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Evaluation of Waste Management Practices of Health Care Units: A Graph Theoretic and Matrix

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Abstract— The present research has used Graph Theory Matrix and Approach (GTMA) to evaluate Health Care Waste Management(HCWM) index. This index will be an indication of the degree of effectiveness of HCWM practices in the HCU's. Responses collected through a questionnaire based survey was used to develop a GTMA model to evaluate Waste management Index(WMI). A frame work also has been proposed to calculate theoretical best and worst value of WMI. The WMI of any HCU could be compared with theoretical best and worst values of WMI to check its closeness to these values. If the WMI value of any organization is closer to best value in comparison to the worst value then it could be inferred that the HCU is doing good in managing its waste. The WMI value would help HCUs in identifying the weaker areas of HCWM practices of their organization.

Index terms: Health Care Waste Management(HCWM), Graph Theory Matrix and Approach (GTMA), Health Care Unit(HCU)

I. INTRODUCTION

Healthcare waste (HCW) or medical wastes are the discarded or unusable items derived from any category of healthcare facilities which are originated through their usual course of activities and it usually contributes a small percentage by weight to the municipal solid waste (MSW) streams[1]. The sources of healthcare waste are classified into two groups as major or minor according to the quantities of waste production. Major sources of HCWM includes Waste produced from Government hospitals, nursing homes, dispensaries, private hospitals, paramedical services and from research centers, Primary health centers, Blood banks, mortuaries and autopsy centers, Veterinary colleges and animal research centers and Biotechnology institutions. The minor sources of HCWM include Waste from physicians and dentists clinics, blood donation camps and vaccination centers.Study conducted by World Health Organization in 2015 reveals that only 15% of total waste generated from health care establishments, exhibit hazardous characteristics[2]. These wastes are called hazardous waste which is further categorized on the basis of its risk of causing infection and injury during its management process. Contaminated blades, needles, dressings, pathological waste, materials contaminated with blood or body fluids, anatomical body parts, microbiological cultures, instruments containing mercury, radioactive wastes etc fall under this hazardous waste category[3]. It has been observed due to defective implementation of regulations and dearth of awareness, supplied color coding drums are misused and unfair source segregation system is followed. It leads conversion of non-infectious waste to Infectious and thus hampers the utilization of treatment and recycling opportunity of HCW[4].The wastes generated by the healthcare sector leave permanent effects in the air, water and earth thus posing serious environmental risks with the additional hazards of injection agents and viruses[5]. HCW contains large amounts of (Organic Solid Waste) OSW, which are estimated as the main sources of leachates. Besides, it contains a minor but significant quantity of chemicals and drugs which act as a great source of (terrestrial ecotoxicity)TET potential if it is disposed of unfair way. Moreover, illegal disposal of large volume of OSW, even landfills is liable for leachate emissions which contribute in the TET potential. Fresh water aquatic ecotoxicity (FWAET) occurs due to the transfer of toxic substances to fresh water aquatic ecosystems from HCWM system such as dumping and land filling. Human toxicity reflects the impacts on human health of toxic substances, e.g. dioxins and heavy metal(HM). Dioxins as well as HMs(e.g.,Hg,Pb,Cd) are particularly toxic air emissions generated by HCW open burning and incineration. India is a developing country and its population and economic growth is very fast. As a result, their environmental foot print is accelerating day to day. In contrast, environmental conscious among mass people is growing up. So government has strengthened existing regulations and still continued. International donors and buyers are giving pressure to government and industrial owners to improve environmental condition.

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Hence, management of HCUs are searching for better technology to find out associated environmental burdens with their process and wastes along with substitute techniques to reduce environmental pollution.

HCWM implementation is a complex task and its success is challenged by many factors. One of the important factor is lack of indicators to measure the effectiveness of the HCWM practices. In this regard an attempt has been made in this paper to develop a waste management index(WMI) which will indicate the degree of success of the HCWM practices of any HCU. This research employed graph theoretic and matrix approach(GTMA) to evaluate WMI for any HCU.

II. LITERATURE REVIEW

Romero and Carnero[6] developed a framework using AHP to carryout environmental impact assessment in Spanish health care units. Their model considered twelve indicators for environmental impact assessment which are further categorized into three major factors such as ‘environmental performance’, ‘environmental management’ and ‘environmental situation’.

Delmonico et al.,[7] investigated challenges experienced by Brazilian HCUs during management of their waste. This study identified 12 factors and categorized them under three major barriers, ‘infrastructural’, ‘human factors’ and ‘management’.

Study by Gunawardana,[8] on waste management practices in Colombo’s health care units identified 10 factors that influence effectiveness of waste management practices. The empirical study analyzed data collected from 156 hospitals and revealed that positive attitude of staff towards waste management practices could improve environmental performance of HCUs.

Duane et al.,[9] Studied waste management issues in British dental hospitals. This study highlighted the types of waste generated and proposed several ways to improve the waste management practices. The study also identified few factors that encourage success of waste management practices.

Doylo et al.,[10] assessed knowledge and practices of staffs of health care organizations of Ethiopia towards management waste. The study employed multivariable logistic regression model and revealed that 47.7% of the health care staffs demonstrate good knowledge while 42.3% exhibit good practices of waste management.

Eren and Tuzkaya,[5] evaluated the risk of occupational health hazards associated with different stages of waste management practices in the HCUs of Turkey. They identified three major steps of waste management process as ‘collection’, ‘temporary storage’ and ‘transportation’ and employed AHP to evaluate the potential transmission of infectious diseases to health care workers based on the responses collected from the health care staffs.

Scanning of theses past literatures reveal that none of the studies have attempted to evaluate the effectiveness of Waste Management practices.

From the literature we identified 12 indicators to evaluate waste management practices which are further categorized into 3 major categories as shown in the table below.

Table:1 Waste Management Indicators

Waste Management Indicators		Contributors
WR	**Waste Reduction**	
WR_1	Management of stock levels	[9]
WR_2	Green purchasing	[6],[9],[11]
WR_3	Reducing the impact of nitrogen	[6]
WR_4	waste audit	[6]
R	**Recycling**	
R_1	Use of reusable instruments	[6],[9]
R_2	waste segregation	[6],[11],[12],[13]
R_3	Energy production from food waste	[6]
R4	Composting	[6]
WTD	**Waste Treatment and Disposal**	
WTD_1	Incineration	[11],[12],[13]
WTD_2	Autoclaving	[8]
WTD_3	Chemical disinfection	[8]
WTD_4	Dumping/Land filling	[8]

III. METHODOLOGY & RESULTS

The present research has used Graph theory matrix approach (GTMA) to evaluate HCWM index. This index will be an indication of the degree of effectiveness of HCWM practices in the HCU’s. GTMA keeps up the hierarchical structure and simultaneously use interdependencies between attributes. It is a consistent, systematic and versatile tool that being used in numerous applications was started from combinatorial mathematics. Graph theory matrix approach helps to evaluate and recognize the system as a whole by distinguishing framework and sub-framework up to the section or part level. It helps in choosing the most appropriate decision from among an enormous number of choices for a given issue. The graphs are utilized to signify practically any physical circumstance including discrete articles and relationship among them. A graph is utilized to characterize the factors and their interdependencies in the form of nodes and edges. Matrices produce an easy and refined means of demonstrating digraph, as it provides one-to-one demonstration. The perpetual of a matrix is utilized to describe setups of a framework or the structure of a graph and to build up a distinctive depiction, that is free of labeling. It is a systematic and intelligent multi criteria decision making methodology and has been utilized for the evaluation purposes in earlier researches. The propelled hypothesis of GTMA have been utilized for modeling and investigation of different systems, and demonstrated to be choice by deciding material appropriateness index.

Muduli et al.,[14] distinguished and ranked the barriers to GSCM in mining industries in India. GTMA is used to evaluate sustainable supply chain for medium and small scale industries[15]. This approach is utilized to determine maximum and minimum cost efficiency index for remanufacturing[16]. Supply chain management environmental index is developed and assessed by using this approach[17]. In GTMA, nodes and edges are two essential components which are utilized for representing correlation among nodes as directional graph (digraph). Here nodes represent as selection attribute. Selection attribute is characterized as a factor that sways the alternative best selection judgment.

A. Model Development Using GTMA

Graph theory examines and comprehend the framework in general by distinguishing the framework and subsystem up to the part level. That's why it has been used as multipurpose model in wide applications[18]. The mathematical model created by graph theoretic approach considers both the influence of features itself and the degree of reliance among the features. Representation of the digraph is suitable for modeling and graphical assessment whereas representation of matrix is suitable for evaluating the digraph model. In this model the system is characterized by permanent function. Its index depicts the exceptional number helpful for correlation, level ranking and determination of optimum combination. The GTMA is classified into three sections.

(i) Representation of digraph
(ii) Representation of matrix
(iii) Representation of permanent function

Representation of digraph: Performance factors and their interrelationships are represented by using a digraph in terms of edges and nodes. Direction is not assigned in an undirected graph to the edges whereas or digraphs or directed graphs are assigned with directional edges. The digraph or directed graph contains a set of nodes P = {pi} with i=1, 2… M and a set of directed edges E= {nij}. A node pi signifies ith parameter and edges signifies the interrelationships between factors. The total number of nodes, M = Number of factors taken for the system. If a node i has comparative importance over another node j, then a directed edge or arrow is drawn from node i to node j (nij). If a node j is having relative importance over i, then a directed edge or arrow is drawn from node j to node i (nji) [19-22]. The digraph becomes more difficult when the number of nodes and their relative importance increases. Experts, from both academia and industry, have been consulted in identifying and developing the appropriate relationship between the factors. The digraph is useful in envisaging the relative importance effortlessly and quickly. Digraph is converted into a square matrix, known as relative importance matrix in which the off-diagonal factors characterize the relative importance of one attribute over another. The following elements or factors are taken into consideration as nodes in this research which has been utilized in Graphical representation:

Node 1- Waste Reduction(WR); Node 2- Recycling (R); Node 3- Waste Treatment and Disposal (WTD)

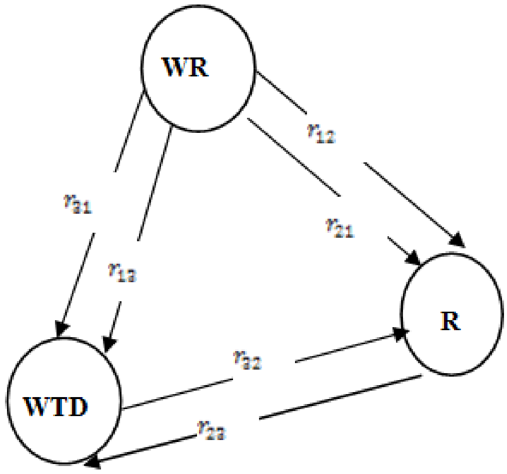

Figure-1: WMI Diagraph

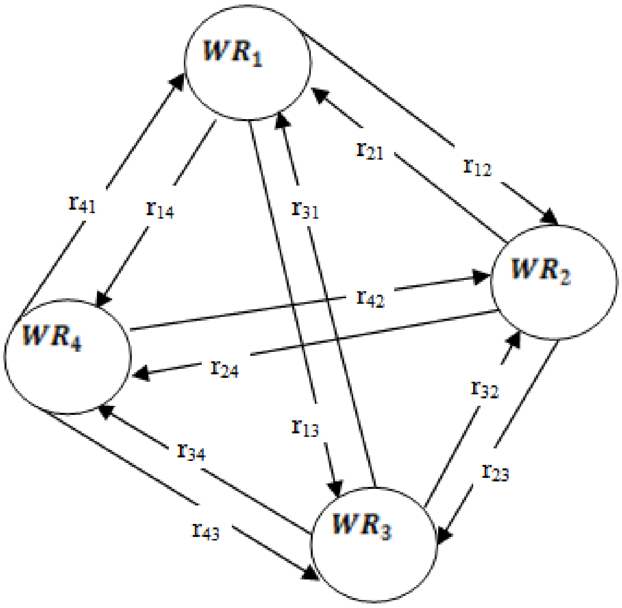

Figure 2: Diagraph for Attribute Waste Reduction(WR)

Representation of matrix: As the number of nodes increases, the matrix representation of a digraph is framed to reduce its complicacy and also matrix representation of selection criteria digraph presents a one-to-one correlation among attributes and their comparative importance. When the digraph consists of M nodes, the attribute's matrix is of size M ×M. The attributes are represented as diagonal factors Wi and the comparative importance between attributes is depicted as off diagonal factors . The relative importance values of the attributes could be selected from the table-2 as suggested by Muduli et al.,[14]. The matrix for WMI digraph-1 is given below. Similarly, the diagraph of attribute Waste Reduction(WR) could be represented as the matrix WR.

$$WMI = \begin{pmatrix} WR & r_{12} & r_{13} \\ r_{21} & R & r_{23} \\ r_{31} & r_{32} & WTD \end{pmatrix} \qquad \ldots\ldots\ldots\ldots.(1)$$

$$WR = \begin{pmatrix} WR_1 & r_{12} & r_{13} & r_{14} \\ r_{21} & WR_2 & r_{23} & r_{24} \\ r_{31} & r_{32} & WR_3 & r_{34} \\ r_{41} & r_{42} & r_{43} & WR_4 \end{pmatrix} \text{..........(2)}$$

Table 2: Relative Importance of Attributes (r_{ij})

Class Description	Relative Importance of Attributes	
	r_{ij}	r_{ji} = 10- r_{ij}
Two attributes are of equal importance	5	5
One attribute is slightly important	6	4
One attribute is very important over The other	7	3
One attribute is most important over the other	8	2
One attribute is extremely important over the other	9	1
One attribute is exceptionally important over the other	10	0

Representation of permanent function: Permanent is a typical matrix function and is utilized to find the solution using combinatorial analysis[23]. The diagonal factors or variables denote the specific importance of attributes to the structure or inheritance. If in the structure, the matrix will vary with varying in number of attributes, a typical method of matrix function called as permanent function is calculated rather than the matrix from the determinant. Permanent function matrix is similar to determinant. The permanent function as well as the determinant, is a polynomial in the entries of matrix [22],[24]. These both are important cases of a general function of a matrix. It may possible that some information may be lost in case of determinant function of a matrix due to the presence of negative signs. Therefore researchers and scholars favored to consider the permanent function of advantageous to sort out real life problems in the area of science and technology [24-26] used GTMA for material a matrix for considering the entire information without any ignorance[19].

In our research 3 major indices considered and each index include 4 factors. Hence, each index could be represented by a 4×4 matrix. Evaluation of each index requires calculation of permanent of a 4×4 matrix. Hence, the general expression for permanent evaluation could be rewritten for a 4×4 factor matrix with diagonal elements as Wi and off-diagonal elements as given in equation 3.

Per(W)=

$$\prod_{i=1}^{4} W_i + \sum_i \sum_j \sum_k \sum_l r_{ij} r_{ji} W_k W_l + \sum_i \sum_j \sum_k \sum_l (r_{ij} r_{jk} r_{ki} + r_{ik} r_{kj} r_{ji}) W_l + [\ \sum_i \sum_j \sum_k \sum_l (r_{ij} r_{ji})(r_{kl} r_{lk}) + \sum_i \sum_j \sum_k \sum_l (r_{ij} r_{jk} r_{kl} r_{li} + r_{il} r_{lk} r_{kj} r_{ji})]$$

IV. RESULTS AND DISCUSSION

This research employed GTMA tool to evaluate the waste management index(WMI). The development of matrix is based on the responses collected from health care staffs. To collect responses from health care staffs a questionnaire based survey was conducted. A closed end questionnaire with 12 items was provided to the respondents. The respondents were requested to provide weigh each of the elements in a scale of 5. The average value of the respondents score was used to find the value of any attribute and the relative importance was selected from table-2. The respondents working in health care units of Odisha were selected for this study. Our sample comprises of respondents working in various fields such Doctors, Nurses, Lab technicians and Waste administrators. The matrix for each of the attributes were developed using the average score of respondents for the constituent elements of that attribute and values provided in table-2. Then Using equation 3 permanent value of each index is calculate as follows.

$$\text{Per}\ (WR_1) = \begin{pmatrix} 4 & 5 & 8 & 7 \\ 5 & 4 & 9 & 7 \\ 2 & 1 & 2 & 4 \\ 3 & 3 & 6 & 3 \end{pmatrix} = 6717, \text{..............................(4)}$$

$$\text{Per}\ (R_1) = \begin{pmatrix} 3 & 4 & 6 & 6 \\ 6 & 4 & 7 & 7 \\ 4 & 3 & 2 & 5 \\ 4 & 3 & 5 & 2 \end{pmatrix} = 8366, \text{..............................(5)}$$

$$\text{Per}\ (WTD_1) = \begin{pmatrix} 3 & 3 & 3 & 6 \\ 7 & 4 & 5 & 8 \\ 7 & 5 & 4 & 8 \\ 4 & 2 & 2 & 2 \end{pmatrix} = 7434, \text{........................(6)}$$

Finally, the values of each index and their interrelationship matrix could be represented as given below.

WMI=Per (W)

$$= \begin{pmatrix} 6717 & 3 & 4 \\ 7 & 8366 & 6 \\ 6 & 4 & 7434 \end{pmatrix} = 4177.5\times 10^8, \text{.......(7)}$$

The theoretical best and worst values of WMI also could be calculated as given below.

$WMI_{best} =$

$$\begin{pmatrix} 15000 & 5 & 5 \\ 5 & 15000 & 5 \\ 5 & 5 & 15000 \end{pmatrix} = 3375.0 \times\times 10^9, \text{.............(8)}$$

WMI_{Worst}

$$= \begin{pmatrix} 6776 & 5 & 5 \\ 5 & 6776 & 5 \\ 5 & 5 & 6776 \end{pmatrix} = 3111.15 \times\times 10^8, \text{...........(9)}$$

V.CONCLUSION

Health care units generate several kinds of waste materials during the process of offering health care services. With the advancement of technology and the changing life style of people the quantity and risk associated with health care waste also has grown significantly. Despite of attempts at several levels, governments, NGOs, research organisations and HCUs a little success has been attained in managing these wastes properly or controlling the environmental and health hazards caused by these health care waste. One significant step in this regard would be to develop a technique to measure the degree of success of waste management practices. This research proposed a framework to calculate WMI that would represent the degree of effectiveness of the waste management practices as a numerical value. The research further proposed techniques to evaluate theoretical best and worst value of WMI. The WMI of any HCU could be compared with theoretical best and worst values of WMI to check its closeness to these values. If the WMI value of any organization is more closer to best value in comparison to the worst value then it could be inferred that the HCU is doing good in managing its waste.

REFERENCES

1. Hossain MM, Alam O. 2013. A deeper look into the inner factors associated to healthcare waste management in Chittagong – the commercial capital of Bangladesh. Proceedings of Sardinia 2013, Fourteenth International Waste Management and Landfill Symposium S. Margherita di Pula, Cagliari, Italy; 30 September – 4 October 2013.
2. Santos, E. D. S., Gonçalves, K. M. D. S., & Mol, M. P. G. (2019). Healthcare waste management in a Brazilian university public hospital. Waste Management & Research, 37(3), 278-286.
3. Khan, B. A., Cheng, L., Khan, A. A., & Ahmed, H. (2019). Healthcare waste management in Asian developing countries: A mini review. Waste Management & Research, 0734242X19857470.
4. Alam O, Hossain AKhME, Hossain MM. 2013. Climate change adaptation and healthcare waste effect on it in Chittagong metropolitan area of Bangladesh. International Conference on Climate Change Impact and Adaptation, 15-17 Nov, 2013, DUET, Gazipur, Bangladesh.
5. Eren, E., & Tuzkaya, U. R. (2019). Occupational health and safety-oriented medical waste management: A case study of Istanbul. Waste Management & Research, 734242X19857802.
6. Romero, I., & Carnero, M. C. (2019). Environmental assessment in health care organizations. Environmental Science and Pollution Research, 26(4), 3196-3207.
7. Delmonico, D. V. D. G., Santos, H. H. D., Pinheiro, M. A., de Castro, R., & de Souza, R. M. (2018). Waste management barriers in developing country hospitals: Case study and AHP analysis. Waste Management & Research, 36(1), 48-58.
8. Gunawardana, K. D. (2018). An analysis of medical waste management practices in the health care sector in Colombo. Management of Environmental Quality: An International Journal, 29(5), 813-825.
9. Duane, B., Ramasubbu, D., Harford, S., Steinbach, I., Swan, J., Croasdale, K., &Stancliffe, R. (2019). Environmental sustainability and waste within the dental practice. British dental journal, 226(8), 611-618
10. Doylo, T., Alemayehu, T., & Baraki, N. (2019). Knowledge and practice of health workers about healthcare waste management in public health facilities in Eastern Ethiopia. Journal of community health, 44(2), 284-291.
11. Mishra, S.S., Muduli, K., Dash, M.R, Paridaa, U.C. & Pumwa, J.(2018) When Sustainable Development Matters in Health Care Supply Chain: An analysis of Influential Factors of Waste Management, Indian Journal of Public Health Research & Devdopment, Vol. 9 No. 12, pp 229-236.
12. Mishra, S.S., Muduli, K., Dash, M.R,, & Yadav, D.K.. (2018). PROMETHEE-Based Analysis of HCWM Challenges in Healthcare Sector of Odisha. Smart Innovation, Systems and Technologies , volume 77, pp. 163-170.
13. Muduli K, Barve A. (2012). Barriers to Green Practices in Health Care Waste Sector: An Indian Perspective. International Journal of Environmental Science and Development. 3(4), 393-399.
14. Muduli, K., Govindan, K., Barve, A., & Geng, Y. (2013). Barriers to green supply chain management in Indian mining industries: a graph theoretic approach. Journal of Cleaner Production, 47, 335-344.
15. Faisal, M. N. (2012). Sustainability metrics for a supply chain: the case of small and medium enterprises. International Journal of Services and Operations Management, 13(3), 392-414.
16. Sabharwal, S., & Garg, S. (2013). Determining cost effectiveness index of remanufacturing: A graph theoretic approach. International Journal of Production Economics, 144(2), 521-532.
17. Gupta, T. K., & Singh, V. (2015). A systematic approach to evaluate supply chain management environment index using graph theoretic approach. International Journal of Logistics Systems and Management, 21(1), 1-45.
18. Singh, M., Khan, I. A., & Grover, S. (2011). Selection of manufacturing process using graph theoretic approach. International Journal of System Assurance Engineering and Management, 2(4), 301-311.
19. Rao, R. V., & Padmanabhan, K. K. (2006). Selection, identification and comparison of industrial robots using digraph and matrix methods. Robotics and Computer-Integrated Manufacturing, 22(4), 373-383.
20. Muruganandham, R., Md. R. Basha, A. Venkatesh, K.Sathish (2018).Applying Graph Theory Matrix Approach method to identify the major influencing factor for customer preferences in construction industry, International Journal of Pure and Applied Mathematics, 118 (20), 185-201
21. Rao, R. V., & Gandhi, O. P. (2002). Digraph and matrix methods for the machinability evaluation of work materials. International Journal of Machine Tools and Manufacture, 42(3), 321-330.
22. Geetha, N.K.& Sekar, P. (2016). Graph theory matrix approach–a review. Indian Journal of Science and Technology, 9(16), 1-4.
23. Jurkat, W.B., Ryser , H.J., 1966. Matrix factorization of determinants and permanents. Journal of Algebra 3
24. Jain, V., & Raj, T. (2016). Modeling and analysis of FMS performance variables by ISM, SEM and GTMA approach. International journal of production economics, 171, 84-96.
25. Rao RV. (2007). Decision making in the manufacturing environ-ment: using graph theory and fuzzy multiple attribute deci¬sion making methods, fourth edn. Springer: London.
26. Agrawal, S., Singh, R. K., & Murtaza, Q. (2016). Outsourcing decisions in reverse logistics: sustainable balanced scorecard and graph theoretic approach. Resources, Conservation and Recycling, 108, 41-53

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