SSRG International Journal of Civil Engineering
ISSN: 2348-8352 / https://doi.org/10.14445/23488352/IJCE-V9I11P104

Volume 9 Issue 11, 23-32, November, 2022

Original Article

Health Risk Index Development for Municipal Solid Waste using TOPSIS model

Divyanjali Singh[1], Pradeep Kumar[2]

[1,2]*Department of Civil Engineering, Harcourt Butler Technical University, Kanpur, India.*

Received: 01 October 2022 Revised: 04 November 2022 Accepted: 17 November 2022 Published: 30 November 2022

Abstract *- Most human accomplishments create waste and are picked up, stored, collected, and disposed of, which can stance risks to the environment and public health. Economic improvement, urbanization and amended living standards in cities increase the quality of intricacy of generated solid waste. Generally and customarily discussing solid waste,specific categories of waste are well recognized as they are very common. The results data are analyzed using the TOPSIS (Technique of Order Preference by Similarities to ideal solution) model with the help of MATLAB 2019a version. All the six steps of the TOPSIS model in the MATLAB are commanded and run the method to generate the Health Risk Index (HRI) value for each location for the area of Rasoolabad, Mehdauri Colony, Govindpur, Salori, and Phaphamau, respectively. After the HRI value for each location of Rasoolabad, Mehdauri Colony, Govindpur, Salori, and Phaphamau, respectively, are found, the HRI value with the rank is located to map with the geographical location using ArcGIS. The consequences of health hazards are evaluated using various models, and an Index is generated for minimizing the further ill effects of such wastes.*

Keywords *- TOPSIS model, MSW, HRI, Aggregation Model.*

1. Introduction

Currently, the vast majority of urban poor live in informal settlements, which have a tenuous connection to critical services such as garbage collection systems [9, 16, 17]. Most of the time, the rubbish they produce is only disposed of in the immediate areas around them. This waste causes soil and water contamination, jeopardizing human and environmental health [4, 6, 8, 17, 25]. Human garbage pickers in the majority of underdeveloped and developing countries rely on this publicly abandoned junk for their daily requirements, even though it poses a threat to their health due to the highly filthy home waste and harmful products it contains [1, 5, 8, 14, 17]. Garbage collection and disposal that is not well organized is a significant cause for concern for the human and environmental health of communities that are not as large. It includes buried household solid wastes, non-hazardous solid waste discharged by industrial, commercial, and institutional institutions, market garbage, yard waste, and street sweepings [6, 10, 13, 22, 26]. As a direct consequence of this, the management of solid waste has emerged as a concern on a worldwide scale, particularly in countries with lower incomes. Because of our poor use of energy and resources, the vast majority of human actions will, sooner or later, produce waste [8, 15, 17, 21, 24].

The concept of risk is increasingly incorporated into a diverse array of individual research fields and even scientific divisions. Environmental health is "the concept and practises of analyzing and managing environmental components that may have a detrimental influence on the health of current and future generations," as defined by the World Health Organization (WHO). When it comes to environmental health, a critical systems approach considers both the natural and the social environments. It provides food and shelter for rats and other insects that might spread disease, which is one of the most significant unintended consequences [3, 4, 5, 12, 15, 18, 21, 27, 28]. Through the use of risk assessments, MSW will be able to differentiate between high, medium, and low-risk levels. Risk assessments will assist communities in prioritizing preventive efforts and information on the possible damage and the severity of that harm [2, 8, 17, 19, 23, 26].

This study takes a novel approach to generate risk assessment regions inside municipal limits in order to analyze the rate of solid waste generation (SWG) and the Health Risk Index (HRI) utilizing an aggregation model and the Technique of Order Preference by Similarities to ideal solution (TOPSIS) Technique. This research was carried out to understand the relationship between these two factors better. In addition to excessive exploitation and starvation, municipal trash and inhabitants live and work in conditions that pose significant health risks that are often unrecognized. It is usual for dumpsites to have insufficient water supplies for drinking and washing, and sanitary facilities. Because of this, there is a need for increased health and welfare services. The current study establishes a health risk index in each municipal location and identifies the risk locations, types of illnesses, and their impact on human health caused by municipal solid waste. Additionally, the study identifies the impact of these illnesses on human health. Each dwelling in the Prayagraj Municipal Ward produces between 1.5 and 2 kg of municipal solid garbage every single day [8, 11, 14, 17, 18].

2. Materials and Methods

2.1. Study area and Process of Data Collections

The city of Prayagraj is located in the state of Uttar Pradesh in northern India. It is about 205 kilometres south of the state capital of Lucknow. The city of Prayagraj

serves as the administrative centre of the Prayagraj District in the Indian state of Uttar Pradesh. Prayagraj District is one of the essential populous districts in Uttar Pradesh. Prayagraj district is at 25 degrees 28 minutes north latitude and 81 degrees 54 minutes east longitude. It is a component of the Prayagraj Division. The Prayagraj District is split up into blocks, and those blocks are further broken down into tehsils. As of 2011, there are a total of 20 blocks spread throughout 8 tehsils. The focus area is on the five municipal wards within the administrative jurisdiction of Phulpur in Prayagraj Nagar Nigam (PNN). These wards are Rasoolabad, Mehdauri Colony, Govindpur, Salori, and Phaphamau. The waste collection system was studied during the first part of the study, and then the places where solid waste was moved were identified as primary transfer stations or municipal corporation primary collecting bins, as illustrated in Table 1. The primary and secondary data used to compile the focus area were used to answer the questions asked in the study's questionnaire. These five municipal wards were used to establish the health risk index caused by municipal solid waste. In these wards, the data was gathered via questionnaires, and the number of households was determined roughly close to the spot where solid waste is dumped on open sites or at main transfer stations.

Table 1. Selected location of Municipal wards

S. No.	Ward Name	No. of Location
1	Rasoolabad	20
2	Mehdauri Colony	15
3	Govindpur	29
4	Salori	14
5	Phaphamau	15

2.2 Mathematical Model for Developed HRI

Data collected through questionnaires and field observations were translated into numerical values using the Aggregation model, followed by TOPSIS (Technique of Order Preference by Similarity to Ideal Solution). The Excel 2019 version solved aggregation models, and TOPSIS was solved using the MATLAB 2019 version. The HRI (Health Risk Index) developed from TOPSIS of five areas: Rasoolabad, Mehdauri Colony, Govindpur, Salori, and Phaphamau.

2.2.1. Aggregation Model

The aggregation model is critical in calculating the environmental health risk index. It affects the quality of the outcomes in various ways because the aggregation procedure simplifies the majority of the time. Aggregation models include additive, multiplicative, and maximum or minimum operators [8, 17]. We are using 6 models in this investigation. Because maximum and minimum operators are biased at extremes, they were eliminated from this investigation. Table 2 shows the models used for Municipal Solid Waste index development.

Table 2. Aggregation model

SN.	Forms of Aggregation Model	Formulation
1	Weighted root sum power (WRSP)	wrsp = HH* $(\sum_{i=1}^{n} w_i S_i^{10})^{1/10}$
2	Square Root Harmonic Mean (SRHM)	srhm = HH $*$ $(1/N \sum_{i=1}^{n} S_i^2)$^0.5
3	Weighted root sum square (WRSS)	wrss =HH* $\left(\sum_{i=1}^{N} wiSi\right)^{\frac{1}{2}}$
4	Geometric Mean (GM)	gm =HH* $\prod_{i=1}^{n} S_i)$^$1/N$
5	Root sum power addition (RSPA)	rspa =HH* $(\sum_{i=1}^{n} S_i^4)^{1/4}$
6	Weighted root mean square addition (WRMSA)	wrmsa =HH* $(w/N \sum_{i=1}^{n} S_i^2)^{1/2}$

**HH = No. of Household*
**S_i= Diseases weightage, i = 1, 2… n; n = No. of diseases*
**w= ward worker and respondent household weightage value*

2.2.2. TOPSIS Technique

Technique of Order Preference by Similarities to ideal solution (TOPSIS). TOPSIS is a technique for sorting the priority of options based on the similarity to the ideal solution [27]. This functional anduseful method is used for ranking. The primary premise of TOPSIS is that the chosen alternative should be the closest to the positive ideal solution and the furthest away from the negative ideal solution. The steps for HRI develop given as follows:

Step 1: The construction of a multi-criteria decision matrix: It is based on "n" as an alternative, "m" as an index, and "aij" as a raw score of the i-th option in the jth criteria as aij (i=1...,m; j=1...,n). The choice matrix then looks like this:

$$A = (aij)mxn = \begin{bmatrix} a11 & a12\cdots & a1n \\ a21 & a22\cdots & a2n \\ \vdots & \vdots & \vdots \\ \vdots & \vdots & \vdots \\ am1 & am2 & amn \end{bmatrix} \quad (1)$$

Step 2: Creating normalized choice matrix: 'A' decision matrix must be normalized to establish distinct comparative criteria. Consequently, the normalized decision matrix is "B=(bij)mn." The following limiting strategy was applied to lower the computational complexity of TOPSIS.

$$bij = \frac{aij - \min(aij)}{\max(aij) - \min(aij)} \quad (2)$$

$$bij = \begin{bmatrix} b11 & b12 & \cdots & b1n \\ b21 & b22 & \cdots & b2n \\ \vdots & \vdots & \vdots & \vdots \\ bm1 & bm2 & \cdots & bmn \end{bmatrix} \quad (3)$$

Step 3: Normalized decision matrix weight calculation: The weight of each w_j index is determined using $\sum_{j=1}^{n} w_j = 1$. Important indexes are given more weight in this regard, resulting in the following matrix:

$$(C_{ij})mxn = b_{ij} x w_j$$

$$Cij = \begin{bmatrix} w1b11 & w2b12 & \cdots & wnb1n \\ w1b21 & w2b22 & \cdots & wnb2n \\ \vdots & \vdots & \vdots & \vdots \\ w1bm1 & w2bm2 & \cdots & wnbmn \end{bmatrix} \quad (4)$$

Step 4: Identifying Ideal Positive and Negative Solutions: Both the positive and negative obtained data of ideal solutions form

$$C_j^+ = \left\{\max_{1 \le i \le m} C_{ij}\right\},$$

$$C_j^- = \left\{\min_{1 \le i \le m} C_{ij}\right\};$$

$$j = 1, 2 \ldots n$$

As follows:

$$V^+ = C_1^+, C_2^+ \ldots C_n^+$$

$$V^- = C_1^-, C_2^- \ldots C_n^-$$

(V^+) is the best number of i[th] criteria among all options, and (V^-) is the worst one. Options that are placed in (V^+) and (V^-) represent quite clearly better and worse options, respectively.

Step 5: Calculating the size of separation: A separation size is used to calculate the distance between ideal locations and each alternative. The Euclidean distance metric can be used to compute a separation. In this stage, the distance between the positive ideal solution (d_i^+) and the negative ideal solution (d_i^-) is computed for each alternative using the formulae below.

$$d_i^+ = \sqrt{\sum_{j=1}^{n}\left(C_{ij} - C_j^+\right)^2}$$

$$d_i^- = \sqrt{\sum_{j=1}^{n}\left(C_{ij} - C_j^-\right)^2} \quad (5)$$

Step 6: Calculating Relative Proximity to Ideal Point of (C_i^+): The similarity Health Risk index of deciding coefficient that is used in this phase is**:**

d_i^+ = the distance of the ideal alternative.
d_i^- = the distance of minimum alternative.

$$C_i^+ = \frac{d_i^-}{d_i^+ + d_i^-} \quad (6)$$

$$i = (1, 2 \ldots\ldots m)$$

Ranking is based on the amount of C_i^+.

The highest ranking is the High Health Risk area to the lowest ranking is the lowest-risk area.

3. Results and Discussions

After completing the questionnaire survey, weightage and disease impact value was assigned with the help of survey analysis, expert, and different literature surveys. The assigned weightage and disease impact value were categorized into four and nine parts based on questionnaire impact. Of the six different aggregation models, out of six models, three have disease weightage with impact value, and the remaining three only have disease impact value. Analyzed the theoretical value to numerical value; with these six aggregation models of five selected areas Rasoolabad, Mehdauri Colony, Govindpur, Salori, and Phaphamau, respectively. For each selected location of these five areas, calculate the six aggregation models shown in Figure 1 for Rasoolabad, Figure 2 for Mehdauri Colony, Figure 3 for Govindpur, Figure 4 for Salori, and Figure 5 for Phaphamau respectively.

3.1 Comparison of six Aggregation models for each five area

Figures 1, 2, 3, 4, and 5 graphs are aimed at the comparison of six Aggregation models with R^2 and Pearson r value for Rasoolaad. The six Aggregation models are wrsp, srhm, wrss, gm, rspa, and wrmsa, respectively. In this model, the three models wrsp, wrss, and wrmsa is, weightage with impact value and the remaining three models, srhm, gm, and rspa with only impact value. The graph shows the upper triangular scatter matrix of the six Aggregation models. Each model is compared with other models and has the unique R2 and Pearson r values. The highest R^2 and Pearson r value for Rasoolabad are 0.953 and 0.978 between wrsp and rspa shown in Figure1, for Mehdauri Colony 0.935 and 0.969 between wrsp and rspa shown in Figure 2, for Govindpur 0.956 and 0.979 between wrsp and rspa shown in Figure 3, for Salori R^2 value 0.985 between wrsp and wrmsa and Pearson r value 0.994 between srhm and rspa shown in Figure 4, for Phaphamau 0.96 and 0.981 between wrsp and rspa shown in Figure 5, respectively. That means out of the six aggregation models, two models, wrsp and rspa more effective for Rasoolabad, Mehdauri Colony, Govindpur, and Phaphamau. For Salori, out of the six aggregation models, two models, wrsp and wrmsa more effective for HRI development. The lowest R^2 value for Rasoolabad is 0.527 between wrsp and gm, and the lowest Pearson r value is 0.73 between wrss and gm, shown in Figure 1. For Mehdauri Colony, the lowest R^2 and Pearson r values, 0.453 and 0.701, between wrsp and gm, are shown in Figure 2. For Govindpur, the lowest R^2 and Pearson r values are 0.562 and 0.762 between wrss and gm, shown in Figure 3. For Salori, the lowest R^2 value is 0.843 between gm and wrmsa, and the lowest Pearson r value is 0.92 between wrsp and gms, shown in Figure 4. For phaphamau, the lowest R^2 and Pearson r values, 0.486 and 0.723, between wrss and gm, showed in Figure 5. That means out of six Aggregation models, two models, wrsp and gm least, are effective for Rasoolabad, Mehdauri Colony, and Phaphamau, respectively. For Govindpur, two models, wrss and gm; for Salori, two models, gm and wrmsa least effective. Therefore when the weightage with impact value and only impact value combine study with the matrix, then found the good relation of R^2 and Pearson r value. So that the TOPSIS method is best suitable for the analysis of HRI for Rasoolabad, Mehdauri Colony, Govindpur, Salori, and Phaphamau, Respectively.

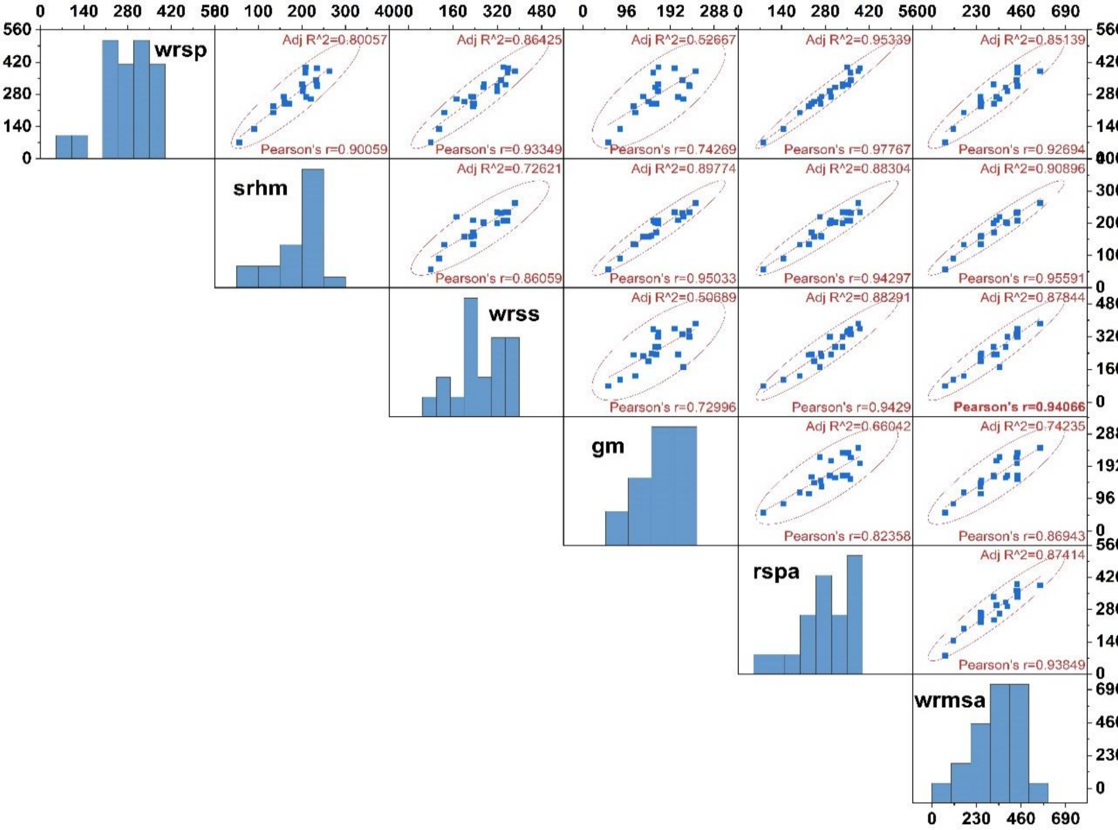

Fig. 1 Upper triangular scatter matrix of six aggregation model for Rasoolabad

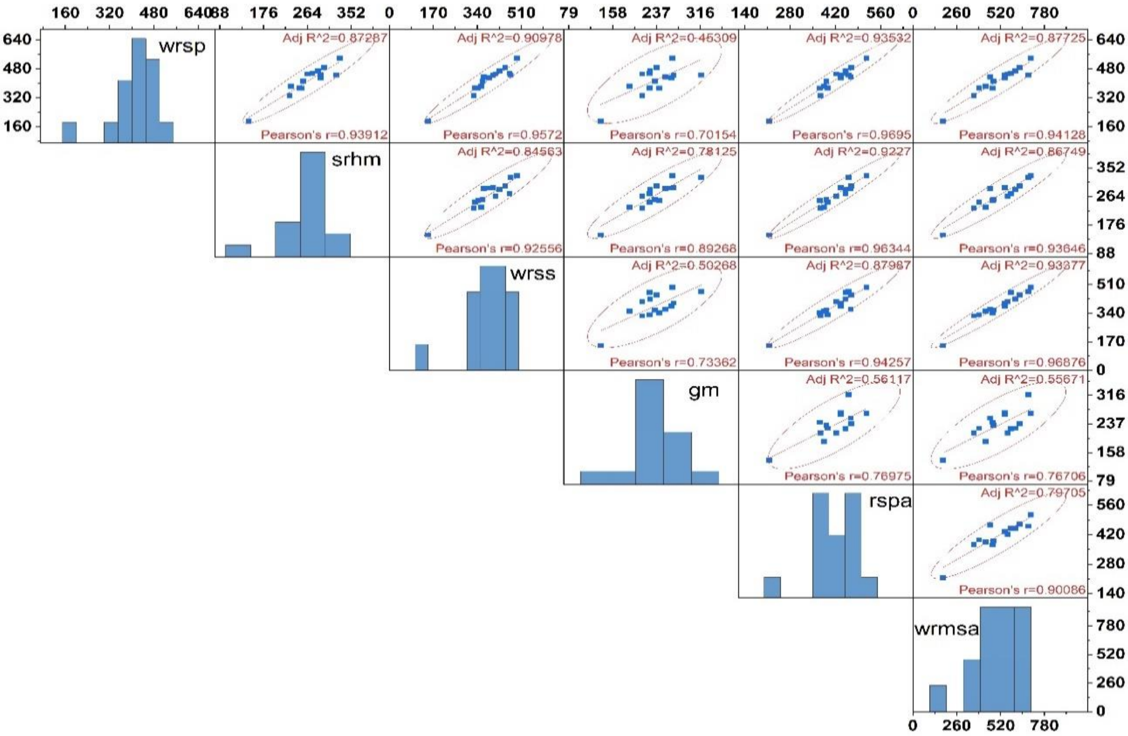

Fig. 2 Upper triangular scatter matrix of six aggregation model for Mehdauri Colony

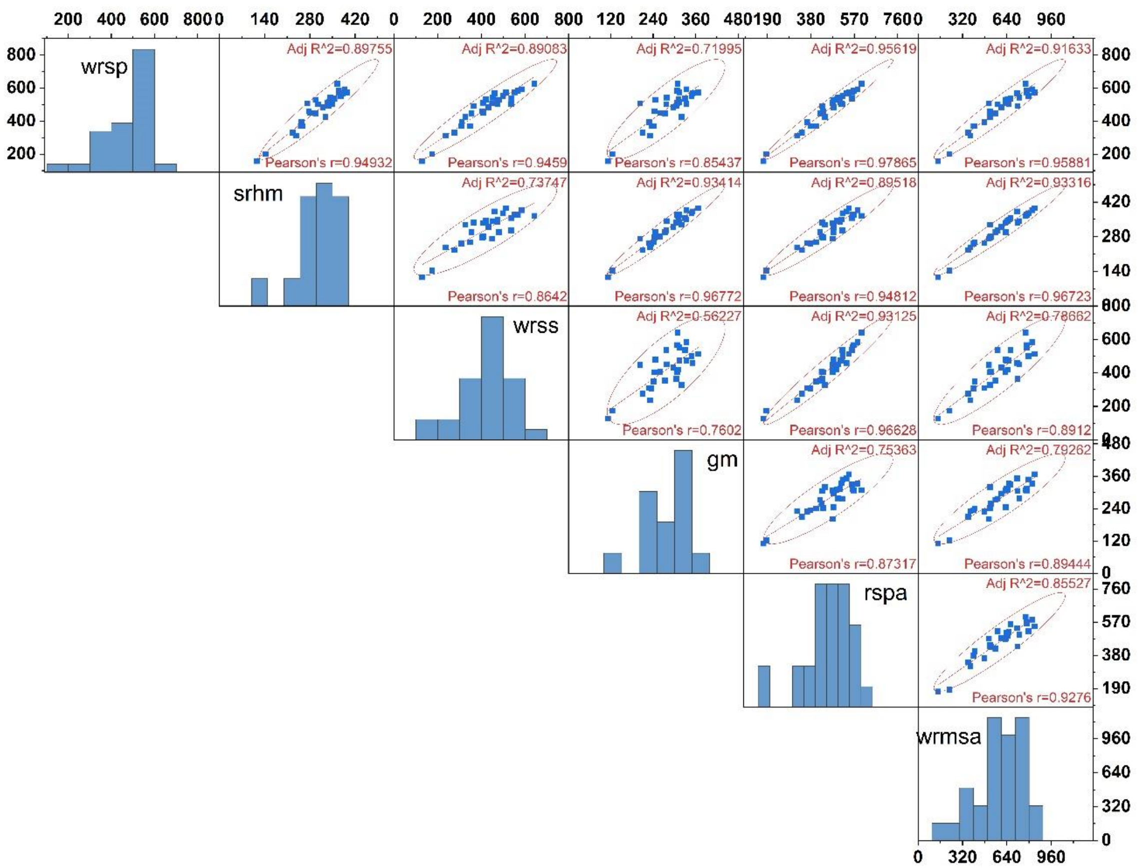

Fig. 3 Upper triangular scatter matrix of six aggregation model for Govindpur

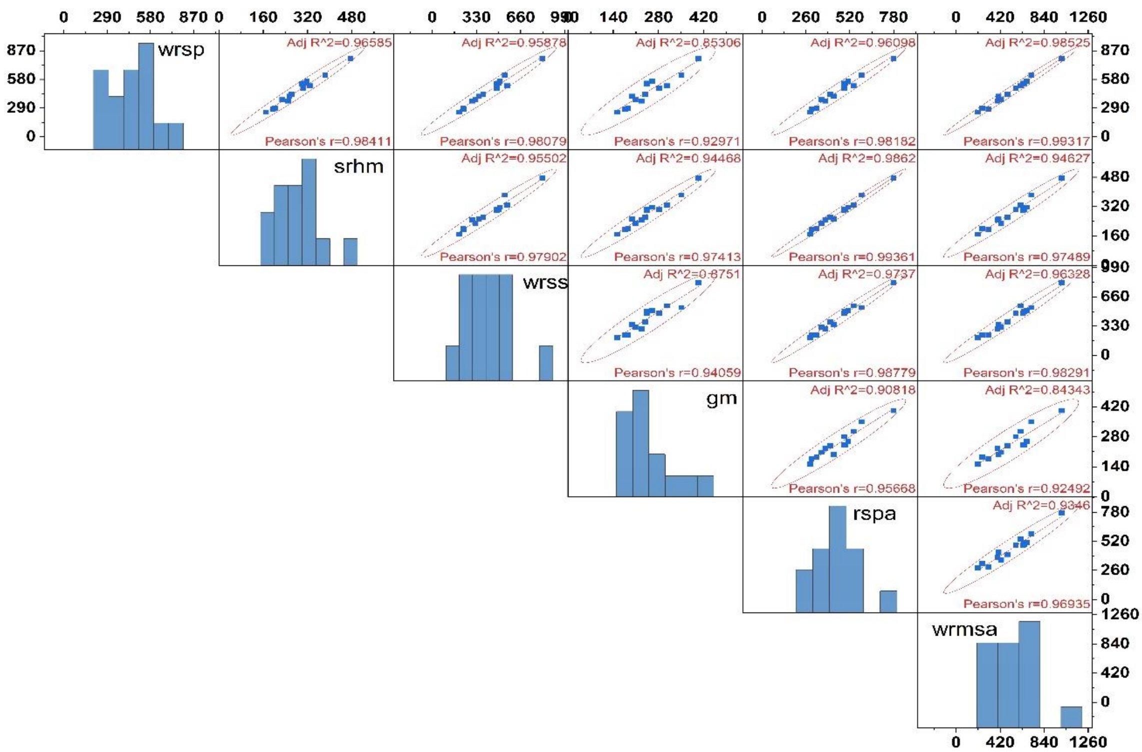

Fig. 4 Upper triangular scatter matrix of six aggregation model for Salori

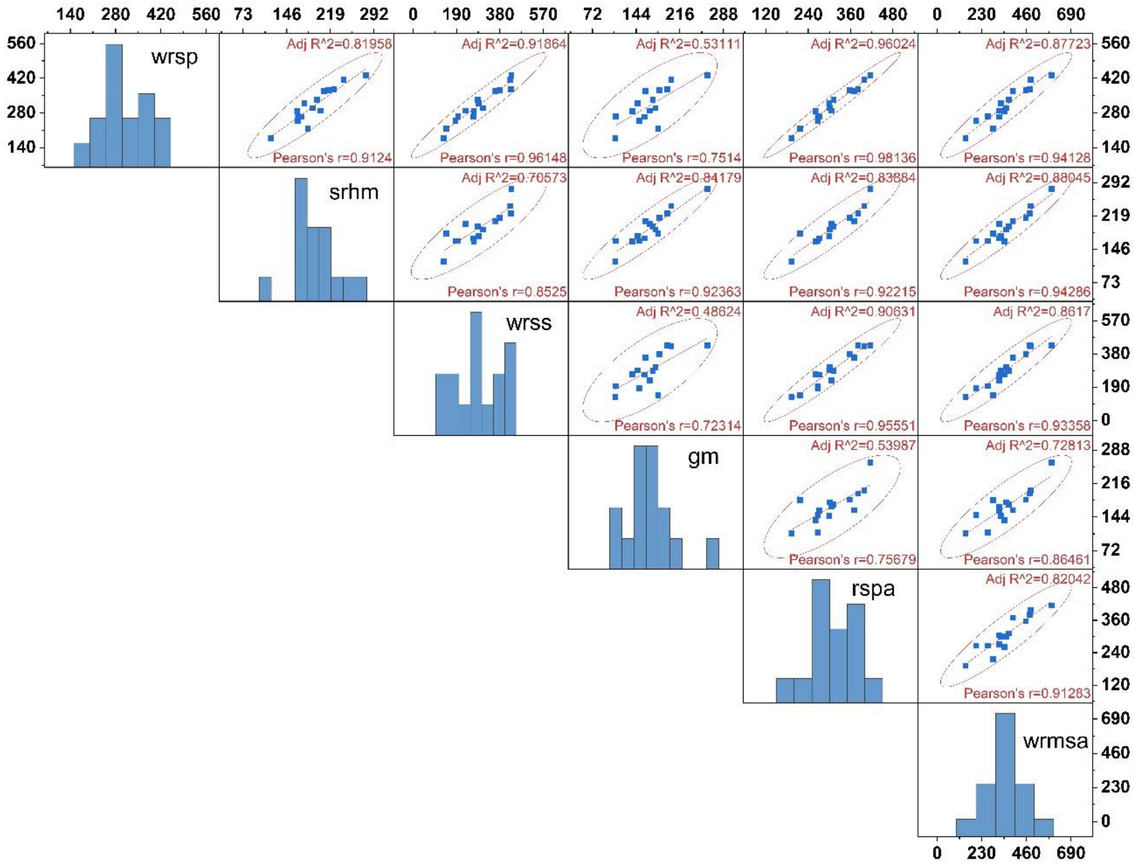

Fig. 5 Upper triangular scatter matrix of six aggregation models for Phaphamau

3.2. Development of Health Risk Index (HRI) of Five Selected Area

The developed six distinctive models for each defined location to make a matrix (m*n) for Rasoolabad (20*6), Mehdauri Colony (15*6), Govindpur (29*6), Salori (14*6), and Phaphamau (15*6) respectively. Here 'm' shows the number of locations, and 'n' shows the six aggregation model value for the development of HRI using the TOPSIS model solved by the MATLAB 2019a version. The developed HRI value is shown in Table 4, and mapping with rank using ArcGIS is shown in Figure 6 (a), (b), (c), (d), and (e).

Table 3. HRI value for five selected area

Location	Govindpur	Rasoolabad	Mehdauri Colony	Phaphamau	Salori
Location 1	0.5493	0.4861	0.4595	0.3685	0.3705
Location 2	0.5379	0.4454	0.4649	0.5259	0.4114
Location 3	0.5239	0.543	0.4313	0.4219	0.4009
Location 4	0.5164	0.501	0.4478	0.5307	0.4831
Location 5	0.4307	0.5648	0.5148	0.3608	0.399
Location 6	0.4651	0.4331	0.5233	0.4217	0.3565
Location 7	0.4393	0.5445	0.4922	0.4106	0.4384
Location 8	0.414	0.4384	0.478	0.4532	0.3423
Location 9	0.4728	0.6122	0.5732	0.5149	0.5236
Location 10	0.5465	0.5501	0.4841	0.3621	0.5522
Location 11	0.4073	0.4279	0.4199	0.4808	0.5055
Location 12	0.5792	0.4728	0.4235	0.5044	0.3299
Location 13	0.4746	0.533	0.4007	0.4823	0.5304
Location 14	0.5011	0.6146	0.4934	0.38	0.3917

Location 15	0.5171	0.5422	0.4711	0.4298	
Location 16	0.4617	0.4041			
Location 17	0.4591	0.6557			
Location 18	0.4336	0.4663			
Location 19	0.4524	0.5654			
Location 20	0.4511	0.3469			
Location 21	0.5959	**HRI (Health Risk Index)** * Govindpur (29 number of selected locations) Rasoolabad (20 number of selected locations) Mehdauri and Phaphamau (15 number of selected locations) Salori (14 number of selected locations)			
Location 22	0.4198				
Location 23	0.4676				
Location 24	0.4294				
Location 25	0.4829				
Location 26	0.3972				
Location 27	0.5393				
Location 28	0.5272				
Location 29	0.4952				

Table 3 shows the HRI value, and Figure 6 (a), (b), (c), (d), and (e) shows the rank in order of highest to the lowest value of HRI for Rasoolabad, Mehdauri Colony, Govindpur, Salori, and Phaphamau, respectively. Rank 1 shows the highest HRI value, which means this surrounding household suffers from a higher health risk from solid waste. The lowest rank shows that the lowest health risk area and that location cleaned and more effectively collection of solid waste. In Table 3 and Figure 6 (a), Rasoolabad, out of twenty locations, rank 1 was found for location 17 and rank 20 for location 20. This means location 17 was in the higher health risk zone and surrounding the area. People suffer from some severe diseases. Location 20 was in the lowest health risk zone, and surrounding area people lowest risk zone or in good zone livening. In Table 3 and Figure 6 (b), for Mehdauri Colony, out of fifteen locations, rank 1 was found for location 9 and rank 15 was found for location 13. This means location 9 was in the higher health risk zone, and people suffer from some severe diseases surrounding the area. Location 13 was in the lowest health risk zone, and surrounding area people lowest risk zone or in good zone livening. In Table 3 and Figure 6 (c) for Govindpur, out of twenty-nine locations, rank 1 was found for location 21 and rank 29 was found for location 26. This means location 21 was in the higher health risk zone, and people suffer from some severe diseases surrounding the area. Location 26 was in the lowest health risk zone, and surrounding area people lowest risk zone or in good zone livening. In Table 3 and Figure 6 (d) Salori, out of fourteen locations, rank 1 was found for location 10 and rank 14 was found for location 12. This means location 10 was in the higher health risk zone, and people suffer from some severe diseases surrounding the area. Location 12 was in the lowest health risk zone, and surrounding area people lowest risk zone or in good zone livening. In Table 3 and Figure 6 (e), Phaphamau, out of fifteen locations, rank 1 was found for location 4 and rank 15 was found for location 5. This means location 4 was in the higher health risk zone, and people suffer from some severe diseases surrounding the area. Location 5 was in the lowest health risk zone, and surrounding area people lowest risk zone or in good zone livening. The HRI rank was shown on the geographical map using ArcGIS for Rasoolabad in Figure 6 (a), for Mehdauri Colony in Figure 6 (b), for Govindpur in Figure 6 (c), for Salori in Figure 6 (d), and Phaphamau in Figure 6 (e), respectively. In this figure, located rank was shown with identified latitude and longitude during the survey taken by us.

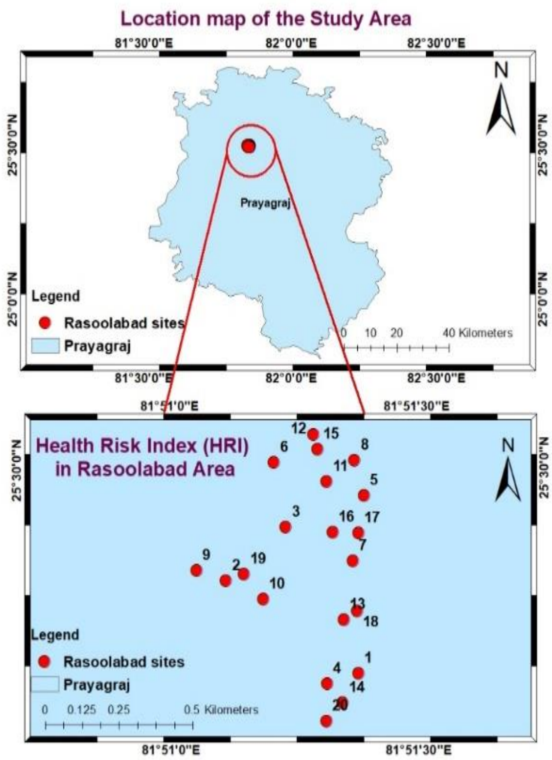

Fig. 6 (a) HRI rank of Rasoolabad for twenty selected location

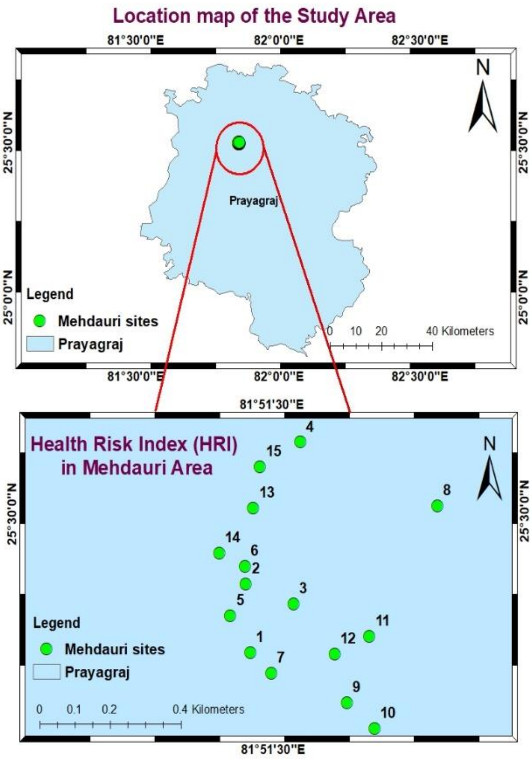

Fig. 6 (b) HRI rank of Mehdauri Colony for fifteen selected location

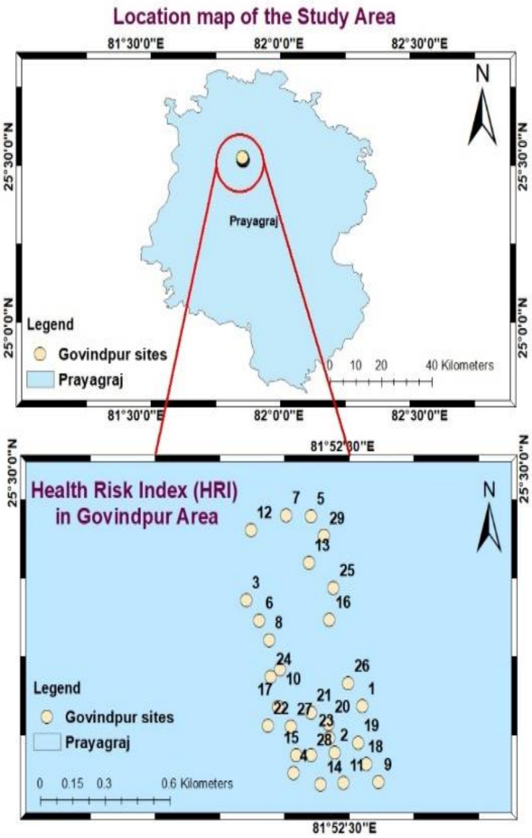

Fig. 6 (c) HRI rank of Govindpur for twenty nine selected location

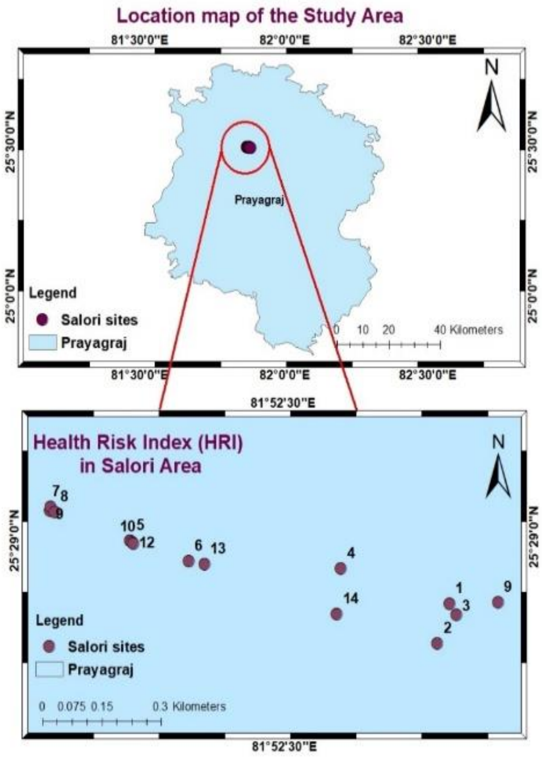

Fig. 6 (d) HRI rank of Salori for fourteen selected location

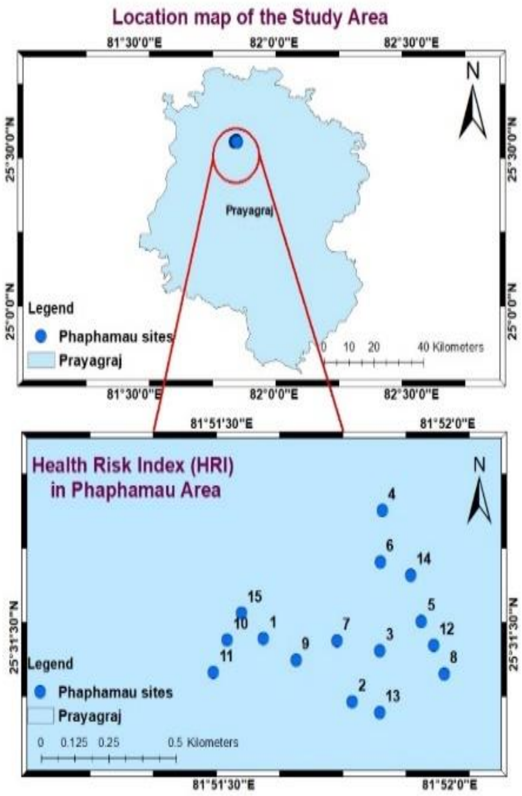

Fig. 6 (e) HRI rank of Phaphamau for fifteen selected locations

4. Conclusion

The results data was analyzed using the TOPSIS model with the help of MATLAB 2019a version. Command all six steps of the TOPSIS model in the MATLAB and run the method to generate the HRI value for each location for the area of Rasoolabad, Mehdauri Colony, Govindpur, Salori, and Phaphamau respectively. After finding the HRI value for each location of Rasoolabad, Mehdauri Colony, Govindpur, Salori, and Phaphamau, respectively, all HRI values with ranks locate to map with the geographical location using ArcGIS. From the resulting output, these areas were denser and waste through open areas in high health risk zones, affecting health. In this regard, in the Rasoolabad area, out of 20 locations, location 17 was the 1st rank for HRI and location 20 was the lowest 20th rank. It means location 17 was the high-health-risk zone that frequently required cleaning, and location 20 was the lowest health-risk zone, which means this area was cleaned. In the Mehdauri Colony, out of 15 locations, location 9 was the 1st rank and location 13 was the 15th rank for HRI. It means location 9 was the high health risk zone in that area, and location 13 was the lowest health risk zone. In Govindpur, out of 29 locations, location 21 was the 1st rank, which means high health risk zone, and location 26 was the 29th rank, which means lowest health risk zone. In the Salori area, out of 14 locations, location 10 was the 1st rank, which means high-risk zone, and location 12 was the 14th rank, which means the lowest health-risk zone. In Phaphamau, out of 15 locations, location 4 was the 1st rank meaning high health risk zone, and location 5 was the 15th rank, which means the lowest health risk zone found. Thus, index analysis utilizing the TOPSIS model is an excellent technique for evaluating problems and will bring new insights (environmental, economic, social, and practical) for municipal solid waste management system sustainability planning. The government and relevant authorities can readily and clearly comprehend the details of the object's level of danger.

Acknowledgments

Extending heartfelt thanks to Prof. Pradeep Kumar, Department of Civil Engineering, HBTU Kanpur, for all his support, guidance and encouragement.

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