Exhaust Re-entrainment and its Effect on Building Design

Ontario Association of Architects

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- Member of Air and Waste Management Association

Engineers and scientists
Focus on climate responsive design for the built environment
Clients include architects, planners, engineers & developers
Established in 1972
>320 people worldwide
Course Objectives

Through this course, we will teach the participants:

- Fundamentals of wind flows around buildings and how it affects exhaust dispersion.
- The effect of wind flows on building performance and the health and safety of the users and the neighbours.
- Modelling of exhaust dispersion and the wind environment including wind tunnel testing and computer simulations and how this modelling can be used to promote safe and efficient building design.
- Typical mitigation options that can be implemented by designers to ensure acceptable air quality.
- Understand how this fits in with the Environmental Compliance Approval (ECA) process in Ontario.
“What is Exhaust Re-entrainment?”

- Many exhausts can contain toxic pollutants or strong odours.
- It refers to entry or re-entry of exhausts into a building that can lead to indoor air quality problems (protect worker’s health)
- Also includes impacts on outside locations without re-entry into the building (e.g., exposure of workers on roofs) “Self-Contamination”
- Exhausts can also impact off-site locations “Cross-Contamination”
Exhaust Re-entrainment "Self Contamination"

Exhaust is being drawn into the wake of the building where the air intakes and operable windows are located.

Exhaust Re-entrainment "Cross Contamination"

"Why is it Important in Building Design?"

- Ensure the well being and safety of workers and neighbours
- Avoid liability from health impacts
- Avoid odour complaints
- Minimize lost work time
The Assessment Process

- Identify Pollutant or Odour Sources of Concern
- Develop Design Criteria
- Determine Impacts through Dispersion Modelling
- Develop Mitigation Measures (if Design Criteria not Met)

Common Problematic Sources

- Laboratory exhausts
  - Fume hoods
  - Radioisotope hoods
  - Bio-safety hoods/cabinets
  - Pharmacy
- Combustion sources
  - Boilers
  - Emergency generators (gas and diesel)
  - Vehicles using loading docks & parking garages
  - Road traffic
- Cooling towers
- Building exhausts (e.g., kitchen grease hoods)
- Emissions from neighbours
- Any exhaust that emits a pollutant or odour to the outside

Some examples…

Laboratory and Fume Hood Exhausats

- Solid Screen wall that is bad for air movement
- Poor design as air intake is too close
- Exhaust emitted from stacks with downward motion
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Fume Hood Exhausts with Rain Caps

Laboratory and Fume Hood Exhausts

Better performance from these stacks but aesthetic consideration

Diesel Generators: Source of Pollutants & Strong Odours
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- Re-entrainment of biocides & scaling inhibitors
- Moisture Loading
- Legionella

- Pollutant & Diesel Odour Emissions from idling Trucks in Confined Spaces

- Odours at Nearby Intakes (can persist for large distances)
The design criteria depend on the emissions rates of pollutants and odours, and the corresponding health limits and odour thresholds.

- Safety (Health)
  - Lethal
  - Toxic
  - Carcinogenic
- Odour (Annoyance)

### Design Criteria: Major Types of Health Limits

- **Occupational**
  - healthy workers (e.g., MOL, OSHA)
- **Ambient**
  - general population (e.g., MOE, US EPA)
- **Emergency response** (e.g., IDLH)

### Design Criteria: Examples

<table>
<thead>
<tr>
<th>Exhaust Type</th>
<th>Basis of Criterion</th>
<th>Dilution Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Laboratory Fume Hood</td>
<td>Health &amp; Odour</td>
<td>3,000:1</td>
</tr>
<tr>
<td>Boiler</td>
<td>Health</td>
<td>Typically &lt;500:1</td>
</tr>
<tr>
<td>Diesel Generator &amp; Diesel Truck</td>
<td>Health &amp; Odour</td>
<td>Typically &lt;500:1</td>
</tr>
<tr>
<td>Cooling Tower</td>
<td>Health &amp; Odour</td>
<td>20:1</td>
</tr>
<tr>
<td>Kitchen</td>
<td>Odour</td>
<td>600:1</td>
</tr>
</tbody>
</table>
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Determining Health-Based Criteria: Combustion Sources

- Boilers, generators and vehicles
- Emissions of concern: NO\textsubscript{x}, CO, SO\textsubscript{2} and PM
- Emissions determined through manufacturer’s specifications, stack testing, engineering calculations or published data
- Based on the pollutant with the highest ratio of high emission and low air quality standard

Limiting Pollutant for Combustion Sources

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Source Conc. (ug/m\textsuperscript{3})</th>
<th>Criterion (ug/m\textsuperscript{3})</th>
<th>Dilution Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>NO\textsubscript{x}</td>
<td>620,000</td>
<td>500</td>
<td>1,240:1</td>
</tr>
<tr>
<td>SO\textsubscript{2}</td>
<td>104,000</td>
<td>830</td>
<td>125:1</td>
</tr>
<tr>
<td>CO</td>
<td>243,000</td>
<td>6,000</td>
<td>41:1</td>
</tr>
<tr>
<td>PM</td>
<td>37,000</td>
<td>100</td>
<td>375:1</td>
</tr>
</tbody>
</table>

Limiting Pollutant - NO\textsubscript{x} 1,240:1

Determining Odour Criteria

- Published odour thresholds
  - Ontario Ministry of the Environment
  - Published Journal Articles
  - AIHA

- Odour panel tests
Determining Odour Criteria: Take Odour Samples

Odour Sample being taken from an Idling Diesel Truck

Determining Odour Criteria: Conduct Odour Panel Tests

Panellist Inhaling from Sniff Tubes during an Odour Panel Test

Determining Odour Criteria: Create Odour Response Curves

Odour detection and annoyance thresholds established based on odour response curves (1 OU = 50% detection)
**Determine Impacts**

**What Can be Done?**

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**Four Assessment Levels**

- Field Tests
- Design Consultation
- Numerical Modelling
- Wind Tunnel Modelling

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**Field Tests**

- Excellent visuals
- Provides results for limited wind conditions that may not be worst case
- Not useful for design of new buildings
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**Design Consultation**

- Based on past experience
- "Red flag" potential problems
- Save headaches later
- Fast turnaround
- Inexpensive

**Design Consultation**

**Goals:**

- Locate air intakes to use building massing for protection
- Extend exhausts above highest roof level
- Locate exhausts and intakes to take advantage of prevailing winds

**Mitigation Scheme 1**

**Mitigation Scheme 2**

**Numerical Modelling: Computer Models**

- Conservative estimate of air and exhaust flow behaviour around buildings
- Simple terrain and buildings
Numerical Modelling: Computational Fluid Dynamics

- Useful for more complex situations (e.g., emissions that have densities higher than air such as water droplets)
- Computer Intensive

Wind Tunnel Modelling

- Most accurate and reliable
- Fine-tuning designs
- Includes design detail
- Complex geometry
How does building shape and massing affect exhaust dispersion?

What are practical solutions to minimize air quality impacts?
Increase Stack Heights

Low Stack Within Separation Bubble

Increase Stack Heights

Tall Stack Outside Separation Bubble

Effective Stack Height ($H_s$)
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**Change Stack Location**

**Consider Wind Frequency**

Optimal placement of stacks to reduce entrainment based on wind frequency.

**Increase Exit Velocity**

Upper limit 3,000 to 4,000 fpm due to noise impacts (generators are the exception)
Increase Exit Velocity

Exit Velocity (W) vs. Wind Speed (U)

Increase Exit Velocity

Wind Speed Distribution at 30 ft

Manifold or Increase Flow Rate
**Manifold or Increase Flow Rate**

Internal Dilution (Fume Hood Exhaust)

- Spill scenario evaluation considers one spill at a time in only one fume hood
- Other fume hood exhausts relatively clean and dilute the exhaust from the fume hood with the spill

**Optimally Place Intake**

Move intake location especially to side of building, but away from grade or low-level sources.

**Use Porous Screens**

Solid screen walls can cause plume downwash
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Use Porous Screens

Porous screen walls allow some flow through

Case Study, Toronto Rail Lands - Issues
Case Study, Toronto Rail Lands - Issues

- New construction along major transportation routes and near industries in downtown Toronto
- Air quality concerns with respect to emissions from the routes and industry
- City of Toronto requires Air Quality Impact assessments, which includes the impact of the environment on the new construction and vice versa

Case Study, Toronto Rail Lands - Solutions

- Avoid intakes facing major transportation (rail corridor, Gardiner Expressway)
- Place intakes high up or in protected areas such as courtyards
- Positively pressurize building to create a net flow outward to minimize infiltration of dust and odours into units
- Install high efficient particulate filters on intakes
- Install controls on intakes to shut down when high CO or NOx levels occur

Other Mitigation Options

- Emission controls (low NOx burners, low sulfur fuel oil, scrubbers, selective catalytic reduction)
- Operational measures (e.g., reduce operations and emissions under certain wind conditions, no idling policy, turn off intakes)
**What is a Environmental Compliance Approval (ECA)?**

- A legal document issued by the Ontario Ministry of Environment (MOE) that permits a facility to operate equipment that emits contaminants to the environment.
- Replaced the Certificate of Approval on October 31, 2011

**When Do You Require an ECA?**

Under the Environmental Protection Act (EPA), if you are a facility and you plan to:

- **Construct, alter, extend or replace any building, structure, equipment, or thing** that may discharge a contaminant into the environment other than water; or
- **Alter a process or rate of production** that may alter the rate of discharge of a contaminant.

**What is a Contaminant?**

“...any solid, liquid, gas, odour, heat, sound, vibration, radiation, or combination of any of them resulting directly or indirectly from human activity that causes or may cause an adverse effect.”
Two Compliance Methods in Ontario:
- Environmental Activity and Sector Registry (EASR)
- Environmental Compliance Approval (ECA)

EASR
- Online application for immediate permits
- Only applies to standby power systems, heating systems, automotive paint booths
- Requirements noted in Ontario Regulation 245/11
  - Eligibility and operating requirements include size of units, noise requirements, etc.
- Must register eligible activities / sectors or request Director’s order under s.20.18 to include in ECA

ECA
- Unique / More Complex Processes / Facilities
- Online Environmental Compliance Approval

Four new activities / sectors under review
- Waste collection and transport by truck
- Ready mix concrete manufacturing
- Concrete product manufacturing
- Digital printing

Next Round is to include:
- Fume hoods
- Small Gensets used for peak shaving
Air quality standards apply to facility contribution only, even if other sources are nearby.

- Same standards apply in both pristine and polluted environments.

Continuous noise limits are the HIGHER of:
- Minimum limits in the table below or
- Measured background sound levels or
- Modelled traffic noise.

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>Class 1: Urban</th>
<th>Class 2: Urban</th>
<th>Class 3: Rural</th>
</tr>
</thead>
<tbody>
<tr>
<td>0700 – 1900</td>
<td>50</td>
<td>50</td>
<td>45</td>
</tr>
<tr>
<td>1900 – 2300</td>
<td>47</td>
<td>45</td>
<td>40</td>
</tr>
<tr>
<td>2300 – 0700</td>
<td>45</td>
<td>45</td>
<td>40</td>
</tr>
</tbody>
</table>
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**Typical Air & Noise Sources**

- **Mechanical & Ventilation Systems**
  - Air makeup units/heaters
  - Chillers or cooling towers
  - Boilers
  - Emergency generator
  - Incinerator

- **Workshops**
  - Dust collectors
  - Paint spray booths
  - Welding exhausts
  - Grinder exhausts
  - Plasma cutters

- **Labs**
  - Fume hoods
  - Specialty hoods

**Emissions Inventory**

- Mass balance
- Engineering estimates
- Published emission factors
- Manufacturer’s specs
- Stack testing
- Sound power levels

**Options in Case of Non-Compliance**

- **Step 1: Refine Assessment**
  - Emission Rates and Operating Scenarios
  - Dispersion Models and Supporting Data

- **Step 2: Develop Mitigation Strategies**
  - Engineering Controls
  - Process or Operational Changes
  - Improved Dispersion

- **Step 3: Request for Alternative Air Standard**
Plan Ahead

- Develop mitigation strategies early, if needed.
- Design reviews for planned changes and expansions.
- Conduct dispersion modelling assessments with refined models.
- Saves time and money!

Plan Ahead - Benefits of Early Design Involvement

The best time to consider air quality and noise impacts is as early as possible when problems can be identified and corrective action can be easily incorporated.

Ease of Change vs Cost of Change

Pre-concept Design | Conceptual Design | Schematic Design | Design Development | Construction Documents | Construction | Post-Occupancy

Thank you for your time.

Questions?

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