Assessment of lead contamination in urban soils in an area of southern Italy

Ilaria Guagliardi[A], **Gabriele Buttafuoco**[B], Domenico Cicchella[A], Rosanna De Rosa[C]

[A]Dipartimento di Studi Geologici ed Ambientali, Università degli Studi del Sannio, Benevento Italy, Email ilguagli@unisannio.it, cidom@unisannio.it
[B]CNR - Institute for Agricultural and Forest Systems in the Mediterranean (ISAFOM), Rende (CS), Italy, Email gabriele.buttafuoco@cnr.it
[C]Dipartimento di Scienze della Terra, Università della Calabria, Ponte Bucci, 31-C, 87036 Rende (CS), Italy, Email derosa@unical.it.

Abstract
Lead concentration of urban soils in Cosenza-Rende territory (southern Italy) was investigated to asses and map contaminated areas. Samples were collected at 149 residual and not residual topsoils (0.20 m) and were analysed for lead (Pb) using X-Ray Fluorescence Spectrometry method. Geostatistical methods were used to study spatial structure and risk assessment of lead concentration in urban soils. Results showed areas in which lead concentration values were higher than the Italian regulatory values regarding soil pollution with lead. These polluted areas were quite large and it is likely that they could create a significant health risk for human beings and vegetation in the near future. The results demonstrated that the proposed approach can be used to study urban soils contamination to produce geochemical maps, identify hot-spot areas and assess the probability of exceeding given regulatory values for soil lead concentration.

Key Words
Urban soils, lead in soils, soil pollution, geostatistics, stochastic simulation

Introduction
The influence of environmental geochemistry on human health is extremely important above all if some heavy metals, such as lead (Pb), appear to cause ill health through either deficiency or toxicity or both (Oliver 1997). Soil in urban environment has a direct influence on public health not related directly with production of food (Madrid *et al.* 2002). Urban soil acts as a sink for heavy metals and many other pollutants (Biasoli *et al.* 2005; Lee *et al.* 2005). Sources of heavy metals and other pollutants are related to human activities, such as vehicular emissions, industrial discharges and urban development (Wong, 2006). Among these sources, a vehicular emission is commonly known to be significant and increasing source of soil pollution in urban environment (Rossini and Fernádez 2007). Many urban soils are contaminated with high concentrations of lead and exposure to it disrupts the development of the nervous system, causing delays in growth and learning disabilities. Geostatistical methods provide us a valuable tool to study spatial structure of lead concentration and mapping its spatial distribution. Stochastic simulation is a development of geostatistics and estimates the conditional cumulative distribution functions at each location. Statistical information deriving from stochastic simulation allows us to estimate the probability that each pixel exceeds a threshold value and to produce the probability map of high lead concentrations in urban soils. The main objective of this study was to explore the spatial structure and risk assessment of lead concentration in urban soils in Cosenza-Rende territory (southern Italy).

Methods
The study area (92 km^2), characterized by high vehicular traffic load, was located in the Cosenza-Rende territory (southern Italy) (Figure 1). Soil samples (Figure 1) were collected from residual and non-residual topsoil (0.20 m) and from flower-beds in the urban areas at 149 georeferenced locations. The total number of samples was dictated by financial constraints. Fine earth fraction (< 2 mm) of soil samples was analyzed for lead by X-Ray Fluorescence spectrometry (XRF). Geostatistical methods (Matheron 1971) were used to explore the spatial structure and risk assessment (Deutsch and Journel, 1998) of lead in urban soils. Soil lead data were used to yield 500 alternative equi-probable images of the unknown soil lead concentrations using conditional sequential Gaussian simulation (SGS) (Deutsch and Journel 1998). Stochastic sequential Gaussian simulation estimates the conditional cumulative distribution functions (CDFs) at each location, using neighbouring sample data and neighbouring estimates obtained previously. Statistical information was extracted from the set of the simulated images: 1) averaging the values for each pixel and producing the map of the “expected” soil lead concentration at any node of the interpolation grid (E-type or Expected-value estimate) and 2) counting the number of times that each pixel exceeded the threshold value and converting the sum to a proportion in order to produce the probability map of exceeding the threshold.

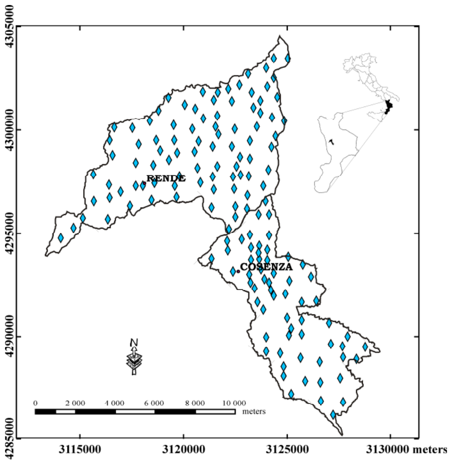

Figure 1. Study area and sample data location.

Results

Lead concentration data were characterized by a positively skewed distribution (Figure 2) with values 3 times higher than the local background.

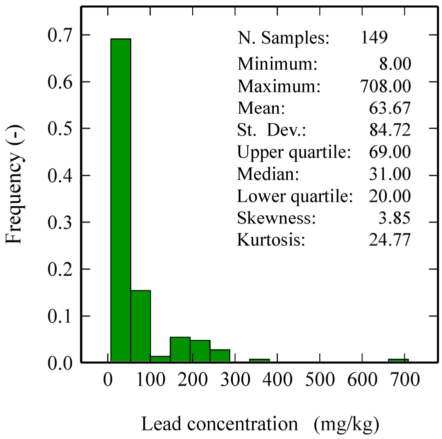

Figure 2. Histogram and basic statistics of lead concentration.

Conditional sequential Gaussian simulation is based on a multiGaussian model and it required a prior Gaussian transformation of the initial lead concentration data into a Gaussian-shaped variable with zero mean and unit variance. Such a procedure is known as Gaussian anamorphosis (Wackernagel, 2003) and the lead concentration values were transformed by using an expansion in terms broken to the first 30 Hermite polynomials. An isotropic variogram model was fitted to experimental semivariance values (Figure 3) because no anisotropy was observed in the variogram map (not shown). The model fitted (Figure 3) to the experimental variogram has three basic structures: (1) a nugget effect of 0.2079; (2) an exponential model with a practical range of 2000 m and a sill of 0.5453; (3) a spherical model with a range of 8000 m and a sill of 0.1790.

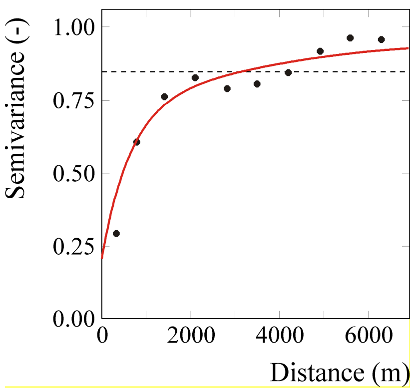

Figure 3. Variogram of lead concentration transformed to Gaussian values. The points are the experimental variances and the solid line is the fitted model.

Map of mean simulated lead concentration (Figure 4a) and probability map (Figure 4b) show a clear evidence of a strict correlation between location of emission sources, i.e. roads, (Figure 5) and the highest values of lead concentration.

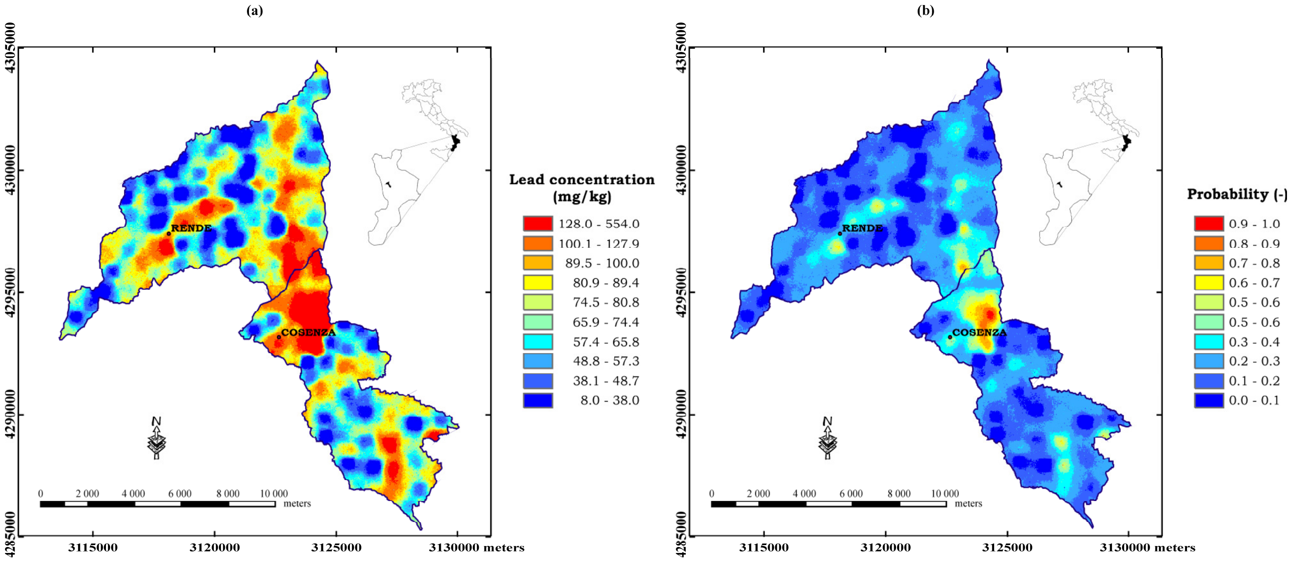

Figure 4. Maps of the mean simulated lead concentration (a) and of the probability of exceeding the threshold of 100 mg/kg

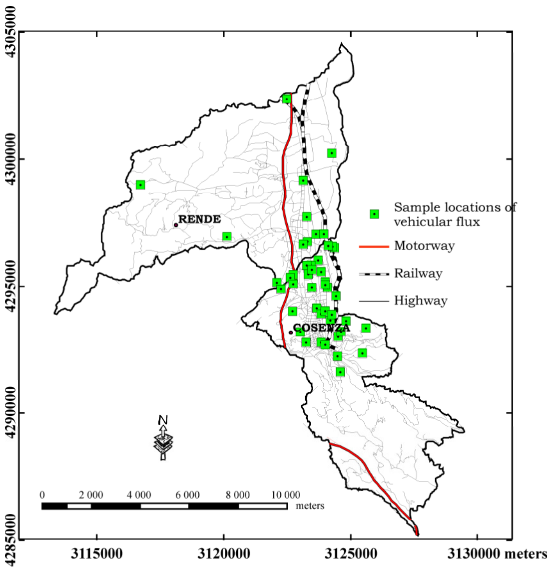

Figure 5. Road network.

The polluted areas were quite large and this is likely to create a significant health risk for human beings and vegetation in the near future.

Conclusion
The study showed that the proposed approach can be useful in contaminated urban soils from lead to produce geochemical maps, identify hot-spot areas and assess the probability of exceeding given regulatory values for soil lead concentration.

References

Biasioli M, Barberis R, Ajmone-Marsan F (2006) The influence of a large city on some soil properties and metals content. *Science of the Total Environment* **356**, 154-164.

Deutsch CV, Journel AG (1998) 'GSLIB: Geostatistical Software Library and User's Guide' (Oxford University Press: New York).

Lee CSL, Li XD, Shi WZ, Cheung SC, Thornton I (2005) Metal contamination in urban, suburban and country park soils of Hong Kong: A study based on GIS and multivariate statistics. *Science of the Total*

Environment **356**, 45-61.

Li X, Poon C, Liu PS (2001) Heavy metal contamination of urban soils and street dusts in Hong Kong. *Applied Geochemistry* **20**, 611-625.

Madrid L, Díaz-Barrientos E, Madrid F (2002) Distribution of heavy metal contents of urban soils in parks of Seville. *Chemosphere* **49**, 1301-1308.

Oliver MA (1997) Soil and human health. *European Journal of Soil Science* **48**, 573-592.

Rossini Oliva S, Fernández Espinosa AJ (2007) Monitoring of heavy metals in topsoils, atmospheric particles and plant leaves to identify possible contamination sources. *Microchemical Journal* **86**, 131-139.

Wackernagel H (2003) 'Multivariate Geostatistics: an introduction with Applications' (Springer-Verlag: Berlin).

Wong CSC, Li XD, Thornton I (2006) Urban environmental geochemistry of trace metals. *Environmental Pollution* **142**, 1-16.