VOL. 16, NO. 24, DECEMBER 2021 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

MANAGEMENT OF MUNICIPAL SOLID WASTE OF UDAIPUR TOWN, TRIPURA, INDIA USING ANALYTICAL HIERARCHY PROCESS

Sukanta Chakraborty[1], Manish Pal[2], Kaberi Majumder[3] and Pankaj Kumar Roy[4]
[1]Department of Public Works, Govornment of Tripura, Tripura, India
[2]Department of Civil Engineering, National Institute of Technology Agartala, Tripura, India
[3]Department of Electrical Engineering, Tripura Institute of Technology Narsingarh, Tripura, India
[4]School of Water Resources Engineering, Jadavpur University, Kolkata, India
E-Mail: sukanta.chakra@gmail.com

ABSTRACT

Municipal Solid Waste management is an important part of modern city planning. Under the present scenario, the appropriate selection of treatment and disposal technique for Municipal Solid Waste management under multi-criteria decision making approach is a key factor for newly developed urban areas. In the study, an effort is made to ascertain the most suitable Municipal Solid Waste Management technique for the developing urban town named Udaipur of the state of Tripura, India through Analytical Hierarchy process under Multi-criteria decision making atmosphere. The study shows the Sanitary Landfilling which is the most appropriate technique for the urban body to dispose the municipal solid waste followed by Composting and Vermicomposting. This result interprets the rural bias of the study area.

Keywords: municipal solid waste, analytical hierarchy process, multi-criteria decision making.

INTRODUCTION

Municipal solid waste management is one of the major environmental problems of modern towns. Improper management of municipal solid waste (MSW) causes hazards to inhabitants. Studies have identified that about 90% of MSW is disposed unscientifically mainly in open dumps and landfills, creating problems to public health and the environment especially in developing and under developed countries. In urban areas, MSW clogs drains, creating water logging problem accelerating the suitability for insect breeding and floods during rainy seasons. Uncontrolled burning of MSW and improper incineration contributes significantly to urban air pollution. Greenhouse gases are liberated from the decomposition of organic wastes in uncontrolled landfills, and untreated leachate pollutes surrounding water bodies. Insect and rodent vectors are attracted to the waste and can spread diseases such as cholera and dengue fever. The U.S Public Health Service has identified 22 human diseases that are linked to improper municipal solid management. Waste workers and pickers in developing countries are often getting into direct contact of hazards of solid waste. The co-disposal of hazardous and medical wastes with MSW poses serious health threat to the unprotected waste workers and pickers. Exhaust fumes from waste collection vehicles, dust stemming from disposal practices and the open burning of waste also contribute to overall health index, where the people are not willing to pay for environmental improvements (Sharholy *et al*, 2008: Jha *et al*., 2003: UNDP, 2010: Singh *et al*., 2008; Jha *et al.*, 2011).

Recently solid waste management is becoming a major public health and environmental concern in urban areas of many developing countries. Several countries are imposing minimum priority on the issue and spending negligible portion of budgeted fund for disposal of MSW. In absence of requisite priority, the available legislations are also finding difficulties in their enforcement. Consequently, public sectors which are responsible for MSW management cannot take effective measures for efficient scientific disposal of generated MSW and inhabitants are exposed to the degraded environment. Constrained fund provision is resulting in indiscriminate dumping of MSW in the low lying areas of the cities exposing the people of that area to all the ill effects of unscientific MSW disposal. Thus effective disposal and treatment mechanism selection and enactment is the need of the hour and should be considered with utmost priority.
A number of alternatives are available for the disposal and treatment of municipal solid waste. The different techniques available for solid waste disposal have their respective merits and demerits. Thus the final selection of alternatives depends upon a number of factors. The individual alternative has to be judged against the available resource and problem condition. Employment of appropriate decision making technique is very important since such situations. The decision making system is generally classified under conditions of uncertainty, using linear programming; risk, using expected value and decision trees, depending on the degree with which the future environment determining the outcomes of these decisions is known (Salminen *et al.*, 1998). The Analytic Hierarchy Process (AHP), introduced by Thomas Saaty (1980), is an effective tool for dealing with complex decision makings, and may aid the decision maker to set priorities and make the best decision. In the present study, an effort is made to decide the most appropriate MSW disposal and treatment alternative among available ones for urban localities of Tripura (Costi *et al*., 2004).

STUDY AREA

Tripura is situated in the north-eastern part of India having its capital city at Agartala. Agartala city is presently upgrading into a smart city. Besides Agartala, there are some other towns in Tripura which are gathering pace to re-mould themselves into modern urban bodies.

VOL. 16, NO. 24, DECEMBER 2021 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

Udaipur (area 8.60 sq km) is one such ancient urban bodies of the state located in the southern region which is being upgraded very rapidly into well-equipped town. The local municipal authority has taken numerous plans & projects to uplift the infrastructural and socio-economical status of the town in a parallel way compared to Agartala city. The rapid growth of urban infrastructures leads to a gradual increase in the populations of the town. As a result, the pressure of efficient waste management system has increased a lot on the urban authorities in Agartala city as well as in this newly developed town. As the urban planning is in progress for this town, it is the best moment for selection of best possible alternative of waste management through MCDM framework. In the present study, the AHP tool is used to ascertain the best possible alternative of waste disposal for this town of Tripura.

Figure-1. Map showing the study area (Source: Tripura State Portal).

METHODOLOGY: ANALYTICAL HIERARCHY PROCESS

Analytical Hierarchy Process (AHP) has been applied as an effective tool to evaluate the importance weight of each parameter by performing the pair wise comparison of different parameters and attributes in case of multi-criteria decision making approach (MCDM) (Saaty 1980; Hill *et al.*, 2005; Marinoni, 2004; Thirumalaivasan *et al.*, 2003; Ying *et al.*, 2007; Chang *et al.*, 2001; Ramanathan, 2001). Saaty's (1980) 9-point scale as given in Table-1 is used to select the individual weightage of each parameter in evaluation process. The basic steps of AHP are as follows:

- A hierarchy of decision attributes is first developed and then interrelationships among these attributes are established.
- Pair-wise comparisons are performed to evaluate the relative weights of each attributes. Relative weights of all attributes are evaluated by normalizing each column of the "decision matrix".
- After obtaining relative weights for each attribute, the priority vector's scores are generated locally corresponding to the given hierarchy level and the final score of each criteria/alternative is evaluated. These scores suggest ranking of each criteria/alternative.
- Further the Consistency Ratio (CR) is checked to verify whether pair-wise comparisons are consistent enough or not. It is suggested that the CR must be less than or equal to 0.10 for inconsistency to be within the tolerable limit (Saaty, 1980).

Table-1. Saaty's original scale for pair-wise comparison (Saaty, 1980).

Intensity of importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	Intermediate values between the two adjacent judgments
3	Moderate importance	Experience and judgment slightly favor one activity over another
4	Moderate plus	Intermediate values between the two adjacent judgments
5	Strong importance	Experience and judgment strongly favor one activity over another
6	Strong plus	Intermediate values between the two adjacent judgments
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong	Intermediate values between the two adjacent judgments
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation
Reciprocals of above	If i^{th} activity has one of the above non-zero numbers assigned to it when compared with j^{th} activity, then j^{th} activity has the reciprocal value when compared with i^{th} one.	
1.1-1.9	If the activities are very close	May be difficult to assign the best value but when compared with other contrasting activities the size of the small numbers would not be too noticeable, yet they can still indicate the relative importance of the activities.

The criteria for identification of the suitable disposal measure among different alternatives are as follows:

a) **Infrastructure Development Fixed Cost (IDFC):** This criterion indicates the amount of fixed cost that will be incurred for development of infrastructures if a certain disposal alternative is adopted.

b) **Infrastructure Development Variable Cost (IDVC):** This indicates the amount of variable cost that will be incurred for development of infrastructures for a particular disposal alternative.

c) **Socio-Economic Benefit (SEB):** This criterion shows the advantageous Socio-Economic effects that may be created when a certain alternative is adopted.

d) **Environmental Benefit (EB):** Environmental Benefit includes the reduction of pollution load, up-gradation of land use pattern etc. under the heading of positive impacts.

e) **Socio-Economic Hazards (SEH):** This criterion will represent the hazards or negative impact that may be aggravated due to the implementation of a certain disposal alternative.

f) **Environmental Hazards (EH):** This criterion will show the degradation of natural resources and landscapes and probability of environmental pollution due to the introduction of a certain disposal alternatives.

g) **Technical Hazards (TH):** The disposal alternative that is to be adopted must be technically feasible. These criteria will depict the technical hazards or compromises that may be required to be adopted for the implementation of certain disposal option.

Considering the expert's opinion obtained by standard questioner, pair-wise comparisons of all attributes are performed using Saaty's scale. Here each of the attributes was rated relatively by the experts with respect to other attributes. The relative weights of the attributes are shown in the Table-2.

VOL. 16, NO. 24, DECEMBER 2021 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

Table-2. Normalized rating values of different attributes.

	IDFC	IDVC	SEB	EB	SEH	EH	TH	Weightage (W_a)
IDFC	X	0.870	0.778	0.889	0.667	0.625	0.435	0.609
IDVC	1.150	X	0.875	0.909	0.700	0.750	0.455	0.691
SEB	1.286	1.143	X	1.143	0.857	0.857	0.571	0.837
EB	1.125	1.100	0.875	X	0.750	0.750	0.500	0.729
SEH	1.500	1.429	1.167	1.333	X	1.000	0.667	1.014
EH	1.600	1.333	1.167	1.333	1.000	X	0.625	1.008
TH	2.300	2.200	1.750	2.000	1.500	1.600	X	1.621

RESULT AND DISCUSSIONS

As discussed in the earlier section, the normalized rating values of different attributes are calculated based on the expert opinion received through a survey. Now, the disposal techniques available are rated against each of the above mentioned attributes. The disposal methodologies adopted for the current study include sanitary landfilling (M_1), pyrolysis (M_2), incineration (M_3), composting and vermicomposting (M_4), open dumping and burning (M_5). Based on the expert survey and views, each of these disposal alternatives is rated against all the mentioned attributes for both the towns considered in the study. The normalized ratings of this analysis for Udaipur town are presented in Tables 3 to 10.

Table-3. Normalized rating values of disposal alternatives with respect to IDFC.

IDFC	M_1	M_2	M_3	M_4	M_5	Weightage
M_1	X	0.889	0.889	0.889	0.400	0.613
M_2	1.125	X	1.000	1.000	0.455	0.716
M_3	1.125	1.000	X	1.000	0.455	0.716
M_4	1.125	1.000	1.000	X	0.500	0.725
M_5	2.500	2.200	2.200	2.000	X	1.780

Table-4. Normalized rating values of disposal alternatives with respect to IDVC.

IDVC	M_1	M_2	M_3	M_4	M_5	Weightage
M_1	X	0.875	0.875	1.000	0.375	0.625
M_2	1.143	X	1.000	1.143	0.429	0.743
M_3	1.143	1.000	X	1.143	0.429	0.743
M_4	1.000	0.875	0.875	X	0.375	0.625
M_5	2.667	2.333	2.333	2.667	X	2.000

Table-5. Normalized rating values of disposal alternatives with respect to SEB.

SEB	M_1	M_2	M_3	M_4	M_5	Weightage
M_1	X	1.000	0.875	1.000	0.375	0.650
M_2	1.000	X	0.875	1.000	0.375	0.650
M_3	1.143	1.143	X	1.143	0.429	0.772
M_4	1.000	1.000	0.875	X	0.375	0.650
M_5	2.667	2.667	2.333	2.667	X	2.067

Table-6. Normalized rating values of disposal alternatives with respect to EB.

EB	M_1	M_2	M_3	M_4	M_5	Weightage
M_1	X	0.833	0.778	0.500	0.222	0.467
M_2	1.200	X	0.875	0.750	0.250	0.615
M_3	1.286	1.143	X	1.167	0.250	0.769
M_4	2.000	1.333	1.167	X	0.286	0.957
M_5	4.500	4.000	4.000	3.500	X	3.200

Table-7. Normalized rating values of disposal alternatives with respect to SEH.

SEH	M_1	M_2	M_3	M_4	M_5	Weightage
M_1	X	0.875	0.667	0.625	0.333	0.500
M_2	1.143	X	0.842	0.842	0.429	0.651
M_3	1.500	1.187	X	0.909	0.500	0.819
M_4	1.600	1.187	1.100	X	0.500	0.877
M_5	3.000	2.333	2.000	2.000	X	1.867

Table-8. Normalized rating values of disposal alternatives with respect to EH.

EH	M_1	M_2	M_3	M_4	M_5	Weightage
M_1	X	0.857	0.857	1.143	0.455	0.662
M_2	1.167	X	1.000	1.333	0.400	0.780
M_3	1.167	1.000	X	1.333	0.400	0.780
M_4	0.875	0.750	0.750	X	0.375	0.550
M_5	2.200	2.500	2.500	2.667	X	1.973

Table-9. Normalized rating values of disposal alternatives with respect to TH.

TH	M_1	M_2	M_3	M_4	M_5	Weightage
M_1	X	0.857	0.857	1.152	0.556	0.684
M_2	1.667	X	1.000	1.333	0.667	0.933
M_3	1.167	1.000	X	1.333	0.667	0.833
M_4	0.868	0.750	0.750	X	0.667	0.607
M_5	1.800	1.500	1.500	1.500	X	1.260

Table-10. Decision making matrix and ranking of alternatives.

	IDFC	IDVC	SEB	EB	SEH	EH	TH	NW	RANK
W_a	0.609	0.691	0.837	0.729	1.014	1.008	1.621		
M_1	0.691	0.625	0.867	0.556	0.550	0.657	0.686	0.583	1
M_2	0.837	0.743	0.600	0.650	0.657	0.800	0.933	0.705	3
M_3	0.729	0.743	0.718	0.772	0.800	0.800	0.833	0.730	4
M_4	1.014	0.625	0.600	0.650	0.800	0.550	0.575	0.597	2
M_5	1.008	2.000	1.933	3.200	1.800	1.800	1.350	1.751	5

CONCLUSIONS

The present study encompasses the application of MCDM technique into the waste management procedure to make the process more versatile. This will ensure the efficiency of the waste management technique as it is largely based on the stakeholder opinion. The study is made to determine the most appropriate process of municipal solid waste treatment and disposal technique for Udaipur town of the state of Tripura. The results of the AHP analysis show that the sanitary landfilling is the most appropriate technique for disposal. The study can further be extended for other urban localities of Tripura which are presently in developing or under planning stage to initiate sustainable development.

REFERENCES

Arvind k. Jha, A.K., Singh S.K., Singh G.P., Gupta P.K. 2011. Sustainable municipal solid waste management in low income group of cities: A review. International Society for Tropical Ecology. 52(1): 123-131.

Chang Yu-Hern., Yeh Chung-Hsing. 2001. Evaluating airline competitiveness using multi attribute decision making. Omega. 29(5): 405-415.

Costi P., Minciardi R., Robba M., Rovatti M. & Sacile R. 2004. An environmentally sustainable decision model for urban solid waste management. Waste management. 24(3): 277-295.

Hill M. J., Braaten R., Veitch S. M., Lees B. G., Sharma S. 2005. Multi-criteria decision analysis in spatial decision support: the ASSESS analytic hierarchy process and the role of quantitative methods and spatially explicit analysis. Environmental modelling & software. 20(7): 955-976.

Jha M.K., Sondhi O.A.K., Pansare M. 2003. Solid waste management - a case study. Indian Journal of Environmental Protection 23(10): 1153-1160.

Marinoni O. 2004. Implementation of the analytical hierarchy process with VBA in ArcGIS. Computers & Geosciences. 30(6): 637-646.

Ramanathan R. 2001. A note on the use of the analytic hierarchy process for environmental impact assessment. Journal of environmental management. 63(1): 27-35.

Saaty T. L. 1980. The Analytic Hierarchical Process. New York: McGraw-Hill. 841.

Salminen P., Hollanen J., Lahdelma R. 1998. Comparing multicriteria methods in the context of environmental problems. European Journal of Operational Research. 104, 485-496.

Sharholy M., Ahmad K., Mahmood G., Trivedi R.C. 2008. Municipal solid waste management in Indian cities - A review. Journal of Waste Management. 28: 459-467.

Singh A. P., Vidyarthi A. K. 2008. Optimal allocation of landfill disposal site: A fuzzy multi-criteria approach. Iranian Journal of Environmental Health Science & Engineering. 5(1): 25-34.

Thirumalaivasan D., Karmegam M., Venugopal K. 2003. AHP-DRASTIC: software for specific aquifer vulnerability assessment using DRASTIC model and GIS. Environmental Modelling & Software. 18(7): 645-656.

UNDP, 2010. Regional Human Development Report for Latin America and the Caribbean, 2010. United Nations Development Programme, Costa Rica.

Ying X., Zeng G.M., Chen G.Q., Tang L., Wang K.L., Huang D.U. 2007. Combining AHP with GIS in synthetic evaluation of eco-environment quality-a case study of Hunan Province, China. Ecological Modelling. 209(2): 97-109.