Spatial variation of heavy metal pollution on an urban road network

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Background

Urban Diffuse Pollution

Road Traffic Sector

Surrounding land uses

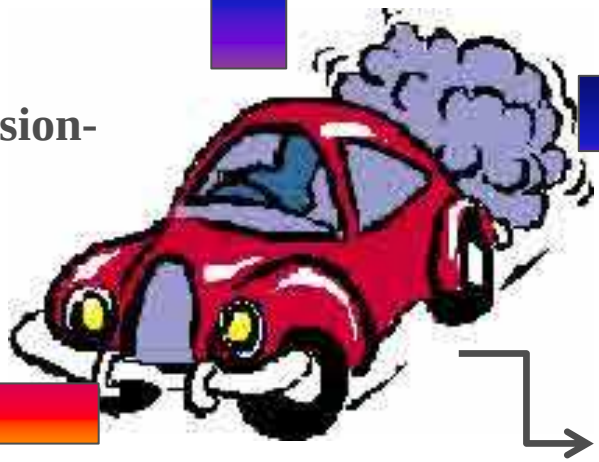
Atmospheric deposition

1. **A wide range of pollutants have been shown to be present in roads sediments**

2. **Awareness of traffic as one of the major diffuse metal emission sources – need *more detailed information* about traffic related sources and how and where the metals are dispersed (Hjortenkrans et al., 2006)**

Background

Evaporative Emission-VOCs



Resuspension-PM

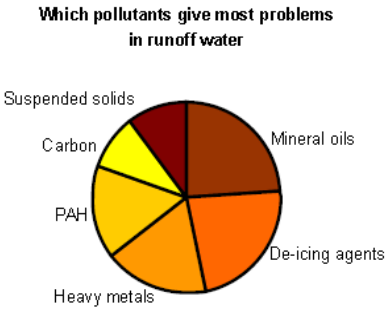
Exhaust Emission- *Cu, Cr, Cd, Pb, Zn*

Abrasion (PM)

-Tyre wear: Zn

-Brake wear: Cu, Cd, Ni, Sb, Zn

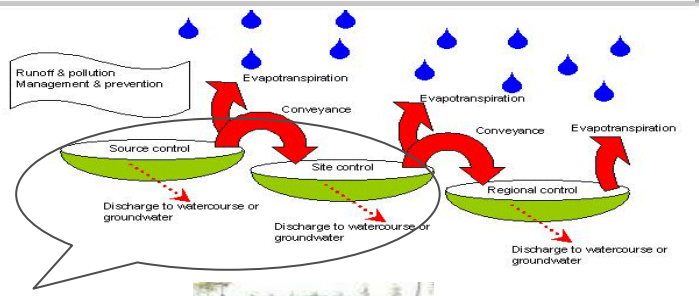
-Road surface wear: Cd, Cr, Cu, Ni, Zn



Other sources include road paint (Cu, Pb), road infrastructures (Zn, Cr, Ni)

Heavy Metal Pollution is More Common than You Think

Key issues



- BMPs
- SUDS for Roads

Site control

✓Where (location specific) and What to select as the most appropriate treatment systems?

Objectives

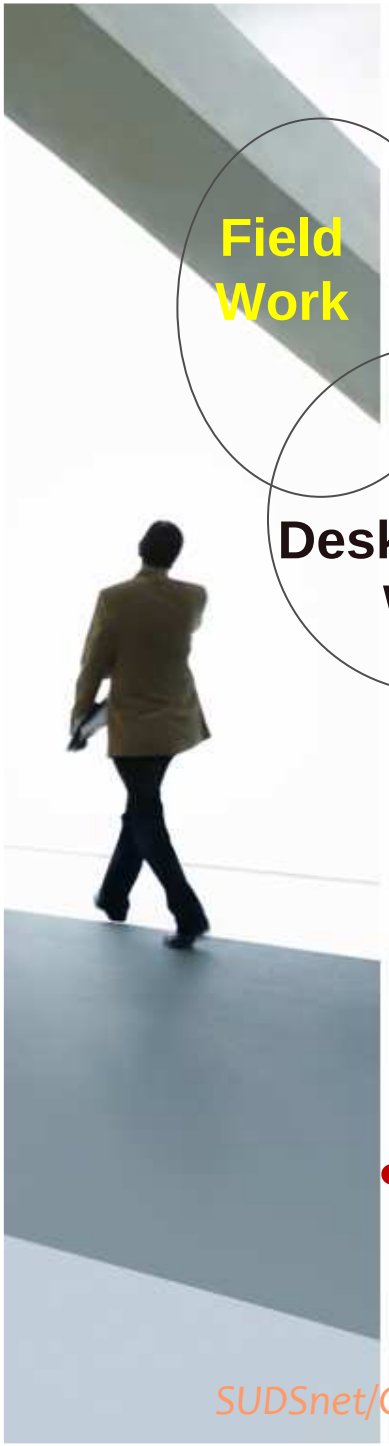
- To analyse road deposited sediment (RDS) metal concentrations in order to explain spatial variability of metal emission patterns in the road traffic environment

- To assess contamination levels of RDS metals across the sampling sites in a framework of environmental pollution

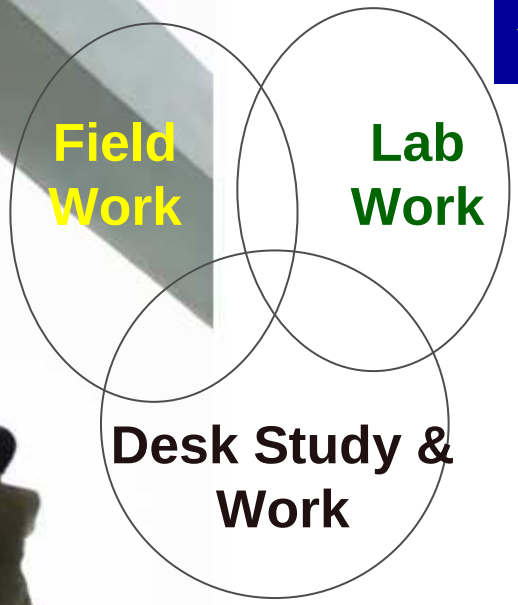
- To identify pollutant hot spot areas based on heavy metal pollution

Site Description

- 2 lanes of traffic with asphalt road surface for all sites
- Traffic volume measured as *200 VPH* for site 1-4; 230, 250, 265, 285 VPH for 5, 6, 7, 8; ***650*** for site 9-10; 550 ***VPH*** for site 11 respectively
- Road condition is good for all sites, except S-6 (poor), S-8 (fair) and car park (fair)



Methodology



• RDS Sampling

-RDS collection (Robertson and Taylor, 2007; Kim et al., 1998)

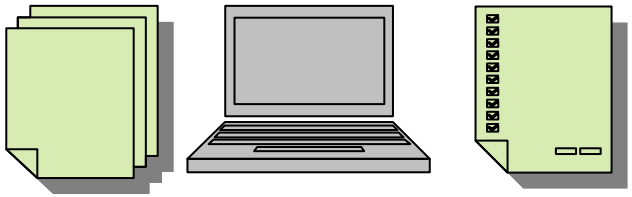
-Sampling period -10 months

-No of sample varied between 3 to 25 from each sites over 1 to 14 ADD

•Lab Work

-Sample handling, preservation and preparation for chemical analysis [QC/QA were as specified in Stormwater Monitoring Protocol Guidance Manual (Caltrans, 2000)]

•Desk Work



Laboratory Work Details

Analytical protocol for RDS metal determination

Dry sample at 105^{0}C overnight

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Accurately weigh approximately 1.0 g

↓

Add 10 ml of conc. Anala R (70%) HNO_3

↓

Heat in water bath at 85^{0}C for 1 hour until white fumes given off and sediment got a colour

↓

Allow solution to cool, then pass through Whatman No. 42 filter and add de-ionised water to make up to 50 ml in a volumetric flask

↓

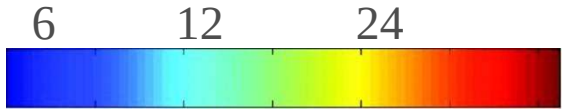
Use a Perkin Elmer 200 AAS instrument to analyse for Zn, Cu, Cd, Cr, Ni, Pb, Fe

Note: The details of analytical protocol can be found in Pal et al. (2011), Robertson and Taylor (2007), Deletic and Orr (2005)

Metal Pollution Assessment

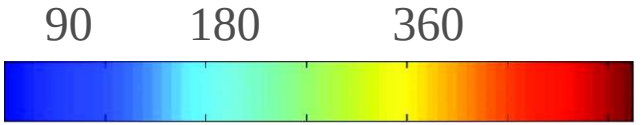
Degree of contamination (CD) and Ecological risk index (RI) Proposed by Hakanson (1980) are estimated as follows:

- CD $$CD = \sum_{i=1}^{n} C_f^i \Longrightarrow C_f^i = \frac{C_s^i}{C_B^i}$$



C^i_f is the single metal pollution index; C^i_s is the concentration of metal i in the samples; C^i_B is the reference value for metal i

- RI $$RI = \sum_{i=1}^{n} E_r^i \Longrightarrow E_r^i = T_r^i \times C_f^i$$

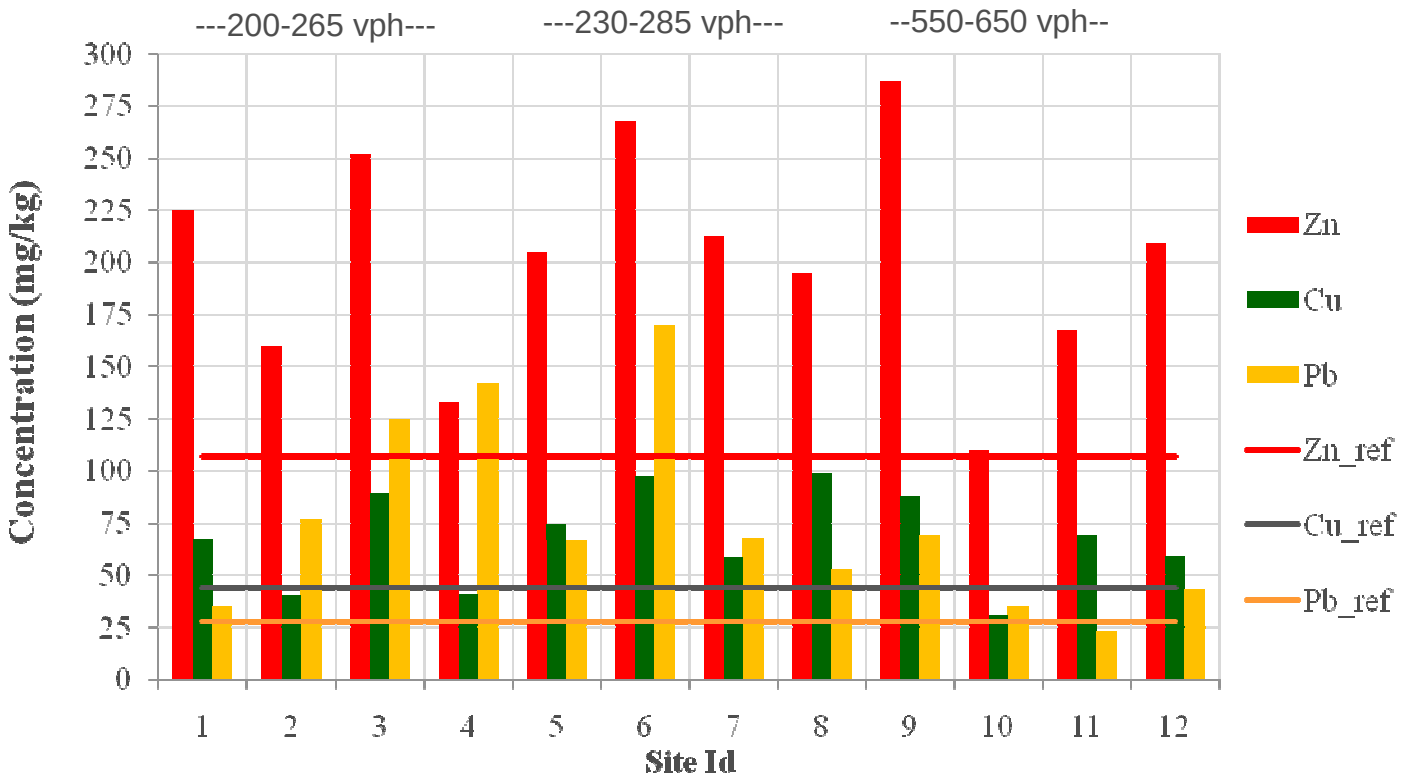


E_r^i is the monomial potential ecological risk factor and T_r^i is the metal toxicity factor

T_r^i : Zn=1<Cr=2<Cu=Ni=Pb=5<Cd=30 (Hakanson, 1980)

Results

RDS total metal concentrations



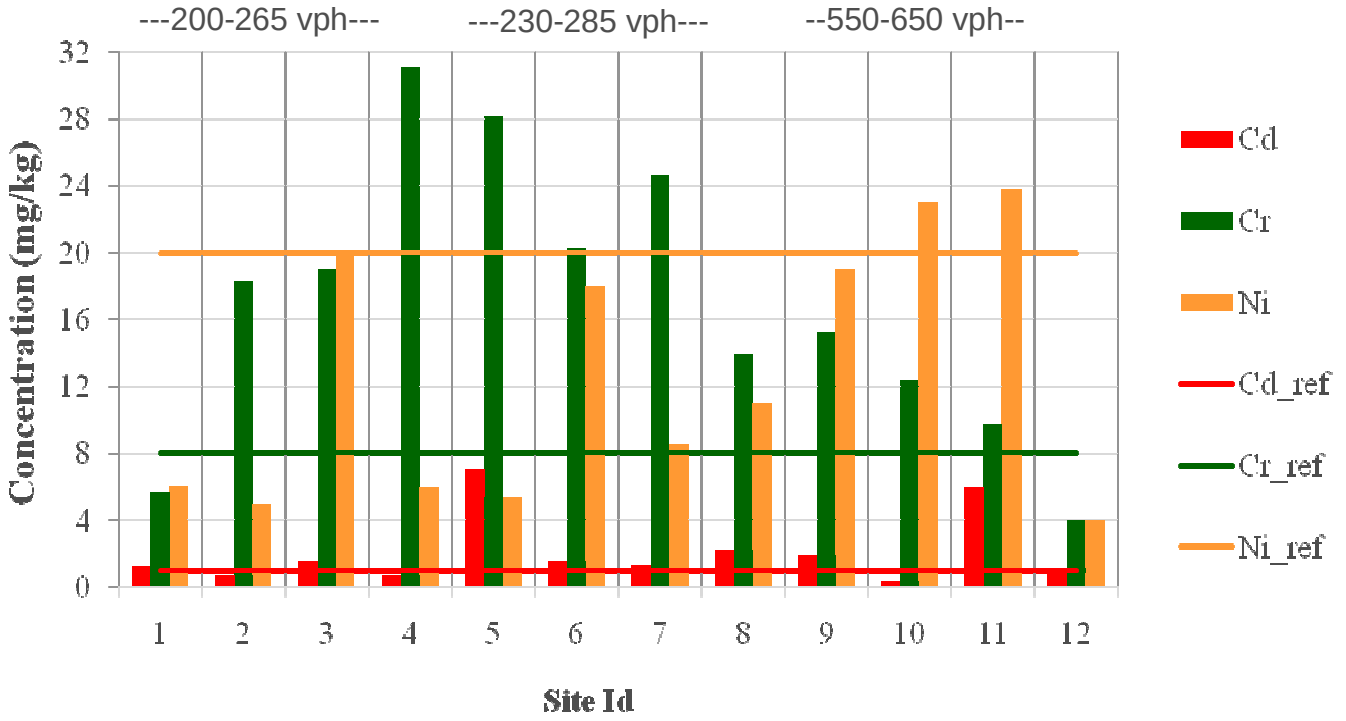
✓Accumulation Index, AI_{Zn} ≥2.0 is found for Site 1, 3 (2.4), 6 (2.5), 7 and 9 (2.7)

✓AI_{Cu} ≥1.5 is found for Site 1, 3 (2.0), 5, 6 (2.2), 8 (2.3), 9 and 11

✓AI_{Pb} ≥2.0 is found for Site 2, 3 (5.0), 4 (4.0), 5, 6 (6.1), 7, 9

Results

RDS total metal concentrations



✓AI_{Cd} ≥1.5 is found for Site 3, 5 (7.0), 6, 8 (2.2), 9 and 11(6.0)
✓AI_{Cr} ≥2.0 is found for Site 2, 3, 4 (3.9), 5 (3.5), 6 and 7 (3.2)
✓AI_{Ni} ≥1.0 is found for Site 10 and 11

Metal Pollution Assessment

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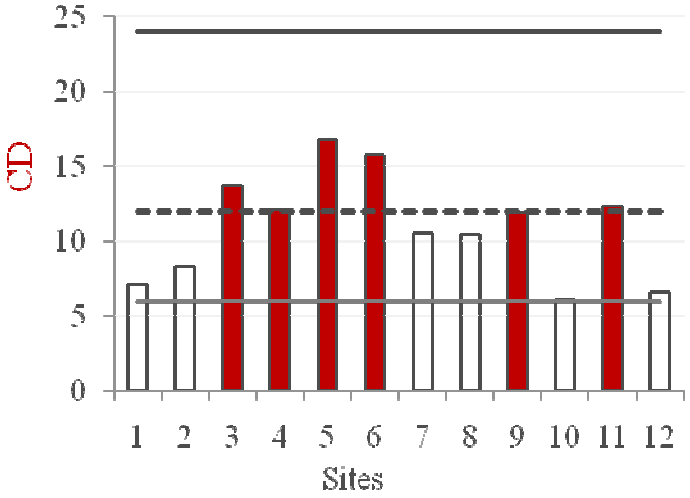
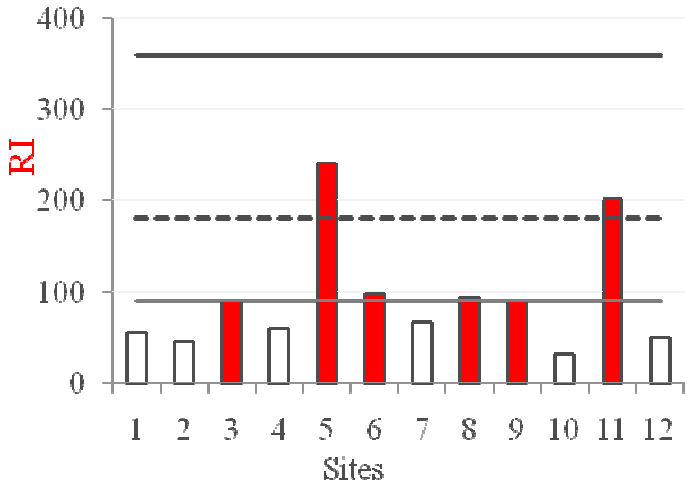
- Contamination based on CD



Grey, dotted and solid lines represent upper limits of low, moderate and considerable degree of overall contamination, respectively.

- Contamination based on RI



Grey, dotted and solid lines represent upper limits of low, moderate and considerable degree of overall ecological risk, respectively.

Summary & Conclusion

•A spatial variation of heavy metal emission pattern is found to occur across the sampling sites along the road network

• Based on average accumulation coefficients for all metals ≥ 1.50 across the sampling sites, high metal emissions are found in the order of Bus stops > Road with speed controls > Road bend > Road intersection

•Site specific attributes (such as road lay-out and road surface condition) are found to be major drivers of difference in heavy metal emission patterns in the RDS

•Based on pollution assessments , Bus stops, Road with speed controls , Road bend , Straight road (S-9), Road intersection are identified as pollutant hot-spot sites that are very likely to pose a moderate to considerable level of risk to the urban ecological system in the study area.

Thanks for your attention

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