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ASSESSMENT OF HAZARDOUS WASTE MANAGEMENT PROPOSAL: USING THE ANALYTIC HIERARCHY PROCESS

Mohsin Ali
School of Management & Economics (SME),
University of Electronic Science and Technology of China (UESTC), China
&
International Islamic University, Islamabad, Pakistan
mohsinali757@gmail.com

Amit Yadav
School of Management & Economics (SME),
University of Electronic Science and Technology of China (UESTC), China
amitaryan2u@yahoo.com

Maira Anis
School of Management & Economics (SME),
University of Electronic Science and Technology of China (UESTC), China
maira7pk@hotmail.com

Abstract

Rapid change in technology, increased disposable products either in electronic stuff or daily used items, in result increased waste production. The waste that can affect any sort of life either human beings, plants or sea life known as hazardous waste. The current era of technology affected the quantity of hazardous waste in all over the USA (United State of America). However, it is not an easy task for the government of USA to prepare well managed hazardous waste proposal because the citizens, professionals and other concerned parties have their own expectations which are difficult to come up with at a once. Even it is impossible to satisfy all concern parties, it is preferred to have proposals conforming to the interest of the bulk and beneficial to the present and future generation. This paper adopts the AHP (Analytical hierarchy process)to give the most sustainable design proposal of hazardous waste. AHP is a robust

MCDM (multi-criteria decision making) method for solving decision making problems in different sectors such as social, government and corporate. From our findings, we found that northeast region which ranked top on overall regions and Maine State is ranked top in all states of USA, which need to take in consideration for sustainable hazardous waste management. It is also recommended that other MCDM methods can also be applied to get comparative results. This paper helps to give the sustainable hazardous waste proposal with the help of AHP, so that this proposal can be used for the improvement of hazardous waste management.

Keywords: Hazardous waste, AHP, Multi-criteria decision making, Proposal, USA

INTRODUCTION

Hazardous waste is any type of unwanted material, the disposal of which causes a threat to the environment, i.e. it is explosive, flammable, poisonous, oxidizing, infectious, radioactive, corrosive and/or toxic. There are different sources of hazardous waste such as industrial waste, hospitals, timber treatment, petrol storage, metal finishing, paint manufacturing etc. These wastes can be treated chemically (i.e. by neutralization, oxidation, reduction, hydrolysis, precipitation), physically (i.e. encapsulation, separation), biologically using microorganisms or thermally by incineration. From those waste, most treated waste is then deposited in landfills. In 21st century, hazardous waste is one of the biggest problems facing by world as well as it is also one of the major causes for global warming. USA is one of the developed countries facing lot of challenges regarding hazardous waste management. In recent years, politicians and the public have become cognizant of the menaces of hazardous waste to the environment and to the population due to the problem of contaminated places and related health problems. Even in small quantities, hazardous substances in waste can have a very negative impact on the environment. There are lots projects have been conducted on waste but many of them fail to achieve their goals and generate environmental and social problems in the community (Ng et al. 2001; Chui 2003).There are some people argue that hazardous waste management is not well managed and due to this there are environmental concerns. Therefore, the respective authorities and the concerned parties attempt to improve the design of the proposal by promoting sustainability concept (Fung 2001). From this research it is to be believed that in future this proposal can give better achievement by managing hazardous waste. Even it is hard task for the government to give appropriate hazardous waste management proposal accomplishing sustainable development objectives even though intends to do so and has made great effort. A lot of tradeoff decisions have to be made because to determine sustainable hazardous waste management proposal is a difficult and complicated process.

Well-handled concerns of surrounding environment either in land, water or air, no threat to life leads us not to execute any site remediation, if the hazardous content at industrial, commercial and agricultural sites were properly handled, stored, transported and/or disposed of. With this concept in mind, this research is conducted to propose hazardous waste management proposal for achieving pollution prevention, well managed hazardous waste and all lives including human health protection in United States. Due to rapid development and improvement of various industrial technologies, products and practices frequently increase the production rate of hazardous waste. In order to ensure that the final proposal on hazardous waste is winning over, systematic and sophisticated method to make tradeoff decision is required. In deciding on the best method for managing any waste there is a hierarchy for decision making. Therefore, this paper boosts the use of analytical hierarchy process (AHP) in dealing with decision making challenges.

LITERATURE REVIEW

In deciding on the best method for managing any waste there is a hierarchy for decision making which addresses issues. It is applied to existing or advised practices, starting at the top of the hierarchy, examining and testing these at each level. Hazardous waste is one of the major factor which degrade environment and causes of pollution in country like USA. Different states have their own generation of hazardous waste, but by looking at number of generation cannot decide which state or which city need to be taken most in consideration for improvement in hazardous waste management. There must be different factors that can play their role in production of high or low quantity of hazardous waste. To handle such a complex situation, multi-criteria decision making (MCDM) methods are worthful for making important decisions that cannot be determined straightforwardly. It is necessary to know the general characteristics of different methods, in order to select the most advantageous method of this study. De Montis el al. (2000) conducted study shows a summary comparing the features of various MCDM methods and it can also be observed that AHP (Analytical Hierarchy Process) has fantabulous performance in dealing with interdependent criteria and the local problems involving both quantitative and qualitative issues.

In people life each individuals or group of people that can be trivial or important, expected or unforeseen, repetitive or novel, decision making is a daily occurrence (Cooke 1991). AHP is a decision making method for assigning a priority to alternatives when multiple criteria must be considered. AHP methodology has been used in lot of specific application and areas for decision making process such as education, politics, sociology and environment, budget or resources allocation, marketing, project and portfolio selection, economic and

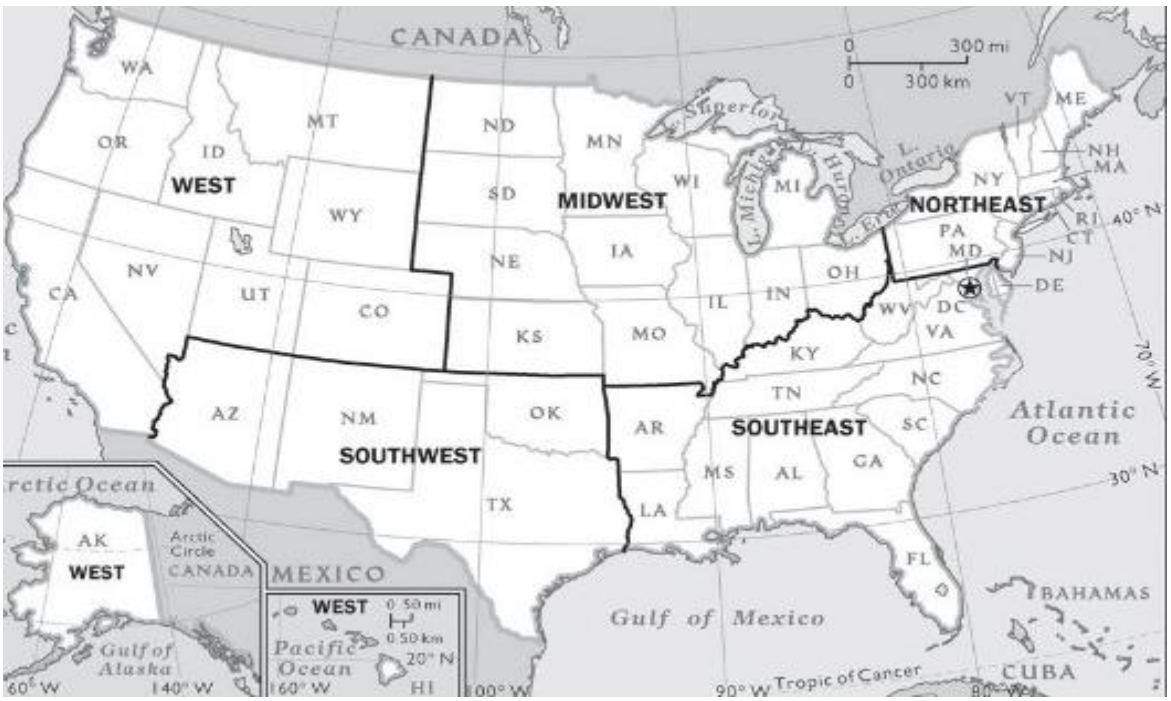
planning, energy, conflict resolution and arms control, health, material handling and purchasing, manufacturing system, passenger airlines selection, manpower selection and performance measurements (Saaty 1980, Saaty& Vargas 1982, Cook et al. 1984, Zahedi 1986, Shen et al., 1998, Cheng et al., 2005, Banai 2005, Amit 2015).Very few researchers have used MCDM method for hazardous waste decision making process. To structure complex problems in the form of a hierarchy or a set of integrates levels, MCDM method allows the decision makers to take the best decision (Robert 1992).Similarly, supplier selection problem can be solved with MCDM and had been widely used, out of which quantities criteria have been considered in the previous and existing decision models (Chen-Tung, Ching-Torng & Huanget 2006).This study concerning about the hazardous waste which is commonly considered as a social problem, anticipated that AHP is the suitable methods for analysis and findings (Chan and Lee 2007). The AHP has found widespread application in decision making problems and has the ability to structure complex, multi-person, multi-attribute and multi-period problems hierarchically (Liu & Hai 2005, Yusuff 2001). An AHP model is a hierarchical decision problems model that consists of multiple levels of criteria having simplex relationships developed by Saaty 1980. Generally hierarchy structure had been separated into three levels such as goal, criteria and alternatives. For this hazardous waste management problem, goal is to proposed sustainable hazardous waste management by finding the state and city in USA need to be taken in consideration for improvement of hazardous waste from criteria and alternatives taken for our analysis. The decision maker's action based on the judgments concerning the importance of the criteria and which they are adjoin by each alternative. AHP methodology helps to rank the alternative courses by it respective weight. The mathematical calculation and proofs of AHP are developed by Saaty (1980). In AHP, pairwise comparison is an important step. The environmental performance of manufacturing process in the pulp manufacturing industry and investigated the suitability of various flexible manufacturing system and cellular manufacturing configuration system, AHP was used for decision making (Pineda 2002, Chan 1996).

These above study are the evidence that the AHP had been widely used in various sectors and its skillfulness is applicable in different areas. Hazardous waste is also a major problem and due to improper decision making process, still struggle with miss management and environment degradation. To give proper decision and to propose sustainable hazardous waste management this study is taken in consideration. This research is separated into five parts, first gives the brief about hazardous waste, 2nd explain brief about previous study using AHP, 3rd shows the steps followed and data is analyzed, 4th explain the result finding from analysis and discuss about it and at last is the opinion of researcher from this result towards improvement of hazardous waste in USA.

METHODOLOGY

This research has been conducted using the secondary data from Right to Know Network (RTKNET), a data base for hazardous waste generated, managed, treated and shipped off for all states of USA from 1989 till todate. The objective of this research is to evaluate the current situation of hazardous waste management in different states of USA. For analysis only data of 2011 (last updated data) has been taken, so that to analyze latest hazardous waste condition of each region as well as each state of USA. The region consists of areas of land that have common features such as natural, geographic features (forests, wildlife or climate). There are total 5 regions and 50 states of USA has been considered in this study. The quantity of generation of hazardous waste data has been collected with the help of The Biennial Reporting System (BRS) and this is one of the EPA's (Environmental Protection Agency) primary tools for tracking the generation, shipment and receipt of hazardous waste. This data information contains from the Hazardous Waste Report that must be filled every two year under the RCRA (the Resource Conservation and Recovery Act) program. RCRA is the federal statute that regulates the generation, treatment, storage, disposal or recycle of solid and hazardous waste. The quantity of generation of hazardous waste can be affected by different factors i.e., economy (GDP, Per Capita Income, etc, population (Density, Age, Gender, familiar about hazardous waste, literacy rate, etc), area (percentage land area or water area, domestic area, industrial area, rural, urban, etc).

Figure 1: Regions and States of USA



Data is given in tons by RTKNET and those values were taken for our analysis. Each region and each state overall value is given for throughout the year of 2011. These regions are The West, The Southwest, The Midwest, The Southeast and The Northeast (Fig 1). Sate names of USA have been mentioned in hierarchy structure (Fig 2).To find the quantity of hazardous waste generated by per person in each region, divide the total generated hazardous waste by each region with total number of population in that region (eq 1). Similarly, to find the per person hazardous waste generation in each state is calculated. As the data is scattered, therefore, it has been preprocessed for analysis after collected from RTKNET. Static normalization is applied to normalize the scattered data (eq 2). Each column of hazardous waste generation is divided by its maximum value to get the normalized data.

Per person hazardous waste generation = waste generated (Tons)/ Population …… (1)

Scaling formula used, F(x) = (a+X)*(b-a)/(Max B-Min A). . . . . (2)
Whereas, a = the minimum scaling value, b= maximum scaling value, Min A= minimum value in data, Max B = maximum value in data and X= value of variable.

There are many scales that could be used for judgment process but for AHP the scale given by Saaty (1980) is considered as standard. This step is followed because hazardous waste generation depends on population. Pairwise comparison is an important step in AHP, which is completed with the help of experts. Especially when a large number of criteria or alternatives are involved, AHP is widely criticized for such deadening process. Because people are very likely to feel tired during decision making process and lose patience and may not make their judgments scrupulously. In this research study, data are secondary data taken for findings. So, we will not face problems of missing or loosing data.

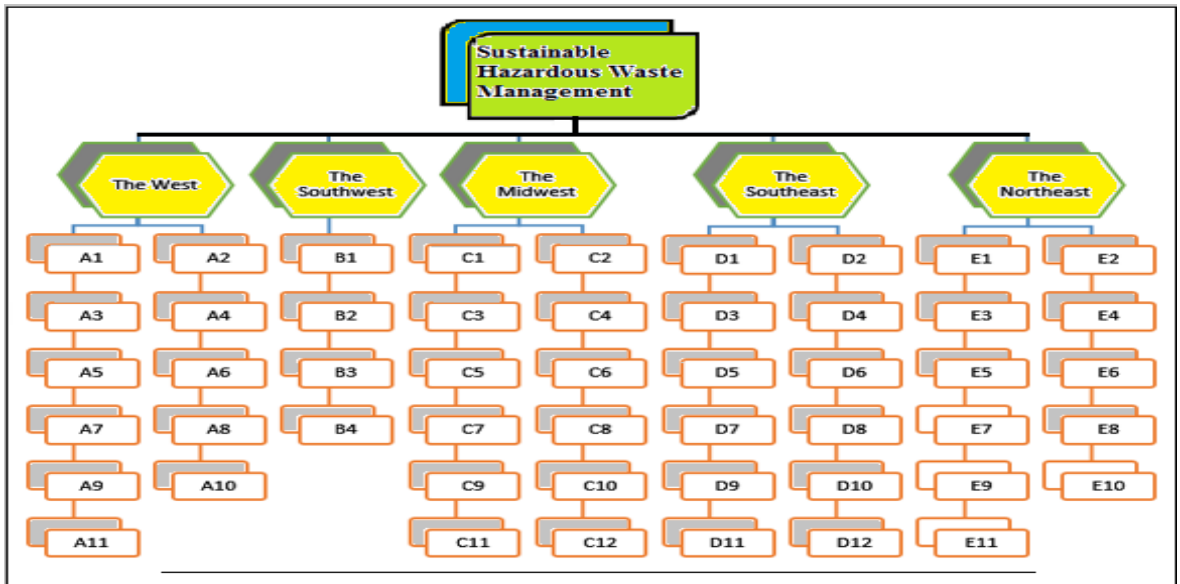
Although AHP is regarded as the most appropriate method for this study because pairwise comparison form of data input is straightforward and convenient for the user. In this study complicated mathematical algorithm is skipped and brief description of this method is explained by Grace and Lee (2008) and Robert (1992).Mat lab software is used for findings of relative weights of the objectives, corresponding criteria and the consistency ratios of the matrices are calculated. If we found any matrix with an unacceptable C.R. value i.e.>0.10 then the expert needed to make judgment on the matrix again until value is acceptable. By multiplying the local weight of criteria and local weight of sub-criteria the global weights are calculated.

Table 1: The Saaty (1980) rating scale

Intensity of importance	Definition	Explanation
1	Equal importance	Two factors contribute equally to the objective
3	Somewhat more important	Experience and judgement slightly favour one over the other.
5	Much more important	Experience and judgement strongly favour one over the other.
7	Very much more important	Experience and judgement very strongly favour one over the other. Its importance is demonstrated in practice.
9	Absolutely more important.	The evidence favouring one over the other is of the highest possible validity.
2,4,6,8	Intermediate values	When compromise is needed

The steps of the hierarchies of goal, criteria, sub criteria and alternatives as required in the AHP helped by identifying the variables and in figure 2 have mentioned the hierarchical structure of this paper. Pairwise comparisons express the relative importance of once item against another in meeting a goal or criteria. An appraisal of the ratio of the weight of the two criteria being compared is represented by pairwise comparison. This ration scale for processing human judgments had been implemented to various decision making problems in other fields. Ratio scale is utilized by AHP and the alternative weights contemplate the relative importance of the criteria in achieving the goal.

Figure 2: Hierarchical structure of Sustainable Hazardous Waste Management



A1: Hawaii, A2: Washington, A3: Oregon, A4: Utah, A5: California, 6: Nevada, A7: Colorado, A8: Wyoming, A9: Montana, A10: Alaska, A11: Idaho, B1: Texas, B2: New Mexico, B3:Arizona, B4: Oklahoma, C1: Iowa, C2: North Dakota, C3: Indiana, C4: Ohio, C5: Minnesota, C6:Wisconsin, C7: Illinois, C8: Missouri, C9: Michigan, C10: Nebraska, C11: Kansas, C12:South Dakota, D1: Mississippi, D2: Arkansas, D3: Kentucky, D4: Alabama, D5: South Carolina, D6: Louisiana, D7: West Virgin, D8: Georgia, D9: Tennessee, D10: Florida, D11:North Carolina, D12: Virginia, E1: Delaware, E2: New Jersey, E3: Pennsylvani, E4: New York, E5:Maryland, E6: Rhode Island, E7: Connecticut, E8: Massachusetts, E9: Vermont, E10: New Hampshire, E11: Maine

ANALYSIS AND FINDINGS

Sustainable hazardous waste management is one of the important factors for developed country like USA to give healthy environment. As country moving towards development, we still think that there is lack efficient thoughtful planning for hazardous waste. Preparing sustainable hazardous waste management proposal still have to make an effort to work out the detailed design based on the resources available. At the design process needs to balance the interest of different parties and make lot of tradeoff decisions as it is impossible for hazardous waste proposal to satisfy all affected citizens and concerned groups having their own condition, desire and expectations in which come of them many belie one another, cannot be fully meet with existing resources. So, to ensure that appropriate tradeoff decisions are made and sustainable hazardous waste management proposal is prepares, practitioners have to think over various design criteria and identify those that can effectively contribute to sustainable development and satisfy the majority.

Table 2: Pair wise comparison between the regions and their weight and rank

Regions	West	Southwest	Midwest	Southeast	Northeast	weight	Rank
West	1	0.5	0.5	0.2	0.11	0.1531	2
Southwest	2	1	1	0.5	0.33	0.00084	5
Midwest	2	1	1	1	0.5	0.0051	4
Southeast	5	2	1	1	1	0.0153	3
Northeast	9	3	2	1	1	0.8265	1

From our research discussion, we decided to use eq.1 so that analysis result will be more satisfied. From data we saw that small city have less waste production and large city with more population, better economic condition have much high waste production. Data variation was much high and much low in some condition. Using eq.1, this problem had been fixed and our data analysis result is much better shown in table 3.

Table 3 demonstrates the absolute weights of the sustainable hazardous weight objectives, final weights of the criteria and ranking is done after calculating the data. In table 2, results show that the northeast region with local weight (0.8265) had been prioritized as the first rank region produce more hazardous waste than that of other region. The northeast region should be considered in top most priority for improvement and sustainable hazardous waste management for USA followed by the west region local weight (0.1531) is ranked 2nd, the southeast region local weight (0.0153) is ranked 3rd, the Midwest region local weight (0.0051) is ranked 4th and last (5th) is ranked to the southwest region with local weight (0.00084181).

Table 3. The final weight & rank of regions and states of USA for the sustainable hazardous waste management and design criteria

Region	Region weight	State	State Weight	Global Weight	Rank
The West	0.1531	A1	0.0001	0.00001531	43
		A2	0.00026	0.000039806	37
		A3	0.0083	0.00127073	15
		A4	0.0083	0.00127073	16
		A5	0.0167	0.00255677	13
		A6	0.0333	0.00509823	9
		A7	0.0666	0.01019646	5
		A8	0.0666	0.01019646	6
		A9	0.0833	0.01275323	4
		A10	0.1166	0.01785146	3
		A11	0.5998	0.09182938	2
The Southwest	0.0008418	B1	0.00052	0.000000438	50
		B2	0.001	0.000000842	48
		B3	0.0868	0.000073069	33
		B4	0.9116	0.000767394	18
The Midwest	0.0051	C1	0.00014	0.000000714	49
		C2	0.0011	0.00000561	46
		C3	0.0026	0.00001326	44
		C4	0.0026	0.00001326	45
		C5	0.0053	0.00002703	38
		C6	0.0053	0.00002703	39
		C7	0.0053	0.00002703	40
		C8	0.0053	0.00002703	41
		C9	0.0053	0.00002703	42
		C10	0.0105	0.00005355	34
		C11	0.0105	0.00005355	35
		C12	0.9462	0.00482562	10
The southeast	0.0153	D1	0.00021	0.000003213	47
		D2	0.00342	0.000052326	36
		D3	0.00834	0.000127602	31
		D4	0.01446	0.000221238	28
		D5	0.0265	0.00040545	24
		D6	0.0265	0.00040545	25
		D7	0.033	0.0005049	22
		D8	0.033	0.0005049	23
		D9	0.078	0.0011934	17
		D10	0.1517	0.00232101	14
		D11	0.2925	0.00447525	11
		D12	0.4388	0.00671364	7
The Northeast	0.8265	E1	0.00014	0.00011571	32
		E2	0.00017	0.000140505	30
		E3	0.00022	0.00018183	29
		E4	0.00028	0.00023142	26

Table 3….

E5	0.00028	0.00023142	27
E6	0.00085	0.000702525	19
E7	0.00085	0.000702525	20
E8	0.00085	0.000702525	21
E9	0.0034	0.0028101	12
E10	0.0064	0.0052896	8
E11	0.987	0.8157555	1

DISCUSSION

AHP steps are followed for analysis as mentioned above in literature and methodology. After complete mathematical calculation, comparison of each region and state of USA (Figure 1) is done and allocating those weights for each region as well as states in each level is performed. According to largest weight value of region, it would be most important for consider for the sustainable hazardous waste management. These regions and states are ranked according to weight value shown in table 1. After calculating global weight for the state of each region, it is overall ranked with respect to global weight value as given in table 1. From the above result, we can also see that the region with large areas have large number of population and these regions states are well equipped with good economic condition which is also major causes of production of hazardous waste. Hazardous waste production is also causes due to number of industrial area, its disposed waste and way of treatment process of waste from those industries.

According to global weight in table 1, we have ranked state (figure 1) of USA as highest weight is on top or ranked as 1st and respectively in descending order. Table 1 give the finalized AHP decision model for bringing on sustainable hazardous waste management for USA. The ranking list of state can be seen that Maine state of the northeast, the state of the west Idaho, Alaska, Montana, Colorado, Wyoming have taken over the top most ranking in the list. The top ranking state is Maine (0.8157555) belongs to northeast region have population 1,222,000 produce 2,495 tons of hazardous waste. Similarly, 2nd rank is the Idaho (0.09182938) lies to the west region have population 1,014,000 produce 3,742 tons of hazardous waste, 3rd rank is Alaska (0.01785146) also belongs to the west region have population 527,000 produce 2,523 tons of hazardous waste, 4th rank Montana (0.01275323) is also in the west region have population 806,000 produce 5,883 tons of hazardous waste. At the bottom end, 47th rank is Mississippi (0.000003213) belongs to the southeast region have population 2,621,000 produce 1,828,969 tons of hazardous waste, 48th rank New Mexico (0.000000842) is in the southwest region have population 1,528,000 produce 1,037,437 tons, 49th rank Iowa (0.000000714) is in the Midwest region have population 2,840,000 produce 4,399,787 tons and last 50th rank is

Texas (0.000000438) belongs in the southwest region have population 16,991,000 produce 15,683,408 tons of hazardous waste.

From our result, we observed that the state and region with large population produce large amount of hazardous waste but those state have well managed hazardous waste than that of less populated area. Even in less population and less developed areas produce much less amount of hazardous waste in comparison to the larger ones but due to mismanagement as well as avoidance this small amount are causing vulnerable to the state because those states are mostly in the top order in ranking table. We can also see that global weight values are taken in to 9 decimal values, this is because of our large number of state and its weight value varies with very less difference.

CONCLUSION AND RECOMMENDATION

Hazardous waste is one of the major problems that USA faces and its precaution measure still not well managed. From analysis result, we found that small populated areas generate less hazardous waste but those waste are not well managed. These analysis results have given idea about factor for hazardous waste generated and from where should government take action to make well managed. By the generator the vast majority of hazardous waste in the U.S. is treated or disposed on-site. Most of this waste is in liquid form and is treated in wastewater treatment plants or put in underground on-site wells. Government also needs to take serious action for the industry that all industry needs to have waste treatment plant within industry so that waste of industry will be treated and then sent to open environment. This step will take great action to keep environment safe from hazardous waste. Most of hazardous waste in USA is sent off-site to commercial hazardous waste facilities are injected underground. For the government of USA, preparing sustainable hazardous waste management proposal is one of the major decision problems because it is very difficult to make compromise decision based on the resources available. Divergent opinion of different concerned parties and to make sure that the hazardous waste proposals are sustainable and good for the present and future. So, this paper designates to use AHP to facilitate such problem solving process even AHP is not the only one or the best method for solving all daily decision problem. But it is widely known that this methodology is an effective tool to provide a fair and coherent solution for the decision makers. In order to clarify how AHP can bring into use, this paper had given a decision model for sustainable hazardous waste management proposal for USA regions and states. Table 1 have given the final weights of the design criteria and it is believed to be very useful for assessing the sustainability level of the potential hazardous waste proposal in future.

As mention above that AHP is not only the best method for solving daily decision problems. It has been suggested that in future, other MCDM methods can be applied to determine best evaluation methods for hazardous waste management. Comparative study of different models can also lead us to hazardous waste free region. So that it will be clearer and result will be more transparent that will be helpful for the decision makers. This also will help to know that which factor need to take in consideration for more accurate result and which method is good for such type of result findings.

The data we have taken for findings from RTKNET with limitation under the act of RCRA (Resource Conservation and Recovery Act). Choosing AHP for judgment process, relative importance of the sustainable hazardous waste management objectives and design criteria can be identified. The final weight of regions and states is very useful for assessing the sustainability level the potential hazardous waste management proposal in future. It can help EPA (Environmental Protection Agency) US to take decision related to finance as well as to manage the hazardous waste and can also help government to make policies for coming generations.

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