Trans. Inst. Indian Geographers
Vol. 32, No. 1, 2010

A Critical Analysis of Existing Municipal Solid Waste Management Practices in Madurai City

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Abstract

Waste is an unavoidable by product of human activities. Urbanization and improving living standards in cities, have led to increase in the quantity and complexity of generated waste. Rapid growth of population and industrialization degrades urban environment and places serious stress on natural resources. Inefficient management and improper disposal of solid waste are obvious causes for degradation of environment in most cities of the Third World Countries. At present municipal solid waste management in India has severe problems. Very high rate of urban growth is a major reason for the increased solid waste management problems. Mumbai, the commercial capital of India, generates about 6256 tones of waste per day. The per capita waste generation of 0.450 kg in Mumbai is among the highest in Indian cities. Thus it is a serious problem that most of the fast growing million cities of India are facing.

The term municipal solid waste refers to solid waste from houses, streets and public places, shops, offices and hospitals. Its disposal, in most of the cases, is the responsibility of municipal authorities. In general solid waste means, material which is not in liquid form and it has no value to the person. Synonyms to solid waste are terms such as, garbage, trash, refuse and rubbish.

As a growing metropolis, Madurai is dominating the urban centrality of the entire South Tamil Nadu. Madurai has a population of one million and being a major tourist centre, it receives an equal number of people as the floating population. The environmental quality in the city shows serious signs of degradation. Considering this, an attempt has been made to analyze the existing nature of solid waste management practices in Madurai City.

Introduction

Urban environment in modern India has come under a constant threat due to increasing pressure on land and the growing population. Developmental activities in a city and the changing life style of its people demand more goods and services. Inevitably, this changing economic and social scene on Indian urban landscape produces large quantities of unwanted solid waste, some are reusable and some are toxic, but all are polluting the urban environment. For a common frame of references 'solid waste' in this paper is defined as any garbage, refuse, sludge and non-degradable waste both domestic and commercial, generated in the city limits.

Keeping this in mind an attempt has been made to analyze the existing nature of solid waste management practices in Madurai the second largest city in Tamil Nadu and home to a growing population of a million and above.

Aims and Objectives

1. To study generation of solid waste and the methods of their disposal in the city.
2. To understand the link between land use types and solid waste management.
3. To identify the problem areas for solid wastes and to suggest better planning strategy.

Data Base and Methodology

The data related to land use, spatial distribution of population, spatial pattern of solid waste generation and disposal methods were collected from different sources. The identification of environmentally degraded areas has been attempted with the help of SPSS 14 Version. For this purpose factor analysis was carried out using different variables related to population characteristics and waste management. Maps are prepared in Arc View 3.2a. Finally field verification has also been carried out by the investigator.

Madurai city – Study area

The city of Madurai on the both sides of the Vaigai River lies at a low altitude between 100 to 120 meters above mean sea level. The city area extend from 78° 07' 04 to 78°10" E longitude and from 9° 53' to 9° 59' N latitude and occupies a position in the south central part of Tamil Nadu (Fig 1). It is located at a distance of 500 km from Chennai. The city core is built around the famous Meenakshi Amman temple with a square pattern of concentric roads. The actual expansions of the city started after the advent of the British. The city has grown on the banks of the river in an almost rectangle pattern in the midst of beautiful hills and hillocks around. This geographical feature gives the city, a basin like form. The river Vaigai flowing through the city from north-west to south-east, divides it into two equal parts such as the north zone and south zone. The first onslaught in the river is its new role of receiving sewage produced on either side.

The northern zone is having the concentration of administrative, educational, health and other public and semi public activities. Due to urban expansion, this area has witnessed an increase in new residential units and their associated activities in the peripheral

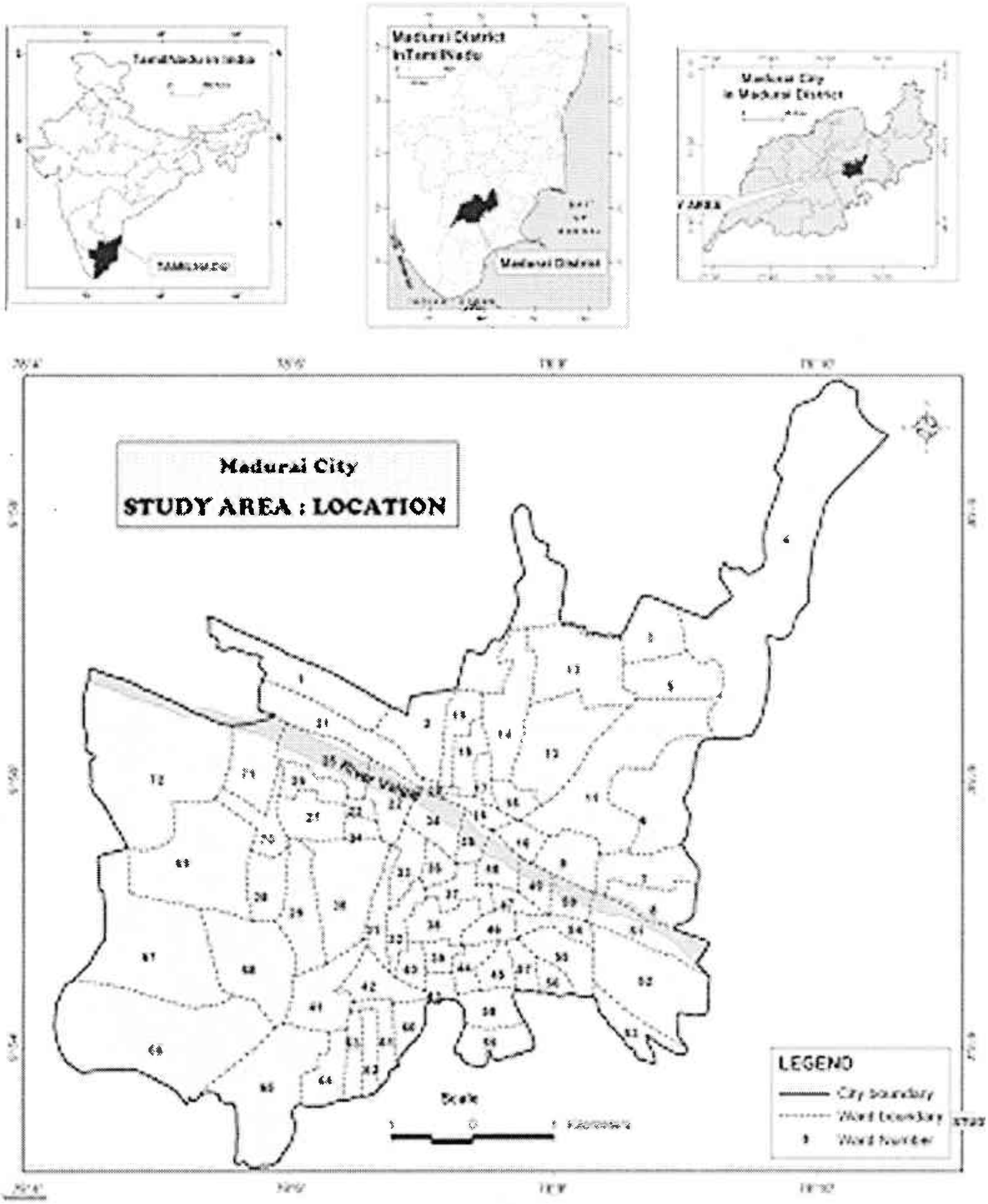

Fig. 1

zones of the city boundary. The southern zone is the core area where all the functional activities such as wholesale and retail business, recreation etc. are concentrated. The eastern zone has the extension of all city core functions specific to small-scale industries. The western zone includes more areas of newly added rural areas hence the newly developing residential, commercial and industrial activities are added in this zone. The southern border of the city has also large and wide depressions known as Madakulam, Villapuram that are reacting negatively to the current cultural and economic changes while all the other sides are reacting positively with multiple functions and with high floating population.

The average decadal growth rate of the population from 1991 to 2001 for Madurai is -1.72 percent. The population has increased by 13 times during the course of the century. The distribution of the population over the city remains uneven due to several social and cultural factors. Characteristically the areas around the southern and eastern sides of the city are the high density area. This density pattern continued to exist from the early 1930's. Recent trend shows gradual but it steady increases of population in the peripheral areas due to the upcoming new residential colonies, especially in the northern periphery and the western parts of the city.

City Environment

The bulk of the built-up area in the city is devoted to residential purpose and the other to domestic use. The solid waste generation and its disposal are mostly conditioned by the quality of the residential population. Hence, the distribution of city population has been taken as an important measure in the study. The population density is very high in the city core and the adjacent eastern zones, whereas the density is less in the northern and western zones.

Table 1 shows the differential pattern of the distribution of population, solid waste generation, methods of collection, transportation and disposal. Though the north zone has the highest population with a corresponding number of households, the density of population is less, whereas the southern and eastern zones have high density of population. It indicates the intensity and concentration of population corresponds to the agglomeration of activities in the core area of the city. Accumulation of the household waste is high along the streets in the southern zone, where all types of complex urban activities take place. The household ratio per street is medium in east zone and low in the west and northern zones. The western and northern zones have more urban areas due to recent development; hence, the number of households in each street and number of streets are less. According to Madurai City Development Plan Report, the city on an average generates 450 million tons of wastes very day in various forms. The per capita share of solid waste generation per day is about 406 grams.

The solid waste components are classified as degradable and non degradable. The total degradable waste – paper, gunny bags, cotton, wood, paddy straw, cow dung, banana stem, coconut husk, baggage, vegetable and fruit waste, leaves waste and food wastes – is calculated at 288 tons per day. The main sources of degradable wastes are households, restaurants, marriage halls, wholesale and retail vegetable markets and various service institutions. The non-degradable waste – plastics, metals, glass, rubber and rexins – constitute 108 tons per day, markets and residential areas being their sources. Waste generation from small scale industries is less. The spatial distribution and different type of waste generation corresponds to the level of concentration of major land use and functional activities in each zone.

The generation of paper waste is high in the north and the south zones. This is due to educational and administrative activities in the north, and the presence of market and commercial functions in the south zones. The waste from baggage, gunny bags are high in southern zone, due to the concentration of wholesale and retail markets. Cotton waste concentration is high in the north and south zones due to the agglomeration of small-scale, textile industrial units and their associated activities. Wastes from wood are more in the south and the north zones, where commercial and business activities are in an increasing level.

A notable feature is the generation of paddy straw more in the east zone due to the food processing units in the north. A huge quantity of banana stem

Table 1: General Characters of Solid Waste Disposal Details in Madurai City

Particulars	North Zone	East Zone	West Zone	South Zone	Total
No. of Wards	21	16	16	19	72
Population	444219	231025	258012	271029	1204295
Area in (sq. km)	19.5	6.12	18.78	7.4	52.00
Households	56088	46392	33941	55667	192088
Weekly Markets	6	9	5	7	27
Marriage Halls	64	45	41	43	193
Hotels	104	28	24	47	203
Dust Bins	388	164	268	155	975
Total Garbage Waste (tons/day)	150	74	116	110	450
Per Capita Share (Grams /day)	101	83	132	90	406

Table 2 : Solid Waste Generation in different landuse zones

Sources	Quantity (Tons/day)
Residential Areas	288.00 (64)
Commercial Areas	108.00 (24)
Industrial Areas	---
Hospitals and Clinics	18.00 (4)
Others	36.00 (8)
Total	450.00 (100)

(Figures in bracket indicate percentage).

waste and coconut husk generated in the east zone. It is due to the agricultural activities in the near by peripheral areas, the vegetable waste, fruit waste and leaves wastes are high in south zone. This is because of the high concentration of population, more number of marriage halls, restaurants, hotels and lodges. The animal base waste such as cow dung and fish wastes are more in the east zone. The general degradable biological wastes are found more in the south and the east zones. These zones comprise the city core and adjacent areas. (Table 2)

The non-degradable wastes such as plastics, resins and rubber are found more in the south and the north zones. The industrial activities in these zones generate more plastics and rubber materials of throw away nature. Metal waste and glass wastes are high in the south and the north zones. Of the total non-degradable waste, a higher share comes from the south zone where the core area of the city is located. The slit accumulation on rainy days is another form of solid waste generation. Slit alone contribute 36 tons per day of the total waste in the city. Of the total the degradable waste from vegetable and animal base alone contribute to 64%. Slit accounts for 8%, the non-degradable waste is 24% and clinical waste only 4%. Speaking of the environmental quality related aspect of solid waste generated in the city most are degradable and eco-friendly. But the improper collection and disposal methods may harm the city environment. Thus, the disposal methods of solid waste generation need to be analyzed in detail through statistical measures. Keeping this in mind multivariate factor analysis is used for the present analysis.

Analysis

To analyse a number of socio-economic variables and their structural complexity a factorial multivariate analysis is useful. Berry (1970) attempted to study the unobservable dimensions in urbanization, industrialization and agricultural development through factor analysis. It is a technique designed primarily to synthesize a large number of variables into a smaller number of general components, which explain greater proportion of varince and help to present a descriptive account. The description of given set of variables such as population density, household density, residences (of class I, II, II as IV),

Table 3: Total Variance

Component	Initial Eigen values			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.106	24.155	24.155	3.081	18.121	18.121
2	2.302	13.543	37.698	2.638	15.517	33.638
3	1.514	8.904	46.602	1.697	9.983	43.621
4	1.432	8.421	55.023	1.554	9.141	52.762
5	1.216	7.150	62.173	1.407	8.277	61.039
6	1.153	6.784	68.957	1.346	7.918	68.957

commercial establishments, (of class I, II, II as IV), secondary workers, tertiary workers, no. of slums in each ward, slum population, literate share, garbage weight, drainage connections and no. of dust bins are suggests the dimensions (components) for statistical relationship among them. The factor analysis used in the present study is urban demographic characters and the solid waste disposal. The identification of problem areas are evaluated through factor score. Table no.3 shows the factorial loadings of six components of possible factors. The importance of each component is explained by the eigen values which in turn helps to determine the selection of number of factor.

In the varimax rotated factor solution, the first component accounts for 24.1% of the variance. Likewise the second component accounts for 13.5%. The third component accounts 8.9%, fourth component explains 8.4%, fifth component accounts 7.1% and the sixth component accounts 6.7% in a component set. The variables with higher loadings have a greater influence in the set. The factor score considered in the present analysis is plus or minus 2 or above. The positive and negative scores in the factor score table help to analyse the spatial dimensions of solid waste disposal and management. Factor scores of each ward for urban index and management index are given in appendix. The location of ward are indicated in fig.1.

The first component explains 24.1% of the total variation and loadings significantly with five variables. Table 4 explains the extractions of principal component. In the first component set of five variables is highly associated and explains the urban population characters. Hence, this first factor is named as urban population index. The factor score of the first set of urban population index are loaded in both directions. With reference to the spatial units the scores are ranging from +2 to less than -1. The variation plus or minus 2 in both directions explains high positive and high negative conditions pertaining

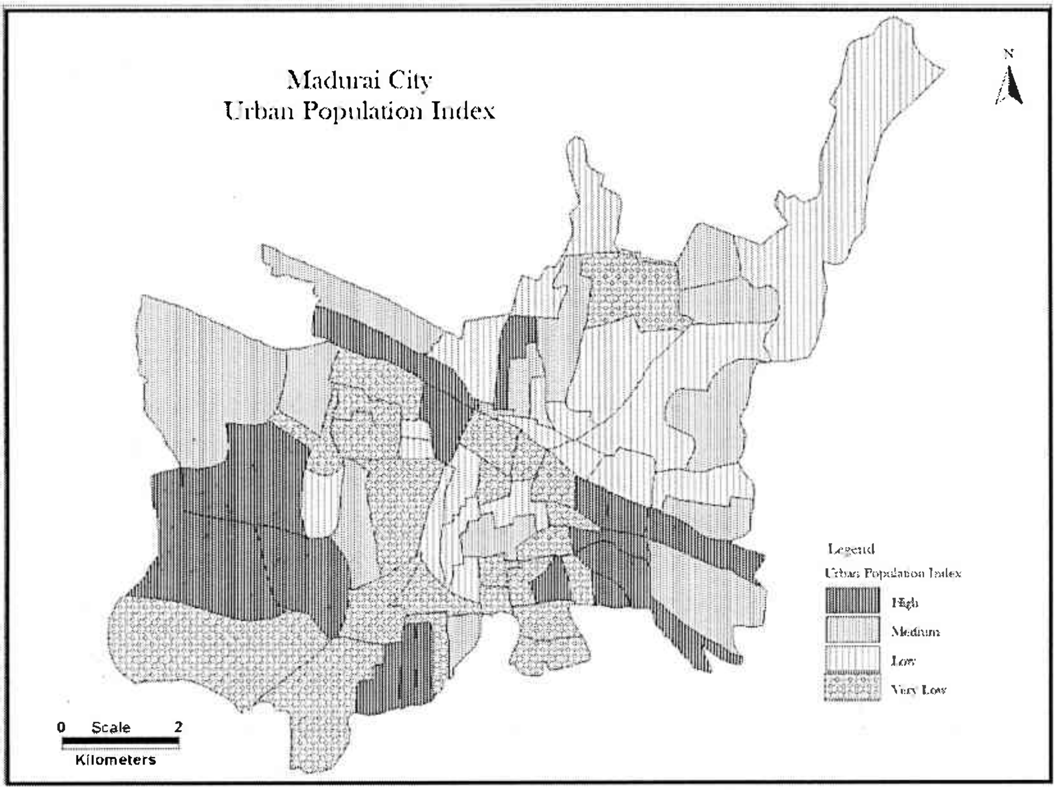

Fig. 2

to urban population and solid waste disposal and management whereas index value less than two in both direction indicates minimum urban population characters with high problem related to solid waste management.

Spatial characters of wards and their explicit significant position are shown in the table & map. Regarding urban population index five wards such as Vilangudi (1.8), Bibikulam (4.4), in the north, Ellisnagar (2.2), Pethaniyapuram (2.4) and Kochadai (1.6) in the west are having good position. The above said wards are having low density of households with higher level of tertiary workers. Hence, these wards are considered as good position in urban population index (fig. 2). In addition to this dimension other status are associated to the households, literacy and work participation considered as medium position, fair position and low. A map showing the factor scores on urban population index in different wards of Madurai city is given in fig 2. This factor is based on variables like household density, literacy status, secondary and tertiary workers and residences in class III. It may be noted that the city core areas record low to very low values and

Table No: 4 Extraction of Principal Component

Component Matrix						
Name of the Variables	**Component**					
	1	**2**	**3**	**4**	**5**	**6**
Household Density	.918	--	--	--	--	--
Literacy Share	.898	--	--	--	--	--
Tertiary Workers	.786	--	--	--	--	--
Secondary Workers	.531	--	--	--	--	--
Commercial Establishments Class III	--	.786	--	--	--	--
Garbage Weight	--	.727	--	--	--	--
Commercial Establishments Class II	--	.717	--	--	--	--
Commercial Establishments Class IV	--	.631	--	--	--	--
Residences Class IV	--	--	.843	--	--	--
Drainage Connection	--	.481	.599	--	--	--
No. of. Bins	--	--	.487	--	--	--
Residences Class II	--	--	--	.921	--	--
Residences Class III	.476	--	--	-.516	--	--
Slum Population	--	--	--	--	.773	--
No. of. Slums	--	--	--	--	.740	--
Population Density	--	--	--	--	--	-.863
Class IV Residences	--	--	--	--	--	.467
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.						

this zone of low to very low factor score by and large extends in SW-NE direction through the city region. These are the areas of high population densities. The eastern zone is basically an extension of city core functions. In the western zone wards like Ponmeni, Pazhanganatham and Madakulam record high scores. These are the areas with low densities and high concentration of tertiary services.

The second component explains 13.1% to the total variance. The factor loadings in both directions are similar. Here also the five variables explain the dimension of urban solid waste. Hence the second component is named as urban solid waste index. As per the factor score values five wards are having good status in urban solid waste index. Then another 18 wards for medium status, 36 wards carries fair level and 13 wards pertain to low dimension in solid waste disposal and management index (fig. 3).

In the present study the investigator is interested to highlighted the problem areas (medium and fair status) of the city with the help of score values in

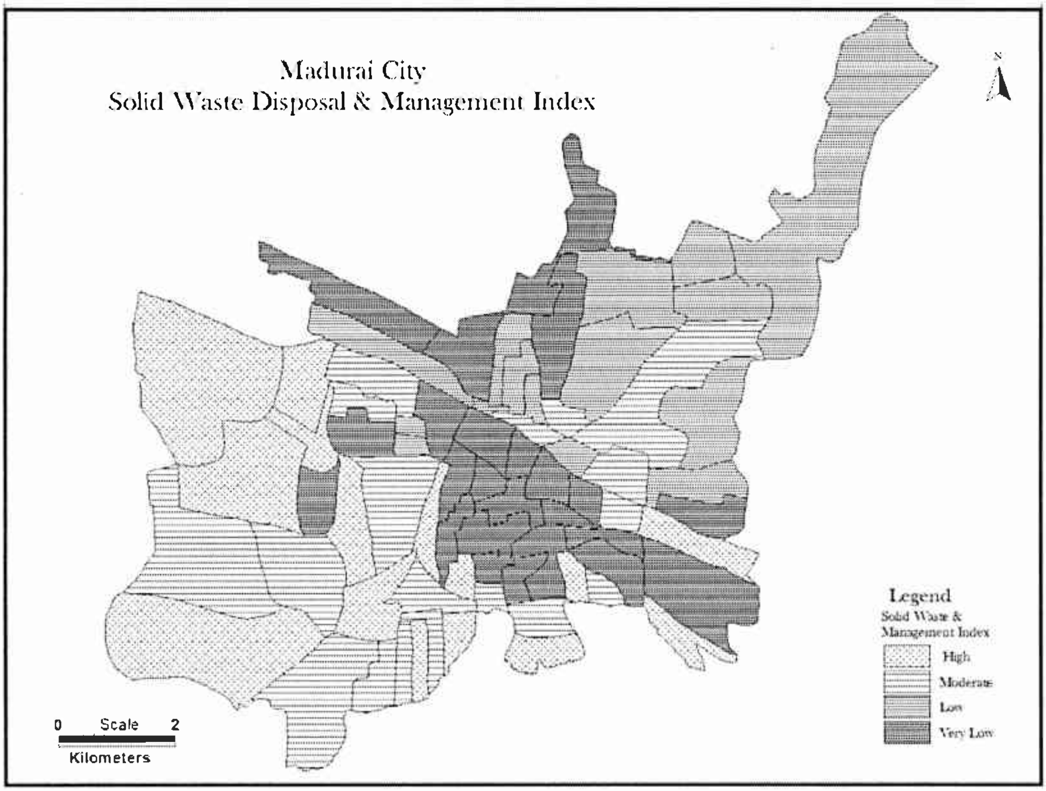

Fig. 3

both dimensions. There are four wards represented in the index of urban and solid waste dimensions with low status. Subramaniyapuram, Sundharajapuram wards located in the south peripheral area, Visuvasapuri and Pandhalkudi wards situated nearer to the river bed area are having low status of urban population index and solid waste management and disposal. Apart from this Jaihindipuram in south periphery, Muthuramalingapuram in western peripheral area, Arasaradi and Arapalayam wards in river bed location carries low environmental quality with solid wastes disposal and also to urban demographic characters. Pandhalkudi ward needs for essential planning for proper cleaning methods of solid wastes in the city environment.

Figure 3 shows the conditions related to waste disposal management as depicted by the management index. The eastern half of the city stands out clearly as the zone of low to very low factor scores indicating poor management of waste disposal. These zones (low and very low) include the areas of high concentration of retail business, high population densities, as well as small scale industries. This is also the area where the frequency of visits by floating population is quite high. As against this the western half of the city that covers the areas of new residential units records moderate to high scores on management index. It also has commercial and industrial units. The frequency of visit by floating population is much lower than what we find in the core and eastern parts; as a result generation of solid waste is relatively low and its management is fairly well.

Following table gives the distribution of wards into different categories (high to very low) on urban population index and management index.

It may be observed that only 5 (7%) wards have satisfactory conditions as far as the waste management is concerned. As many as 49 wards (65 %) in the city the conditions of waste disposal management leave room for improvement. Some comments highlighting the nature of problems and futuristic trend regarding a few wards in particular are given in the following section.

Findings

1. MariammanTheppakulam (ward no 52), Balarengapuram (ward no 55), Navarathnapuram (ward no 54) wards in the east and Ponnagaram (ward no 22) in the riverbed of the city holds medium (positive) index values in urban population and solid waste characters. Mariamman Theppakulam (ward no 52) in the east have registered equal values in both dimensions. This area may face problems in future due to over agglomeration in population. Hence to maintain the quality the administration of civil bodies and residences should take care of the environment.
2. Similarly the wards of Subramaniyapuram (ward no 42), Sundharajapuram (ward no 41) are situated at city fringe, Visuvasapuri (ward no 26) and Arapalayam (ward no 25) wards located in southwest of river bed area, Jaihindipuram (ward no 61) and Muthuramalingapuram (ward no 66) wards in the western periphery of the city, SappaniKovil (ward no 43) nearer to city core and Pandhalkudi (ward no 17), Karpaga Nagar (ward no 4) and Thallakulam (ward no 11) areas in the northern part, Sellur (ward no 16) and Mathichiyam (ward no 9) in the northern river bed part of the city carry low index values in population and solid waste disposal and management. However Pandhalkudi (ward no-17) area leads

	High	Moderate	Low	Very low	Total
Urban Population Index	5	27	31	9	72
Waste Management Index	5	18	36	13	72

Factor Scores of Wards of Madurai City
(for locations of wards refer Fig 1)

Ward No	Name of the Ward	Componnent Scores Urban Index	Management Index
1	Vilangudi	1.9829	0.0152
2	Bibikulam	4.2811	0.1780
3	Lourde Nagar	0.1792	-0.4329
4	Karpaganagar	-0.0630	-0.1681
5	Pudur	1.0327	-0.0574
6	KK nagar	0.1137	-0.4669
7	Annanagar	-2.2727	-0.3158
8	Sathamangalam	0.3174	-0.0810
9	Mathichiyam	-0.2782	-0.2277
10	Azhawarpuram	-1.0440	-0.3741
11	Tallakulam	-0.6292	-0.1894
12	Reserve line	-0.3493	-0.4730
13	Chokkikulam	-0.4909	-0.5485
14	Narimedu	1.2289	-0.0413
15	Goripalayam	-0.8421	-0.2897
16	Sellur	-0.4397	-0.5784
17	Pandalkudi	-0.4353	-0.3116
18	Ahimsapuram	0.8716	-0.5418
19	Meenambalpuram	0.1298	-0.3377
20	Kailasapuram	0.6737	-0.3701
21	Thathenari	0.0348	-0.3222
22	Ponnagaram	-0.0208	0.0864
23	Krishnapalayam	-0.8871	-0.6669
24	Azhagaradi	-0.7323	-0.6828
25	Arapalayam	-0.2261	-0.4676
26	Visuvasapuri	-0.6189	-0.4830
27	Melaponnagaram	-0.5659	0.4284
28	SS Colony	-1.2103	-0.6822
29	Ellisnagar	2.2075	-0.1058
30	Railway Colony	-0.5475	-0.4627
31	Madhura Bhaskaradoss Nagar	-1.1150	-0.1102
32	Perumal Theppakulam	-1.0060	1.7564
33	Krishnarayar Theppakulam	-1.2367	1.6343
34	Thamizhsangam	-0.6434	1.0811
35	Sokkanadhar Kovil	-0.5946	-0.0578
36	Vadakku Krishnan Kovil	-0.9323	1.5545
37	Meenashi Kovil	-1.2078	2.7380
38	Jadamuni Kovil	1.0078	6.4028
39	South Krishnan Kovil	-0.4150	0.7063
40	Kajimar Street	-1.1164	-0.3456
41	Sundhararajapuram	-0.8044	-0.5283
42	Subramaniyapuram	-0.9123	-0.4738
43	Sappani kovil	-0.3384	-0.4025
44	Manjanakkara	-0.3468	-0.1198
45	Dropathi Ammam Kovil	0.2159	0.0213
46	Mahal	-1.0389	0.1819
47	Lakshmipuram	-0.7386	0.8435
48	Swamisannadhi	0.0640	0.4870
49	Ismayilpuram	0.3473	0.8384
50	Sowrashtra High School	0.1041	-0.5586
51	Pankajam Colony	0.0207	-0.3392
52	Mariamman Theppakulam	0.7788	1.2236
53	Anuppanadi	0.8152	-0.4057
54	Navarathnapuram	0.3517	-0.3629
55	Balarengapuram	0.5761	0.2911
56	Kamarajapuram	0.4539	-0.3835
57	St. Mary's	-0.0109	-0.3154
58	Keeraithurai	-0.0425	-0.4357
59	Villapuram	-0.1181	-0.2087
60	Sholaiyazhagupuram	0.9508	-0.5853
61	Jaihindipuram	-0.6306	-0.5655
62	Veerakaliyamman Kovil	0.3901	-0.4778
63	Thennagaram	0.1323	-0.4255
64	Kovalan Nagar	0.4070	-0.4350
65	TVS Nagar	-0.6568	-0.3910
66	Muthuramalingapuram	-0.1261	-0.4972
67	Madakulam	0.2739	-0.4246
68	Pazhanganatham	0.1060	-0.5117
69	Ponmeni	0.9969	-0.3521
70	Arasaradi Othakkadai	0.2426	-0.2867
71	Pethaniyapuram	2.5230	-0.5058
72	Kochadai	1.8735	-0.2836

the low quality in urban environment. Thus planning is necessary to expand the good quality of environment.

Conclusion

This paper is the outcome of an in-depth urban geographical study of generation, management and disposal of solid waste in the city of Madurai. Spatially, the study has identified two areas called 'medium area' and 'fair position area', depending on the quantity of waste produced and the methods employed to dispose them. The selected two dimensions of factor score, namely urban population index and solid waste disposal and management index, specially designed for this study lay heavy emphasize on the need for a better system of scientific planning that would ensure desired results. Heritage sites like, Mariamman Theppakulam (ward no- 52) and Mahal (ward no- 46) situated either the core area or not, deserve special attention from governmental agencies to retain their pristine glory. For the sustainable development Pandhalkudi (ward no- 17) area require more importance than other wards.

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