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A COMPARATIVE ANALYSIS OF ENVIRONMENTAL QUALITY ASSESSMENT METHODS FOR HEAVY METAL-CONTAMINATED SOILS

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ABSTRACT: Four evaluation approaches were used to assess the environmental quality of eight soils at a contaminated heavy metal industry. The entire index model is more rational than the one-factor index method to analysis outcomes. In contrast to the pollution index, membership features have been utilized in fluctuating mathematical approaches to identify the limits between different pollution classes, and pollutant contributing variables have been identified using weights. The dominating feature was highlighted more in the single-factor approach, with the effects of the other factors being diminished. In the weighted average model, however, each element contribution was thoroughly examined, and weights were given according to contribution level. For various mathematical methodologies, membership functions were utilized to show the bounds between various pollution levels, and various weights were taken into account in the pollution contribution factor. The inclusion of the membership level and the weight of the different mathematical models in the evaluation of environmental quality made methods conceivable.

Keywords: environmental quality, heavy metal, single-factor approach, pollution levels

1. INTRODUCTION

Soil for human survival and development is one of the most vital and necessary resources. Significant quantities of heavy metals have been the problem in soil in India for several years [1]. Heavy metal pollution, while non-ferrous metals smelt, is part of its emissions from the metallurgical sector. Potential hazardous elements are promoting potential contamination of the food chain and endangering human health and ecological safety in soil construction [2]. Pollutants and heavy metals contaminate the soil [3]. In order to achieve resource-limited sustainable soil development [2 & 3], the impact on soil from human activities is required in addition to assessing the environmental consequences of heavy metal contaminated soil. The environmental quality of the ground was largely assessed by the Pollution Index. Methods are used to identify and quantify scales of soil contamination [4]. However, there is ambiguity or fluidity in relation to the environmental hazard in every environmental evaluation due to the incoherence and features of each soil pollutant. The usage of sharp borders is difficult to justify in classification systems. This volatility has led to the creation of advanced evaluation systems based on fuguous logic by some environment researchers [8]. Fuzzy methods thoroughly examine the contribution of the numerous contaminants by default and limit the member's functions' fluidity. A detailed study of the problem of the flight frontier and the effect of supervision errors on the evaluation findings were successful [5].

Emitting material from rapidly developing industries, mining apparel, heavy metal disposal, combustion waste and air deposition may harm heavy metals and soils, fertilizers and animal fillings, waste water sludges, pesticides, irrigation of waste water and air disposal [7 & 8].

In contaminating areas, pram (Pb), chrome (Cr), arsenic (As), zn (Zn) (Cd), copper (Cu), mercury (Hg), and nicellular were the most commonly identified group of heavy metal compounds [5] (Ni). The land constitutes the main sink of heavy metals which have been released in the environment by previous human and organic pollution, and reduces microbial carbon (IV) activity [6]. However, several kinds of biological disposability and chemical (species) may be present. Dangerous metals of the soil can seriously inhibit the biological decomposition of organic pollutants [11 & 12]. Soil and ecosystems can cause heavy metal contamination to endanger humans and ecosystems, lead to a direct intake or contact with polluted soils, feed chains, the use of water as a result, the reduction in toxicity of plants' quality of food, the reduction of the risk of soil and the risk to humans and ecosystems caused by food insecticides.

Proper protection of the soil and re-establishment of heavy metal soils must be measured and re-established [4 & 6]. The present environmental and public health protection regulations at national and global levels give statistics characterizing chemical characteristics for environmental occurrences, particularly in our food chain [8]. Events to correct heavy metal soil contaminated will include knowledge on the source of the pollution, the essential chemical substances and the risk of the sentimental and the related health effect on these heavy metals. Although earth characterization will provide insights into the speciation and bioavailability of heavy metal [4]. Risk assessment is a useful scientific method to manage sites that are expensively contaminated and to ensure the health of individuals and ecosystems [9].

The best way available to restore heavy metal contaminated sites (DSLs) is often supplied on the basis of property, soil purification and fit-restore methodologies. Despite its economic efficiency and environmentally benign applications, these technologies are only registered in advanced countries [3 & 4]. These technologies are still commercially available in most undeveloped countries, perhaps because they are not aware of their own intrinsic advantages and operating principles. The Scientific Communities are increasingly trying to develop techniques that heal contaminated sites by government and the public with better knowledge of human and animal health [8 & 11].

In developing countries, which are highly densely populated and limited in resources to restore the environment, accessibility of land resources for agricultural production, food safety improvement and the more comprehensive treatment of land tenure problems are low-cost and environmentally viable solutions [12].

This study collects dispersed literature to analyze possibly polluted sources, fundamental chemistry and the accompanying risks related to the use of heavy-metal priority treatments and cures.

1.1. Process of environmental impact assessment

The EIA procedure steps depend on the country or the demands of the donor. However, the majority of EIA procedures have a shared structure; crucial phases are a fundamental standard [28 & 30].

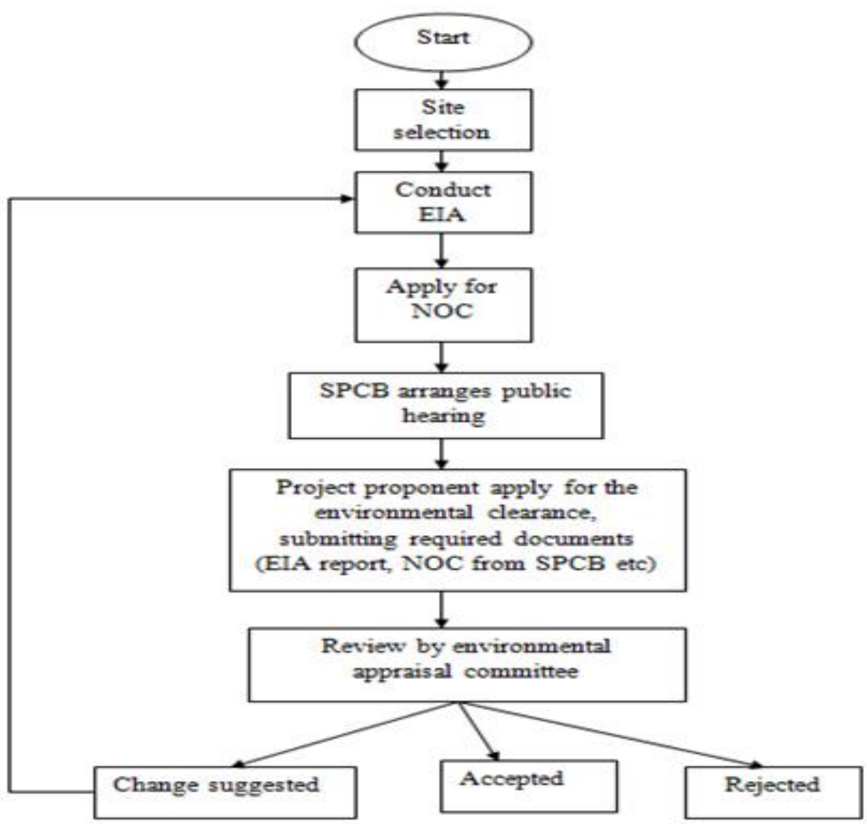


Figure.1. EIA Process Overview

The environmental impact assessment includes eight steps, each of which is equally important to the overall performance of the project [29]. The environmental impact assessment is divided into two parts: the preliminary phase and the final phase [26].

The EIA process normally begins with testing to ensure that time and resources are spent on ecologically sound concepts and concludes with some form of monitoring of the report's contents and activities to ensure that they are being followed up on [22].

1.2. Environmental quality assessment

As with other forms of environmental evaluations it is necessary to define the particular objectives of the study [31]. Therefore, its basic objectives have to be clearly identified and stated from the beginning of the research, since they will be utilized as proposals for the development of all sampling and analytical processes [34]. For instance, testing for heavy metal in soil can be permitted if the goal of the study is to determine whether the soil is to be poisoned with heavy metals. Knowledge of system sampling methodologies is yet essential to regional heavy metal distribution in soles. The Internet should be provided with early information on the soil type, the parent, the region, and activities [35]. This information contributes to the construction and interpretation of the sampling procedure. It is also crucial that we draw up all relevant legislation including soil regulatory requirements during the preliminary evaluation and clean-up phase. Sensitivity to the legal and regulatory principles allows an adequate assessment of ground contamination and conformity to purification requirements [31 & 32].

2. Aim of research work

The goal of the research is to gather information on heavy metal sources, effects, and processes, such as arsenic, penicillin, and mercury [32]. It also investigates in detail the methodologies of plant remediation, including the mechanisms of heavy metal absorption, and various researches. In addition the benefits of this sort of technology for decreasing, heavy metal absorption processes, and elements that have an impact on the absorption system are described by many sources and their environmental impact. Several plants for the phytoremediation of plants have also been described and can minimize pollution [41].

2.1. Objectives of research work

The following were the research objectives:

1. Evaluate, using contamination indicators and fluent, the environmental risk of heavy metal in soils around a ferroalloy factory
2. Compare the evaluation outcomes in order to determine how an evaluation process is feasible.
3. Exploring potential for metal-contaminated soils spectral reflectance management.

3. PROPOSED METHODOLOGY

3.1. Pollution index techniques calculation formulas

Two distinct pollution index methodologies evaluated the environment of eight polluted soils (single factor index method and complete Nemerow Index method). The format to calculate the one-factor index is as follows:

The single-factor index technique can be calculated as:

$$\mathrm{Pi} = \frac{\mathrm{Ci}}{\mathrm{Si}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3.1)$$

The Nemerow integrated index method's mathematical formula is:

$$P = \sqrt{(1/n \sum_{i=1}^{n} Pi)^2 + \frac{(Max(Pi))^2}{2}} \ldots\ldots\ldots\ldots (3.2)$$

Where Pi is the heavy metals pollution index, CI refers to the genuine heavy metal monitoring data I (mg•kg-1). If the environmental quality criterion is reached, the data are obtained from the grade a standards set out in Provisional Soil Environmental Index (HJ350-2007) [36].

3.2. Establishment of evaluation criteria

To evaluate eight polluted soils, the inorganic elements (Zn, As, Ni, Cr, Cu, and Cd) have been selected [21]. Criteria for the assessment were developed on the basis of the national Chinese environmental quality and local context standards [51 & 56]. The soil quality was categorized into 5 levels: Good I, Clear III, Slightly Vulnerable III, Substantial IV and Grade V pollution. Soil quality (Table.4.2).

Table.3.1. Environmental quality standard for soil: (mg·kg-1)

S.No.	Heavy metal	Zn	As	Ni	Cr	Cu	Cd
1.	Evaluation standard	200.01	20.00	50.00	190.01	63.05	1.00

Table.3.2. Classification of environmental quality for soils affected by heavy metals

S.No.	List of heavy metal	I (excellent)	II (clean)	III (slightly polluted)	IV (moderately polluted)	V (heavily polluted)
1.	Zn	100.00	200.01	250.05	300.09	500.00
2.	As	12.03	17.00	20.00	25.02	30.00
3.	Ni	40.00	50.01	65.03	80.053	200.20
4.	Cr	78.09	150.09	250.07	350.31	400.06
5.	Cu	35.4	50.00	100.00	150.09	400.067
6.	Cd	0..21	0.32	0.46	0.61	1.04
7.	Namerow comprehensive index (p)	P≤ 0.71	0.710<P ≤ 1.01	1.01<P≤1.71	1.71<P≤2.81	P>2.81

3.3. Pollution index methods assessment and findings

Equations 1 and 2 from the actual Heavy Metal Surveillance (Ci) data for each of the eight soles examined were used to calculate the individual factor index and the global pollution index. Table 4.3[46] shows both the findings of Ci and the evaluation.

3.4. FUZZY MATHEMATICAL METHODOLOGY

3.4.1. Functions of fuzzy environmental quality

Membership functions are the degrees to which Fuzzy is a member [43]. With a set of membership formulas heavy metal membership grades at each level can be quantitatively defined:

$$u_{i,m} = \begin{cases} 1-u_{(m-1)}(C_i) & e(m-1) \le Ci \le e(m) \\ \left[e(m+1)-C_i\right]/\left[e(m+1)-e(m)\right], & e(m) \le Ci \le e(m+1) \\ 0 & Ci \ge e(m+1) \end{cases} \quad \text{……………………………… (3.3)}$$

Where m is a Class I member, the present mg•kg-1 heavy-metal monitoring data is ci and the mm grade is mg•kg-1. After monitoring data and evaluation criteria for each heavy metal location were replaced for the member's function, a sample of soil fuzzy matrix was developed [57 & 59]. For instance, the fluid S1 (R1) soil matrix is:

3.5. Weight determination for every heavy metal

Real weight is necessary for all components [60] since the effects of heavy metals on the integrated environmental quality vary considerably between them. The quantity of a certain heavy metal in each control zone shall be determined [43].

$$W_{i,k} = \frac{C_{i,k} / S_i}{\sum_{i=1}^{n} C_{i,k} / S_i} \qquad S_i = \frac{1}{n}\sum_{j=1}^{n} S_{ij} \quad \ldots (4.4)$$

$$R_1 = \begin{vmatrix} 1.00 & 0 & 0 & 0 & 0 \\ 0 & 0.60 & 0.40 & 0 & 0 \\ 1.00 & 0 & 0 & 0 & 0 \\ 1.00 & 0 & 0 & 0 & 0 \\ 1.00 & 0 & 0 & 0 & 0 \\ 1.00 & 0 & 0 & 0 & 0 \end{vmatrix}$$

Table.3.3. Eight polluted soils employing a single factor index and extensive index methodologies environmental quality evaluation results

Soil	Index	Heavy metal						Environment quality	
		Zn	As	Ni	Cr	Cu	Cd	Single-factor index	Comprehensive index
S1	Ci	76.60	18.20	26.20	67.90	21.10	0.01	III	II (P= 0.71)
	Pi	0.38	0.91	0.52	0.36	0.33	0.01		
	Class	I	III	I	I	I	I		
S2	Ci	77.10	7.40	35.60	88.10	29.10	0.02	II	I (P= 0.58)
	Pi	0.39	0.37	0.71	0.46	0.46	0.02		
	Class	I	I	I	II	I	I		
S3	Ci	67.80	12.80	28.40	86.70	25.10	0.02	II	I (P=0.53)
	Pi	0.34	0.64	0.57	0.46	0.40	0.02		
	Class	I	II	I	II	I	I		
S4	Ci	89.80	10.80	20.50	220.00	23.60	0.03	III	II (P= 0.89)
	Pi	0.45	0.54	0.41	1.16	0.37	0.03		
	Class	I	I	I	III	I	I		
S5	Ci	69.80	10.70	30.30	2340.00	39.60	0.02	V	V (P= 8.88)
	Pi	0.35	0.54	0.61	12.32	0.63	0.02		
	Class	I	I	I	V	II	I		
S6	Ci	45.30	10.70	28.60	8640.00	36.00	0.02	V	V (P=32.63)
	Pi	0.23	0.54	0.57	45.47	0.57	0.02		
	Class	I	I	I	V	II	I		
S7	Ci	96.40	7.80	21.50	52500.00	109.00	0.03	V	V (P=198.03)
	Pi	0.48	0.39	0.43	276.32	1.73	0.03		
	Class	I	I	I	V	IV	I		
S8	Ci	76.50	10.10	28.50	90.20	30.40	0.01	II	I (P= 0.49)
	Pi	0.38	0.51	0.57	0.47	0.48	0.01		
	Class	I	I	I	II	I	I		

If k shows the heavy metal I of k, Ci, k is the one with heavy metal contents I of mg•kg-1 of k in soil, Si is average of mg•kg-1. Mg•kg-1 and Si of mg•kg–1 heavy metal test requirements of I. The weights in this study have been selected based on soil quality standards and real monitoring data [49]. Here, Ci, k showed to what degree the average evaluation criterion was exceeded as the difference between pollutants and pollution levels had to be added [37]. The weights of the six heavy metals were collected in the eight soils and displayed as per Equation 4 in Table.4.4.

3.6. Results of fuzzy mathematical methods

We used two fuzzy mathematical methods to evaluate the environmental characteristics of the eight polluted soils: the lone factor decision and the weighted average model, both of which are described below [35]. The following is the procedure for calculating the decision based on the one-factor model:

Table.3.4. Values of heavy-metal-concentrations in tested soils

S.No.	List of tested soils	List of contaminated soils					
		Zn	As	Ni	Cr	Cu	Cd
1.	S1	0.151	0.471	0.167	0.151	0.071	0.010
2.	S2	0.171	0.223	0.256	0.221	0.125	0.023
3.	S3	0.141	0.351	0.194	0.201	0.101	0.024
4.	S4	0.151	0.245	0.112	0.412	0.076	0.032
5.	S5	0.023	0.051	0.032	0.872	0.021	0.012
6.	S6	0.0051	0.012	0.010	0.960	0.013	0.0054
7.	S7	0.0023	0.0023	0.001	0.003	0.0034	0.0021
8.	S8	0.170	0.298	0.190	0.228	0.125	0.0112

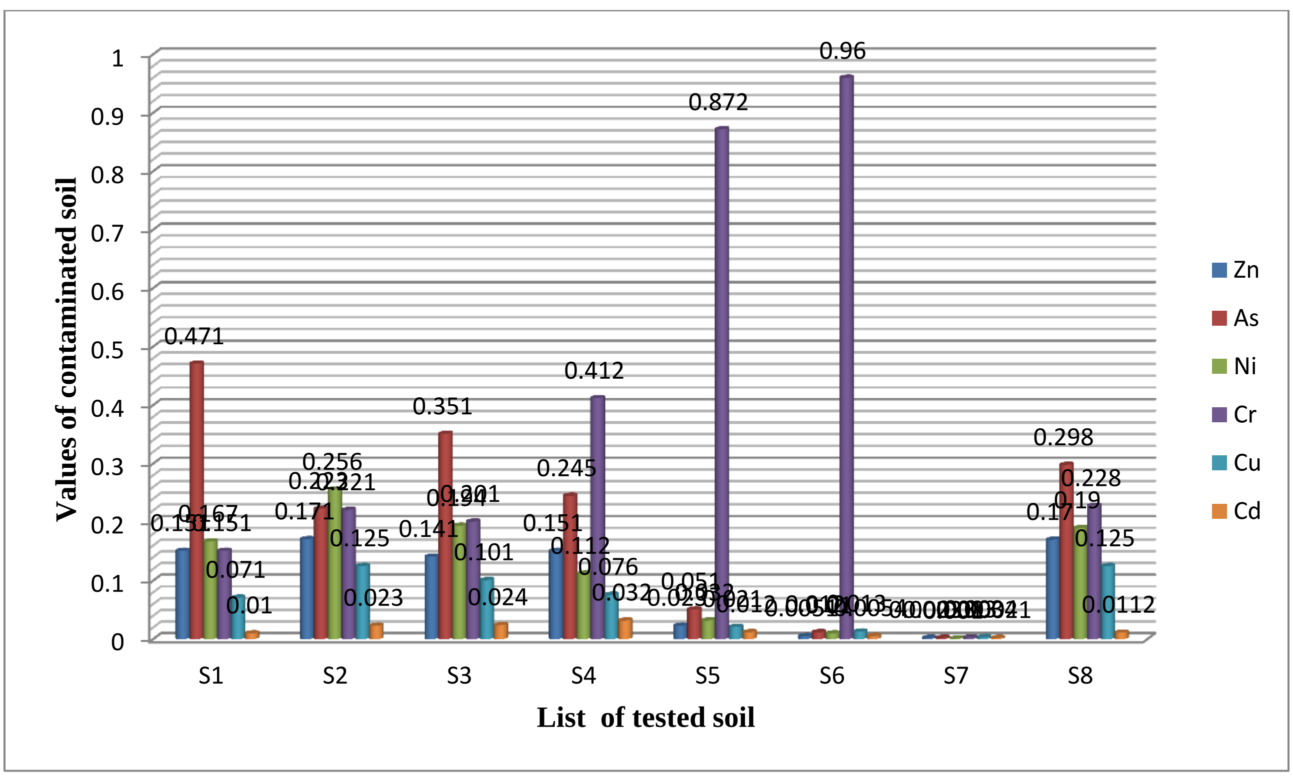


Figure.3.1. Values of heavy-metal-concentrations soils

$$bj = Max\ \{W1u1j, W2u2j, \dots\dots\dots\dots\dots, WnUnj\} \dots\dots\dots\dots\dots\dots\dots\dots (4.5)$$

The weighted average model can therefore be written as follows:

$$bj = \sum_{i=1}^{n} WiUij \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots.. (4.6)$$

If bj is a final class j evaluation, WI is an index of the heavy metal I weight [43 & 47]. The single component model vectors were standardized before the results were used to evaluate the environmental quality of 8 contaminated soils. The weighted average model needs to be evaluated with consistency. Eqs.5 and 6 used two separate mathematical methodologies in the final evaluation of solar samples (Table.5.1.).

4. RESULT AND DISCUSSION

4.1. Comparison of the two pollution index methods

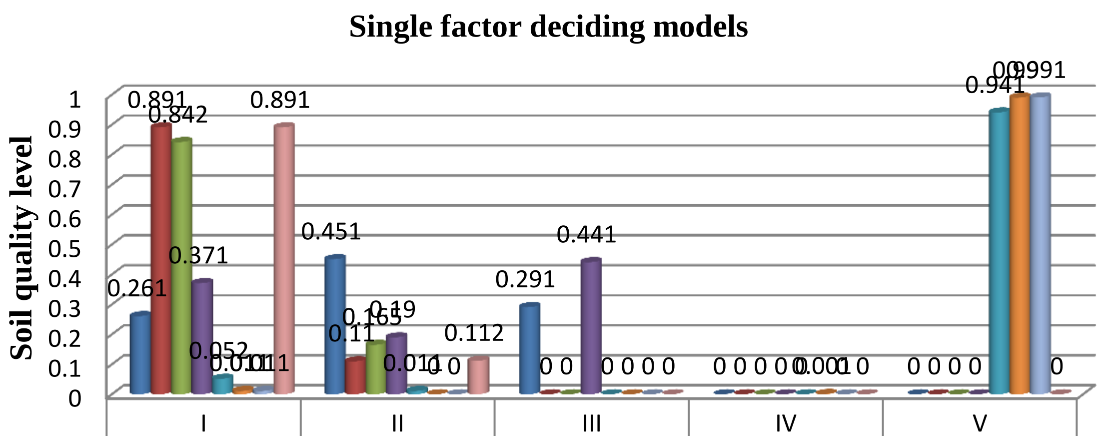
For the eight soils, the results were established for Class III, II, II, III, V, V, V and II according to the maximum membership grading criteria. As shown in Table II. Nonetheless, in classes II, I, I, II, V, V, V and I the comprehensive indexing technique has detected the environmental quality of eight soil areas [52]. In addition to considering the maximum pollution index, the averaging pollution index is also included in Nemerow Comprehensive Index P. The foregoing results suggest that soil quality is worse than the whole index model of a single factor index approach. Value differences were based on the difference in the evaluation principles of the two systems. The single factor index technique only included the most important aspects and excluded other factors. Factors of high (extremely polluted) concentrations are likely to have lethal repercussions in the final assessment findings obtained by the one factor technique. Increased environmental quality was, however, regarded the major criterion and average contribution for both the thorough indexing methodology utilized for existing research and the evaluation outcomes [56]. The above described differences in the two methods of the pollution index can also be illustrated in an example of using Table 5 models. Therefore, the entire index technique is more rational compared to the single factor index method [45 & 49].

4.2. Comparison between two fuzzy mathematical methods

Table 5.1 shows the findings of the environmental evaluation by both approaches of heavy metal pollution. Since the level of membership of each pollution class varies accordingly, the weighted choice quality in the average model is higher than the decision in the individual components. The evaluation outcomes differed depending on the various evaluation goals and ideas [57]. In reality, the single components that determine a model are only the most important aspect. The impact on the outcomes of the evaluation therefore largely reflects greater relative contents and severe pollution in the case study [25]. The assessment findings are derived by individual competitors' indexes, while weighted average models take the importance of each component fully into consideration and distribute the contribution by weight [51]. As in S4, due to the interference of a substantial relative Cr concentration, the assessment of the single-factor model decision is III, but I pick the weighted average model.

Table.4.1. Fuzzy mathematical membership levels at five levels for eight contaminated soils

S.No.	Level of soil	Single factor deciding model							
		S1	S2	S3	S4	S5	S6	S7	S8
1.	I	0.261	0.891	0.842	0.371	0.052	0.011	0.011	0.891
2.	II	0.451	0.110	0.165	0.190	0.011	0.00	0.00	0.112
3.	III	0.291	0.00	0.00	0.441	0.00	0.00	0.00	0.00
4.	IV	0.00	0.00	0.00	0.00	0.00	0.001	0..00	0.00
5.	V	0.00	0.00	0.00	0.00	0.941	0.990	0.991	0.00
	Environmental quality	II	I	I	III	V	V	V	I

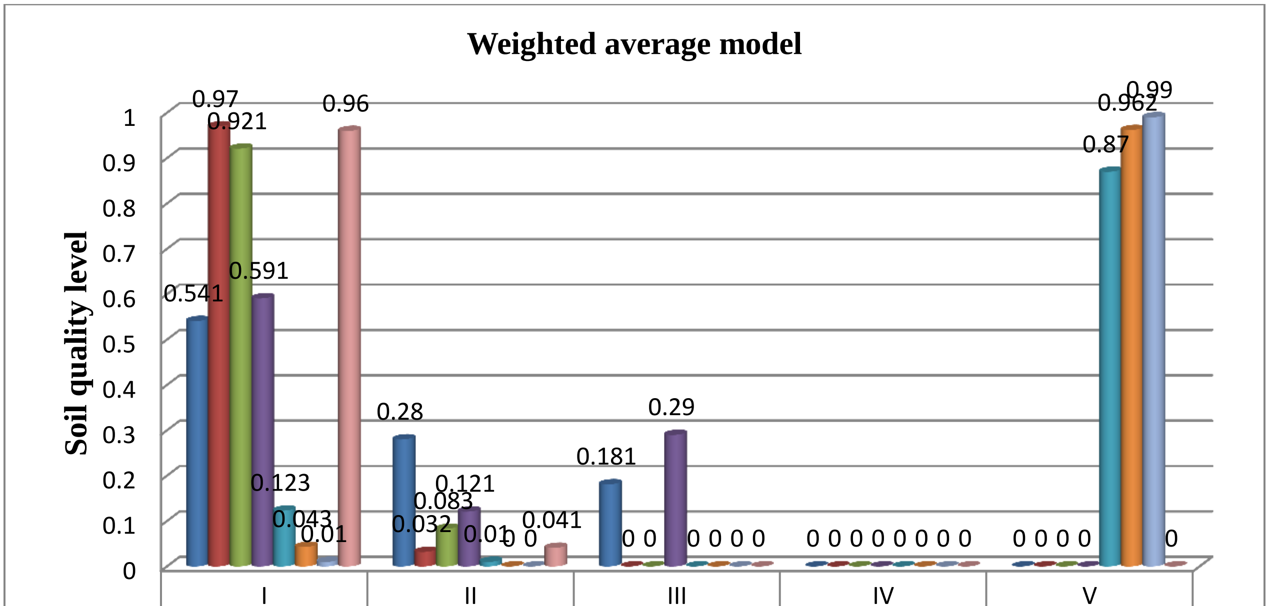


	I	II	III	IV	V
S1	0.261	0.451	0.291	0	0
S2	0.891	0.11	0	0	0
S3	0.842	0.165	0	0	0
S4	0.371	0.19	0.441	0	0
S5	0.052	0.011	0	0	0.941
S6	0.011	0	0	0.001	0.99
S7	0.011	0	0	0	0.991
S8	0.891	0.112	0	0	0

Figure.4.1. Single factor deciding model

Table.4.2. Weighted average model

S.No.	Level of soil	Weighted average soil model							
		S1	S2	S3	S4	S5	S6	S7	S8
1.	I	0.541	0.970	0.921	0.591	0.123	0.043	0.010	0.960
2.	II	0.280	0.032	0.083	0.121	0.010	0.00	0.00	0.041
3.	III	0.181	0.00	0.00	0.290	0.00	0.00	0.00	0.00
4.	IV	0.00	0.00	0.00	0.00	0.00	0.00	0..00	0.00
5.	V	0.00	0.00	0.00	0.00	0.870	0.962	0.990	0.00
	Environmental quality	I	I	I	I	V	V	V	I



	I	II	III	IV	V
S1	0.541	0.28	0.181	0	0
S2	0.97	0.032	0	0	0
S3	0.921	0.083	0	0	0
S4	0.591	0.121	0.29	0	0
S5	0.123	0.01	0	0	0.87
S6	0.043	0	0	0	0.962
S7	0.01	0	0	0	0.99
S8	0.96	0.041	0	0	0

Figure.4.2. Weighted average soil model

The environmental characteristics of the weighted average model were somewhat better than the one-factor technique, such as the link between the two contamination index methodologies. The application offers a further proof of the two hectic mathematical procedures (Table.5.1. and 5.2.). The results differed based on the diverse evaluation objectives and the principle [40 & 49]. The results differ. In a factor paradigm, the dominant element became more evident and its impact was reduced. However, every component was appropriately assessed as a contributing element to the weighted average model and its weights were mostly impacted by its overall effect on all components' weighted average model.

4.3. Comparison between pollution indexes vs. Fuzzy mathematical methods

In the wild mathematical models, results for environmental assessments were assessed in line with the results of Tables II and IV, and results compounded by the pollution index techniques. A single number was displayed as a limit to distinguish between two different pollution degrees as follows [56]. S2 heavy metal Cr is 86.7 mg•kg-1, with 78 (Class I) and 150 mg•kg-1 as closest environmental criterion (class II). However, it has been established that the S2 soil quality has been class II by means of the pollution index approach, with 86.7 being close to 78 instead of 150. The use of sharp criteria is difficult in fluidity techniques to justify [34]. The boundaries between different levels of contamination were defined with membership features. The components 86.7 between 86.7 and 78 are 0.86 and 150 are 1.14, In other words class I is not more environmentally friendly than class II pollution. Metal Cu also cannot be categorized as a class I compatible with the degree of class II that is now measured by S6.

Moreover, many mathematical methods have also been detected with greater emphasis on contributing to integrated pollution of all components, which are different from the pollution index approaches [32]. The weight and the contribution potential for each element are varied. For example, in the sequence Cr>As>Zn>Ni>Cu>Cd the contaminants were listed in S4 according to contribution levels: (Table4.4.). Fluid mathematical tools that give environmental assessment significance are more sensitive than the environmental quality assessment models of the Pollution Index [47]. If the evaluation factor is beyond evidence and this estimation aims to outsource the principle of the unifying factor, the individual factor is applicable (including the index of one factor and the model choice models). The entire method (even though the content is equality with the assessment factors and the assessment aims at externalizing the impact of each element's soil quality, including the Nemerow Pollution Index and the weighted average model) shall nevertheless be used [53]. Therefore in practical work to ensure practical and realistic evaluation results, an appropriate model based on data monitoring and evaluation objectives is important [39 & 60].

5. CONCLUSION AND FUTURE SCOPES

5.1. Conclusions

A pollution index and liquid mathematical approaches on environmental parameters have been used to study 8 heavy-metal soils (S1-S8). The complete index model for soil S1-S8 has been examined for Classes III, II, II, III, V, V, V and II. The overall index model was the dominant parameter and the average contribution for integral environmental quality for all factors II, I, I, II, V, V, V and I compared to a single factor index technique. The two methods of fluid mathematics (average single-factor modeling and model weighted) had identified the environmental features of the single factor method for categories II, I, I, III, V, V, V and I respectively and the weighted average model for categories I, I, I, V, V, V, and I. The assessment aims and principles of the two fluid techniques differed. The pollution index technique incorporates multiple degrees of environmental quality with distinct borders; however finding the stringent limitations of the criterion with the frantic mathematical approach is difficult. Member functions were used to define the limit between different degrees of pollution and to provide varying weights in the fuzzy mathematical method with the pollution contribution of elements. Each factor's membership and weight were incorporated into environmental risk assessment models; the mathematical model was shifted in comparison to present processes.

5.2. Future scopes

This research has proposed that the current metal concentration on soil be used in conjunction with authorized values in order to calculate soil pollution indices following remediation in order to achieve the legal aims of soil remediation, as determined by the results of this research. An indicator of soil contamination was also developed based on the magnitude and stability of the soil metal, as well as other factors [18]. The amount of soil metal pollution has been determined. Specific metals are described in the IR in terms of contamination and soil stability, respectively. Following remediation, the ground quality indices revealed a significant difference. Therefore, the assessment of soil remediation by multiple environmental impact assessments (EIAs) may be relevant. There is a need for additional verification in the treatment of diverse soil types that are polluted with different metals and/or levels of metal contamination [39].

REFERENCES

[1]. Al Maliki, A., Bruce, D., and Owens, G. (2014). Prediction of lead concentration in soil using reflectance spectroscopy. Environmental Technology & Innovation, 1, 8-15.

[2]. Ali, H., Khan, E., and Sajad, M. A. (2013). Phytoremediation of heavy metals—Concepts and applications. Chemosphere, 91(7), 869-881.

[3]. Cheng, S. P. (2003). Heavy metal pollution in China: Origin, pattern and control. Journal of Environmental Science and Pollution Research. 10(3) 192–198.

[4]. Alloway, B. J. (2013). Sources of heavy metals and metalloids in soils. Heavy metals in soils: Trace metals and metalloids in soils and their bioavailability. 3rd ed., Environmental Pollution, Vol. 22, Springer Science & Business Media.

[5]. Li, X.D., Shen, Z.G., Wai, W. H. O. and Li, Y.S. (2000). Chemical partitioning of heavy metal contaminants in sediments of the Pearl River Estuary. Chem. Spec. and Bioavailab., 12, 17-25.

[6]. Ansari, M. K. A., Shao, H.-B., Umar, S., Ahmad, A., Ansari, S. H., Iqbal, M., et al. (2013). Screening Indian mustard Genotypes for Phytoremediating Arsenic-Contaminated Soils. CLEAN – Soil, Air, Water, 41(2), 195-201.

[7]. Appenroth, K.-J. (2010). Definition of heavy metals and their role in biological systems. In I. Sherameti, & A. Varma (Eds.), Soil heavy metals, Soil Biology (Vol. 19, pp. 19-29): Springer-Verlag Berlin Heilelber.

[8]. Zhao, Q. G. (2004). Land resources, mother earth–Protection, construction and sustainable utilization of the land resources of China. Issues that deserve high attention, J. Soils. 36(4) 337–339.

[9]. Banejad, H., and Olyaie, E. (2011). Arsenic toxicity in the irrigation water-soil-plant system: A significant environmental problem. Journal of American Science, 7(1), 125-131.

[10]. Barceló, J., and Poschenrieder, C. (2004). Structural and ultra structural changes in heavy metal exposed plants. In M. N. V. Prasad (Ed.), Heavy metal stress in plants: from biomolecules to ecosystems (Vol. 2nd ed., pp. 223-248): Springer.

[11]. Sun, B., Zhao, F.J., Lombi, E., and McGrath, S.P. (2001). Leaching of heavy metals from contaminated soils using EDTA. Environ. Pollut., 113, 111-120.

[12]. Baveye, P. C., and Laba, M. (2015). Comment on "Potential of integrated field spectroscopy and spatial analysis for enhanced assessment of soil contamination: A prospective review. Horta Geoderma.

[13]. K. Shah, and J. M. Nongkynrih, (2007). Metal hyper accumulation and bioremediation. J. Biologia Plantarum. 51(4), 618–634.

[14]. Baveye, P. C., and Laba, M. (2015). Visible and near-infrared reflectance spectroscopy is of limited practical use to monitor soil contamination by heavy metals. Journal of Hazardous Materials, 285, 137-139.

[15]. Traina, S.J., and Laperche, V. (1999). Contaminant bioavailability in soils, sediments, and aquatic environments. Proc. Natl. Acad. Sci. USA, 96, 3365-3371.

[16]. Chodak, M., Nikli, M., and Beese, F. (2007). Near-infrared spectroscopy for analysis of chemical and microbiological properties of forest soil organic horizons in a heavy-metal-polluted area. Biology and Fertility of Soils, 44(1), 171-180.

[17]. Liu, D, M, Sun, H, Fang, Z, L. (2009). Retrospet and prospect research of soil environmental quality. J. Sichuan Environment. 28(1) 73-77.

[18]. yan, W., Chi, J.S., Gu, S.C., Tang, X.Z. and Chen, Z. (2000). Characteristics and prevention countermeasures of heavy metal pollution of soils (sediments) in industrial areas of the Pearl River Delta. Soil and Environmental Science, 9 (3), 177-182.

[19]. J. Jensen, and M. B. Pedersen, (2006). Ecological risk assessment of contaminated soil, J. Reviews of Environmental Contamination and Toxicology. 186, 73–105.

[20]. S. Khan, Q. Cao, Y. M. Zheng, Y. Z. Huang, and Y. G. Zhu, (2008). Health risks of heavy metals in contaminated soils and food crops irrigated with wastewater in Beijing, China. Environmental Pollution, vol. 152, no. 3, pp. 686—692.

[21]. Clevers, J., and Kooistra, L. (2003). Assessment of heavy metal contamination in river floodplains by using the red-edge index. Presented at the 3rd EARSeL Workshop on Imaging Spectroscopy, Herrsching.

[22]. Clevers, J., Kooistra, L., and Salas, E. A. L. (2004). Study of heavy metal contamination in river floodplains using the red-edge position in spectroscopic data. International Journal of Remote Sensing, 25(19), 3883-3895.

[23]. He, T., Liao, B. H., Zeng, M., Lei, (2007). Investigation on arsenic pollution of paddy fields in 4 mining areas in southern Hunan. J. Asian Journal of Ecotoxicology. 2(4), 470–475.

[24]. de Gandy, Y. P. P. (2010). Spectral Reflectance as an Indicator of Foliar Concentrations of Arsenic in Common Sunflower (Helianthus Annuus). MS dissertation No. 1488735: Department of Chemistry, University of Texas-Pan American.

[25]. M. K. Zhang, Z. Y. Liu, and H. Wang, (2010). Use of single extraction methods to predict bioavailability of heavy metals in polluted soils to rice. Communications in Soil Science and Plant Analysis, vol. 41, no. 7, pp. 820—831.

[26]. Dematte, J., Fiorio, P., and Ben-Dor, E. (2009). Estimation of Soil Properties by Orbital and Laboratory Reflectance Means and its Relation with Soil Classification. The Open Remote Sensing Journal, 2(1), 12-23.

[27]. B.Fisher, (2003). Fuzzy environmental decision-making: applications to air pollution. J. Atmospheric Environment, 37, 1865-1877.

[28]. T. A. Kirpichtchikova, A. Manceau, L. Spadini, F. Panfili, M. A. Marcus, and T. Jacquet, (2006). Speciation and solubility of heavy metals in contaminated soil using X-ray micro fluorescence, EXAFS spectroscopy, chemical extraction, and thermodynamic modeling. Geochimica et Cosmochimica Acta, vol. 70, no. 9, pp. 2163—2190, 2006.

[29]. Wang, H. Y. (2002). Assessment and prediction of overall environmental quality of Zhuzhou City. Hunan Province, China, J. Journal of Environmental Management. 66, 329–340.

[30]. P. Maslin and R. M. Maier, (2000). Rhamnolipid-enhanced mineralization of phenanthrene in organic-metal co-contaminated soils. Bioremediation Journal, vol. 4, no. 4, pp. 295—308.
[31]. W. Ling, Q. Shen, Y. Gao, X. Gu, and Z. Yang, (2007). Use of bentonite to control the release of copper from contaminated soils. Australian Journal of Soil Research, vol. 45, no. 8, pp. 618—623.
[32]. S. Mishra, S. Bhalke, I. V. Saradhi, (2007). Trace metals and organ metals in selected marine species and preliminary risk assessment to human beings in Thane Creek area, Mumbai. J. Chemosphere. 69(6), 972–978.
[33]. N. S. Bolan, B.G. Ko, C.W.N. Anderson, and I. Vogeler, (2008). Solute interactions in soils in relation to bioavailability and remediation of the environment. In Proceedings of the 5th International Symposium of Interactions of Soil Minerals with Organic Components and Microorganisms.
[34]. K. Maturi and K. R. Reddy, (2008). Extractants for the removal of mixed contaminants from soils," Soil and Sediment Contamination. vol. 17, no. 6, pp. 586—608, 2008.
[35]. J.Geldermann, T. Spengler, O. Rentz, (2000). Fuzzy outranking for environmental assessment, Case study: iron and steel making industry. J. Fuzzy Sets and Systems. 115, 45-65.
[36]. H. Zhang, Z. Dang, L. C. Zheng, and X. Y. Yi, (2008). Remediation of soil co-contaminated with pyrene and cadmium by growing maize. International Journal of Environmental Science and Technology, vol. 6, no. 2, pp. 249—258.
[37]. Chang, N. B., K. R. Srilakshmi and G. Parvathinathan, (2008). Comparison of models of simazine transport and fate in the subsurface environment in a citrus farm. J. Journal of Environmental Management. 86(1), 27–43.
[38]. j. Labanowski, F. Monna, A. Bermond (2008). Kinetic extractions to assess mobilization of Zn, Pb, Cu, and Cd in ametal-contaminated soil: EDTA vs. citrate. Environmental Pollution, vol. 152, no. 3, pp. 693—701.
[39]. Dold B., (2008). Sustainability in metal mining: from exploration, over processing to mine waste management. Reviews in Environmental Science and Bio/Technology, 7, 275-285.
[40]. Li, J. B., Liu, L., Huang, G. H. M. (2006). A fuzzy-set approach for addressing uncertainties in risk assessment of hydrocarbon-contaminated site. J. Water, Air, and Soil Pollution. 171(1-4), 5–18.
[41]. Chen, H., Zhuang R., Yao J., Wang F., Qian Y., Masakorala K., Cai M., Liu H., (2014). Short-term effect of aniline on soil microbial activity: a combined study by isothermal microcalorimetry, glucose analysis, and enzyme assay techniques. Environmental Science and Pollution Research, 21, 674-683.
[42]. x. Ke, P. J. Li, Q. X. Zhou, Y. Zhang, and T. H. Sun, (2006). Removal of heavy metals from a contaminated soil using tartaric acid. Journal of Environmental Sciences, vol. 18, no. 4, pp. 727—733.
[43]. Chen H., Zhuang R., Yao J., Wang F., Qian Y., (2013). A Comparative Study on the Impact of Phthalate Esters on Soil Microbial Activity. Bulletin of Environmental Contamination and Toxicology, 91, 217-223.
[44]. R. A. Wuana, F. E. Okieimen, and J. A. Imborvungu, (2010). Removal of heavy metals from a contaminated soil using organic chelating acids. International Journal of Environmental Science and Technology, vol. 7, no. 3, pp. 485—496.
[45]. Brohon B., Delolme C., Gourdon R., (2001). Complementarity of bioassays and microbial activity measurements for the evaluation of hydrocarbon-contaminated soils quality. Soil Biology and Biochemistry, 33, 883-891.
[46]. H. S. Helmisaari, M. Salemaa, J. Derome, O. Kiikkil¨o, C. Uhlig, and T. M. Nieminen, (2007). Remediation of heavy metal-contaminated forest soil using recycled organic matter and native woody plants. Journal of Environmental Quality, vol. 36, no. 4, pp. 1145—1153.
[47]. Andreoni V., Cavalca L., Rao M. A., Nocerino G., Bernasconi S., Dell'amico E.,Colombo M., Gianfreda, L., (2004). Bacterial communities and enzyme activities of PAHs polluted soils. Chemosphere, 57, 401-12. Total nitrogen, Madison, American Society of Agronomy.
[48]. Fu J., Zhao C., Luo Y., Liu C., Kyzas G. Z., Luo Y., Zhao D., An S., Zhu H., (2014). Heavy metals in surface sediments of the Jialu River, China: their relations to environmental factors. J Hazard Mater, 270,102-9.
[49]. Guo H., Yao J., Cai M., Qian Y., Guo Y., Richnow H. H., Blake R. E., Doni S., Ceccanti, B., (2012). Effects of petroleum contamination on soil microbial numbers, metabolic activity and urease activity. Chemosphere, 87, 1273-80.
[50]. Liu G., Yu Y., Hou J., Xue W., Liu X., Liu Y., Wang W., Alsaedi A., Hayat T., Liu Z., (2014). An ecological

risk assessment of heavy metal pollution of the agricultural ecosystem near a lead-acid battery factory. Ecological Indicators, 47, 210-218.

[51]. Xing Y., Si Y. X., Hong C., Li, Y., (2013). Impact of Long-Term Heavy Metal Pollution on Microbial Community in Iron Mine Soil. Research of Environmental Sciences, 26, 1201-1211.

[52]. Yang C.L., Sun T.H., He W.X., Zhou Q.X., Chen S., (2007). Single and joint effects of pesticides and mercury on soil urease. Journal of Environmental Sciences, 19, 210-216.

[53]. Yang J., Chen L., Liu L. Z., Shi W. L., Meng X. Z., (2014). Comprehensive risk assessment of heavy metals in lake sediment from public parks in Shanghai. Ecotoxicol Environ Saf, 102, 129-35.

[54]. Zhuang W., Gao X., (2014). Assessment of heavy metal impact on sediment quality of the Xiaoqinghe estuary in the coastal Laizhou Bay, Bohai Sea: inconsistency between two commonly used criteria. Mar Pollut Bull, 83, 352-7.

[55]. Sönmez, A.Y. (2011). Determination of heavy metal pollution in Karasu River and its evaluation by fuzzy Logic. Ataturk University Graduate School of Agriculture Faculty Department of Fishery Sciences. PhD Thesis. Erzurum, Turkey.

[56]. Su, C., Jiang, L. and Zhang, W. (2014). A Review on Heavy Metal Contamination in the Soil Worldwide: Situation, Impact and Remediation Techniques. Environmental Skeptics and Critics, 3, 24-38.

[57]. Gowd, S.S., Reddy, M.R. and Govil, P. (2010). Assessment of Heavy Metal Contamination in Soils at Jajmau (Kanpur) and Unnao Industrial Areas of the Ganga Plain. Uttar Pradesh, India. Journal of Hazardous Materials, 174, 113-121.

[58]. Rahman, S.H., Khanam, D., Adyel, T.M., Islam, M.S., Ahsan, M.A. and Akbor, M.A. (2012). Assessment of Heavy Metal Contamination of Agricultural Soil around Dhaka Export Processing Zone (DEPZ), Bangladesh: Implication of Seasonal Variation and Indices. Applied Sciences, 2, 584-601. https://doi.org/10.3390/app2030584.

[59]. Afzal, M., Shabir, G., Iqbal, S., Mustafa, T., Khan, Q.M. and Khalid, Z.M. (2014). Assessment of Heavy Metal Contamination in Soil and Groundwater at Leather Industrial Area of Kasur, Pakistan. CLEAN—Soil, Air, Water, 42, 1133-1139. https://doi.org/10.1002/clen.201100715.

[60]. Islam, S., Islam, F., Bakar, M.A., Das, S. and Bhuiyan, H.R. (2013). Heavy Metals Concentration at Different Tannery Wastewater Canal of Chittagong City in Bangladesh. International Journal of Agriculture, Environment and Biotechnology, 6, 355-362. https://doi.org/10.5958/j.2230-732X.6.3.003.