Spatial Variation of Blood Lead Levels in Peripartum Women near a Mining-related Superfund Site

A Zota[1], CJ Paciorek[1], AS Ettinger[1], C Amarasiriwardena[2], JD Spengler[1], M Osborn[3], H Hu[1,2], RO Wright[1,2]

[1]Harvard School of Public Health, Boston,MA; [2]Channing Laboratory, Brigham and Women's Hospital, Harvard Medical School, Boston, MA;[3]Integris Regional Medical Center, Miami, OK

Objective

Limited evidence has shown that geographic proximity to hazardous waste may have consequential health effects particularly for susceptible subpopulations such as pregnant women and infants. Geostatistical techniques provide a powerful way to examine these potential relationships. The purpose of this analysis is to examine if women who live closer to mining waste ("chat") have higher biomarker levels of lead relative to those who live farther away.

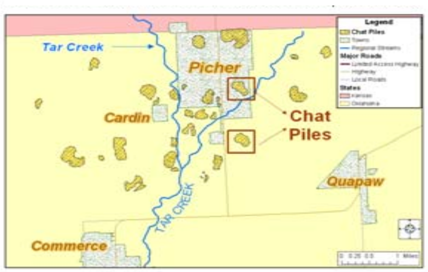
Introduction

Figure 1: Towns Proximate to Tar Creek Superfund Site

Tar Creek Superfund Site:

- Located in the northeastern corner of Oklahoma near Kansas border (Figure 1).
- One of world's largest lead and zinc mining areas from 1891 until 1970's.
- Since 1983, one of the largest Superfund sites in the USA covering an area of 50 square miles.
- 6,400 residents live within site boundaries. in towns of Picher, Cardin, Quapaw, Commerce, and portions of North Miami.

Figure 2: Location of Chat Piles at Tar Creek



Chat Piles: Mining Waste

- Mine tailings ("chat") b-yproduct of mining process
- Solid waste, high in heavy metals, varies is size and shape
- Approximately 75 million tons of chat on Superfund site
- Many chat piles located near residences in the towns of Picher and Cardin (Figure 2)

Methods

Geo-coding

- Geocoded locations of participant residences using TigerFiles from Census
- For spatial models, excluded those who were not geocodeable (n=40) and those who lived outside of Picher/Miami area (n=22).

Summary Statistics

- Examine differences in mean blood lead levels by location using Student's T test

Spatial Modeling Approaches

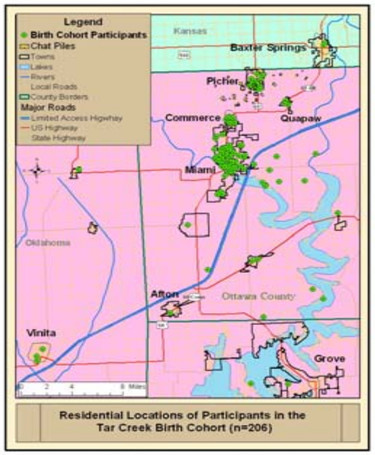
- Log transformed blood pb levels in model
- Explored 4 basic types of models: generalized additive models, thin plate spline models, weighted least squares, and maximum likelihood models

Kriging: Modeling Spatial Covariance

- Examined general and directional variograms
- Modeled data using matern covariance
- Tried variety of initial values, set Kappa=4
- Used 10% of data (n=16) as test data for cross validation
- Tested for anisotrophy
- Used parameter measures and likelihood ratio tests to determine goodness of fit.

Results

Figure 3: Residential Locations of Participants in Tar Creek Study

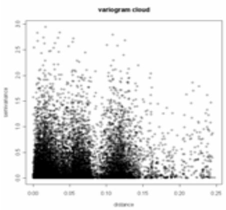


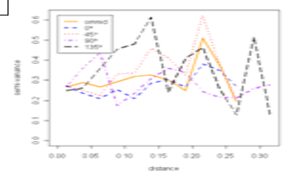
Results

Table 1: Summary of Maternal Blood Lead Levels by Location

Group	N	Mean (SD) (µg/dL)	Median (µg/dL)	T-Test p value
Entire Cohort	184	0.83 (0.47)	0.72	
Superfund Site residents	54	0.98 (0.49)	0.91	0.005
Non-Superfund residents	130	0.77 (0.45)	0.62	
Picher residents	20	1.15 (0.51)	1.13	0.002
Non-Picher residents	164	0.73 (0.45)	0.69	

- Blood lead levels very low
- Women living inside superfund site significantly higher blood leads than those in Miami (p=0.005)
- Women living near chat piles (in Picher) significantly higher blood lead levels (p=0.002)





- Variogram suggests little spatial correlation
- Points not evenly distributed; clustered by town
- Directional variogram suggests differences by direction.

Table 2: Parameter estimates from 3 Geostatistical models

Model	Parameter estimates $\hat{\tau}^2$	$\hat{\sigma}^2$	$\hat{\tau}^2+\hat{\sigma}^2$	$1/\hat{\rho}$	$\hat{\nu}$
Isotropy	0.263	0.027	0.291	0.0119	4
Anisotropy	0.265	0.024	0.289	0.0117	4
Variofit (WLS)	0.267	0.219	0.486	0.0849	3.1

- Isotropy vs Anisotropy: likelihood ratio tests suggest isotropic model is adequate (p=0.77)
- Spatial vs. Non-spatial: likelihood ratio tests suggest spatial component not significant (p=0.14)
- In all 3 models above, non-spatial variance dominates total variability of the data

Table 3: Prediction Quantities from 4 Smoothing Techniques

Smoother	Prediction Quantities: Mean squared error on test set	Prediction coverage on test set	Average length of the prediction confidence interva
Gam	0.58	0.89	2.08
Tps	0.60	0.89	2.08
Isotropy	0.50	0.94	2.08
Anisotropy	0.51	0.94	2.08

- Results from 4 spatial models are comparable
- MSE & Coverage suggest MLE models slightly better fit
- Although Gam and MLE models yield similar MSE and coverage, they produce different spatial surfaces (Figures 4 & 5)
- MLE appears to do more localized smoothing

Figure 4: Predicted spatial surface of Blood Pb concentrations and standard errors using gam model ($g(s_i)$, df= 4.3, p=0.01)

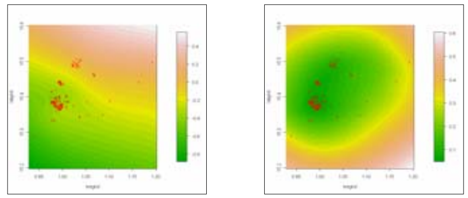
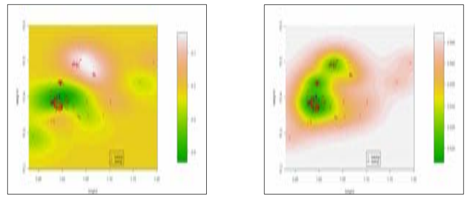


Figure 5: Predicted spatial surface of Blood Pb concentrations and standard errors using isotropic MLE model with matern covariance



Conclusions

These data suggest differences in human exposure by proximity to hazardous waste confirming the hypothesis that contact to toxins may be greater for populations residing near a Superfund site. Failing to detect a significant spatial correlation with kriging may be due to the fact that participants are not evenly distributed throughout this rural region rather they are clustered in dispersed towns. Future studies will evaluate our cohort for personal exposures to mining-related metal contaminants in the home environment.