SOLID WASTE MANAGEMENT AND ITS IMPACT ON SURROUNDING ENVIRONMENT: A CASE STUDY OF FARIDABAD CITY

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SUMMARY

Present study is entitled as Solid Waste Management and Its Impact on Surrounding Environment: A Case Study of Faridabad City. Solid waste management is one of the major problems faced by different cities all over the world. The problem is particularly due to urbanization, industrialization, poor urban planning and lack of adequate resources which contribute to the enormous amount of solid waste generation. This problem has resulted in serious environmental, social and economic complications in the developing countries like India. Population growth and dynamic economic activities in and around the city has resulted in a serious waste management crisis. Hence, keeping this in mind the study has undertaken to examine the solid waste management in an industrial city.

The problem of solid waste management has raised many questions.

- How much household and industrial garbage is generated?
- What are the effects of rapid growth of population and industrial development on solid waste management?
- What is the mechanism of solid waste management?
- How much area is under solid waste dumping sites?
- Which are the suitable locations for dumping of solid waste?
- What are the impacts of solid waste management on surrounding environment?
- What are the solutions to improve the status of solid waste management?

Statement of the Problem:

Since independence, Faridabad has been experiencing phenomenal growth in its population and industrial activities resulting into concomitant changes in its peripheral areas. Population of Faridabad city was 10.56 lakhs in 2001. The city was initially planned only for 3, 00,000 people but the total population of the city is well over 2 million today (http://Faridabad.nic.in). The total quantity of solid waste is large and increasing day by day in Faridabad city due to increase in population and industries. Rapid urbanization, increasing commercial and industrial activities and changing life styles in Faridabad are leading to a
steady increase in the generation of solid waste. Collection and dumping of domestic and municipal wastes is a serious problem in Faridabad city because of its impact on environment and public health. If solid wastes may leave in the open spaces, waste land and street may increase serious environmental problems. This may lead to the pollution of ground and surface water because of leaching. Polluted water flowing from waste disposal sites may cause serious pollution of water supply. The open burning of waste may cause air pollution, causing illness, reducing visibility and making disposal sites dangerously unstable. The gases produced by burning may cause different respiratory diseases. Aerosols and dust may spread fungi and pathogens from uncollected and decomposing waste.

Waste collection workers may face particular occupational hazards, including strains from lifting, injuries from sharp objects and traffic accidents. Dangerous items (such as broken glass, razor blades, other healthcare waste, aerosols cans and potentially explosive containers and chemical from industries) may pose risks of injury of poisoning, particularly to children and people who sort through the waste. Older and poorly managed landfills may create number of adverse environmental impacts. Uncontrolled waste spoils also the aesthetic outlook of the city. Lack of plan in the management of solid waste may lead to epidemic of plague and malaria and the like. The problem of solid waste may cause serious and long term pollution of air and water. Improvement in solid waste management may lead to minimization of environmental impacts.

Hence keeping the above cited issues in mind, the present study has been undertaken.

Objectives:
The major objective and the purpose of the study remains to:

- Examine the exiting solid waste management practices in the study area.
- Evaluate the nature and quantum of solid waste generation and its type.
- Analyze the implications of solid waste generation and management.
- Find out site suitability for solid waste management.
- Identify suggestions for the improvement of the status of solid waste management.

Hypotheses:
The study proposes to examine the following hypotheses:
• Faridabad is a big industrial centre and hence increases in both population and industries generate lot of solid waste.
• Large quantity of solid waste remains outside the preview of municipal solid waste management which inking that current lifting capacity is much less as compared to the waste generated per day.
• Absence of solid waste management of large quantity of solid waste from household and industries can create health hazard.

**Organization of the Study:**

In order to achieve the objectives stated earlier, the present research is taken the following form: The first chapter deals with introduction, review of literature, statement of the problem, objectives, hypotheses and characteristics of the study area. The second chapter describes the research design and methodology. The third chapter examines the existing solid waste management practices. The fourth chapter highlights aspects of solid waste management. The fifth chapter discusses impacts of solid waste management. The sixth chapter has find out site suitability for solid waste dumping. The seventh chapter includes summary of conclusions and suggestions of the study.

**Study Area:**

Faridabad is identified as one of the Delhi Metropolitan Area (DMA)/ Central National Capital Region cities of National Capital Region (NCR) and accordingly it has strong linkages with Delhi. NH 2 from Delhi to Mathura passes through the length of the city and is the central axis of the city of Faridabad. Faridabad is situated on the Delhi-Mathura NH-2 at a distance of 32 km from Delhi, at 28° 25' 16" N latitude and 77° 18' 28" E longitude. The present geographical area of Faridabad is 207.88 sq. km. The population in Faridabad city is estimated to be about 16.62 lakh in 2011. The NCR regional plan for 2021 has projected the population of Faridabad as 25 lakhs. The Faridabad Municipal Corporation consists of Old Faridabad, Ballabgarh and New Industrial Township (NIT). It is the most populated and biggest city of Haryana.

**Research Design and Methodology**

The present research work is based on both primary and secondary sources of data.
Data base and methodology to achieve I objective:

Ist objective refer to the Existing Solid Waste Management Practices in MCF. To achieve this objective secondary information is collected from MCF about existing solid waste management in the study area: It relied on literatures from libraries, governmental documents, reports from health organizations and other sources like books, newspapers, journals and magazines. The secondary data related to population characteristics, ward wise population, zone wise population, population growth, density, literacy, number of household, size of household and the like was collected from village and town directory of Faridabad, Census of India and Municipal Corporation Faridabad and processed with simple statistical techniques.

Data base and methodology to achieve II objective:

Objective II pertains to evaluate the Nature and Quantum of Solid Waste Generation and Its Type and to analyze the Implications of Solid Waste Generation and Management.

It is mainly based on the field enquiry conducted through questionnaire/schedule, field observation and Focused Group discussion (FGD). During the field visit different types of solid waste garbage samples were taken of the selected locations of the city. GPS survey was done to mark the location of dust bins, collection points, dumping sites, transfer stations and compost plant. Primary survey also includes the samples taken from different collection points and field observation of dumping sites / landfill sites and transfer stations to get a fair idea about solid waste management in the city. An interview-schedule with open-ended questions is used to know life style, attitude and perception of society towards waste, its management, their role in it, impact of solid waste on health of the public as well as workers of municipal and other private firms who are involved in the process of solid waste collection and disposal mechanism. It included those workers who are working in Faridabad Municipal Corporation; NGOs working for this purpose are namely private firms such as Ramki (NIT), Vishal Protection Force (Old Faridabad) and International Academy (Balllabgharh). Multilevel sampling is done on stratified, random and proportionate basis. Primary survey also included collection point survey, dumping site / landfill site survey and transfer station survey. Samples were also taken from the landfill sites forgetting a fair idea about solid waste
management in the city.

**Selection of Sampling Sites:**

There are about 342 municipal solid waste collection sites. All these sites are well spread in Faridabad city. Approximately, 600 metric ton/per day MSW is generated from these sites. The characteristics of municipal solid waste depend on the activities near waste collection point and living standard of the population in the area. In order to assess the solid waste characteristics, total 18 sampling sites were selected which are well spread over the entire city. The sampling sites were selected to represent different activities of the population as follows:

- Domestic
- Commercial
- Dairy activities
- Vegetable market
- Food grain market
- Meat market

12 sampling sites were selected from residential area (High, Middle, Low income group and slum (Jhuggi) areas situated at Old Faridabad, Ballabgharh and NIT area. 2 sampling sites were selected from commercial area situated at Old Faridabad, and NIT area. In order to evaluate the characteristics of the wastes generated from dairy activities, vegetable market, food grain market and meat market, one site each was also selected from these locations.

**Sampling Procedure:**

a) The field studies for the collection of municipal solid waste samples was carried out in June and September, 2011 a period covering pre and post monsoon. Separate two sets of samples were collected from 18 selected sites for analyzing relevant parameters.

b) Analysis of Municipal Solid Waste Samples: The following approach (Pollution Control Research Institute, Uttarakhand, 2003) was followed for segregation of different constituents and preparation of sample for detailed analysis:
1. The crude waste was mixed properly to make it homogenous.

2. Representative sample of 120 kg at each location was collected from 18 different points and mixed thoroughly.

3. This homogenous waste was divided into four equal parts of 30 kg each.

4. The two diagonally opposite parts were retained (60 kg) and other two parts were discarded.

5. The retained portion of waste was again thoroughly mixed and further subjected to quartering of 15 kg each.

6. This time the other two parts were retained and made 30 kg. This 30 kg was mixed and split further into 4 parts of 7.5 kg each and two parts of it were discarded.

7. The rest two parts of 7.5 kg each were mixed together and a sample of 15 kg was prepared for physical and chemical analysis.

8. After preparation of solid waste sample, physical segregation was carried out to estimate weight of paper, plastic, metal, glass, organic matter and dirt/ash/soil. The weights of these different constituents were recorded.

**Analysis of Physical Characteristics:**

In the municipal solid waste samples following physical and chemical analysis were carried out:

**Loose Bulk Density:**

The loose bulk density was measured by using Wooden Box of 0.028 cubic meter capacity and spring balance at site.

\[
\text{Volume} = \frac{\pi}{4} (\text{des.})^2 \times \text{height}, \quad \text{Weight of Waste} / \text{Volume} = \text{Density}
\]

The solid waste were taken in the 0.028 cubic meter capacity box from different parts of the heap of the waste, and then weighted with the help of spring balance. After weighing, this smaller box (0.028 m³) weight of the waste was recorded. This has been repeated three times.
The waste was not compacted and the loose bulk density was calculated by dividing the weight of solid waste by the capacity of the box.

**Sieve Analysis:**

The particle size distribution of waste constituents in the samples is important because of its significance in the design of mechanical separators and shredder and the waste treatment process. This varies widely and while designing a system. The smaller size of particle increases the rate of microbial attack. The suitable size is from 13 mm to 50 mm. Proper analysis of the waste characteristics is important. Then sieve size were used: 100mm, 63mm, 31.5mm, 20mm, 16mm, 12.5mm, 10mm, 6.3mm, 4.75mm, 2.30mm, 1.18mm, 850µm, 600µm, 300µm, 240µm and 90µm.

**Procedure:-**

The sample was dried at 105-110°C and 500gm sample was taken. These sieves were placed properly and shake through sieve shaker for 10 minutes. No particle was pushed through sieve. Care has been taken to ensure that sieving is complete. The fraction of solid waste retained on each sieve has been carefully collected in containers and mass of each fraction determined and recorded.

**Proximate Analysis:**

**Moisture Content:**

Information and data of the characteristics of solid waste are important for the selection and design of disposal facilities. The moisture content is a critical determinant in the economic feasibility of the waste treatment and processing methods by incineration since energy must be supplied for evaporation of water and in raising the temperature of the water vapors. The moisture content was determined as per standard procedure and the percentage of moisture content was calculated in the following manner:

\[
\text{Moisture Content (%) = } \frac{\text{Wet Weight - Dry Weight}}{\text{Wet Weight}} \times 100
\]
**Volatile Solids:**

About 5 gm of finely ground samples was placed in silica crucible and heated in a muffle furnace up to a temperature of 600ºC for 2 hours. Now the crucible was allowed to cool in desiccators and weighted again. The volatile substances and non-volatile substance percentage of the original mass was calculated as follows:

\[
\text{Volatile Solids percentage by mass (VS)} = \frac{\text{Initial Mass} - \text{Final Mass}}{\text{Initial Mass}} \times 100
\]

Non Volatile substances percent by mass = 100 - VS

**Questionnaire / Schedule Based Survey Sample:**

In Questionnaire survey an interview-schedule with open-ended questions is used to collect the information from the group of society about the generation of solid waste, its different sources, contents, public opinion about solid waste and its impact on health and surrounding environment. The study is based on multilevel stratified sampling. Purposive random samplings are done at category level and within each category sample were taken randomly. In survey an interview-schedule with open-ended questions has been used to collect the information from the group of society about the generation of solid waste, its different sources, contents, public opinion about solid waste and its impact on health and surrounding environment.

**Selection of sample:**

The study is based on sample survey of 701 from household, commercial establishments, industries, MCF/NGO workers, health institutions and rag pickers. These includes 432 sample of households, 73 samples of commercial activities and 16 sample of industry which were selected proportionately (according to size of households, commercial establishments and industries) from the localities of different economic level groups i.e. very low (slum), low, medium and high income group (Table 2.1 and 2.2 ). Interview-schedule was used to collect data from the workers who were involved in the process of solid waste collection and
disposal mechanism. It includes those workers who were working in municipal corporation Faridabad and NGO’s named Ramki (NIT), Vishal Protection Force (Old Faridabad) and International Academy (Ballabgharh). It also includes 30 samples of those workers who were working in hospitalsto collect information about bio-medical waste. MCF / NGO workers samples have been taken five percent of the total workers. Higher categories officer’s sample are not taken proportionately because their number is low. Only one sample of these categories from each administrative zone has been taken. 24 out of 300 private hospitals and clinic and 6 out of 15 govt. hospitals and dispensaries samples have been taken. One sample each of govt. and private hospital, two samples of dispensaries and six samples of clinics have been taken from each administrative zones of MCF. Apart from that 30 samples of rag pickers have been taken who were involved in the collection of recyclable waste.

**Data base and methodology to achieve IIIrd objective:**

Objective III is to analyze the Implications of Solid Waste Generation and Management. To achieve this objective opinion of the different sections and stakeholders were taken into account through field survey to assess the impact of solid waste and to identify the level of Vulnerability to solid waste in spatial context which has been calculated using the indices of the selected eight parameters such as Slope, Population density, Quantity of solid waste generation, Population – BPL family ratio, Population – collection point ratio, Area-sweeper ratio, Household-sweeper ratio and Literacy rate. The entire city was classified in five categories. Further, five categories were divided according to level of vulnerability i.e. very high vulnerable; high vulnerable; moderately vulnerable; low vulnerable and very low vulnerable. Very high vulnerable category denote to worst condition whereas very low vulnerable category consider better condition. Each ward has been assigned category on the basis of selected criteria and the finally composite index (cumulative score) of the individual criteria for each ward has been calculated. Cumulative vulnerability to solid waste is obtained with the help of Z – score of the eight selected parameters. Obtained Z-score is classified into five categories such as very high vulnerable, high vulnerable, moderate vulnerable, low vulnerable and very low vulnerable.

**Data base and methodology to achieve IV objective:** Objective IV isto find out Site Suitability for Solid Waste Management.
The selection of suitable sites is based upon a specific set of local criteria. The characteristics of a site (e.g. present land use, slope, water quality, population, soils, transportation networks, geomorphology, etc.) influence its suitability for a specific land use type. To assess the solid waste dumping site suitability a scoring and weighting system has been used. At this stage, factor criteria were used to further evaluate these sites according to their suitability in order to indicate the most preferable site for locating landfill. The weight was assigned to each category. These weights indicate the landfill suitability condition ranging from the least to the most suitable. Scores of the criteria are given on the different scales. The pair wise comparisons have been expressed in present study according to a scale proposed by Saaty (1977). Thus, the explanation for each of the factor criteria is in terms of its suitability according to that scale.

Methodology:

The spatial modeling for sitting landfills in GIS has been categorized into following 5 parts:

- Data collection, preliminary analysis and preparation of the decision hierarchy for landfill sitting.
- Calculation of relative importance weight (RIW) to each theme.
- Calculation of relative importance weight (RIW) to various classes in different themes.
- Modeling in order to calculate the spatial distribution of Suitability Index.
- Identification of potential landfill sites.

Consistency ratio (CR): At this stage the consistency ratio (CR) is calculated to measure how consistent the judgments have been relative to large samples of purely random judgments. There are 3 steps to arrive at the consistency ratio:

1. Calculate the consistency Vector: To calculate the consistency measure, we can take advantage of Excel’s matrix multiplication function =MMULT.

2. Calculate the consistency index (CI): CI reflects the consistency of one’s judgment.

\[ \lambda_{\text{max}} - n \]
$$CI = \frac{\lambda_{max}}{n-1}$$

Where:

$\lambda_{max} = \text{Consistency vector / No of criteria}$

$n = \text{No of criteria}$

3. Calculate the consistency ratio (CI/RI where RI is a random index):

**Suitability Index:**

$$S.I. = \sum w_j x_i$$

Where, $S.I. = \text{Suitability Index of each polygon}$

$w_j = \text{weight of particular theme calculated earlier}$

$x_i = \text{weight of the feature in that particular theme, calculated earlier}$

**Processing of Data:**

The collected data was processed with the help of statistical techniques such as correlation, regression and factor analysis. The processed data was displayed with the help of various types of maps and diagrams prepared with the help of software such as Arc GIS 9.3, Erdas Imagine Version 9.1 and Microsoft Office 2007.

**Conclusions and Suggestions:**

**Existing solid waste management practices:**

There is a positive relation between temporal change in population and quantity of generation of waste. Similarly, there is a positive relation in number of industries and solid waste generation. Solid waste of Faridabad city is increasing rapidly due to industrial growth and location in NCR (National Capital Region). The population, urbanization, higher per capita income, standard of living, and changing lifestyle is also contributing to increased solid waste. Rapid urbanization, increasing commercial and industrial activities and changing lifestyles in Faridabad are leading to a steady increase in the generation of solid waste.
Solid waste management is an obligatory function of Urban Local Bodies. Waste collection bins have been placed within the vicinity of the households so that they can use the same. The waste is lifted everyday from the bins and proper measures are taken to avoid spilling of the solid waste in the city. Recently, MCF has engaged three NGOs namely Ramki (NIT), Vishal Protection Force (Old Faridabad) and International Academy (Ballabhgarh) for door-to-door collection and transfers it to nearest collecting points.

It is found that presently, total quantity of solid waste generation is 617.60 T/ per day with per capita generation about 400 grams per day. There is wide variation in the quantity of generation. The quantity of waste generation increased with the population growth. There is positive relationship between population and solid waste generation. It is observed that about two-thirds (470TPD) of the total solid waste of 618 TPD generated in MCF is reported to be collected out of which 270 TPD is transported to landfill sites and 200 TPD for composting. Rest of the 148 TPD remains uncollected which also reflect the very serious problem of solid waste management of Faridabad city. Heaps of garbage, overflowing waste bin and drains area common in various wards localities of Faridabad city.

**Aspects of solid waste management:**

It is found that 27.59% recyclable material and 46.78% biodegradable materials are present in MSW of Faridabad city. Remaining 25.63% are dust, ash and soils. Non-degradable inert material is decreasing and bio-degradable material is increasing (amount), due to constructing activities coming to near standstill. MSW of Faridabad has high moisture content and high organic content, making composting and sanitary land filling the best treatment strategy. It was also observed that the proportion of paper waste increases with the increasing in income.

Loose bulk density is a function of local income, being higher in the low income group. The loose bulk density of Municipal Solid Waste varies from 91.50 kg/m3 to 490 kg/m3 with average value as 293.36 kg/m3. Particle size is an important characteristic for finalizing the treatment/ disposal option for Municipal Solid Waste. Theoretically, the smaller the particle size, the more rapid is the rate of microbial attack. The suitable size is from 13mm to 50 mm.
It has been observed that around 68 percent particles are 10 mm or above. However, more than 50 percent particles are of 16 mm or above.

The efficient composting requires the moisture content of the composting mass be maintained at or above 45 – 50 percent. The proximate analysis of Municipal Solid Waste samples indicates that average values of moisture content, volatile solids and ash content are 41 percent, 25.12 percent and 33.88 percent respectively.

It is found that solid waste collection points are not in enclosure/boundary wall and exist in open areas. Waste collection points are not protected. Lot of stray animals like cow, pigs and dogs etc. are consuming organic matter present in the solid waste at these open sites resulting in reduction of this matter in the analysis of characteristics. Large quantities of polythene bags were observed at collection points. The solid waste is normally disposed in these bags. The recyclable constitutes of MSW are removed by rag pickers. They recover the paper, plastic and metal etc. reducing the proportion of these materials in the solid waste. The majority of solid waste at the collection points is received in the first half of the day.

It has been observed that majority of the household’s i.e.92.59 percent are using bin and about 3.47 percent polythene for the disposal of waste. Most of the population doesn’t know about the requirement of proper disposal of waste in slum area. Majority of the households i.e. 88.43 percent disposed of kitchen waste between 1-2 days and 11.57 percent between 2-3 days. Majority of respondents i.e. 91.67 percent vend recyclable waste to knacker, followed by 5.56 percent dump in the municipal bin and 2.78 percent reuses the recyclable waste. Overwhelming majority of respondents (93.06 percent) recycled the paper waste, construction material (97.92 percent) followed by plastic (81.71 percent) and metal (80.32 percent). Organic waste is recycled only by a fraction of the respondents (0.93 percent).

The lower income group households generate lesser amount of waste in comparison to medium and higher income group. Proportion of garden waste also increased generation rate of high income group. People sort out recyclable waste materials at household level and sell it to the waste buyers. Very low income group has the least preference for door to door collection because this group doesn’t have money to pay for that. Three-fourth of the respondents in the study area have preferred door to door collection of waste and about one fourth of them have preferred the community dustbin. Community dustbins create many
health problems. Usually there are very unhygienic conditions in and around collection points. Garbage littering create not only odour but it also become ideal place for germination of many type of rodents, flies, mosquito and the like. It is observed that location of the dustbin near to the place of residence is considered as a health hazard. Stray animals have suffered untimely death because of the eating of waste from the community dustbins which contain many harmful chemicals and rotten foods along with polythene. The main problem is lack of awareness of peoples. Irresponsible households including from educated background throw their household garbage carelessly from a distance outside the community bin which create unhygienic sanitary conditions around its location and become a health hazard for the local communities living beside it.

Two-thirds H.H. reveals that MCF is collecting waste every day and remaining respondents thinks that it is collected on alternate day. Collection of waste is very difficult in most part of the slum area due to inadequate open space and congestion which make it inaccessible for the garbage collector vehicles. Requirement of a locality as well as container capacity to store waste and cost determine the collection frequency.

Charges of door to door collection of waste depend upon size of household, locality, occupation and income of a family. NGO do cross subsidy i.e. charge are high in high income group residential areas as compared to the slums and low income group areas. Slum respondents were of a view that community dustbin condition would not have been in such a bad condition had it been collected daily.

It is noted that production in large size industry is more than small size industry. So the segregation of waste takes more time than small size industry. Hence, waste collection in large size industries is done on alternate day. Most of the industries do not give weightage to the process of waste materials. Majority of respondents have awareness about hospital waste management policy only one tenth have shown the ignorance which are largely consist of small clinics.

Recycling of waste is an additional source of income and provides easily raw material to produce new product therefore, most of the respondents follow that. Recycling of waste increased from small size industries to large scale due to more quantity of recyclable waste
generated by large size units which become economically more beneficially and remunerative to these units than the small scale factories.

It is noticed that the use of bin is increased with the increase in level of income. Very low income group has tendency for the use of polythene for collection of solid waste. Very low income group is least educated and consist of slum area hence they don’t understand the value of hygiene. Kitchen waste is mainly consisting of organic waste which decomposed speedily and thus odour spread in nearby area causing health hazard. Therefore, most of the respondents disposed kitchen waste in short a time. Very low income group has the least preference for door to door collection because this group doesn’t have money to pay for that. Further, it is observed that location of the dustbin near to the place of residence is considered as a health hazard.

**Impact of solid waste management:**

It has been observed low income group mainly consist of slum population and hence because of low level of education and income either they are unaware of the health hazard of solid waste in term of sited parameters or they have no choice of being poor. Since, they are leaving close to such waste in unhygienic conditions for quite some time, they become habitual to pollution and unsanitary conditions. Moreover, it seems that they have adapted to live in such conditions and thus do not see any health hazard. Contrarily, higher income group is better educated and hence more aware about the importance of health and sanitation. Secondly, they are leaving in planned area where sanitary conditions are far better and have become habitual to leave in such condition.

Further, majority of the low income group consist of small commercial activities either do not see any health hazard as the consequences of epidemic diseases, environmental pollution and smell or its impact is moderate whereas medium and large size establishments feels severe impact.

Workers of industry concerned with size up to 500sq.yds see health hazard as the consequences of epidemic diseases, environmental pollution and smell as negligible or moderate whereas respondents from medium and large size units feels severe impact. Epidemics and environment impacts of medical solid waste are largely considered as
moderate and small group of respondents considered it as severe. However, odor impact is considered severe by larger group. Respondents from bigger health institutions considered severe impact more than the smaller one and it is invariably same across the zones.

Moreover, the higher level workers and official considered more severe impact of these parameters as compared to the sweepers who are more directly exposed to the hazardous waste. This may be because they become habitual to work in such conditions and thus have indifferent attitude towards appalling sanitary conditions.

**Vulnerability:**

There is inverse relationship between slope and vulnerability to solid waste, hence ward 10 and 18 has low vulnerability to solid waste whereas eastern parts towards river Yamuna are low lying areas and hence the vulnerability is very high. There is a significant spatial variation in the level of vulnerability in MCF, 2011. Old part of the city and industrial areas such as ward number 21 and 2 respectively and their surroundings has very high vulnerability. Likewise, peripheral areas of the city namely ward 23, 28 and 32 which are located along river Yamuna in the eastern most part of the city is a low lying area, are inhabited by low income group. High level of illiteracy and BPL families is ample proof of it. Apart from that sweeper – area and sweeper – household ratio is also high. It may be because these areas are occupied by low income group and hence, they are neglected by MCF in making provision of basic urban services hence display high vulnerability. Very low vulnerability areas include ward 10, 14 and 26. Ward number 10 has largely hilly terrain due to which impact of high slope is reflected in the low vulnerability of this ward.

**Site Suitability:**

The overlay analysis helps in categorizing the entire study area into four categories of suitability. The output map is classified into four categories as (i) unsuitable, (ii) less suitable, (iii) moderately suitable and (iv) most suitable according to the weightage allotted and the suitability index value obtained. The area with a suitability index from 0.002 to 0.020 can be generally considered as most suitable areas for landfills which are about 8.82 percent of the study area. Sites with value ranging from 0.020 and above are considered unsuitable area (73.31 percent) for solid waste dumping sites. Higher values of the suitability index refer
to the unsuitable site for waste disposal and lower the value, higher is the suitability. Higher values of the suitability index refer to the unsuitable site for waste disposal and lower the value, higher is the suitability. Ward 10 and 18 in the North - West periphery of the MCF are the most suitable for Solid waste sites.

Suggestions:
The following suggestions are based on the findings of the study.

- Study the statistics of quantity of waste generation in different areas for planning waste management in a more precise manner.
- MCF waste composition suggests that Organic/ Biodegradable waste should be used for making compost and other products which are useful.
- Construction waste should be used for land filling in low lying area. All recyclable materials like paper, plastic, cardboards, glass should be recovered and recycled.
- Rag pickers should be banned and the segregation must be done by the Govt. (MCF) in order to increase the income from the recyclable waste and to save the life of rag pickers as it is a health hazard exercise if conducted unscientifically. Secondly, Utilizing the manpower of rag pickers by providing them with work responsibilities in the waste management system and giving a secured livelihood and a social status in the society.
- Government should provide facility of door to door collection of waste at no cost in slum area.
- There is a an urgent need to frame policies for the proper care of stray animals by allocating some piece of land in the periphery of the city and in the common property resources (Gocharan land) of the adjoining villages.
- Further, adequate number of animal’s shelter houses (Gaushalla/ Pashushalla) shall be opened by motivating the members of the civil society partly aided by the government.
- Solid waste collection points must enclosure/boundary wall and not situated in open areas. Waste collection points should be protected.
- Awareness program should be introduced regarding solid waste management. It should be part of the curriculum at school level and activity in schools.
- Waste should be collected on day to day basis in separate bins for identification and segregation of wastes.
- The selection of type of vehicles for collection, transportation and disposal should prefer keeping in mind type and quantity of waste, distance, road condition, road width and locality and the like.
- Zero waste management model should be followed by the city. The quantity of waste reduces significantly if people changed their habits and lifestyle to conserve the natural resources and reduce the economic burden associated with the solid waste management.
- Presently all three sites for dumping of MSW are located towards eastern periphery of the study area. Two of these sites are located in densely populated area against the locational bye laws.
- Present study has identified suitable sites using standard guidelines for dumping of MSW which are located on the north western periphery of the city in ward 10 and 18. Therefore, it is suggested that one alternate site should be developed in the North-West periphery of the city in ward 10 or 18.
- Revenue should be generated by the composting the organic waste and selling the recyclable waste.
- Use of satellite data imagery instead of old manually developed maps which may contain errors. Recyclable waste bins should be used.
- Route planning for waste collection vehicles should be done and implementations of vehicular tracking systems like GPS on the vehicles to calculate waste collection timings.