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# A Computational Framework for Modeling Air Quality Exposure: From Outdoor to Indoor Environments

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## Abstract

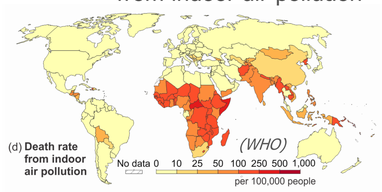
- Indoor air quality (IAQ) is important for human health because people spend 90% of their time indoors
- Outdoor air pollutants enter indoors through doors, windows, cracks, gaps, HVAC systems, etc., driven by wind & temperature differences (natural ventilation) and mechanical ventilation
- Physics-based ventilation & airflow models for calculating IAQ based on outdoor air pollution
- Empirical model for estimating indoor exposure & health outcome
- Building indoor-outdoor connections for air pollution exposure

## Background

**Indoor Air Quality (IAQ)** is a critical aspect of **human health** and affects building **energy use**

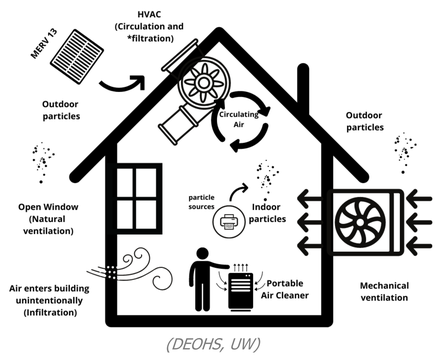
**90%** of time indoors

**3.2M** global premature death from indoor air pollution




**Natural & Mechanical Ventilations** can bring outdoor air pollutants indoors through windows, doors, cracks and gaps in the building envelope, and HVAC systems, influenced by wind, temperature differences


Outdoor air pollution distribution




(DEOHS, UW)

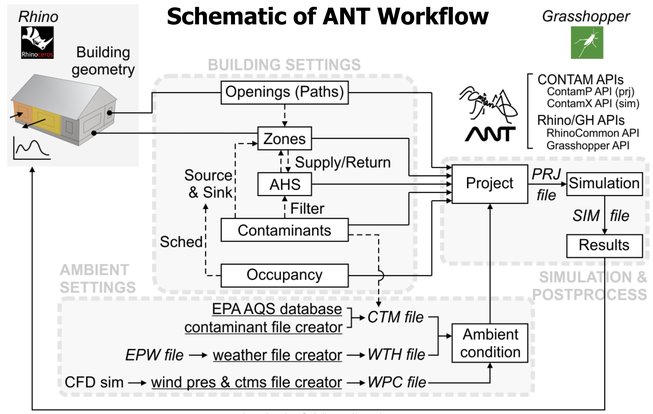
Outdoor-to-indoor transfer

## Whole-Building IAQ and Ventilation Modeling

**CONTAM**
Whole-building IAQ & ventilation analysis tool developed by NIST
Air flow and pollutant transfer modeling across rooms / zones

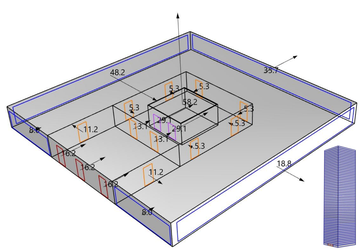
**ANT** (CONTAMinANT)
CONTAM plug-in on architectural design platform (Rhino Grasshopper)
IAQ, ventilation, health, and urban environment modeling

**Schematic of ANT Workflow**

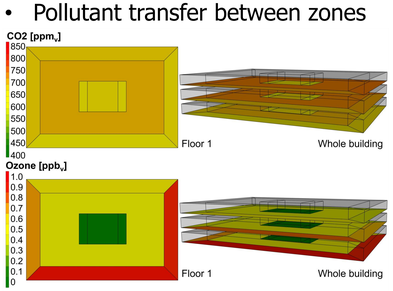



### Applications & Example Cases

Airflow & Ventilation Analysis
- Airflow rates between zones
- Ventilation rates



IAQ Analysis
- Zonal pollutant concentrations
- Pollutant transfer between zones




## Exposure & Health Estimation

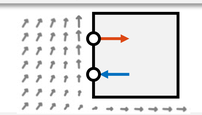
**Exposure Dose** = Pollutant Concentration × Inhalation Rate × Exposure Time
**Disability-Adjusted Life Years (DALYs)** = Exposure Dose × DALY-factor
**Infection Probability** (of Airborne Diseases) = 1 – exp(-1 × Exposure Dose)

## City-Scale Indoor & Outdoor Exposure Modeling

**3D City Models**
Geometries: CityGML, CityJSON, OSM
Building settings: Database & Reference

→ **IAQ Models**
IAQ, ventilation & health calculations with local wind & pollutant distributions

**Outdoor Modeling**

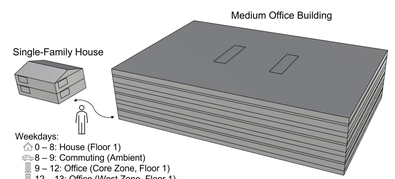



**Ambient Settings**

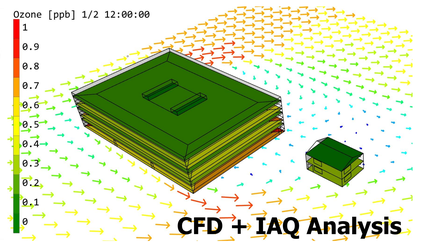
**Urban Environment Modeling**
Computational Fluid Dynamics (CFD) Model
Outdoor wind & pollutant distribution

→ **Boundary Condition**
Wind pressure & pollutant profiles of each external airflow paths

**Applications & Example Cases** (Community-Scale Exposure Analysis)
Medium Office Building + Single-Family House (DOE reference buildings)



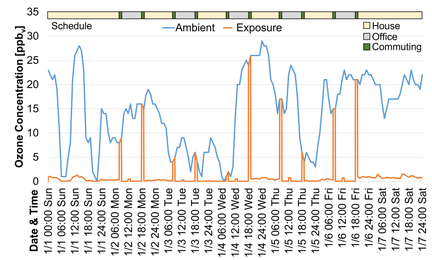

**Building Settings Human Mobility**

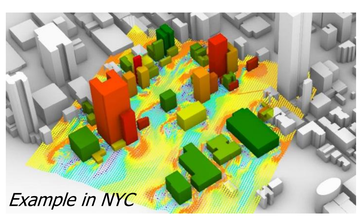



**CFD + IAQ Analysis**

**Pollutant exposure tracking**
Ozone exposure contributions:
- Outdoor: 67.5% (6% of time)
- Home: 30.2% (67% of time)
- Office: 2.3% (27% of time)

DALYs due to ozone exposure:
- 16.6 yrs per 100,000 population per year



*Example in NYC*

**City-Scale Exposure Analysis**
- Real-world city modeling:
- OpenStreetMap (OSM) → 3D building geometries → Outdoor wind & pollutant simulation → IAQ models (single zone for each building) → Human mobility tracking → Exposure estimation

## Related Publications

1. **Shen**, Dols, Polidoro, 2024. ANT: A Multizone Indoor Air Quality (IAQ) and Ventilation Analysis Plug-in for Algorithm Aided Design. SimBuild 2024.
2. Dols, **Shen**, Polidoro, Lorenzetti, Mills, Cole, Sohn, 2025. Development and application of CONTAM APIs. Build. Simul.