Lecture 5: Air Quality Instrumentation and Direct Exposure Assessment

Department of Environmental Health
3rd Year

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1 1. Introduction: Data Integrity and Manual Verification

Modern environmental monitoring relies on **Direct-Reading Instruments (DRIs)**. These devices provide immediate concentrations (ppm or $\mu g/m^3$).

— **The Technical Dependency:** Accuracy is strictly dependent on the physical integrity of the sensor.

— **The Role of the Specialist:** You must extract **Raw Data** to manually apply the **AQI Law** to verify algorithms against **WHO Standards** and correct for "Signal Drift" caused by humidity and heat.

2 2. Gaseous Pollutants: Detection and Pathophysiology

2.1 A. Chemiluminescence (Target: NO_2)

- **Mechanism:** $NO + O_3 \rightarrow NO_2^* \rightarrow NO_2 +$ Light.
- **Health Facts:** Causes acute inflammation of the **Bronchial Epithelium** and impairs **Alveolar Macrophages**, reducing the lung's ability to fight infections.
- **Technical Error:** CO_2 and water vapor cause **Quenching** (Underestimation).

2.2 B. NDIR - Non-Dispersive Infrared (Target: CO)

- **Mechanism:** CO absorbs IR radiation at $4.6\ \mu m$.
- **Health Facts:** Forms **Carboxyhemoglobin (COHb)**, blocking oxygen transport. It triggers **Angina** and causes **Cognitive Impairment**.
- **Technical Error:** Humidity causes **Spectral Overlap** (False High).

2.3 C. UV Fluorescence and Absorption (SO_2 and O_3)

- SO_2 **(Fluorescence):** Triggers acute **Asthma Attacks** and stimulates excess mucus secretion. (*Error: Hydrocarbons interference*).
- O_3 **(Absorption):** Powerful oxidant causing **Oxidative Tissue Damage** and reducing vital lung capacity. (*Error: Mercury vapor*).

2.4 D. Gold Film / Electrochemical (H_2S)

- **Health Impact:** Causes **Olfactory Fatigue** (loss of smell) and **Cytotoxic Hypoxia** by inhibiting mitochondrial respiration.
- **Warning:** Sensor saturation can lead to a **Zero reading** in a lethal environment.

3 3. Atmospheric Dispersion and Exposure Dynamics

Pollutants do not remain at the source; their transport defines the **Risk Zone**.

- **Plume Dispersion (Gaussian Model):** Driven by **Advection** (wind speed) and **Turbulent Diffusion**. High wind dilutes pollutants but transports them to distant residential areas.
- **Temperature Inversion (The Trap):** Normally, air cools with height. During an inversion, a warm air layer acts as a **"Lid"**, trapping pollutants near the ground. This occurs mostly during **Cold, Clear Nights**.
- **Urban Canyon Effect:** High buildings restrict wind flow, creating micro-environments where vehicle emissions reach **Toxic Concentrations** at pedestrian levels.

4 4. Comparison of PM Monitoring Methodologies

Choosing between manual and automated methods involves technical and toxicological trade-offs:

Table 1: **Technical Comparison: Manual vs. Automated Methods**

Feature	**Manual Gravimetric (Filter)**	**Automated BAM (Beta Ray)**
Principle	Physical weighing (Reference Method)	Beta-ray attenuation through tape
Result Type	**Delayed Analysis** (24h + Lab time)	**Direct and Instantaneous**
Toxicology	Ideal for **Heavy Metals** (Pb)	Critical for **Acute Health Alerts**
Error Factor	Potential human weighing error	Humidity causes particles to "swell"

5 5. Advanced Pathophysiology: Site-Specific Deposition

The diameter of the particles (PM_{10} and $PM_{2.5}$) dictates the **Site of Injury**:

1. PM_{10} **(Coarse):** Deposited in the *Tracheobronchial* region; triggers cough reflex and excess mucus.

2. $PM_{2.5}$ **(Fine):** Penetrates the **Alveoli**, triggering **Oxidative Stress** and systemic cytokine release.

3. **Systemic Risk:** $PM_{2.5}$ crosses the blood-gas barrier, causing **Blood Hypercoagulability** (increased risk of strokes and infarctions).

6 6. Discussion and Review Questions

1. **Meteorology:** Why do pollutants reach peak concentrations during an *Inversion* early in the morning?

2. **Data Integrity:** If an instrument shows a "Safe" AQI during high humidity, why must a specialist verify the raw data?

3. **Public Health:** In an *Urban Canyon*, why might a rooftop sensor provide a misleading reading for pedestrians?

7 7. Conclusion

Validation of sensor data through an understanding of **Atmospheric Physics** and **Pathophysiology** distinguishes a specialist from a technician.