1.1 Introduction

Solid waste has been generated from the very beginning of humanity with the advent of settlements. Earlier society had mostly natural products and food wastes as solid waste. Problems were little as waste generated by these earlier societies was quantitatively less and non-persistent due to the biodegradable nature of the waste. However, with the advent of modern age urbanization and rapid growth in urban populations, there was a tremendous change in not only the amount of solid waste but also the composition with the development of newer materials. Humans have built towns and mega cities which are large artificial ecosystems driven and sustained by huge inputs of resources and the outputs from these artificial ecosystems is in the form of polluted water, air and the generation of municipal solid waste.

Another reason for the increase of the waste is the gradual change in the social thinking up to about 20 years ago people used to think twice before consigning anything to the waste bin. Things were reused many times before finally ending up in the waste bin. However due to the dramatic shift in the social thinking we have entered the age of consumerism. This use and throw syndrome has added to the quantity of waste generated by the society. Gradually municipal solid waste has become a problem faced by every country in the world. This municipal solid waste problem has become a serious threat in recent years, and the situation is likely to take a turn for the worse in the coming years if appropriate measures are not taken.

Municipal solid waste if not properly managed has two-fold negative implications. On the one hand, it pollutes the air, water, and land resulting in diseases and destruction of human habitat. On the other hand, improper management deprives us of resource materials for recycling, producing energy, electricity, and manure. The greatest enemy of the environment is the huge and rapidly increasing human population which is casting a gigantic ecological footprint. The world is facing with an ever increasing human population and the associated increasing trend in urbanization has added to the problem of environmental degradation. The available statistical data shows that, although the municipal solid waste generation in developing countries on the per-capita level is low as compared to in developed
world, but still the developing countries account for disproportionately high shares of world’s solid waste generation relative to their share of world income. In general, a 1% increase in population is associated with a 1.04% increase in the solid waste generation, and a 1% increase in per capita income is associated with a 0.34% increase in a total solid waste generation (Wang et al., 2011). The health of the environment is being compromised due to unsustainable waste disposal and management. It is a sensitive and serious problem in today’s world. It is estimated that in 2006 the total amount of solid waste generated globally reached 2.02 billion tons, representing a 7% annual increase since 2003 (Global Waste Management Market Report, 2007).

Due to a rapid increase in the production and consumption processes, societies generate as well as reject solid materials regularly from various sectors like agricultural, commercial, domestic, industrial and institutional. The considerable amount of waste thus generated and rejected is called solid waste. Municipal solid waste includes commercial and residential wastes generated in municipal or notified areas, in either solid or semi-solid form which excludes the hazardous industrial waste but include the treated bio-medical waste (MoEF, 2000).

The direct dumping of the municipal solid waste solid without proper inspection and separation leads to many serious impacts of environmental pollution causing growth in health and environment related problems (Shoba and Rasappan, 2013). Domestic and industrial solid waste is causing environmental pollution and has become a monumental problem for mankind. If this situation is not managed in the proper manner within time, then it would lead to extremely detrimental consequences on a global level (Bhambulkar, 2011). Indiscriminately disposed waste is posing a threat to the environment and human being. Unscientific disposal attracts birds, rodents, and fleas which create unhygienic conditions and transmit disease it also increase the risk of fire hazard, cause odor nuisance, spoils the aesthetic looks causes economic losses and pollution of soil air and water (Jilani, 2002; Suchitra, 2007). It is estimated that about 10% of each person’s production life is lost as a result of waste-related diseases (Ansari et al., 2012). There is an increase in residential, commercial and infrastructural development due to the urban expansion, population growth and living
standard development and all this directly affect the amount of waste generation and disposal. This scenario is leading to enormous solid waste generation in almost all countries. The developed countries are producing more than the developing countries due to their higher waste per capita. The composition of solid waste is varying from country to country as well as from city to city even in the same country. Similarly, the chemical composition is also varying from place to place (Kumar et al., 2009). The collection of waste is one of the biggest problems in the waste management process. The average collection efficiency for solid waste in Indian cities is about 72.5% and around 70% of the cities lack adequate waste transport capacities (Teri, 1998).

The study of solid waste generation, its characteristics, its spatial distribution and mode of collection is necessary for both future planning and present management purpose. Results of such studies are useful in route optimization of waste collection vehicles and selection of suitable dumpsite in regard to public health and lessening its negative environmental effects. As the size of the city and quantity of solid waste increases, the waste management becomes a complex process. Solid waste management requires considerable expertise in many fields such as environmental science, engineering, soil sciences, hydrogeology, topography, sociology, economics, and law. A solid waste management planning must take into consideration a large number of factors such as geographical location, population density, social makeup, secondary waste storage points, habitation, key infrastructure elements, the porosity of the soil, water table depth, and road network. Therefore, the scientific and systematic management involves processing of a significant amount of the data, and much of this data is spatial. The process also involves taking into consideration acceptable criteria’s and regulations. Therefore in a waste management system, a vast amount of data and scientific analysis must be done on all necessary criteria’s like characteristics of generated waste, the economic value of waste, its proper temporary storage, collection and its cost effective and safe deposition to a landfill.

1.2 Potential of GIS in solid waste management

In recent years, Geographical Information System (GIS) has emerged as a very important tool for management practices of solid waste. GIS can recognize, analyze
and correlate the spatial relationship between mapped phenomena, thereby enabling policy makers to link disparate sources of information, perform sophisticated analysis, visualize trends, project outcomes and strategize long-term planning goals (Malczewski, 2004). The work in this field was initiated by McHarge (1969) who propounded the basic mapping principles for site suitability analysis, mainly those that involved finding the best route connecting two points or identifying the best location for a specific application. The methodology involved making thematic maps and superimposing them on top of one another to view the overlapping of the layers so as to decide upon the most suitable location taking into account a number of factors. With the advent of GIS and the subsequent development of GPS, a lot of work was initiated upon its potential application for optimized siting (Sumathi et al., 2008). GIS has vast applications in municipal solid waste management such as in the areas of bin site selection, route optimization for collection from secondary storage sites and identification of suitable waste disposal sites. The use of GIS reduces the time as well as the cost of management, and at the same time also provides a digital data bank for long-term monitoring of the management system, handling and correlating large amounts of complex geographical data, visualization of the results through geographical representation (Sumathi et al., 2008). With the increased use of GIS technology, multiple criteria decision-making methods (MCDM) are more frequently used to assist decision makers with analyzing and solving multiple criteria decision problems (Eldrandaly et al., 2005).

India is a developing country and practices a variety of different management methods for urban & rural and for residential & industrial areas. A group of Solid waste management specialists (constituted by Supreme Court of India) drafted the Municipal Solid Waste (Management and Handling) Rules 2000 that defines the standards that were to be achieved by the end of 2003. “Compliance (with MSW Rules) has been poor to moderate in respect of storage, collection, sweeping and transportation of waste. Compliance has been extremely poor in the area of treatment and disposal of waste (Asnani, 2008). All management practices of urban and rural areas are managed by ULB (Urban Local Bodies). India launched Urban Rural Mission in Dec. 2005 with investment of USD 22 billion (INR 1,00,000 Crore) over a
period of seven years 2005-2012 in 65 priorities cities with a target to benefit 150 million urban population under the Indian under Jawaharlal Nehru National Urban Renewal Mission (JNNURM) and for small and medium towns under Urban Infrastructure Development for Small & Medium Towns (UIDS & MT) schemes (JNNURM, 2012). The above finance was planned to be utilized for approximately 1,00,000 metric ton of MSW daily or 35 million metric tons of MSW annually (Hanrahan et al., 2006). But in 2011 it was estimated that about 1,60,000 MT of MSW was generated daily in India (Nithya et al., 2012), surpassing the quantity planned for in the JNNURM scheme.

Per capita waste generation in major cities ranges from 0.2 Kg to 0.6 Kg as per the data from National Engineering Research Institute (NEERI) (Asnani, 2006). An assessment has been made, that per capita waste generation is increasing by about 1.3% per year with urban population growth rate ranging between 3 to 3.5% per annum. The annual increase in the overall quantity of MSW is assessed about 5% (Sharholy et al., 2008; Virafmehta, 2010). 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, 20-30% on transportation and less than 5% on final disposal of waste (Ghosh et al., 2006; Shoba and Rassapan, 2013). For the integrated solid waste management advanced knowledge-based tools are necessary to support the proper management system and to overcome the complexity in the management system. The application of GIS with MCDM and DSS is appropriate for the systematic and effective outcome for this problem.

1.3 Objectives

In view of the above discussion a study on the application of GIS in the management of Rohtak city, municipal solid waste will be undertaken. It is expected that the outcome of the study will result in improvement in various aspects of solid waste management. The work will focus on the mapping of the spatial distribution of solid waste generation, rationalization of collection points, storage and dumping site, for
the optimization of present municipal solid waste management system in Rohtak municipal area.

In the present study, following objectives has been planned for municipal solid waste management-

1. Waste generation density mapping.
2. Identification of collection sites.
3. Determine the optimum route for solid waste collection and disposal.
4. Selection of dumping site.