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Application of GIS in Solid Waste Management for Kolhapur City

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ABSTRACT

Solid waste management is of the major problem faced by today's world. There is an increase in commercial, residential and infrastructure development due to population growth and it leads to negative impact on the environment. Kolhapur City, with an area of 683.31 sq. km and a population of 549249(As per Census-2011) about generates about 200 tons of solid waste per day. Collected waste is transported directly to disposal ground at dumping ground by KMC vehicles and KMC-hired vehicles. Lack of proper planning and inadequate data regarding solid waste generation and collection compound the solid waste management problem. GIS as a tool can recognize, correlate and analyses relationship between spatial and non-spatial data. It can thus be used as a decision support tool for efficient management of the different functional elements solid waste e.g. bin location, number of bins required, waste transportation, generating work schedules for workers and vehicles. Based on the above focus, the present study focuses mapping of waste bins and waste generation of Kolhapur area and on suggesting and administratively transparent solutions to waste disposal problem.

Keywords: GIS, Population Distribution, Solid Waste Management, Waste Collection, Waste Generation.

1. INTRODUCTION

Solid Waste Management (SWM) is an integral part of public health and Environmental control. Improper SWM leads to both economic and environmental Sufferings. SWM includes control of generation, storage, collection, transfer/transport, processing and disposal of waste. Almost all factors related to SWM has both spatial and Non-spatial components, thus, traditional ways of storing and analyzing data keeps data in Isolated form, which results in inefficient management system. Solid waste management is term that is used to refer to the process of collection and treating solid waste. It also offers solution for recycling items that do not belong to garbage or trash. As long as people have been living in settlements and residential areas, garbage or solid waste has been an issue. Waste management is all about how solid waste can be changed and used as valuable resource. Solid waste management should be embraced by each and every household including the business owners across the world. Industrialization has brought a lot of good things and bad things as well. One of the negative effects of industrialization is a creation of solid waste.

Generally, municipal solid waste is collected and deposited in landfill such unscientific disposal attract birds, rodents and fleas to the waste site and create unhygienic conditions. The degradation of solid waste results in the

emission of Carbon Dioxide (CO2), Methane (CH4) and other gases. The unscientific landfill site may reduce the quality of the drinking water and causes diseases like nausea, jaundice, asthma etc. Municipal solid waste management is one of the major problems that city planners face all over the world. The problem is especially severe in most developing country cities where increased urbanization, poor planning and lack of adequate resources contribute to the poor state of municipal solid waste management (Obirih-Opareh & Post, 2002; Mato, 1999; Doan, 1998; Mwanthi et al., 1997). There is a considerable amount of disposal of waste without proper segregation, leading to both economic and environment loss. There is a tremendous amount of loss in terms of environmental degradation, health hazards and economic descend due to direct disposal of waste. It is better to segregate the waste at the initial stages of generation rather than going for a later option, which is inconvenient and expensive. There has to be appropriate planning for proper waste management by means of analysis of the waste situation of the area.

The environment is heading towards a potential risk due to unsustainable waste disposal. It is a sensitive issue, which concerns about serious environmental problems in today's world. The present situation of direct dumping of the waste without proper inspection and separation leaves a serious impact of environmental pollution causing a tremendous growth in health related problems. Domestic, industrial and other wastes, whether they are low or medium level wastes, they are causing environmental pollution and have become perennial problems for mankind.

Most urban areas in the country are plagued by acute problems related to solid waste management. It is estimated that about 100000 metric tons (MT) of solid waste is generated every day in the country. Per capita waste generation in major cities ranges from 0.12 kg to 0.6 kg as per the data from National Environmental Engineering Research Institute (NEERI). The collection efficiency ranges from 50 to 90% only, leaving the balance unattended. It is estimated that the urban local bodies spend about Rs. 500 to Rs. 1500 per ton on solid waste for collection, transportation, treatment and disposal. About 60 to 70% of this amount is spent on collection, 20 to 30% on transportation and less than 5% on final disposal of waste.

Fig. No.-1 Bawada Site.

Fig. No.2- Overflowing of Collection Bin

Fig. No.3- R.C. Truck lifting the Collection Bin in E-3 Ward, Kolhapur City

Fig. No.4- Scrap Collection Bin in E-2 Ward, Kolhapur City

GIS

Especially, MSW collection and transport are provided at the individual municipality level. Currently, collection and transport of MSW is responsible e for a large portion of the total waste management costs, in the range of 70-100%. This is considerably higher than the typical values, between 50-75%, reported for modern waste management systems because an adequate amount is not used for the disposal of MSW due to the unawareness in pretreatment for materials and/or energy recovery and practicing of illegal dumping. Therefore, the cost effective collection system and finding the appropriate number and location of collection bins can be confronted with applying the sophisticated technologies like GIS and GPS. A Geographic Information System (GIS) is a computer tool for capturing, storing, querying, analyzing and displaying spatial data from the real world for a particular set of purposes. This technique is used to generate optimal route for collecting solid waste. GIS is a tool that not only reduces time and cost of the site selection, but also provide a digital data bank for future monitoring program of the site. Therefore the objectives of the present study are to estimate the ward wise per capita solid waste generation and to prepare a map of collection bins in Kolhapur city.

STUDY AREA

Kolhapur City is taken as study area. Kolhapur City, with an area of 683.31 sq. km and a population of 549249(As per Census-2011) about generates 200 tons of municipal solid waste generates per day and the total waste is collected and transported to open dumpsite every day. To collect solid waste from households from the city area, three wheeled carts with bells are used. Both male and female workers are appointed for collection of waste from door to door. For collection & transportation of municipal solid wastes, Kolhapur Municipal Corporation uses 22 vehicles like, dumpers, R. C. trucks. Transport system is geared up to collect solid wastes daily from sensitive areas like, important places of the city. The collection of solid waste is carried out in three shifts:

1. Morning (6a.m.-2p.m.),
2. Afternoon (2p.m.-10.p.m.),
3. Night (10p.m.-6p.m.)

Every R.C. trucks have capacity of 7-8 tons and every collection bin's capacity is 1tonne. Every R.C. truck has 2-3 workers along with driver. Each R. C. truck takes 5-6 minutes to lift the one collection bin.

Fig. No.5 - Location of the Study Area.

To determine the physical composition of Municipal Solid Waste in Dry Waste Basis in grams and percentage Waste Characterization method is carried out at Bawada Dumping Site. Following Table No.1 shows the various physical components of Municipal Solid Waste in Kolhapur City.

Sr. No.	Waste	Weight(gm)	Weight (%)
1	Plastic	1250	15.94
2	Paper	950	12.11
3	Organic	590	64.92
4	Clothes	200	2.55
5	Rubber	100	1.27
6	Glass	50	0.64
7	Metal	100	1.27
8	Dust	100	1.27

Table No.1- Physical composition of MSW dry weight basis in Grams and Percentage in Kolhapur in Kolhapur City

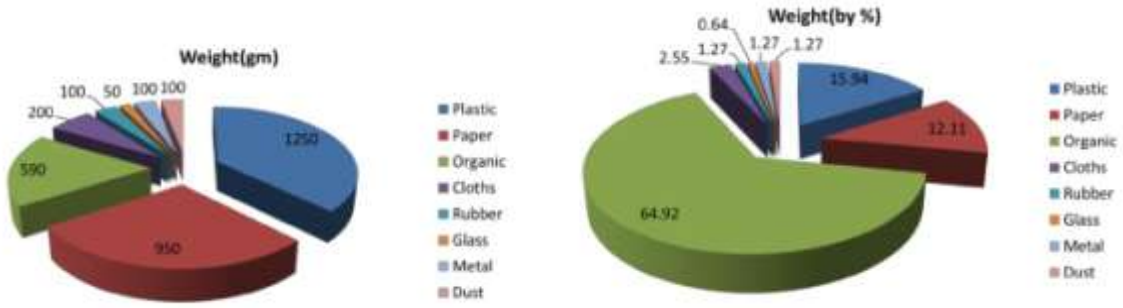

Fig No.6 : Physical components of MSW dry weight basis(in percentage) in Kolhapur City.

Fig no.7- Physical composition of MSW (in dry weight basis (in gm) in Kolhapur City.

A. Population density

The density of population is increasing from year to year and the area has remained unchanged. The collected average population data have been used to calculate the population density of the area, based on population/total area (sq. km). Using the above, a population distribution map is prepared thematically to identify areas based on population. Natural break classifier is used to classify the population into six classes.

2. LITERATURE REVIEW

1. Amirhossein Malakahmad, et.al.- Waste collection becomes more complex in developing countries in terms of fuel and labor cost and air pollutants emission. In this study, solid waste collection routes optimization using Geographical Information System was investigated.

2. Nitin Mundhe, et.al.- The proposed work emphasizes on the assessment of detail process of solid waste management such as collection, storage, segregation, transportation, treatment and disposal by using Geospatial tools like Remote Sensing, GIS and GPS. It may help in sustainable urban development of Pune City.

3. B.Shoba, et.al.- the study focuses mapping the waste generation of Coimbatore City urban area and on suggesting convenient and administrative transparent solutions to the waste disposal problems.

4. Amit Datta, et.al.- this study involves GIS application in assisting locational analysis of waste bins in Kolkata City and optimize the overall solid waste collection process.

3. METHODOLOGY

The conceptual flow of the methodology adopted for identifying the current bin locations and to identify new locations for bin is discussed as follows:

1. Data Collection

The primary and secondary database of MSW management has been collected from the Office of the Kolhapur Municipal Corporation (KMC). The data collected were Number of bins in each ward, Types of bin and their capacity and Collection frequency. The existing location of the collection bins were derived from on-site capturing with the use of GPS technology.

2. Mapping Technique

The Kolhapur Corporation map was obtained from Kolhapur Municipal Corporation. The details were identified using the geographical co-ordinates. The spatial data and attribute date entered into a database to create maps and analysis by Q-GIS 2.14.1 Essentials Software. This includes shapefiles, ward boundaries, population, area, population density.

The vector images were opened in Q-GIS 2.14.1 Essentials as a vector layer using .dbf interchange format. Later this image was projected using projection of geographic latitude and longitude. The option of Attribute table presents in Q-GIS 2.14.1 Essentials adds latitude, longitude and elevation to the attribute table. The created points of collection bins were coordinated to that of the vector layer. Once the map is transformed the line tool was used to digitize the map. A specific tool like point, line or polygon was selected and digitized over the map. Automatically, an attribute table with records for each polygon was created by the platform. Each line was given an ID and additional fields were added to enter records such as average waste generation per day, collection bins and election wards and sanitary wards the entire layer saved as a shapefile.

Spatial Data	Type	Geometry
Road networks	vector	line
Collection Bins	vector	point
Population Data	tabular	-
Election Wards	vector	polygon
Sanitary Wards	vector	polygon

Table No.2- The spatial database- type of data and corresponding geometry

4. RESULTS AND DISCUSSION

The city divided in the 12 sanitary wards namely A-1, A-2, A-3, B, C-1, C-2, D, E-1, E-2, E-3, E-4, E-5. Each sanitary ward is headed by the Sanitary Inspector who is delegated with adequate powers to discharge is functions effectively. Each sanitary ward consists of 3-12 election wards. The total number of collection bins is 680. The distribution of sanitary wards in Kolhapur City is shown in Map No.1.

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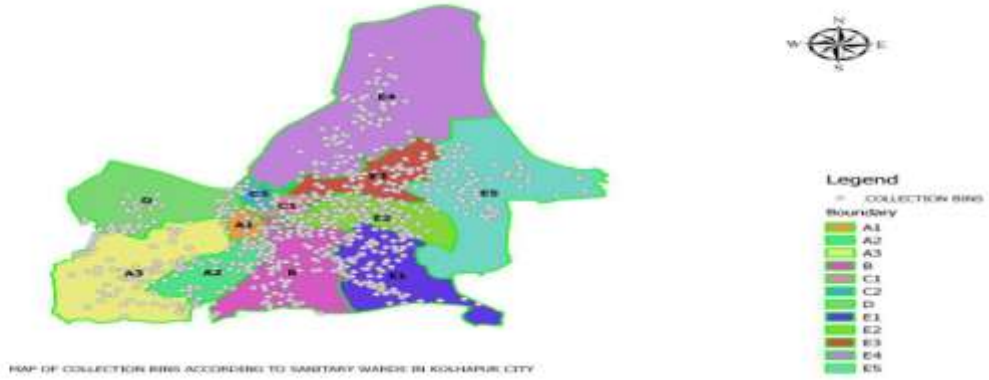
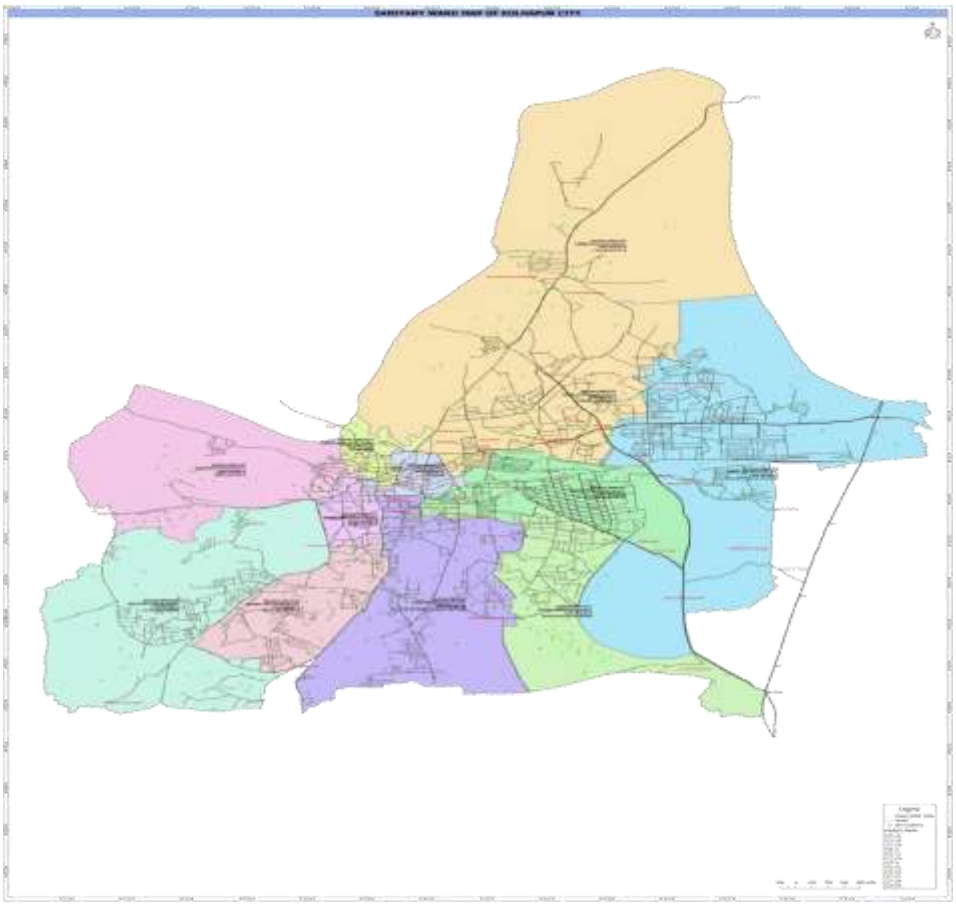


Map No.1 Distribution of Sanitary wards in Kolhapur City



Map No.2- Map of collection bin of Kolhapur city including road networks and sanitary wards.

A thematic map of population density was prepared for the sanitary ward wise population density for Kolhapur Corporation as shown in Map No.2. To arrive at the population density values, the following formula was adopted.

Population Density= No. of Persons / Area of Sanitary Ward.

The field calculator was used to obtain the population density value, which was attributed in the data table. The population density values were further used for Thematic Mapping.

More than 50% of the sanitary wards are identified with density between 602-1524 people per sq. m. these wards are identified are the potential wards for development and high growth rate is attributed to these wards. About one sanitary ward is observed with densities ranging up to 470 persons per sq. m. Low densities wards are attributed to locations along the Corporation periphery, presence of water bodies, hillocks, industrial units or educational institutes.

Table No.3-This table contains no. of collection bins in Sanitary Wards of Kolhapur City.

Sanitary wards in Kolhapur City	Election Wards Included In Sanitary Wards	Total No. of Election Wards	Total no. of Collection Bins
A-1	47,48,49,54,55.	5	21
A-2	56,57,69,70,75,76	6	51
A-3	71,73,74,79,80,81	6	80
B	33,43,44,45,46,58,59,60,67,68,77,78	12	93
C-1	26,27,32	3	14
C-2	28,29,30,31	4	11

D	50,51,52,53,72	5	39
E-1	40,41,42,61,62,63,65,66	8	101
E-2	24,25,34,35,36,37,38,39	8	72
E-3	7,10,11,14,15,16,17	7	60
E-4	1,2,3,4,5,6,12,13	8	72
E-5	8,9,18,19,20,21,22,23,64	9	67

Table No.4- this table contains population and population densities in sanitary wards in Kolhapur City.

Sanitary Wards	Election Wards	Total no. of election wards	Total no. of collection bins	Population	Density
E1	40,41,42,61,62,63,65,66	8	101	55329	1286
C2	28,29,30,31	4	11	26552	3689
C1	26,27,32	3	14	20050	3135
E2	24,25,34,35,36,37,38,39	8	72	55096	1524
B	33,43,44,45,46,58,59,60,67,68,77,78	12	93	78604	1220
E3	7,10,11,14,15,16,17	7	60	46791	1208
A2	56,57,69,70,75,76	6	51	40398	1362
A1	47,48,49,54,55	5	21	33469	4081
D	50,51,52,53,72	5	39	36227	602
A3	71,73,74,79,80,81	6	80	40176	452
E4	1,2,3,4,5,6,12,13	8	72	55680	325
E5	470	470	470	470	470

Based on population of each sanitary ward and the Waste generation of each ward using this per capita waste generation map were prepared. Per Capita waste generation is calculated using per capita solid waste generation. Per capita generation of Kolhapur City is 0.03kg per day.

Per Capita Solid Waste Generation = Total weight of Solid Waste generated per Day/ Population Served.

For each ward area, this method was used to prepare a thematic map of per capita waste generation in Kolhapur City

5. CONCLUSION

The municipal officer involved in the solid waste management should be clear about the function and their role in terms of managing the cities effectively with the help of GIS system. These Thematic maps will help officers to identify and monitoring the more waste generated wards.

The map of Collection bins of Kolhapur City will help to Sanitary Inspectors to identify the Number of collection bins, accurate location of the collection bins in their wards. There is need to improve the data system of solid waste for the monitoring and management to support the environmental reports has been improved.

6. ACKNOWLEDGMENTS

This study was carried out in Kolhapur City and some selected wards in the same. The assistance of Kolhapur Municipal Corporation (KMC) is gratefully acknowledged and regards for the guidance provided by the faculty of Environmental Engineering Department Mrs. M. N. Sarnobat ma'am. Also kind regards for Sanitary Inspectors for their help and support.

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