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The activity has been implemented within the framework of national project
Information and providing advice on improving the quality of environment in Slovakia.
The project is cofinanced by Cohesion Fund of the EU under Operational programme Quality of Environment.

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USING A NOVEL INDEX TO FIND THE MOST APPROPRIATE AGGREGATION FUNCTION FOR COMPOSITE HAZARD RATING OF A WASTE DISPOSAL SITE

Amit Kumar

MNIT Jaipur, India

e-mail: amitrathi.ucf@gmail.com

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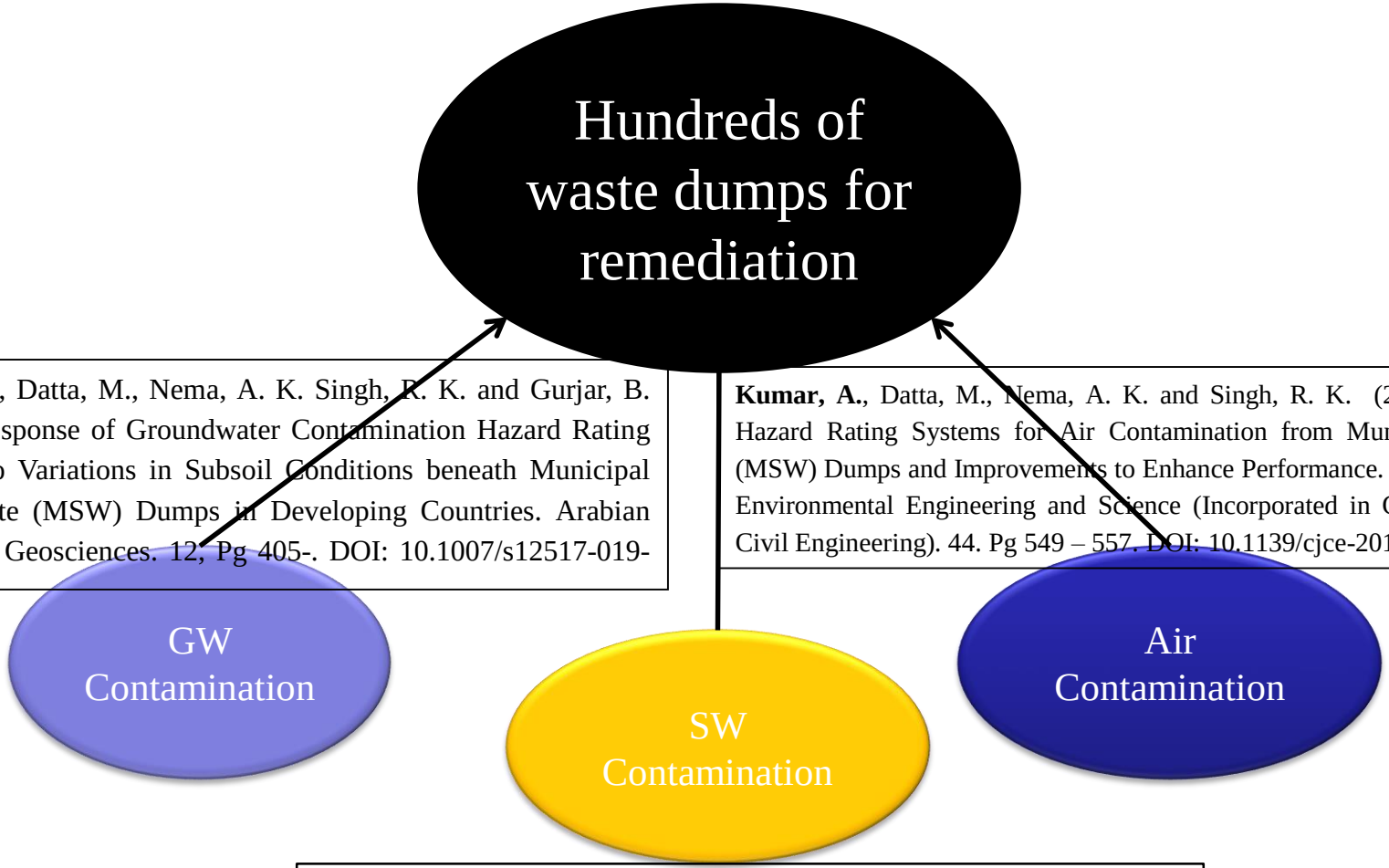
SLOVAK ENVIRONMENT AGENCY

Problems with waste dumps

- Leachate
- Fire & smoke
- Odour
- Groundwater contamination
- Slope failure

Problem Statement



Kumar, A., Datta, M., Nema, A. K. Singh, R. K. and Gurjar, B. (2019). Response of Groundwater Contamination Hazard Rating Systems to Variations in Subsoil Conditions beneath Municipal Solid Waste (MSW) Dumps in Developing Countries. Arabian Journal of Geosciences. 12, Pg 405-. DOI: 10.1007/s12517-019-4560-4.

Kumar, A., Datta, M., Nema, A. K. and Singh, R. K. (2017). Suitability of Hazard Rating Systems for Air Contamination from Municipal Solid Waste (MSW) Dumps and Improvements to Enhance Performance. Canadian Journal of Environmental Engineering and Science (Incorporated in Canadian Journal of Civil Engineering). 44. Pg 549 – 557. DOI: 10.1139/cjce-2016-0500.

Kumar, A., Datta, M., Nema, A. K. and Singh, R. K. (2016). An Improved Rating System for Assessing Surface Water Contamination Potential from MSW Landfills. Environmental Modeling and Assessment. 21. Pg 489-505. DOI: 10.1007/s10666-015-9493-z.

Introduction

- A number of landfills in a region
  - Ranking for remediation
  - Ranking based on groundwater contamination hazard
- Landfills with multiple hazards associated with them
  - GW contamination, SW contamination, air contamination
  - How to rank these?

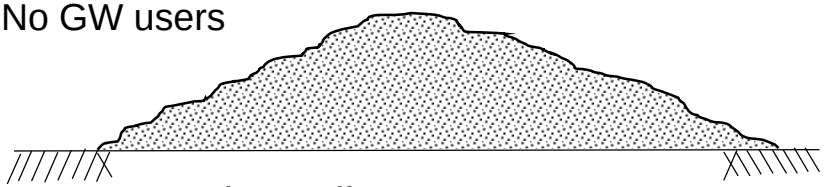
Introduction

- Aggregation function
  - Aggregating various numbers e.g. air quality index

S. No.	Aggregation method	Function expression
1.	Maxima	$HR_{Comp} = maximum(HR_i)$
2.	Average or Simple Addition	$HR_{COMP} = \frac{1}{n}\sum_{i=1}^{n} HR_i$
3.	Weighted Sum	$HR_{COMP} = \sum_{i=1}^{n} w_i HR_i$

Introduction
Clustering index

Min. Rainfall;
No GW users

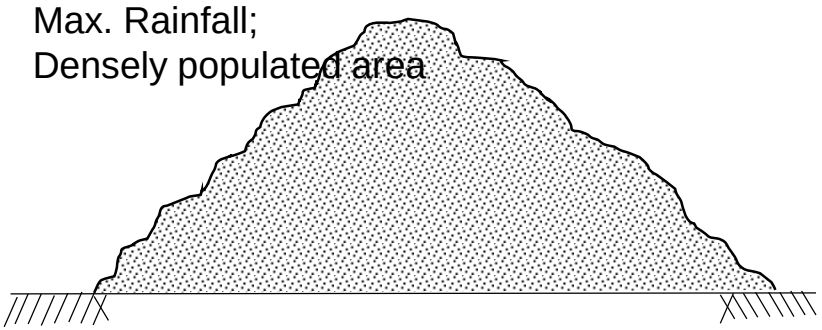


Clay soil

Best Site

01

Max. Rainfall;
Densely populated area

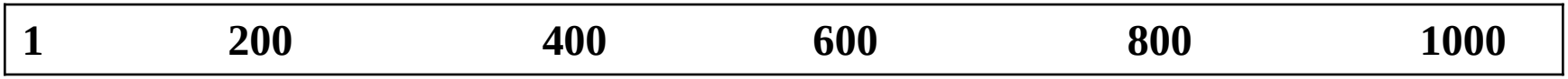


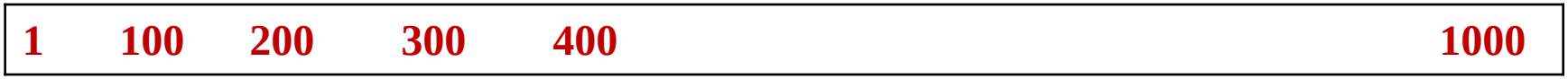
Sandy soil

Worst Site

1000

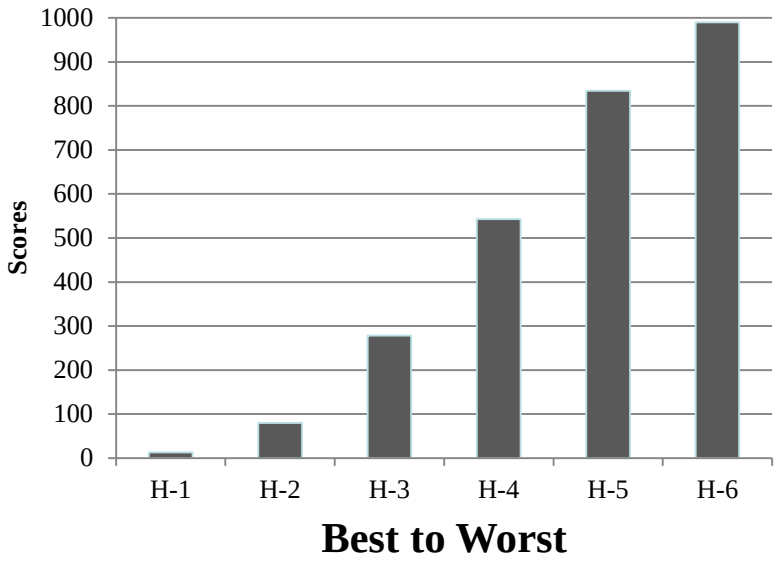
Introduction
Clustering index

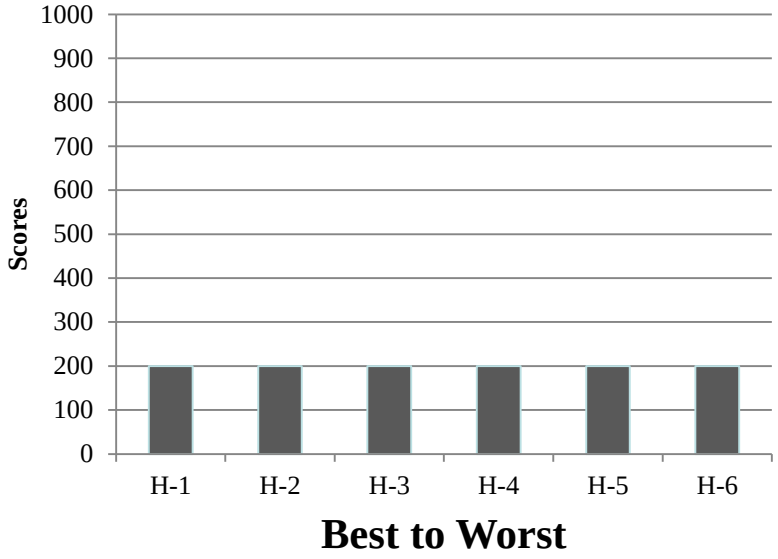




Introduction

Clustering index



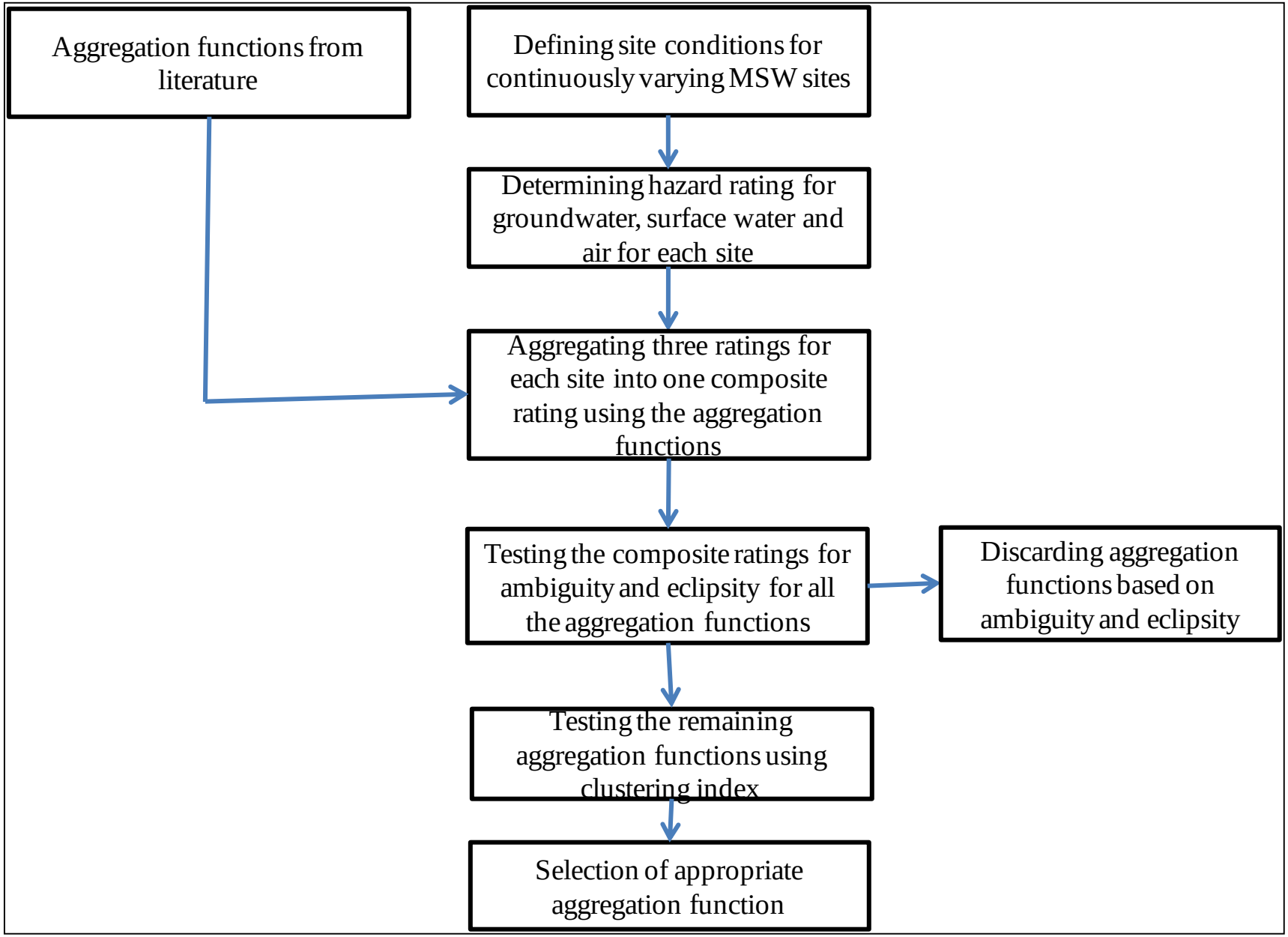


Clustering Index = 0.0

Clustering Index = 1.0

Methodology

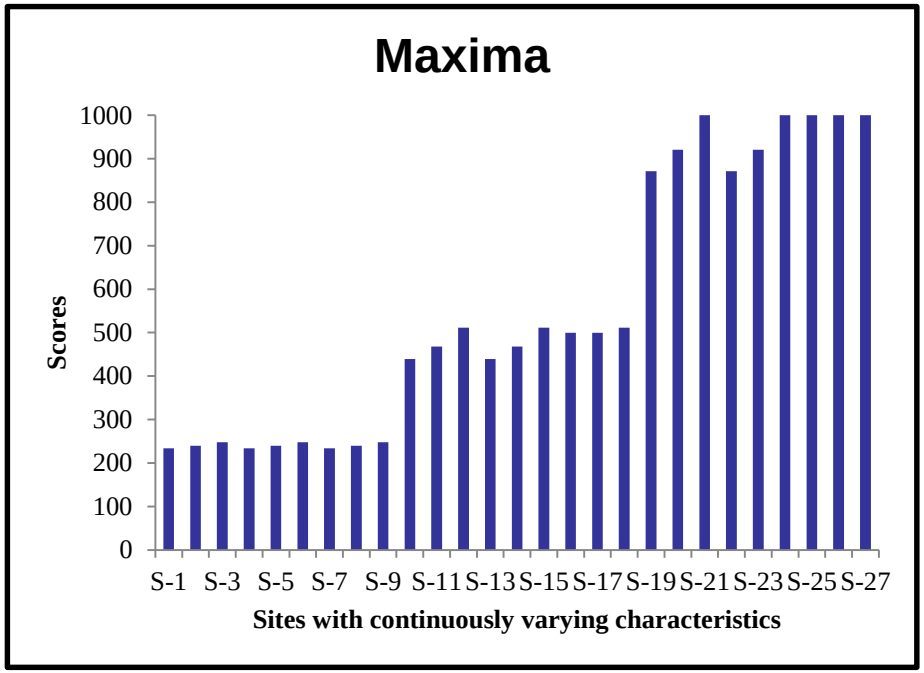
- Step 1: Application of individual new/modified rating systems to sites S-1 to S-27
- Step 2: Application of various aggregation functions from literature to determine composite hazard rating using individual scores from new rating systems
- Step 3: Screening of aggregation methods using ambiguity and eclipsity
- Step 4: Evaluation of initially selected aggregation functions using clustering
- Step 5: Selection of the aggregation method for composite hazard rating
- Step 6: Testing of the aggregation function with least clustering from step 5 for determining the priority for closure
- Step 7: Selection of aggregation function

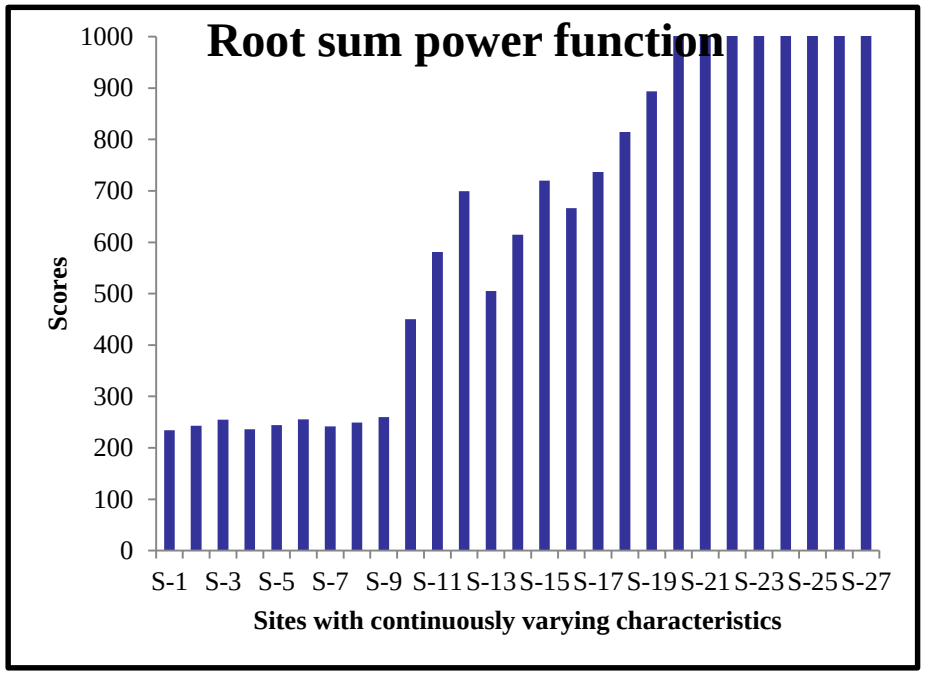

Aggregation functions from literature
Defining site conditions for continuously varying MSW sites
Determining hazard rating for groundwater, surface water and air for each site
Aggregating three ratings for each site into one composite rating using the aggregation functions
Testing the composite ratings for ambiguity and eclipsity for all the aggregation functions
Discarding aggregation functions based on ambiguity and eclipsity
Testing the remaining aggregation functions using clustering index
Selection of appropriate aggregation function

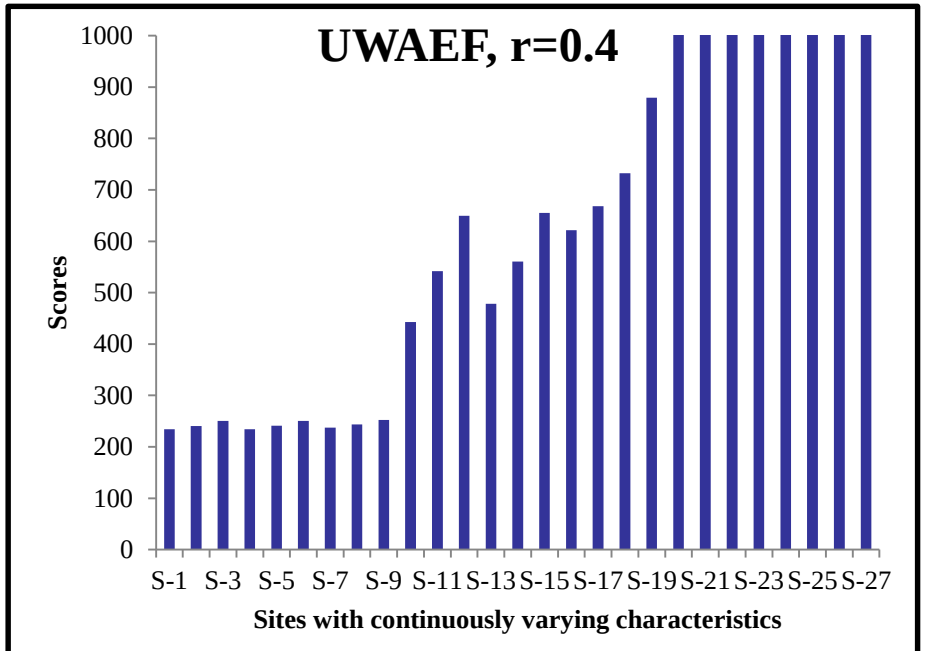
S. No.	Aggregation method	Function expression	Reference(s)
1.	Maxima	$HR_{Comp} = maximum(HR_i)$	[15]
2.	Average or Simple Addition	$HR_{COMP} = \frac{1}{n}\sum_{i=1}^{n} HR_i$	[22]
3.	Weighted Sum	$HR_{COMP} = \sum_{i=1}^{n} w_i HR_i$	[8]
4.	Unweighted multiplicative function	$HR_{Comp} = [\prod_{i=1}^{n} HR_i]^{\frac{1}{n}}$	[12]
5.	Weighted multiplicative or weighted geometric mean function	$HR_{Comp} = \prod_{i=1}^{n} HR_i^{\,w_i}$	[11]
6.	Root sum power function	$HR_{COMP} = [\sum_{i=1}^{n} {HR_i}^2]^{\frac{1}{2}}$	[19]
7.	Weighted root sum power function	$HR_{COMP} = [\sum_{i=1}^{n} w_i {HR_i}^r]^{\frac{1}{r}}$	[9]
8.	Root Mean Square	$HR_{COMP} = [\frac{1}{n}\sum_{i=1}^{n} {HR_i}^2]^{\frac{1}{2}}$	[9]
9.	Weighted root mean square function	$HR_{COMP} = \frac{[\frac{1}{n}\sum_{i=1}^{n} w_i {HR_i}^2]^{\frac{1}{2}}}{\sum_1^n w_i}$	[7]
10.	Unweighted ambiguity and eclipsity free function r=0.4	$HR_{COMP} = [\sum_{i=1}^{n} {HR_i}^{2.5}]^{\frac{1}{2.5}}$	[23]
11.	Weighted ambiguity and eclipsity free function r =0.4	$HR_{COMP} = [\sum_{i=1}^{n} w_i {HR_i}^{2.5}]^{\frac{1}{2.5}}$	[9]
12.	Subindex powered weight function	$HR_{COMP} = \sum_{i=1}^{n} {HR_i}^{w_i}$	[19]
13.	CEPI aggregation function	$HR_{Comp} = maximum(HR_i) + \left(1000 - maximum(HR_i)\right) \times \frac{\prod_1^n HR_i}{} \times \frac{1}{}$	[24]

S. No.	SOURCE	PATHWAY-GW	PATHWAY-SW	PATHWAY-Air	RECEPTOR-GW	RECEPTOR-SW	RECEPTOR-Air
1	Best	Best	Best	Best	Best	Best	Best
2	Best	Best	Medium	Medium	Best	Medium	Medium
3	Best	Best	Worst	Worst	Best	Worst	Worst
4	Best	Medium	Best	Best	Medium	Best	Best
5	Best	Medium	Medium	Medium	Medium	Medium	Medium
6	Best	Medium	Worst	Worst	Medium	Worst	Worst
7	Best	Worst	Best	Best	Worst	Best	Best
8	Best	Worst	Medium	Medium	Worst	Medium	Medium
9	Best	Worst	Worst	Worst	Worst	Worst	Worst
10	Medium	Best	Best	Best	Best	Best	Best
11	Medium	Best	Medium	Medium	Best	Medium	Medium
12	Medium	Best	Worst	Worst	Best	Worst	Worst
13	Medium	Medium	Best	Best	Medium	Best	Best
14	Medium	Medium	Medium	Medium	Medium	Medium	Medium
15	Medium	Medium	Worst	Worst	Medium	Worst	Worst
16	Medium	Worst	Best	Best	Worst	Best	Best
17	Medium	Worst	Medium	Medium	Worst	Medium	Medium
18	Medium	Worst	Worst	Worst	Worst	Worst	Worst
19	Worst	Best	Best	Best	Best	Best	Best
20	Worst	Best	Medium	Medium	Best	Medium	Medium
21	Worst	Best	Worst	Worst	Best	Worst	Worst
22	Worst	Medium	Best	Best	Medium	Best	Best
23	Worst	Medium	Medium	Medium	Medium	Medium	Medium
24	Worst	Medium	Worst	Worst	Medium	Worst	Worst
25	Worst	Worst	Best	Best	Worst	Best	Best
26	Worst	Worst	Medium	Medium	Worst	Medium	Medium
27	Worst	Worst	Worst	Worst	Worst	Worst	Worst

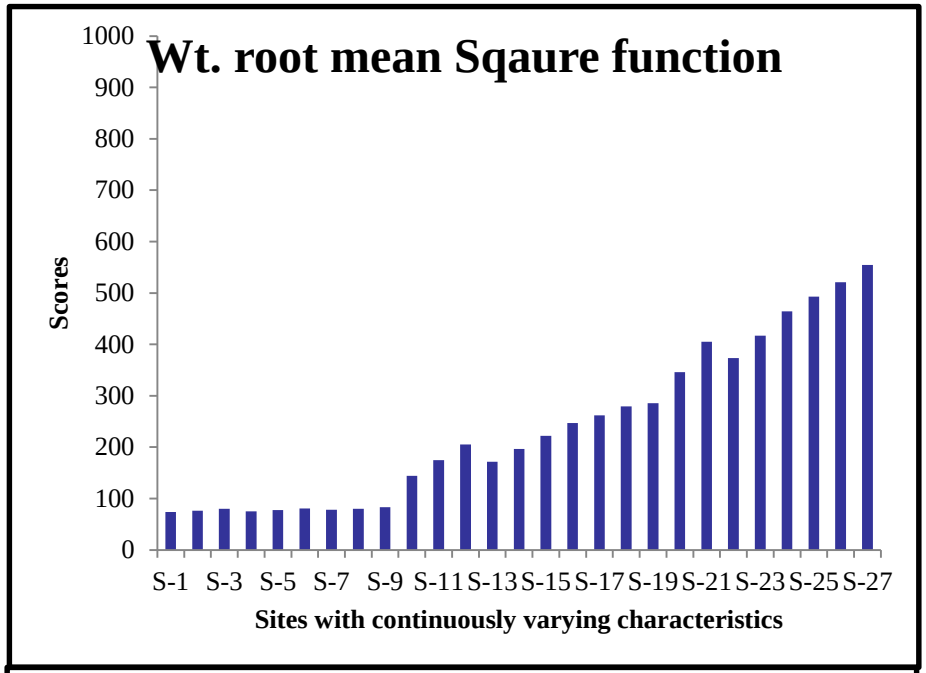
Ambiguous functions

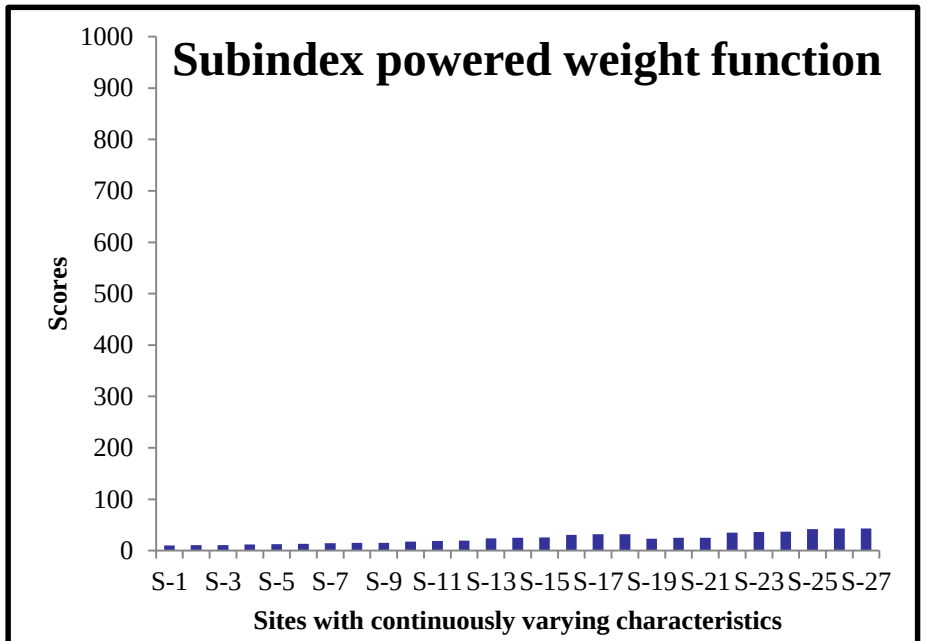


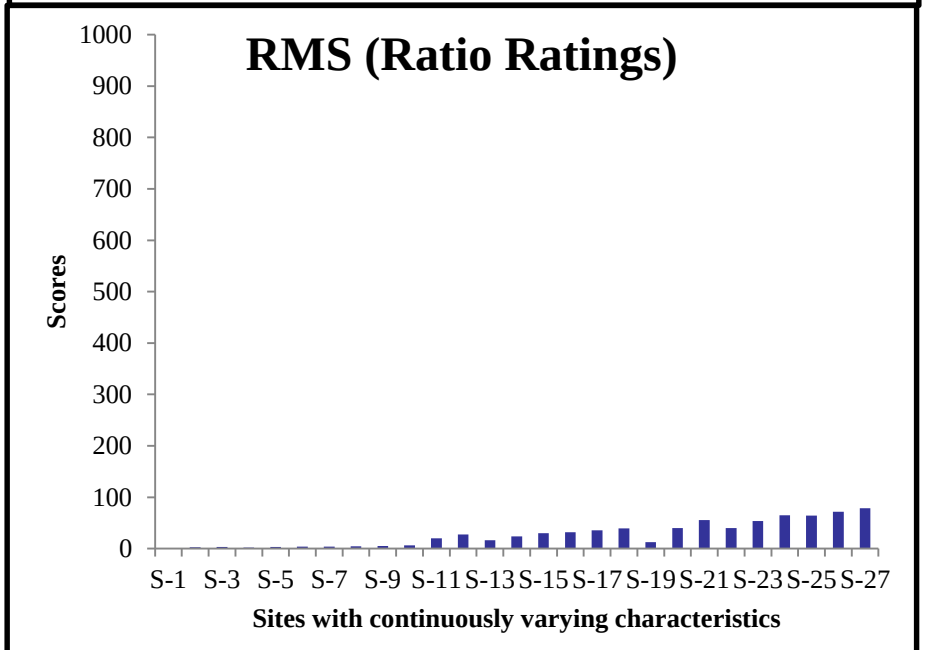


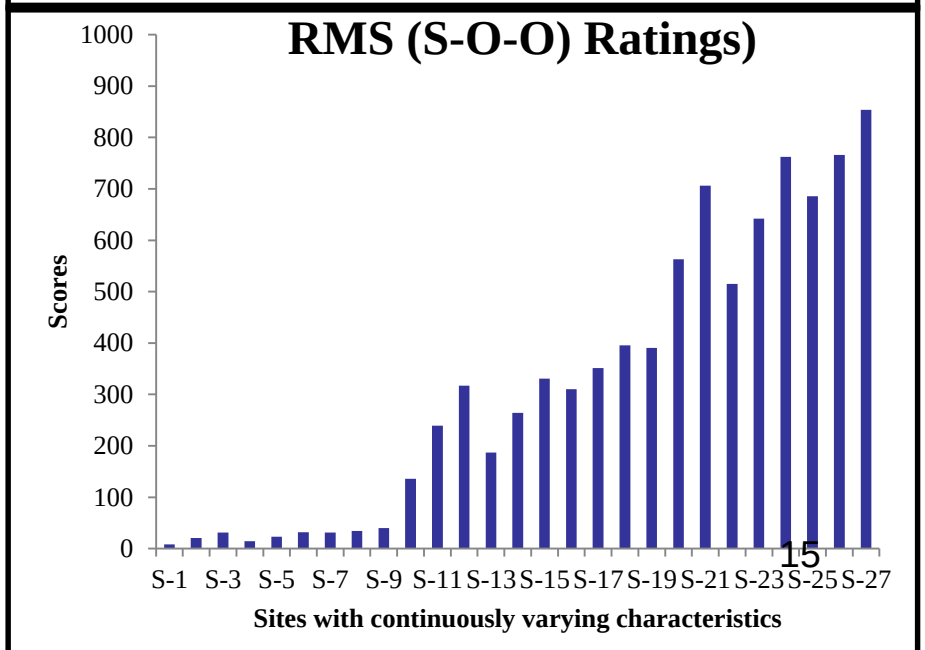


Eclipsed functions

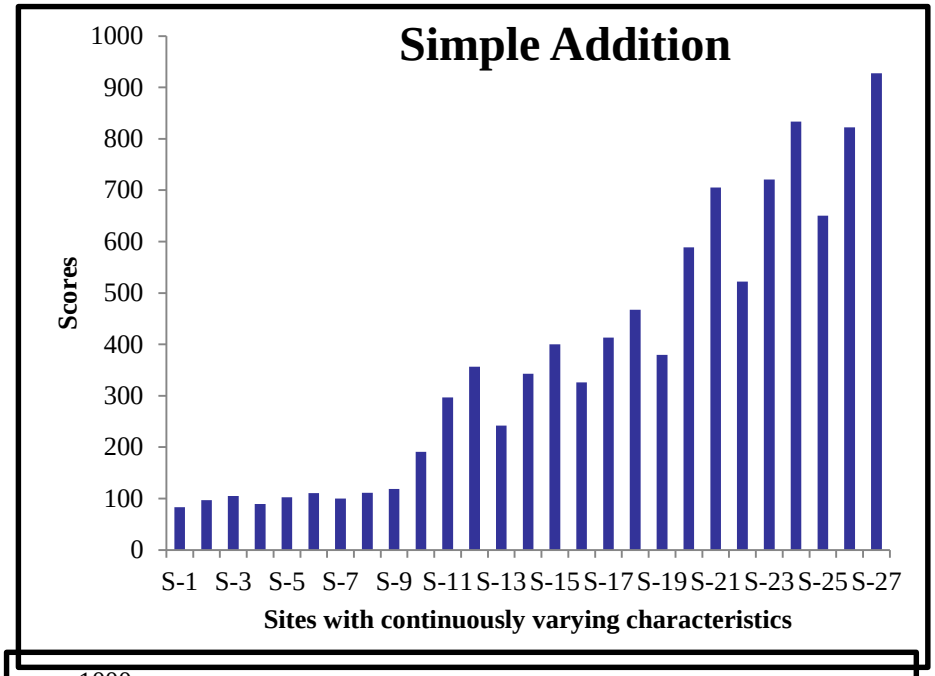


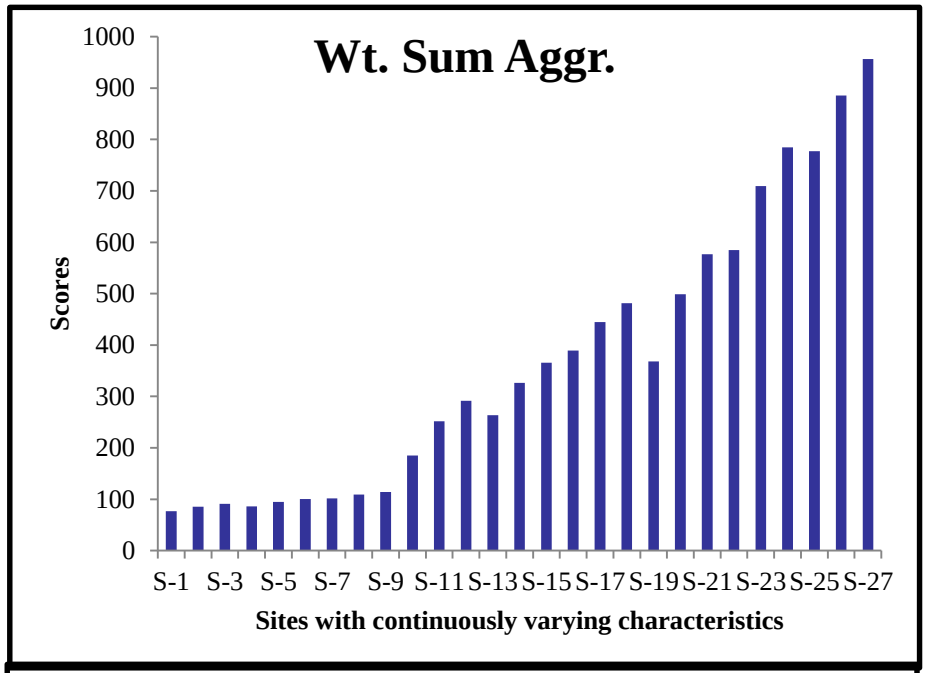


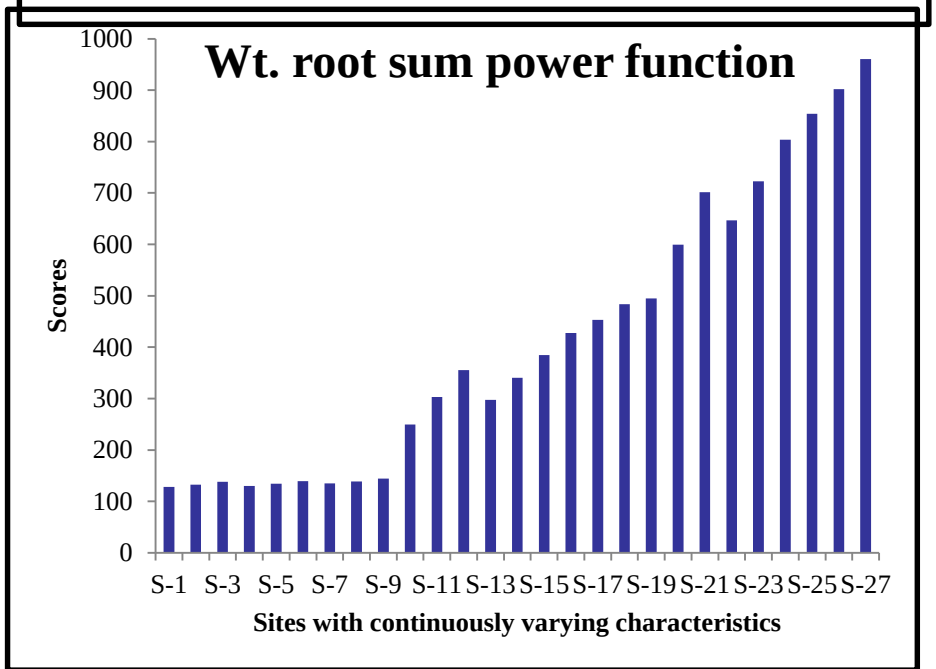


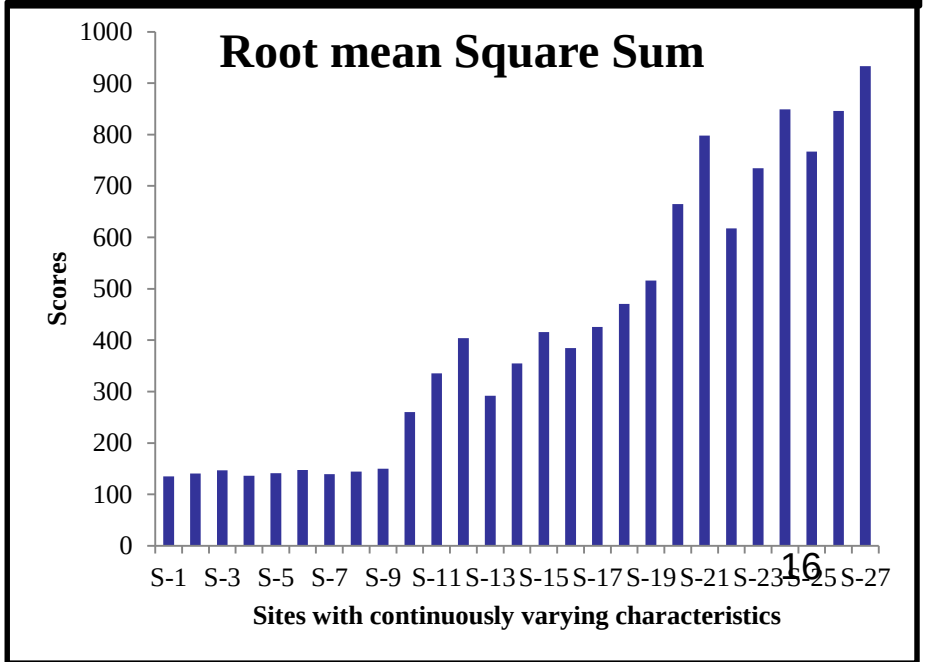


Non-ambiguous, non-eclipsed functions









Clustering index

Aggregation function	Clustering index
Weighted sum aggregation	0.477
Weighted root sum power function	0.483
Root mean square sum	0.433
Wt. ambiguity & eclipsity free r=0.4	0.477
Simple addition	0.437
CEPI Aggregation	0.506

Conclusions

- A large number of municipal waste disposal sites exist in India
  - Polluting the environment in a number of ways e.g. GW contamination, SW contamination and air contamination
  - Needs planning for remediation
  - Ranking may be one of the important means in planning
- The hazards posed by these dumps are of multiple types
  - Ranking should involve multiple hazards and be evolved as a composite ranking
  - For multiple hazards, an aggregation function is required.

Conclusions

- The study tried to find the suitable function for aggregation
  - The aggregation functions may suffer from ambiguity or eclipsity
  - Moreover, the aggregated ranking may be clustered or confined in a narrow range, defying the purpose of ranking.
- The aggregation functions from literature were first tested for ambiguity and eclipsity.
  - The functions suffering from ambiguity or eclipsity were discarded.
  - The functions selected after the above step were tested for clustering.
  - Root mean square function was finally selected as an aggregation function.

Dr. Amit Kumar
Email: amitkumar.ce@mnit.ac.in, amitrathi.ucf@gmail.com
Phone: +91-9654-14-0757
(Risk Assessment, Material flow and solid waste management)

Thank you