

2001 to 2012 Oil or gas well drilled before the home was built

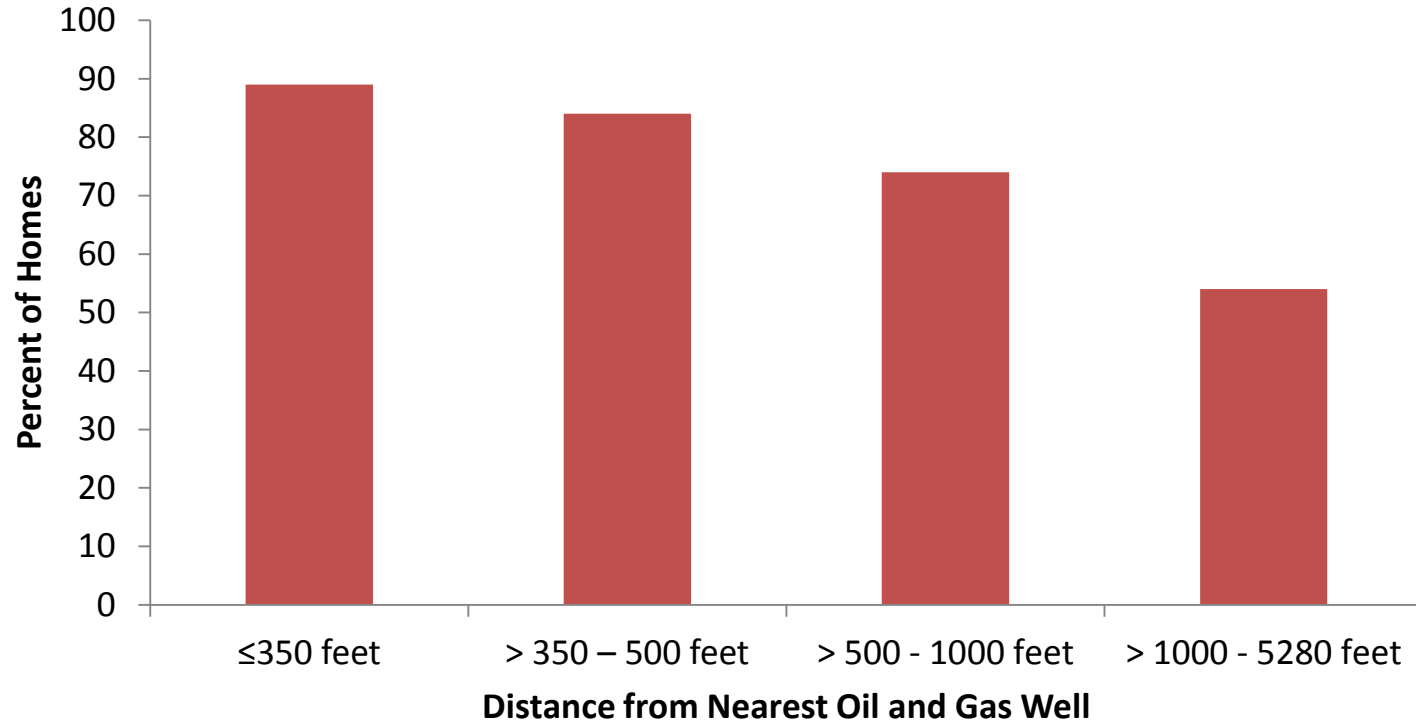


Figure 2: Housing development and growth of an oil and gas site



O&G well 1999



2003, Home built within 448 feet



2006, Well pad expansion begins



2007, Development pits within 190 feet of homes



2008, New well within 343 feet of nearest home, New homes built to the southwest



2012, Nearest homes within 343 and 347 feet of well pad facilities