# Variation of Residential Levels of Nitrogen Dioxide in a Mixed Rural-Urban Setting and its Implication in Childhood Asthma

Chung-Il Wi, Md[a,b], Janneane Gent, PhD[c], Katherine King, MS[d], Joshua Bublitz[d], BS, Euijung Ryu, PhD[d], Keli Sorrentino[c], Julie Plano, MS[c], Julie Porcher, BS[a,b], Philip Wheeler, MUP, FAICP[b], Young J. Juhn, MD,MPH[a,b]

[a]Department of Pediatric and Adolescent Medicine, Mayo Clinic, Rochester, MN; [b]Precision Population Science Lab, Mayo Clinic, Rochester, MN; [c]Center for Perinatal, Pediatric and Environmental Epidemiology, Yale School of Public Health, New haven, CT

## Background

### What is known?

- Observational study at a national level using U.S Census data and model-based traffic-related air pollutants (TRAP) showed that level of ambient $NO_2$ is significantly associated with asthma incidence and outcomes (eg, symptoms)
- Prospective studies examining the association between $NO_2$ and childhood asthma are often conducted in urban communities where traffic volume, level of $NO_2$, and asthma prevalence are relatively higher than in rural or mixed rural-urban areas.
- High prevalence of asthma in Olmsted County, MN, a mixed rural-urban community has been reported (13% in Olmsted County vs. 8% in US)

### What is unknown?

- Little is known of residential level of indoor and outdoor $NO_2$ in Olmsted County, MN, a mixed rural-urban setting, and its implication to childhood asthma outcomes.

## Aim

1. **To identify variation and risk factors of residential $NO_2$ (indoor and outdoor) in a mixed rural-urban community**
2. **To assess the impact of residential levels of indoor and outdoor $NO_2$ during heating season on asthma outcomes among children with asthma**

- **We hypothesize that the levels of both indoor and outdoor $NO_2$ are low, but vary by diverse risk factors, and are associated with increased risk of poor asthma outcomes in a mixed rural-urban community.**

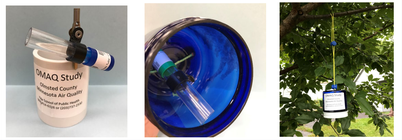
## Methods

- **Study setting, design and subjects**
- Olmsted County, MN, a mixed rural-urban setting
- A prospective cohort study collaboration between Mayo Clinic and Yale University
- A random sample of children with persistent asthma derived from children seen at the Mayo Clinic pediatric primary care
  - **Exclusion**: No place to safely place outdoor monitor, no asthma controller medication, other respiratory condition
- **$NO_2$ measurements (exposure)**
- $NO_2$ passive monitor (Palmes tubes; Figure 1)
- A two-week monitoring period during the heating season (Nov 2018-Mar 2019)
- **Asthma outcomes**
- Asthma symptoms (eg, wheezing, persistent cough, chest tightness, and limited activities), asthma rescue medication use, and unscheduled clinic visits were collected during the same 2 week period through an asthma diary
- Asthma control status based on the National Asthma Education and Prevention Program (NAEPP) 2007 guideline
- **Other covariates**
- Sociodemographic variables, HOUSES index (SES variable), rural/urban classification (Census bureau definition)
- Indoor environment: second hand smoking exposure, presence of electric air cleaner, gas stove for cooking, gas fireplace or logs, and any pets inside at home inside at home
- Outdoor environment: distance from home to the nearest highway

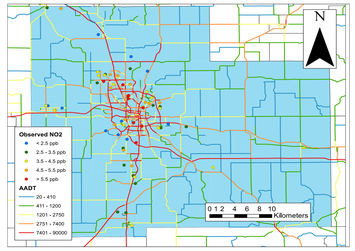
## Statistical analysis

- Descriptive statistics
- Linear regression model (unadjusted) was used for assessing associations between asthma outcomes (frequency of asthma symptoms, medication use, and unscheduled clinic visits) and a median daily $NO_2$ concentration

### Figure 1. Photograph of an $NO_2$ monitor (Palmes tube)




### Figure 2. Spatial distribution of residences classified by levels of observed $NO_2$, Olmsted County, MN




### Tables 1. Basic characteristics of study subjects

| Variables (Total N=62) | Number (%) or median (IQR) |
|---|---|
| Age, years, median (IQR) | 11 (8-14) |
| Female, n (%) | 29 (47%) |
| Non-Hispanic White, n (%) | 54 (87%) |
| Living in rural area, n (%) | 9 (15%) |
| Parental educational level[1], n (%) | |
| Less than college graduate | 6 (10%) |
| College graduate | 23 (38%) |
| Greater than college graduate | 32 (52%) |
| HOUSES[2], n (%) Q1 (lowest SES) | 5 (9%) |
| Q2 | 7 (13%) |
| Q3 | 16 (30%) |
| Q4 | 26 (48%) |
| Any type of allergies, n (%) | 43 (69%) |
| Indoor environment, n (%) | |
| Second hand smoking exposure | 0 (0%) |
| Presence of electric air cleaner | 15 (24%) |
| Gas stove for cooking | 18 (29%) |
| Gas fireplace or log | 30 (48%) |
| Any pet inside at home | 45 (73%) |
| Distance from home to the nearest highway, n (%) | |
| Within 100 yards | 5 (8%) |
| 100 yards – ¼ mile | 9 (15%) |
| ¼ - 1 mile | 12 (19%) |
| > 1 Mile | 36 (58%) |
| Asthma outcomes in the past 12 months (baseline), n (%) | |
| Asthma symptoms ever | 58 (94%) |
| Asthma outcomes, n (%), frequency/week (median (IQR)) | |
| Health care utilization | 6 (10%) |
| Asthma day symptoms | 42 (68%), 0.57 (0.29,1.29) |
| Asthma night symptoms | 12 (19%), 0 (0,0.14) |
| Asthma rescue medication | 39 (63%), 1.28 (0.57, 2.43) |
| Asthma control status[3], n (%) | |
| Well-Controlled | 41 (66%) |
| Not-Well-Controlled | 21 (34%) |
| Very-Poorly-Controlled | 0 (0%) |

[1] Mother or father's educational attainment, which ever the higher by self-report (1 missing); [2] HOUSES: Individual-level socioeconomic status measure (8 missing); [3]Per National Asthma Education and Prevention Program EPR-3 (The control status was composed of two components: a symptom step and rescue medication step. We defined symptom steps as Well-Controlled (≤2 day symptoms/week, ≤1 night symptom/month (or ≤0.25 night symptom/week), and ≤2 rescue medication/week), Not-Well-Controlled (2-6 day symptoms/week, ≥2 night symptoms/month (or 0.25-2 night symptoms/week), and 2-6 rescue medication/week), and Very-Poorly-Controlled (7 day symptoms/week, ≥ 2 night symptoms/week, and 7 rescue medications/week). The poorest category by any of three components (i.e., frequencies of day symptoms, night symptoms, or rescue medications) will dictate the asthma control status for each subject for each season.

### Table 2. Association of $NO_2$ with environmental conditions

| | | Indoor $NO_2$ Median (IQR) | Indoor $NO_2$ p-value | Outdoor $NO_2$ Median (IQR) | Outdoor $NO_2$ p-value |
|---|---|---|---|---|---|
| Correlation between Indoor and outdoor $NO_2$ | | 0.175 | | | |
| Median level for 2 weeks | | 3.4 (1.2,18.6) | - | 3.9 (0.8,7.8) | - |
| Living area | Rural | 6.7 (2.4,16.2) | 0.022 | 2.7 (1.6,4.9) | 0.014 |
| | Urban | 3.2 (1.2,18.6) | | 4.0 (0.8,7.8) | |
| HOUSES | Q1 | 3.1 (1.3,8.2) | 0.54 | 5.2 (2.8,5.6) | 0.026 |
| | Q2 | 4 (2.2,12.8) | | 4.4 (3.5,7.3) | |
| | Q3 | 3.8 (1.5,18.6) | | 4.3 (2.3,7.8) | |
| | Q4 | 3 (1.2,16.2) | | 3.2 (1.6,5.3) | |
| Electric air cleaner | No | 3.1 (1.3,18.6) | 0.016 | 4.0 (0.8,7.8) | 0.61 |
| | Yes | 5 (1.5,16.2) | | 3.5 (2.1,6.6) | |
| Gas stove for cooking | No | 2.9 (1.2,11.4) | <0.001 | 4.1 (1.7,7.3) | 0.040 |
| | Yes | 7.2 (3.1,18.6) | | 3.2 (0.8,7.8) | |
| Gas fireplace or log | No | 4.3 (1.2,18.6) | 0.13 | 4.0 (0.8,7.8) | 0.51 |
| | Yes | 3 (1.3,16.2) | | 3.9 (1.7,6.7) | |
| Pets at home | No | 3.7 (1.3,16.2) | 0.42 | 4.1 (2.1,6.6) | 0.22 |
| | Yes | 3.3 (1.2,18.6) | | 3.9 (1,6,7.8) | |
| Pests at home | No | 4 (2.4, 8.2) | 0.52 | 3.7 (1.6,5.6) | 0.69 |
| | Yes | 3.3 (1.2,18.6) | | 4.0 (0.8,7.8) | |
| Distance from home to the nearest highway, | | | 0.66 | | 0.043 |
| within 100 yards | | 3.1 (2.4,8.2) | | 3.7 (2.1,7.3) | |
| within ¼ mile | | 3.2 (1.3,18.6) | | 4.7 (2.8,7.8) | |
| ¼ - 1 mile | | 5.1 (1.2,12.8) | | 3.7 (1.7, 6.2) | |
| >1 mile | | 3.3 (1.5, 16.2) | | 3.6 (0.8, 7.8) | |

### Table 3. Association of indoor and outdoor $NO_2$ with asthma outcomes (univariate)

| | Odds Ratio (95%CI) Indoor $NO_2$ | Odds Ratio (95%CI) Outdoor $NO_2$ |
|---|---|---|
| Asthma outcomes, | | |
| Health care utilization | 0.69 (0.39, 1.22) | 0.84 (0.46, 1.52) |
| Asthma day symptoms | 0.98 (0.84, 1.14) | 0.93 (0.65, 1.34) |
| Asthma night symptoms | 1.05 (0.89, 1.24) | 0.80 (0.51, 1.25) |
| Asthma rescue medication | 1.48 (0.82, 2.62) | 1.03 (0.58, 1.83) |
| Asthma control status* | | |
| Not-Well-Controlled | 1.03 (0.88, 1.19) | 0.96 (0.67, 1.38) |

*Well-Controlled: reference

## Results & Discussion

- Measuring $NO_2$ in a mixed rural-urban community is feasible, inexpensive, and necessary for understanding which factors contribute to higher levels of indoor and outdoor $NO_2$ in residential areas.
- While residential levels of $NO_2$ measured in our study area were lower than Environmental Protection Agency annual standard level (53ppb), they vary by living area, presence of electric air cleaner or gas stove, and distance from home to the highway.
- We did not find any statistically significant difference between residential level of $NO_2$ and asthma outcomes. This could be due to short length of observation time (2 weeks). An examination of associations between asthma morbidity and air pollutants such as $NO_2$ will require a much larger study with a longer observation period.
- This study suggests that it is feasible to develop traffic-volume, land-use regression model for $NO_2$ based on local data for use in population-based studies for a variety of health effects (e.g., cardiovascular disease, mental illness)

- **Strengths**:
- Measurement of both indoor and outdoor NO2 in a mixed rural-urban area
- **Limitations:**
- Overall higher socioeconomic status of study subjects, small sample size, winter season data only

## Conclusions

- We found a range of indoor and outdoor levels of $NO_2$ in our study area, all of which were below the Environmental Protection Agency annual standard level (53ppb). The high prevalence of asthma in the community suggests that a large population-based study of health effects of exposure to residential and ambient levels of $NO_2$ using techniques described in this study is warranted.

## Acknowledgement

Mayo Clinic Career Development Award 2018, National Institute of Health (NIH)-funded R01 grant (R01 HL126667), NIH R21 (R21 AI142702). We thank Ms. Kelly Okeson for her administrative assistance.