Integration of GPS Technology with Real-Time Particulate Matter Measurement

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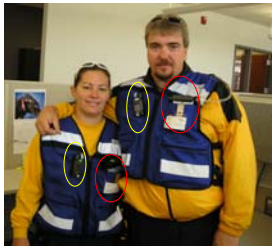
Knowledge to Go Places

1. Introduction

The purpose of this study was to develop an innovative exposure assessment tool by integrating **real-time particulate matter (PM) monitors, global positioning system (GPS) receivers, and a geographical information system (GIS).** These tools allows us to determine ***when*** and ***where*** hazardous exposures occur. By tracking exposure both spatially and temporally, we may gain a better understanding of the sources and factors that contribute to a workers' total exposure budget. Such information may lead to more efficient control strategies, ensuring worker health while saving industrial hygiene resources.



City of Fort Collins Parking Enforcement Officers

2. Instruments and Methods

Courtesy of Thermo Electron Corporation

Nephelometer (pDR1200, ThermoElectron)
- Light-scattering device
- Measures PM concentration in real-time
- 880nm wavelength, 50-90º
- Uses a filter for gravimetric calibration

Courtesy of SKC, Inc.

Pump (Leland Legacy, SKC)
- 10 Lpm flow rate
- 24 hour battery life

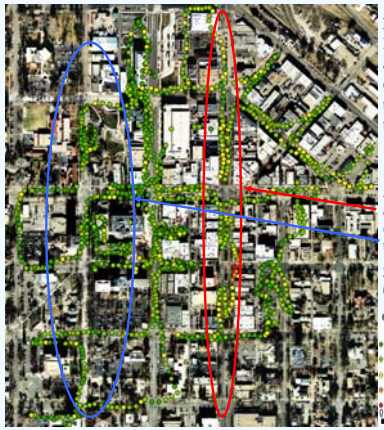
Courtesy of Garmin International

GPS (Geko 301, Garmin)
- Measures location via satellite in real-time
- Weight ~ 3.4 oz
- Position accuracy ~ 3 meters
- Latitude, longitude, altitude, timestamp
- 9 hour battery life

Software (ArcGIS, ArcMap, MS Access)
- Real-time data loaded into *Access* database
- pDR and GPS data merged by timestamp
- Merged data loaded into *ArcGIS* software
- Exposure intensity color-coded

3. Results

Two cohorts from the City of Fort Collins, CO (Parking Enforcement Officers and Natural Areas Rangers) were repeatedly tracked over multiple work shifts. Each worker wore a portable GPS device and a personal nephelometer in conjunction with a pump. The pDR-1200 is capable of sampling PM_{10} (and smaller) aerosol size distributions. Integrated and real time outputs were logged on a 10-second basis and then merged onto a GIS map to visualize worker exposure as a function of location. Results from the Parking Enforcement tracks are shown.



Map of downtown Fort Collins
Each point represents a 10-second average measurement of PM exposure for Parking Officers traveling along prescribed routes through the city.

Spatial Analysis

Average exposures are 15% higher along a major highway (U.S. 287) than on lower density traffic routes within the city.

20 µg/m³ vs. 17 µg/m³
(p < 0.037, paired t-test)

Temporal Analysis

Temporal analyses indicated that workers received significantly higher PM exposures during rush-hour than during non rush-hour on both high and low traffic-density streets.

Table 1. Changes in PM Concentration during Rush and Non-Rush Hour Work

	High Traffic Density Concentration (µg/m³)	Low Traffic Density Concentration(µg/m³)	Paired t-test
Rush Hour	31	25	p< 0.05
Non-Rush Hour	18	16	p< 0.02

4. Discussion

Advantages
- Exposure hotspots can be discovered using simple spatial analyses (and visualized on map).
- Real-time data provides exposure timing and intensity measurement

Disadvantages
- GPS battery life can be an issue for long exposure periods
- GPS receivers cannot operate indoors
- Real-time monitors have high initial costs, require calibration

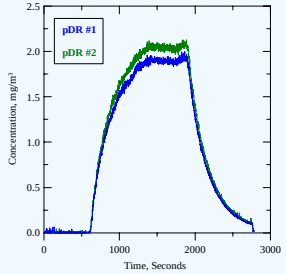
5. Instrument Evaluation

GPS Accuracy

Two co-located GPS devices; notice signal divergence as officer walks under a tree and into a parking garage

Outdoor Resolution: 1-3 m / Indoors: 3 m – no signal

Nephelometer (pDR) Comparison

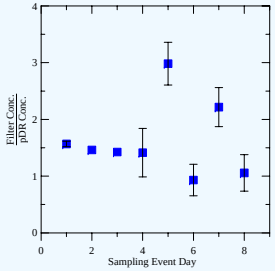


NaCl aerosol
Collison nebulizer
1.0 m³ chamber
MMAD ~ 1.0 µm

Two co-located pDRs sampling transient particle concentrations in a well-mixed aerosol chamber.

Some drift in instruments over wide concentration span

Filter vs. pDR Response



Note: all filter analyses were above method detection limits

The pDR response changes each day, probably due to aerosol size, shape and composition. Within-day variation is much less between pDR instruments.

pDR consistently underestimates the filter mass; calibration is required on a daily basis

6. Conclusions

- **Spatial-temporal exposure assessment allows for rapid identification of peak exposure locations/times**
- **This technique can reduce the time expenditure for practicing Industrial Hygienists working with highly mobile workforces**
- **Although no exposures measured here were deemed unsafe, this method may be adapted for use in more hazardous industries**
- **pDR device requires in-situ calibration with a filter**

7. Future Work

- Characterize PM exposure to young children with severe asthma over multiple 24-hour periods in Denver, CO (collaboration with researchers at National Jewish Medical Research Center)
- Asses exposure to organic grain dust for animal feedlot operators. This industry has a high prevalence of occupational asthma
- Adapt technology to indoor exposures
- Adapt technology to other exposure scenarios suited for real-time measurement (noise, radiation, gases, etc.)

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