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Analysis of Soil Contamination using GIS

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***Abstract*— In India near Chennai, Pammal Panchayat of Tambaram Taluk there are more than 145 tannery industries functioning since 1945. The disposal of tannery effluents not only contaminated the ground water but also affected the soil behavior in the near by area. In order to asses the level of soil contamination in the study area, disturbed and undisturbed soil samples were collected from 33 locations at 0.3m, 0.9m and 1.5m depths for the analysis of chemical properties of soil such as pH, Electrical conductivity, Sulphate, Chlorides, Chromium, and Total dissolved solids and organic matter. The geo co-ordinates of sampling location were obtained using GPS. Based on the concentration of chemical constituents present in the soil in all the locations, a continuous surface has been created by various spatial interpolation techniques such as Inverse Distance Weighted, Spline, Kriging and Trend using GIS technology. By cross validation technique the best interpolation techniques for various chemical parameters were identified. In order to assess the degree of soil contamination, the consistency index was determined by assigning ranking and weightage for various chemical properties, through which map is generated, called as 'contamination index' map. This map can be used to classify the study area as very high, high, moderate, low and very low contaminated soil. Thus the GIS approach of analyzing soil contamination provides permanent base for monitoring contaminated sites and also to understand the level and extent of contamination.**

Keywords—case study; soil contamination; GIS mapping; analysis; interpolation; estimation of toxin; various location.

I. INTRODUCTION

In developing countries like India, rapid industrialization results in voluminous production of the waste and thereby scarcity of land for safe disposal of hazardous waste increases. The waste may be solid or liquid. The liquid waste and lechates generated from the solid waste percolate into the ground and causing problem like ground water contamination, degradation of vegetation, modification of soil properties etc. Contamination of soil causes failure of foundations, land subsidence, land slides, pollution of ground water quality etc (Mitchell, 1997). In Chennai, Tambaram Taluk in Pammal Panchayat there are more than 145 tannery industries functioning from 1945. The liquid and solid wastes coming out from these industries not only contaminate the ground water but also affect the soil behavior. (Soba syrus and Roy Thomas (1996)). To assess the level of contamination of the whole area, it is essential to know the contamination characteristics of soil spatially in and around Pammal, in order to have safe proposed structure and prevention of failure of existing structures. Contamination characteristics of soil can be inferred from the physical, chemical, index and engineering properties. Manual interpolation and model generations are difficult and tedious process. In such cases, GIS approach can be effectively used. Due to the rapid growth and wider application of GIS in various field (Busluglia and Varco (2000)).it is proposed to use this technology in soil contamination analysis and also this study aims that the analysis of chemical properties soil, creating continuous surface using various spatial interpolation techniques, identifying the best interpolation technique and characterization of study area through contamination index map.

II. DETAILS ABOUT STUDY AREA

The study area is about 5.4 sq.km. The mixed patterns of household and cultivated lands are the existing land uses within the Pammal village. The area is covered with the latitude of 12 º58'30"N to 12º 57'30"N and Longitude of 80 º07'00'E to 80º 08'30"E. The chemical properties such as pH, TDS, Chlorides and Sulphate of tannery effluents before treatment are 7.5 to 8.5, 80 to 150mg/lit, 14000-20500mg/lit, 3200 to 4500 mg/lit and 2500 to 500mg/lit respectively. The same properties after treatment are 6 to 9, 20mg/lit, 5670mg/lit, 250mg/lit and 1000mg/lit respectively, which are grossly exceeding the stipulated norms of Tamilnadu pollution control board, India.

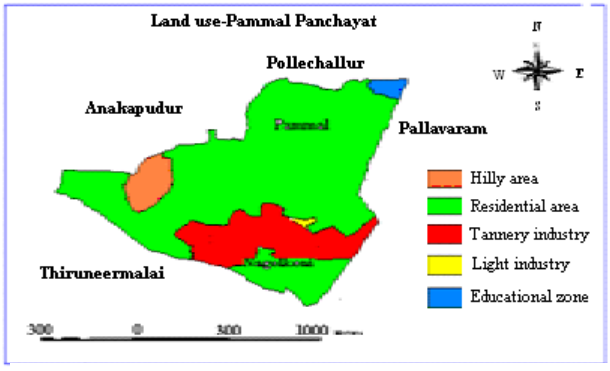

FIG 1: Land Use Map of Pammal Panchayat, Chennai, Tamilnadu, India.

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III. METHODOLOGY

A. Preparation of Base Map and Location of Sampling Points

The location map of Pammal Panchayat at Tambaram Taluk, Chennai was prepared from topomap. The Pammal area is about 5.4 sq.km. Pammal Panchayat authority prepared the land use map. To locate the sampling points, a grid point method is adopted and hand held GPS was used to locate the samples. Latitude and longitude are observed to interpret the sampling location for digitizing location map. Both disturbed and undisturbed soil samples were collected from 33 locations at 0.3m, 0.9m and 1.5m depths and the soil samples were used for the analysis of chemical properties. The important chemical parameters present in the tannery affected soil such as pH, Electrical conductivity (Ec), Sulphate, Chlorides, Chromium, Total dissolved solids (TDS) and Organic matter (OM) were determined by standard methods.

B. Digitization of topography and En-coding the data

The digitization is a process of obtaining latitude and longitude of all points in a map by using GPS by setting out reference point in field. The digitization process involves encoding analog in the logical data.

C. Working methodology in GIS

GIS is a computer systern that can hold and use data describing places on the earth's surface. It consists of set of tools for collection, storing, retrieving, and transforming and display spatial data from real world for particular set of purposes. The information obtained from various sources (Maps etc.,) are digitized and stored in geographical information system (GIS), a database is created that can be queried for specific applications. GIS allows for the query and manipulation of the database to compute new characteristics by logical and arithmetic operations on the existing data and linkage of attributes and image database to provide necessary models. Fig 2 shows the flow chart describing the working methodology in GIS for the contamination analysis. After digitizing the base map, various chemical parameters are given as input to GIS to develop the spatial model by various interpolation techniques such as IDW, Spline, Kriging and Trend for different depths. After identifying the best interpolation technique using Analytical hierarchical process method (AHP), the consistency index values were found by assigning weightage and ranking for various parameters which were later used for overlay analysis. Contamination index model has been arrived by reclassifying the weighted overlay map.

D. Spatial Interpolation technique to generate spatial model

Interpolation is the procedure of estimating the value of properties at unsampled sites within the area covered by existing point observations called interpolation. The continuous surface was created for different chemical parameter and depths by various spatial interpolation methods such as Inverse Distance weighted, Spline, Kriging and Trend surface analysis. The results obtained from chemical analysis are taken as input parameter such as pH, Ec, TDS, etc., for varying depths and locations. To create the spatial model for the whole area various interpolation techniques were used with help of 3D analyst. With the use of mathematical programming for the respective technique the values for the adjacent surroundings are interpolated. (Chaosheng zhang (2006))

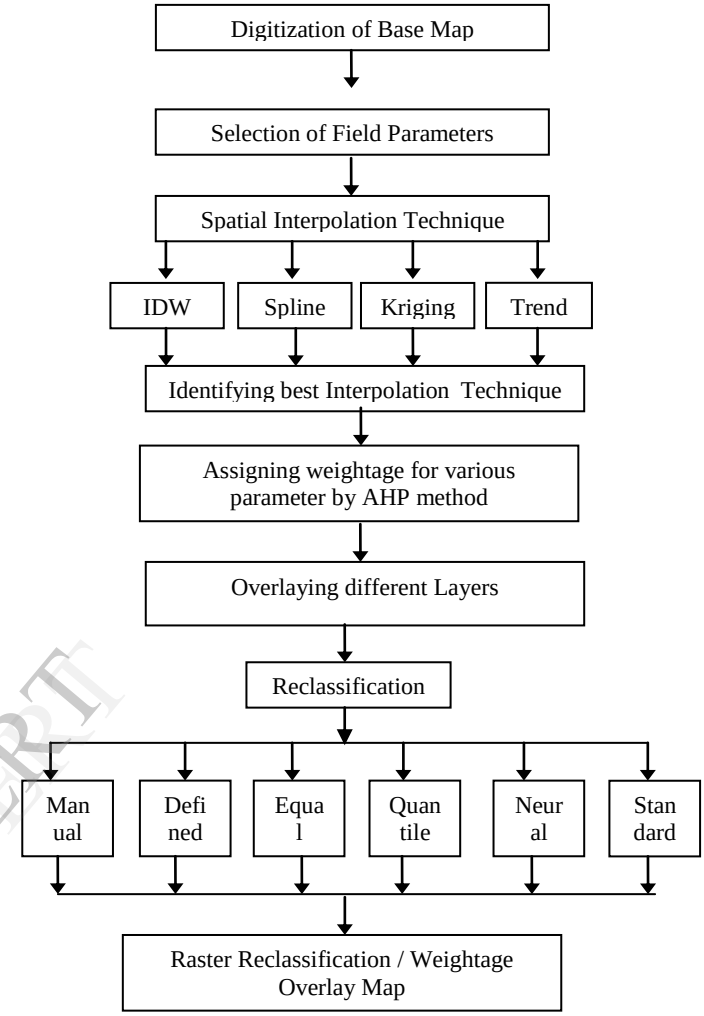

FIG 2: Flowchart showing for working methodology

E. Identification of Best Interpolation technique

The determination of best interpolation technique for various parameters and depth can be found out by using cross validation technique. That is, spatial model has been developed using 29 points out of 33 points.(source points) and the remaining four points are withheld from interpolation (check point). At these four sampling locations whose observed values (obtained by laboratory testing) and predicted values (obtained by spatial interpolation techniques) are known, observing the closeness to each other is defined as "cross validation" or identification of best interpolation concept. The interpolation method in which observed and predicted value are close to each other is said to be the best interpolation method. By this process one can find the best suitable method of interpolation technique for a particular parameter.

F. Assessment of level of Contamination

The main objective of this study is to assess the level of contamination and also the variation of concentration spread

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with depth. Hence using the spatial model generated by knowing the suitable techniques, the ranking and weightage have been assessed. By statistical correlation, overlay analysis map is generated through which contamination index can be assessed.

G. Contamination index

Contamination index is an empirical number that distinguish the degree of contamination. It is arrived by fixing the boundaries for the obtained cumulative concentration of contamination. By this classification, it is easy to characterize a contaminated site as very high, high, moderate, low and very low depending upon the contamination spread. The contamination index map for various depths can be arrived as specified above and the cumulative concentration of contamination map can be generated by overlaying the three-contamination index map respectively for 0.3m, 0.9m, and 1.5m depths.

IV. RESULTS AND DISCUSSION

A. Chemical Properties

Chemical properties such as pH, Ec, Sulphate, Chlorides, Chromium, TDS and Organic matter are determined at 33 locations for three different depths. It is observed that the pH of soil generally reduces with depth. The electrical conductivity is ranging from 200 to 3000µs/cm. Sulphate is ranging from 300 to 860mg/lit. Concentration of chloride varies from 100 to 200mg/lit in all the locations except location 22. Hexavalent chromium is very high in all the locations. TDS varies from 100 to 6500mg/lit, which is more than the permissible limit in all the locations. Organic matter in soil varying from 0.5 to 16% in all depths. In general the concentration of contamination in all the location decreases as the depth increases except chromium.

B. Comparison of Different Interpolationt Technique with Reference to Chemical Characteristics.

To locate the best suitable method, a comparison was made among the various interpolation techniques based on its chemical concentration. By cross validation technique the best interpolation technique can be identified. The check points are selected in such a way that the points are in extreme end of four directions in Pammal.

C. pH and Electrical conductivity

The predicted value of pH (by interpolation) is not in agreement with actual value upon using 'IDW', Kriging', and 'Spline'. However the predicted and observed value or more or less same in case of trend surface analysis, which implies that the 'Trend' is an ideal method as for as pH is concerned. In case of Ec, the actual value is ranging from 400 to 3000 mg/lit in all the locations. By interpolation method, the predicted values are not much close in Spline, Kriging and Trend analysis. But it seems to be very close in IDW analysis, which indicates that IDW is the best suitable method for Ec.

D. Sulphate and chlorides

The presents of Sulphate and Chlorides are much higher than the recommended TPCB norms and also these two parameters are found as the main causes of ground water contamination and degradation of foundation structures. The observed value of Sulphate and chlorides are 50 to 400 mg/lit and 50 to 200 mg/lit respectively. Through interpolation, 'Kriging' and 'Trend' show much deviation from the actual value, 'IDW' gives a very closer value as far as Sulphate and Chloride is concerned.

E. Chromium, Total dissolved solids and Organic matter.

The abnormal amount of TDS and chromium present in the soil make the study area unusable for residential and cultivation purpose. The actual value of chromium and TDS are varying from 50 to 590mg/lit and 100 to 6500 mg/lit respectively. Compare to other surface analysis, IDW gives closer relation for both the chemical parameters. Kriging method of spatial interpolation gives the better results for organic matter in all the depths compared to other interpolation methods.

From the overall differences between interpolated and actual values of different chemical parameters, it can be summarized that the ' Trend' analysis is ideally suiting to the pH variations where as for Ec, Sulphate, Chromium, and TDS variations, ' IDW' method yields accurate results. In case of organic matter, ' Kriging' method interpolates the values better than other methods. Table 1 shows the best interpolation techniques for varying depths, among the four spatial interpolation methods attempted. For the analysis of soil contamination at Pammal area as a whole, IDW seems to satisfactorily interpolates all the seven parameters such as pH, Ec, Sulphate, Chloride, Chromium, TDS and organic matter within the study area, compared to other interpolation techniques.

TABLE 1: Best Interpolation Techniques for Various chemical Parameters

Parameters	**0.3m**	**0.9m**	**1.5m**
pH	Trend	Trend	Trend
Ec	IDW	IDW	IDW
Sulphate	Spline	IDW	IDW
Chloride	Spline	IDW	IDW
Chromium	IDW	Spline	IDW
TDS	IDW	Spline	IDW
Organic matter	Kriging	Kriging	Kriging

F. Obtaining Consistency Index Through AHP.

The ranking for various parameters are assigned by expert's opinion and the weightage for various parameters is obtained by manipulating the ranking by pairwice matrix system through Analytical hierarchical process (AHP). The rankings and weightage are assigned in the order of TDS>Chromium> Chlorides> pH> Sulphate> Ec >OM. The higher weightage for TDS and Chromium are assigned because tannery contaminated soils have been reported to have always high TDS and chromium content (Jay Singh 2004, John Kennedy 1998). Consistency index values are 0.1, 0.06, 0.06, 0.16,

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0.24, 0.35 and 0.03 respectively for pH, Ec, Sulphate, Chlorides, Chromium, TDS and Organic matter.

G. Contamination index

The contamination index map for various depths can be arrived as specified above and on the other side the cumulative concentration of contamination map can be developed by overlaying the entire three contamination index map respectively for 0.3m, 0.9m, and 1.5m depths. Fig 3 shows the typical contamination index map of the study area for the depth of 1.5m. The black color indicates very high contaminated zones, red color represents highly contaminated zones, green color represents moderate contamination and blue represents low contaminated zones.

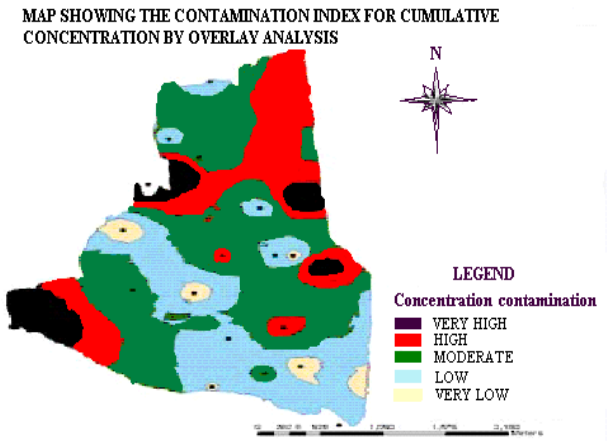

FIG 3: The Contamination Index Map At 1.5m Depth

V. CONCLUSION

To assess the level of contamination in Pammal area the soil samples were collected in 33 locations at 0.3m, 0.9, and 1.5m depths. With the chemical analysis data spatial models were developed by various interpolation techniques. Through suitable spatial interpolation technique the contamination index model is derived. The specific conclusions drawn from the study are as follows.

1. The abnormal amount of TDS and chromium present in the soil make the study area unusable for residential and cultivation purpose. The Electrical conductivity, pH and Organic matter are also found to be much higher than permissible values.
2. The pH, Ec, Sulphate, Chlorides, Chromium, TDS and organic matter are used for assessing the level of soil contamination using various interpolation techniques such as IDW, Spline, Kriging and Trend. It is observed that the IDW method is the best suitable technique for all the chemical parameters, which is found by cross validation technique.
3. Consistency index arrived through AHP by assigning ranking and weightage for various chemical parameters, can effectively used to generate contamination index map.
4. The contamination index map generated in the present study clearly represents the level and extent of soil within the study area. Soil contamination can be effectively classified as very high, high, moderate and low contaminated zones. It is observed that more than 50% of the area highly contaminated.

It is hoped that the proposed contamination index model will be a very useful tool not only to assess the level of contamination and also monitoring the contaminated sites

REFERENCES

[1] Busluglia H.J. and Varco(2000), "Comparison of sampling design in the Detection of Spatial variability of Mississipi Delta Soil'. *Soil Science society of American Journal* Vol.5:1140 – 1185.

[2] Chaosheng zhang (2006), "Using Multivariate analysis and GIS to Identify pollutants and their spectral patters, in urban soils in Galway, Ireland.*". Indian Geotechnical conference*, Vol.2:775-782.

[3] John Kennedy (1998), "Pollution from tanneries and options for treatment of Effluent", *J. environmental engrg*, Vol.18 (9):672-678.

[4] Jaya Singh, (2004), "Impact of Chromium on Environmental Pollution", *Journal of Geo Environmental Engineering*, Vol 36: 146-156

[5] Mitchell J.K.(1997) " Geotechnics of soil – waste material interactions" J.Environmental Geotechnics, Vol.12:1311-1328.

[6] Sobha cyrus and Roy .M Thoms (1996), "Effluent of tannery waste on the behavior of soils*", Indian Geotechnical conference*, Vol 2 pp544-546.

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