Spatial Prediction of Heavy Metal Pollution for Soils in Coimbatore, India based on Universal Kriging

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ABSTRACT
Industrialization and urbanization taking place at faster rate in Coimbatore city. Hence the discharge rate of industry effluents and wastes are increasing at alarming rate. These effluents and wastes are being discharged randomly on soil, river, lake and road side without any treatment. They pollute productive soil, natural water system as well as ground water. Assessment of heavy metal content in soil and wetland from various localities of Coimbatore, Tamil Nadu was undertaken. Heavy metal pollution generally a non-stationary variable, the technique of universal kriging is applied in preference to ordinary kriging as the interpolation method.

Topsoil samples (0-20 cm) were taken at various locations with reference to latitude and longitude. The concentration of heavy metal Cr, Pb, and Fe were analyzed in the Atomic Absorption spectrometer. Universal Kriging model was developed with suitable empirical semivariogram model. The model having the least error was selected by comparing the observed table values with the values predicted by empirical semivariogram models. It was determined that the presence of Fe is high at Electroplating Industrial areas and traffic junctions. Presence of Pb is high in Velangulam Lake Ukkadam, and at the Sungam Lake. Presence of Cr is high at Ganapathy and X - cut road and is 3.6 & 3.5 ppm respectively because of electroplating industries. The aim of this analysis is to investigate the level of heavy metal contamination in soil and prediction of heavy metal at various locations in the vicinity of industries and around Coimbatore city.

Keywords
Spatial analysis, Heavy metals, Geo-accumulation, Universal kriging, Semivariogram, Soil pollution.

INTRODUCTION
There are so many metal-based industries located in Coimbatore in an unorganized manner and is the second largest industrial centre in Tamil Nadu. The major industries include textile, electroplating, motor and pump set, foundry and metal casting industries. According to the recent survey, about 5600 textiles, 2100 electroplating industries, 280 dyeing units and 178 foundries are present in Coimbatore district. Industrial waste water and effluent are being discharged randomly on soil, into canal and river along road side or in the vicinity of industry operations without any treatment. They pollute productive soils, natural water system as well as ground water. Industrial effluents and municipal waste contain medium amount of heavy metals such as Cr, Pb, and Fe.

Apart from these industries, sewers numbering about twenty thousand (Somasundaram, 2001 and Malarkodi et.al, 2006) are running through various zones and finally discharging into the sewage farm located in Ukkadam. To adopt any type of remedial measures, it is necessary to determine the heavy metal load in the contaminated soil. Against this background information, it is necessary to analyze the heavy metal concentration in and around Coimbatore, Tamil Nadu. 130 Soil samples (three replicates) at surface level (0–20 cm in depth) were collected from various locations to cover industrial, commercial, residential areas and wetland area. Concentration Heavy metal pollution generally a non-stationary variable, the technique of universal kriging is applied in preference to ordinary kriging as the interpolation method.

Kriging is a technique of making optimal, unbiased estimates of regionalized variables at un-sampled locations using the structural properties of the semivariogram and the initial set of data values (David 1977). Kriging takes into consideration about the spatial structure of the parameter and hence it is having definite advantage over other methods like arithmetic mean method, nearest neighbor method, distance weighted method, and polynomial interpolation. Also, kriging provides the estimation variance at every estimated point, which is an indicator of the accuracy of the estimated value. This is considered as the major advantage of kriging over other estimation techniques.

Kriging has been used in soil science by Bardossy and Lehmann 1998; Araghinejad and Burn 2005. In this paper, application of kriging to interpolate the heavy metal concentration, as observed in the part of Coimbatore, Tamil Nadu, India, has been shown.

1. METHODOLOGY
Kriging techniques are well presented by Isaaks and Srivastava (1989), Vijay Kumar and Remadevi, (2006), a brief account of the relevant methods used is reproduced here. The first step in kriging is the calculation of the experimental semivariogram using the following equation.

$$\gamma^{*}(\mathrm{h}) = \frac{1}{2\mathrm{N[h]}} \sum_{\mathrm{i}=1}^{\mathrm{N[h]}} \{\mathrm{z}(\mathrm{x_i}) - \mathrm{z}(\mathrm{x_i}+\mathrm{h})\}^2 \quad \text{----} \quad (1)$$

Where $\gamma^*(h)$ = estimated value of the semi variance for lag h; N (h) is the number of experimental pairs separated by vector h; z (x_i) and z (x_i +h) = values of variable z at x_i and x_i+h, respectively; x_i and x_i+h = position in two dimensions.

Experimental semivariogram were calculated using the computer program (in FORTRAN language) written by Kumar (1996).

The experimental semivariogram were fitted with various theoretical models like spherical, exponential, Gaussian, linear and power by the weighted least square method. The theoretical model that gave minimum standard error is chosen for further analysis. The adequacy of the fitted models was checked on the basis of validation tests. In this method, kriging is performed at all the data points, ignoring, in turn, each one of them one by one. Differences between estimated and observed values are summarized using the cross-validation statistics: mean error (ME), mean squared error (MSE), and kriged reduced mean error (KRME), and kriged reduced mean square error (KRMSE). If the semivariogram model and kriging procedure adequately reproduce the observed value, the error should satisfy the following criteria.

$$\mathrm{ME} = \frac{1}{\mathrm{N}}\sum_{\mathrm{i}=1}^{\mathrm{N}}\{\mathrm{z}^*(\mathrm{x_i}) - \mathrm{z}(\mathrm{x_i})\} \cong 0 \qquad \text{----} \quad (2)$$

$$\mathrm{MSE} = \frac{1}{\mathrm{N}}\sum_{\mathrm{i}=1}^{\mathrm{N}}\{\mathrm{z}^*(\mathrm{x_i}) - \mathrm{z}(\mathrm{x_i})\}^2 \text{ minimum} \qquad \text{----} \quad (3)$$

$$\mathrm{KRME} = \frac{1}{\mathrm{N}}\sum_{\mathrm{i}=1}^{\mathrm{N}}\{\mathrm{z}^*(\mathrm{x_i}) - \mathrm{z}(\mathrm{x_i})/\sigma_{\mathrm{ki}}\} \cong 0 \qquad \text{----} \quad (4)$$

$$\mathrm{KRMSE} = \frac{1}{\mathrm{N}}\sum_{\mathrm{i}=1}^{\mathrm{N}}\{\mathrm{z}^*(\mathrm{x_i}) - \mathrm{z}(\mathrm{x_i})/\sigma_{\mathrm{ki}}^2\} \cong 1 \qquad \text{----} \quad (5)$$

Where, $z^*(x_i)$, $z(x_i)$ and σ_{ki}^2 are the estimated value, observed value and estimation variance, respectively, at points x_i . N is the sample size. As per the rule, the MSE should be less than the variance of the sample values and KRMSE should be in the range $1\pm2\sqrt{2/N}$.

In all interpolation techniques, interpolated value of z at any point x_0 is given as the weighted sum of the measured values i.e.

$$z^*(x_0) = \sum_{i=1}^{N}\lambda_i z(x_i) \;\; i = 1,2,3,\ldots,N \qquad \text{----} \quad (6)$$

Where, λ_i is the weight for the observation z at location x_i. In kriging, the weights λ_i are calculated by equation (7) so that $z^*(x_0)$ is unbiased and optimal (minimum squared error of estimation).

$$\begin{cases} \sum_{j=1}^{N}\lambda_j\gamma(x_i,x_j) + \mu = \gamma(x_i,x_{0j}) \;\; i = 1,2,3,\ldots,N \\ \sum_{j=1}^{N}\lambda_j = 1 \end{cases} \qquad \text{- (7)}$$

Where,

μ = Lagrange multiplier

γ (x_i, x_j) = semivariogram between two points x_i and x_j

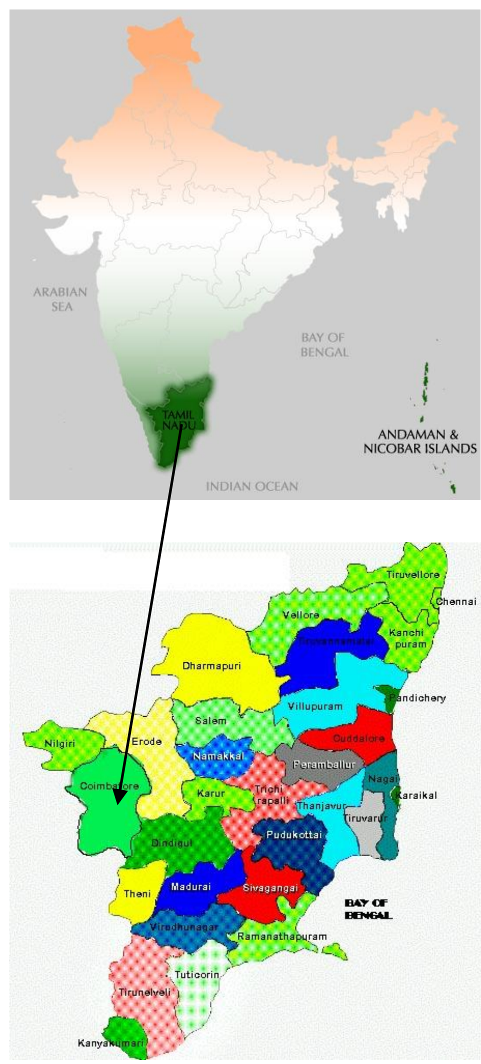
The minimum squared error estimation is also a measure for the accuracy of estimates, which is known as estimation variance, or kriging variance, and is given by

$$\sigma_k^2(\mathrm{x_0}) = \sum_{\mathrm{i}=1}^{\mathrm{N}}\lambda_j\gamma(x_i,x_0) + \mu \qquad \text{----} \quad (8)$$

Where, μ is the Lagrange multiplier..

2. STUDY AREA

The study area (Fig. 1) is located in the southern part in the state of Tamil Nadu, India



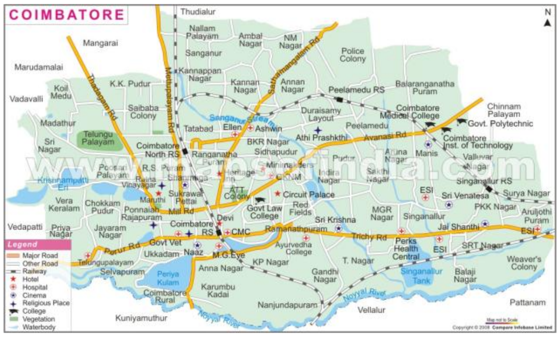


Fig. 1. Location map of study area

130 locations were selected in the study area to collect the soil samples for analysis. To avoid contamination of the sample was thoroughly clean, Black polythene bag was used in the collection of soil samples. To clean black polythene bags were dried at lower temperature. The soil samples were collected at random by digging the soil to about 1 meter at the specific refuse dumps.

3. MATERIAL and METHODS

The collected soil samples were air-dried and sieved into coarse and fine fractions. Well-mixed samples of 2 g each were taken in 250 ml glass beakers and digested with 8 ml of aqua regia on a sand bath for 2 hours. After evaporation to near dryness, the samples were dissolved with 10 mL of 2% nitric acid, filtered and then diluted to 50 mL with distilled water. Heavy metal concentrations of each fraction was analyzed by Atomic Absorption Spectro photometry using GBC Avanta version 1.31 by flame Atomization. Quality assurance was guaranteed through double determinations and use of blanks for correction of background and other sources of error.

The GLOBEC Kriging Software Package – EasyKrig3.0 was used for creating the prediction model. The soils with potential risk of heavy metal pollution were located in isolated spots mainly in the northern part of the study region.

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Table.1 Observed Data

SL.No	Station	LAT	LONG	Pb PPM	Cr PPM	Fe PPM
1	Othakkalmandapam	10º52'27.96"N	7700'27.39"E	0.579	0.650	0.067
2	Myileripalayam	10º52'35.41"N	77º0"15.12"E	0.120	0.560	0.678
3	Kovilpalayam	11º08'29.54"N	77º1'51.76"E	0.032	0.410	2.340
4	Nanjundapuram	11º5'22"N	76º52'31"E	0.410	0.341	1.900
5	Ganapathy	11º2'18.78"N	76º8'39.81"E	2.440	3.600	0.140
6	100 Feet Road	11º1'9.92"N	76º57'45.09"E	2.120	3.520	0.780
7	Sivananthapuram	11º3'28.2"N	76º9'31.38"E	0.760	2.341	0.912
8	Gandhipuram	11º1'4.77"N	76º57'56.82E	2.890	0.230	4.890
9	Railway station	11º0'2.82"N	76º58'5.38"E	3.200	0.0231	3.910
10	Puliampatty	11º15'25.01"N	76º57'49.84"E	2.390	0.015	0.230
11	Annur	11º14'0.84''N	77º6'22.97"E	1.234	0.012	0.004
12	Chinnavedampatti	11º3'47.27"N	76º8'57.01"E	0.890	0.032	0.023
13	Kurumpampalayam	11º12'53.01"N	77º6'14.99"E	0.432	0.012	0.006
14	Ganesapuram	11º10'26.6"N	77º3'28.78"E	1.450	0.019	0.340
15	Onni Palayam	11º12'51.01"N	77º6'14"E	0.020	0.018	0.043

16	Annur	11º14’0.84”N	77º6’22.97”E	1.890	0.025	0.450
17	Goundampalayam	11º2’44”N	76º56’48.97”E	7.300	0.020	0.600
18	R.S.Puram	11º0’40.26”N	76º57’12.45”E	1.237	0.043	0.670
19	Saibaba kovil	11º1’34.79”N	76º57’2.86”E	0.310	0.020	0.760
20	Ariyan Motors	11º1’33.79”N	76º57’29.6”E	1.340	0.45	0.780
21	Jothipuram	11º9’51.14”N	76º58’54.88”E	0.010	0.008	1.234
22	GCT	11º1’2”N	76º6’6.43”E	0.012	0.000	0.000
23	Ondipudur	11º0’3.42”N	77º3’2.44”E	0.023	0.000	0.005
24	DB Road	11º0’28.75”N	76º57’3.31”E	6.020	0.067	0.890
25	Ram Nagar	11º0’34.57”N	76º57’9.89”E	0.004	0.560	4.074
26	X Cut Road	11º0’57.56”N	76º57’49.84”E	0.001	3.568	5.830
27	Vellalore	10º58’59.16”N	77º1’24.24”E	2.150	0.025	0.900
28	Sungam	10º59’57.29”N	76º58’20.89”E	0.000	0.001	0.950
29	Hope College	11º1’30.5”N	77º1’18.94”E	0.000	0.780	4.12
30	Lakshmi mill	10º58’57.29”N	76º58’21.89”E	0.000	0.612	5.12
31	Pothanur	10º58’17.75”N	76º59’19.7”E	0.000	0.003	0.960
32	Aadhupalam	10º59’55.36”N	76º57’37.89”E	0.001	0.009	0.000
33	Kovaipudur	11º56’37”N	76º56’18.44”E	0.002	0.004	.005
34	Kuniamuthur	11º57’47.16”N	76º56’49”E	0.000	0.001	0.002
35	Madukarai	11º54 ’34.79”N	76º57’11.59”E	0.002	2.980	0.000
36	Goundan palayam	11º2’44”N	76º56’48.44”E	1.820	1.002	0.980
37	Thudiyalur	11º5’0.4”N	76º56’0.67”E	8.376	0.029	0.980
38	Chinniampalayam	11º3’48.26”N	76º58’58.73”E	0.890	0.012	1.200
39	Somanur	11º4’12.48”N	76º52’56.2”E	0.568	0.022	1.290
40	Kovilpalayam	11º8’27.19”N	76º1’1.92”E	0.000	0.081	0.022
41	Sathiyamangalam	11º12’0.84’’N	77º10’22.97”E	0.000	0.004	0.310
42	Karamadai	11º14’19.4”N	76º57’31.78”E	0.231	0.065	1.320
43	Kurichi	10º57’4.86”N	76º58’16.9”E	1.150	0.005	1.810

44	Town Hall	10º59’37.95”N	76º57’38.86”E	8.560	0.0870	0.000
45	Sanganur Road	11º2’13”N	76º57’1.92”E	2.580	0.003	2.030
46	Aanaikatti	10º56’30.36’’N	76º53’52.93”E	0.002	0.090	0.067
47	Maruthamalai	11º2’37.32”N	76º57’2.86”E	0.780	0.0011	2.130
48	Vadavalli	11º1’28.98”N	76º54’14.26”E	0.011	0.007	5.120
49	Pal company	11º0’35.43”N	76º57’0.20”E	0.021	0.002	2.930
50	Palanthurai	11º0’40.26”N	76º57’12.45”E	0.270	0.050	2.300
51	Saravanampatti	11º4’43.63”N	77º0’7.11”E	1.590	0.028	2.360
52	Peelamedu	11º1’52.76”N	76º59’59.32”E	6.140	0.001	2.490
53	Ramanathapuram	10º59’23.22”N	76º59’3.67”E	1.590	4.200	2.530
54	Siganallur	10º59’57.29”N	76º58’20.89”E	4.120	3.210	4.93
56	Oththakkal Mandapam	10º53’2.99”N	77º0’3.426E	0.135	0.013	3.190
57	Kinathukadavu	10º49’4.8”N	77º1’35”E	0.890	0.067	3.210
58	Najundapuram	11º5’22”N	76º52’31”E	0.546	0.013	3.210
59	Gandhipuram	11º1’4.77”N	76º57’56.82E	0.134	0.043	4.300
60	Sundarapuram	10º57’37.14”N	76º52’5.6E	1.000	0.120	4.560
61	Residential Area**	10º57’37.14”N	76º52’5.6E	2.420	0.020	4.570
62	Thadagam	11º4’35.16”N	76º57’56.82E	3.210	0.021	4.590
63	Kanuvai	11º3’46.24”N	76º54’28”E	0.000	0.004	0.000
64	Madhampatti	10º58’10.10”N	76º51’35.3E	0.000	2.980	0.000
65	Sulur	11º0’21.67”N	77º07’32.80E	2.870	0.040	5.380
66	Palladam	10º55’25.46”N	77º17’10.87E	2.134	0.987	0.099
67	Viraiyanpalayam	11º0’40.26”N	76º57’12.45”E	0.112	2.87	5.590
68	Eachanari	10º55’36.98”N	76º58’53.64E	2.340	2.980	0.000
69	KovilPalayam	11º08’29.54”N	77º1’51.76”E	2.230	0.023	5.608
70	Malumichampatti	10º54’7.31’’N	76º59’45.55”E	1.200	0.100	5.640
71	Pannimadai	11º4’54.83”N	76º54.50.3”E	8.20	0.025	5.670
72	Karumbukadai	10º58’40.3”N	76º87’38.56”E	2.890	0.034	4.65

73	Podanur	10º57’14.81”N	76º59’36.02”E	5.120	0.076	2.123
74	KURCHI Lake	10º57’4.86”N	76º58’16.99”E	4.560	2.89	5,400
75	Valankulam	10º59’01”N	76º57’36.62”E	8.912	0.920	2.123
76	Kurchi	10º58’24.28”N	76º57’54.92”E	7.654	0.675	3.230
77	Sungam Lake	10º59’44.51”N	76º59’0.95”E	8.670	1.040	5.120
78	Perur Lake	10º58’49.22”N	76º55’19.88”E	1.543	0.067	3.120
79	Signanallur Lake	11º59’37.63”N	77º1’12.9”E	1.670	0.054	4.560
80	Sulur lake	11º1’48.88”N	77º07’12.11”E	2.982	0.54	5.340
81	SBOA Lake	11º0’5.88”N	76º56’46.10”E	3.500	0.890	0.000
82	Selvachinthamani lake	10º59’31.54”N	76º56.521.13”E	2.380	0.387	1.123
83	Velankulam	11º0’40.26”N	76º57’12.45”E	1.870	0.245	0.000
84	Kumarasamy lake	11º0’10.6”N	76º56’38.04”E	0.980	0.170	0.230
85	Selvampatti lake	10º59’31.54”N	76º56.521.13”E	2.300	0.190	0.340
86	Perur	10º57’43.89”N	76º55’41.65”E	5.820	0.034	4.678
87	Kurchikulam	10º58’53.91”N	77º5’18.69”E	5.420	2.345	3.231
88	Sivanandha colony	11º1’24.75”N	76º57’25.22”E	0.000	0.005	0.003
89	Aavarampalayam	11º4’0.39”N	77º5’18.69”E	0.002	0.000	0.678
90	Irugur	11º0’12.55”N	77º4’18.33”E	0.000	0.000	0.003
91	Neelalampur	11º4’0.39”N	77º5’18.69”E	0.000	0.002	0.000
92	Keeranatham	11º5’45.10”N	76º59’47”E	0.002	0.005	2.567
93	Karamadai	10º59’44.51”N	76º59’0.95”E	0.004	0.453	3.245
94	Narasimanaikkapalayam	11º7’3.86”N	76º56’7.2”E	0.190	0.389	4.234
95	Karunya nagar	10º56’22.66”N	76º44’47.8”E	0.000	0.007	0.345
96	Thondamuthur	10º59’24.02”N	76º50’31.36”E	0.000	0.000	0.234
97	Narasipuram	10º59’29.55”N	76º48’15.77”E	0.000	0.000	0.0005
98	Chitra	11º0’48.17”N	7702’29.9”E	0.678	0.832	1.780
99	Aerodram	11º1’49.17”N	77º2’29.9”E	0.654	0.567	2.980
100	Karumathampatti	11º1’18.08”N	77º10’39”E	0.003	0.000	0.006

101	Pachapalayam	10º56’22.66”N	76º44’47.8”E	0.002	0.000	0.045
102	Selvapuram	10º59’0.59”N	76º56’23.85”E	0.001	0.008	0.071
103	Ondipudur	11º4’0.39”N	77º5’18.69”E	0.000	0.021	0.067
104	Keeranatham	11º5’37.47”N	76º0’46.31”E	0.0001	0.001	0.003
105	Vadakkalur	11º0’48.17”N	77º2’29.9”E	0.000	0.000	0.000
106	Therampalayam	11º16’13.15”N	76º59’56.74”E	0.000	0.000	0.000
107	Punjampuliampatti	11º20’52.26”N	77º 10’7.07”E	0.003	0.000	0.000
108	Valampalayam	11º03’36.47”N	77º15’57.97”E	0.000	0.000	0.004
109	Irugur	11º1’11.73”N	77º4’14.34”E	0.005	0.002	0.006
110	Kannampalayam	11º59’49.16”N	77º5’33.98”E	0.003	0.001	0.006
111	Velanthavalam	11º48’45.42”N	76º51’28.61”E	0.000	0.000	0.002
112	Sathyamangalam	11º30’18.07”N	77º14’14.49”E	0.000	0.003	0.008
113	TNAU	11º0’48.11”N	76º58’9.86”E	0.054	0.000	0.011
114	Kovai Kutralam	10º57’48.23”N	76º52.9.32”E	0.001	0.001	0.001
115	Arivoli Nagar	10º56’23.48”N	76º56’35.4”E	0.000	0.002	0.001
116	Nanjappa Road	11º0’39.45”N	76º58’3.6”E	0.053	0.002	0.098
117	Okkilipalayam	10º53 43.69”N	7700’53.35.4”E	0.000	0.000	0.004
118	Puchiyur	10º51 43.09”N	7700’47.35.4”E	0.012	0.000	0.001
119	Arisipalayam	10º49 7.88”N	77º03’19.65”E	0.002	0.001	0.001
120	Chettipalayam	10º47 4.09”N	77º03’31.03”E	0.023	0.104	0.403
121	Tata Bad	11º1’41.52”N	76º57’40.6”E	0.031	0.002	0.109
122	Sivanandha colony	11º1’24.7”N	76º57’25.27”E	0.057	0.003	0.003
123	NGGO Colony	11º5’35.02”N	76º56’41.27”E	0.006	0.001	0.054
124	Poosaripalayam	11º2’54.9”N	76º58’14.1”E	0.000	0.000	0.000
125	Pethanaickenpalayam	11º7’6.69”N	77º02’32.6”E	0.071	0.000	0.001
126	Thelungu palayam	11º10’54.47”N	77º04’47.64”E	0.000	0.000	0.002
127	Kariyampalayam	11º12’ 5.7”N	77º4.39’30”E	0.032	0.001	0.003
128	Sirumugai	11º19’27.1”N	77º0’51.21”E	0.001	0.001	0.000

129	Vellingiri	11º0’40.26”N	76º57’12.45”E	0.000	0.001	0.001
130	Poondi	11º0’42.26”N	76º57’12.45”E	0.001	0.00	0.001

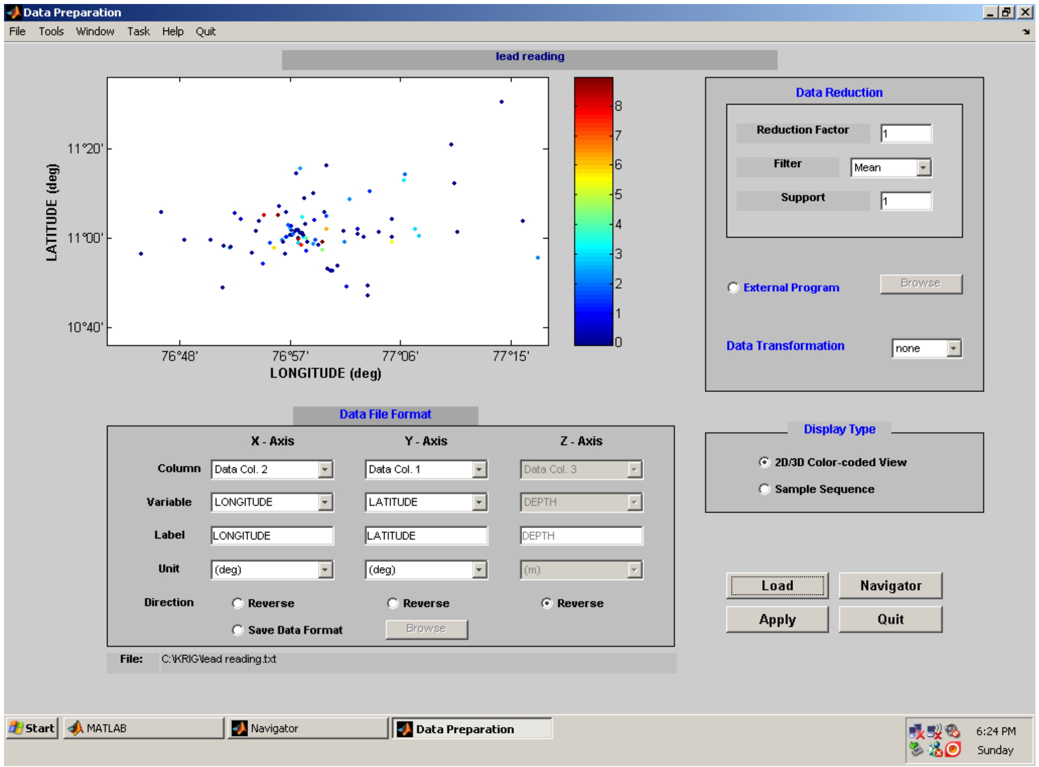

Fig. 2. Data Preparation – Lead

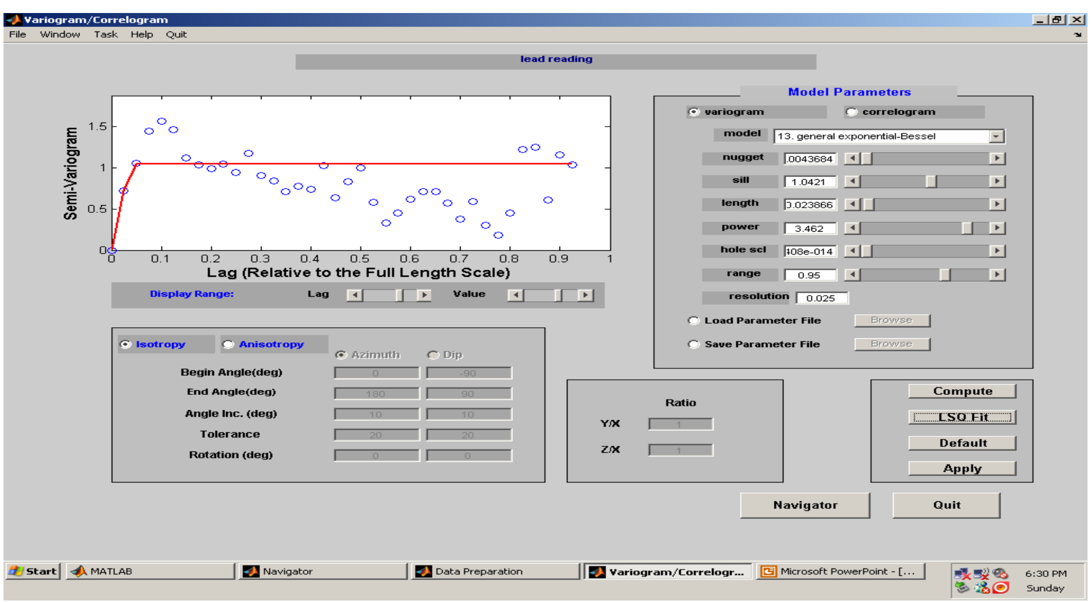

Fig. 3. Variogram - EasyKrig3.0 Software

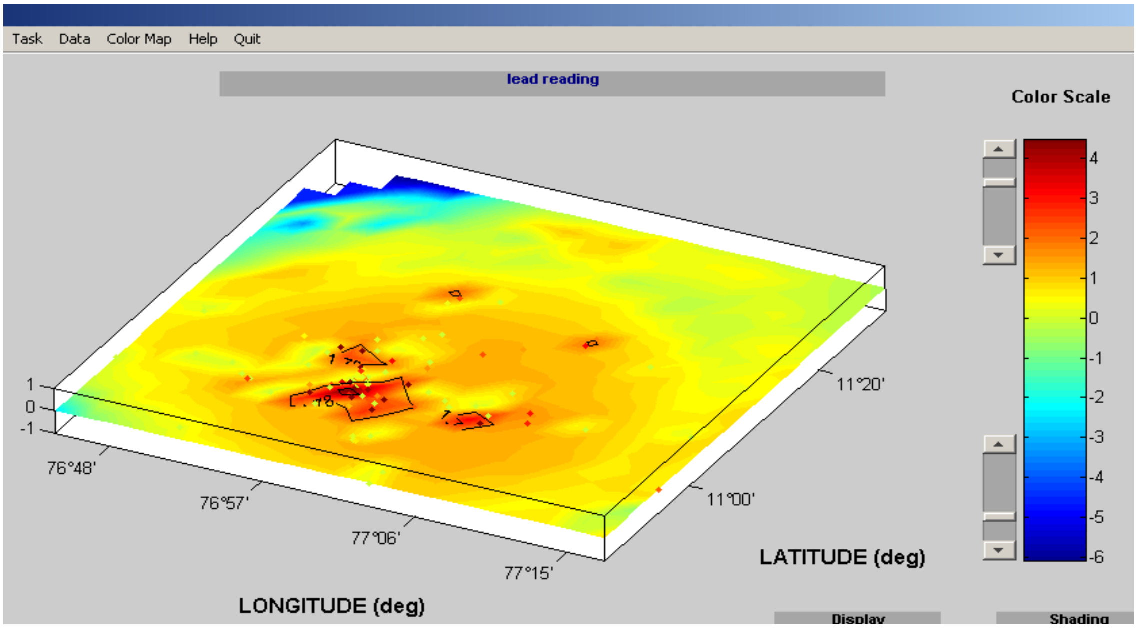

Fig. 4. Pb Concentration Map

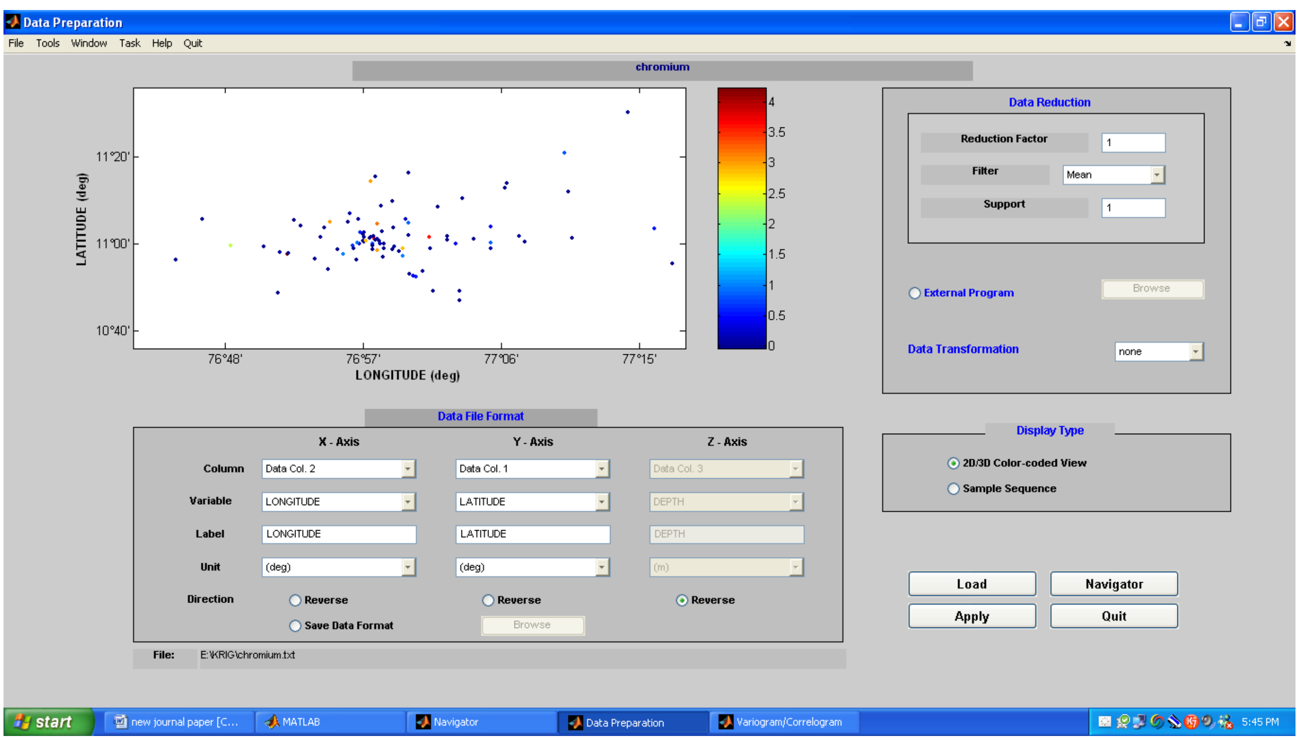

Fig. 5. Data Preparation – Cr

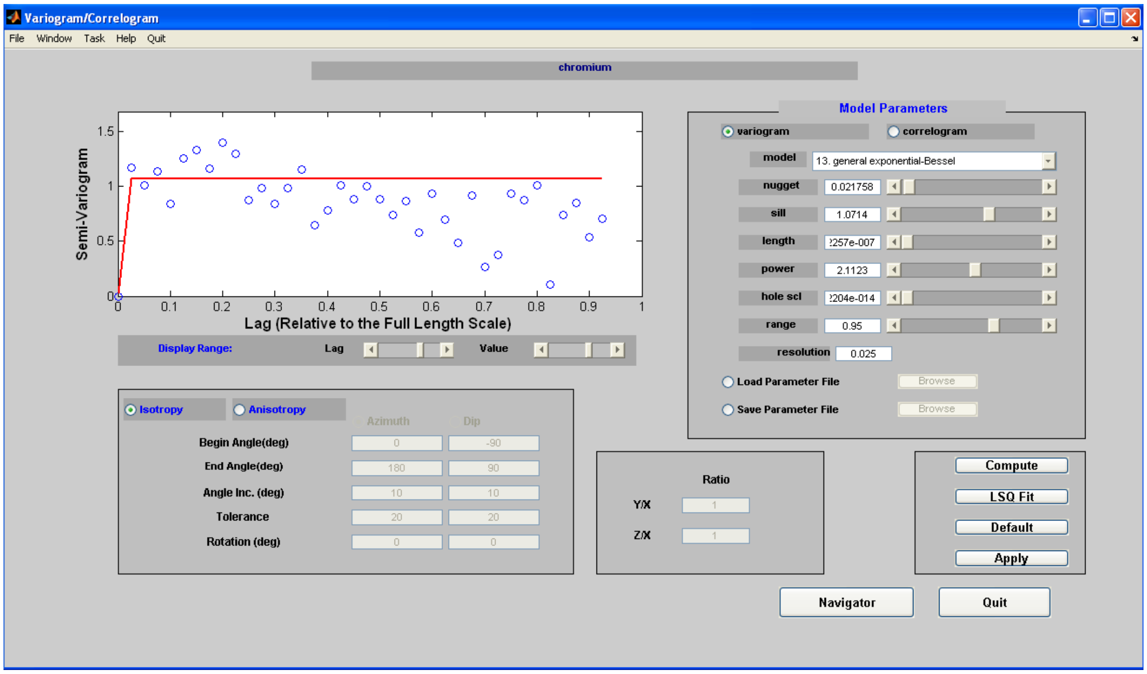

Fig. 6. Variogram - Cr

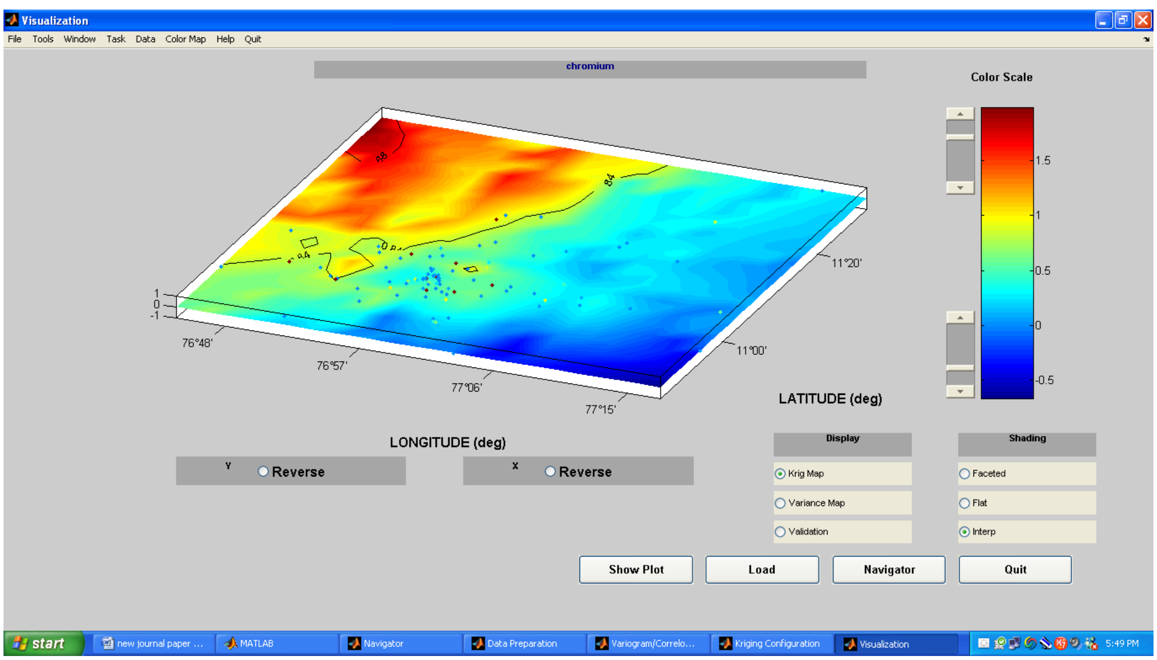

Fig. 7. Cr - Concentration Map

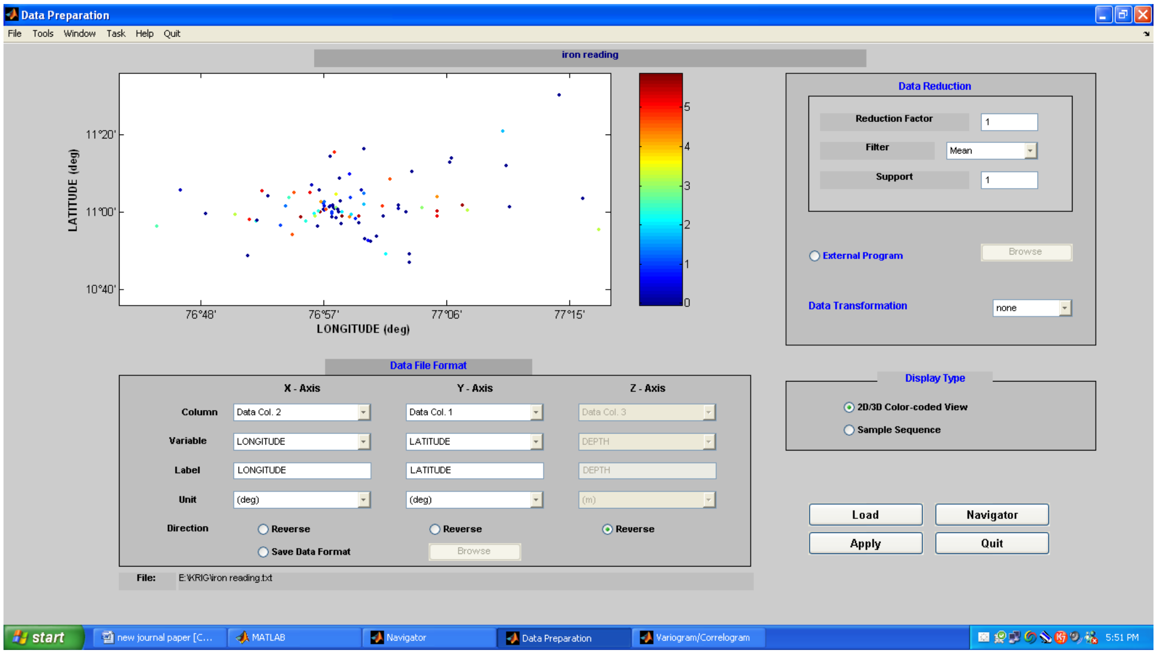

Fig. 8. Data Preparation – Fe

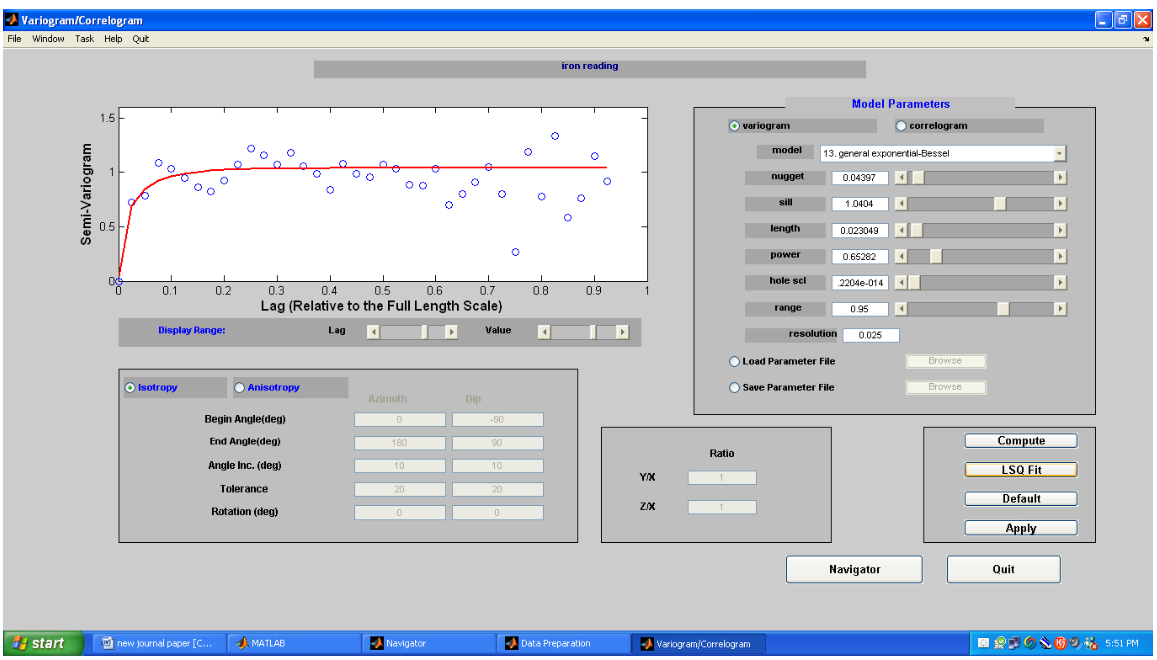

Fig. 9. Variogram - Fe

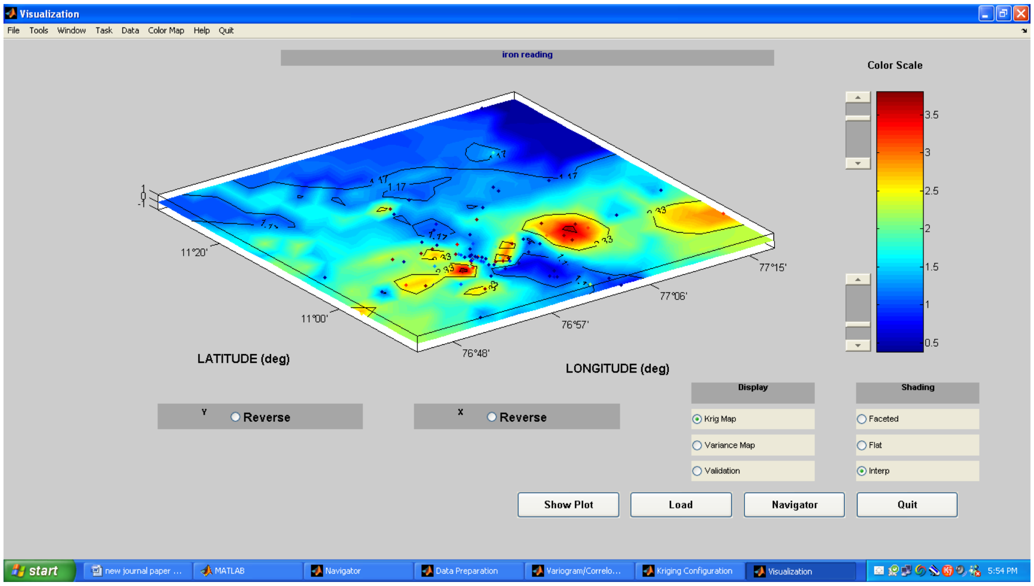

Fig. 10. Fe - Concentration Map

4. RESULT AND DISCUSSION

The heavy metal from various localities including wetland soil sample were collected, analyzed and the results were reported. The metals analyzed were Cr, Pb and Fe. Lead Pb concentration varies from 0 to 8.900ppm.Maximun 8.9ppm at Ukkadam Lake. Reason for maximum Pb at Ukkadam Lake is due to discharging of sewage water into lake. Cr concentration ranged between 0 - 3.6 ppm. Maximum concentration was in Ganapathy because of the concentration of foundry industry. Fe ranged between 0 – 5.29. Maximum at Sidco Industrial Estate and Singanallur because of the concentration of electroplating industry. It is observed that maximum heavy metal pollution near the industrial, traffic junction where traffic jams and the legendary 'go-slow' of automobiles is the order of the day and in localities of large population concentration and relatively small areas under poor conditions of sanitation. Kriging model was used to predict the heavy metal at the unknown point. From the model of heavy metals we can conclude that the residential areas are uncontaminated with Cr and moderately contaminated with Pb and Fe. In the Electroplating Industrial areas and traffic junctions the concentration of Fe is maximum. Heavy metal accumulation in few prominent wetlands of 10 localities was analyzed. Pb is maximum in Velangulam Lake Ukkadam, and at the Sungam Lake. Concentration of Fe is maximum at sidco and signallur.

5. CONCLUSION

Monitoring of heavy metal has been done through efficient way to access the qualitative and quantitative differences in metal concentration at distinct location and at local. Under the present ecological condition the heavy metal load is significant in Ukkadam lake, Ganapathy and Goundampalayam dumping site. Many metal based industries like electroplating, foundries, casting, textile and dyeing industries apart from huge amount of sewage water production are the main sources of heavy metals contamination in Coimbatore, Tamil Nadu. The highest concentrations of heavy metals in these industrially polluted areas are not only problem with respect to plant nutrition and food chain contamination but also causes a direct health hazards to human and animals, which is still in need of an effective and affordable technological solution.

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