

Application of GIS in Landfill Siting for Municipal Solid Waste

Debishree Khan¹ and S.R. Samadder²

*¹Department of Environmental Science & Engineering,
Indian School of Mines, Dhanbad-826004, India.*

*²Department of Environmental Science & Engineering,
Indian School of Mines, Dhanbad-826004, India.*

Abstract

Uncontrolled growth of the urban population in developing countries in recent years has made solid waste management an important issue. Today municipal solid waste management (MSWM) is one of the most challenging issues in urban cities, which are facing a serious pollution problem due to the generation of huge quantities of solid waste. This results in development of environmentally sustainable and efficient waste management systems. The main objective of MSWM is to protect the health of the population, maintain environmental quality by promoting sustainable practices, which in turn would provide support to economic productivity. Sanitary landfill constitutes one of the primary methods of municipal solid waste disposal. Selecting an environmentally acceptable landfill site is a complex land use planning problem involving the collection and processing of the information that relates to environmental, socio-economic as well as socio-political issues. It also requires an extensive evaluation process in order to identify the optimum available disposal location. This paper presents a method based on Geographical Information Systems (GIS) modeling to identify a set of criteria which needs to be considered for the proposed MSW landfill site in the city. GIS technology is used to generate spatial data for site assessment. The digitization and analysis of the thematic maps were performed using GIS software. Supervised classification was done to depict the land use in accordance with SWM. Several factors were considered in the siting process including geology, water resources, land use, sensitive sites, air quality and groundwater quality.

Keywords: Geographical Information System, Landfill Site, Solid Waste Management.

1. Introduction

Increase in growth of the urban population in developing countries in recent years has made solid waste management an important issue. Due to a lack of serious efforts by city authorities, the management of garbage has become a tenacious problem. MSWM is the major problem being faced by municipalities because it involves a huge expenditure and receives scant attention (Bhide and Sundersan, 1983). It is not only a technical problem but it is also strongly influenced by political, legal, socio-cultural, environmental and economic factors, as well as available resources. Moreover, these factors have interrelationships that are usually complex in waste management systems (Kum et al., 2005). Many cities in developing Asian countries face serious problems in managing their solid waste. The annual waste generation increases in proportion to the rise in population and urbanization, and issues related to disposal have become challenging as more land is needed for the ultimate disposal of these solid wastes. MSW is normally disposed of in an open dump in many Indian cities and towns, which is not the proper way of disposal because such crude dumps pose environmental hazards causing ecological imbalances with respect to land, water and air pollution (Kansal et al., 1998). Increasing population levels, rapid economic growth and rise in community living standards will accelerate the future MSW generation rate within Indian cities. The problem of MSWM is acute in cities and towns as the scientific disposal facilities have not been able to keep pace with the quantum of wastes being generated. In general, an effective solid waste management system should include one or more of the following options: waste collection and transportation; resource recovery through waste processing; waste transportation without recovery of resources, i.e., reduction of volume, toxicity, or other physical/chemical properties of waste to make it suitable for final disposal; and disposal on land, i.e., environmentally safe and sustainable disposal in landfills (Tchobanoglous et al., 1993, Kreith, 1994 and CPHEEO, 2000). Poor waste management systems coupled with hot climatic conditions results in increasing environmental problems with significant local as well as global dimension. In spite of the increasing stress towards the waste reduction at the source, as well as recovery and recycling of the solid waste, disposal of solid waste by landfilling remain the most commonly employed method. The development of a municipal solid waste landfill requires the acquisition of large tracts of land and its suitable siting in a pre-existing urban matrix comprised of diverse competing land uses. Siting decisions are governed by the pre-existing land use dynamics of the urban area as well as the nature of potential interactions of the landfill with the pre-existing environmental, geologic, hydrological, and socio-economic parameters of the area. Identification of landfill sites for solid waste disposal remains a critical management issue wherein the selection should be based on a number of considerations (Dipanjan et al., 1997; CPCB, 1999). Several important factors and criteria were considered to arrive at the optimum siting decision including the pre-existing land use, location of

sensitive sites, infiltration, water bodies, water supply sources, groundwater quality, air quality, fault line and geology. Thematic maps of the selected criteria were developed within the paradigm of standard GIS software. Subsequently, weightings were assigned to each criterion depending upon their relative importance, and ratings in accordance with the relative magnitude of impact. A GIS-based overlay analysis was performed to identify the optimum site for the landfill, one which fulfilled all of the desired attributes.

2. Landfill Siting and the Potential Application of GIS

Siting a sanitary landfill requires an extensive evaluation process in order to identify the optimum available disposal location. The evaluation of a new waste disposal site is a complicated process and it takes into considerations parameters such as distance to roads, habitation, key infrastructure elements and the propensity of soil to leach contaminants. Therefore, the siting of a solid waste landfill must also involve processing of a significant amount of spatial data, regulations and acceptance criteria, as well as an efficient correlation between them (sumathi et al. 2008). GIS has been found to play a significant role in the domain of siting of waste disposal sites. Many factors must be incorporated into landfill siting decisions and GIS is ideal for this kind of preliminary studies due to its ability to manage large volumes of spatial data from a variety of sources. The integration of GIS and Analytical Hierarchy Process (AHP) is a powerful tool to solve the landfill site selection problem, because GIS provides efficient manipulation and presentation of the data and AHP supplies consistent ranking of the potential landfill areas based on a variety of criteria. AHP is a systematic decision approach first developed by Saaty (1980). This technique provides a means of decomposing the problem into a hierarchy of sub-problems that can be more easily comprehended and subjectively evaluated. The subjective evaluations are converted into numerical values that are ranked on a numerical scale (Bhushan and Rai, 2004).

3. Methodology

In this study, 11 input map layers including topography, settlements (urban centers and villages), roads (Highway and local roads), slope, geology, land use, floodplains, aquifers and surface water are evaluated and prepared to be used in the analysis in GIS environment. Thematic maps of the selected criteria were developed within the paradigm of standard GIS software. All the data layers are derived and prepared from the related maps by scanning, georeferencing, georectifying and digitizing the relevant information. The information compiled from literature about the safe distances to a landfill site is used to determine the buffer zones for each layer. After creating the classes for each layer by using buffer zones, each layer is converted into individual raster maps. After the preparation of all input data layers, the method AHP is selected among the decision rules to analyze the data for landfill site selection by using GIS and hence the output map is prepared.

4. Discussions and Conclusions

In this study, all the input data required for the analyses are generated from three map sources, which are topographical maps, geological maps and land use maps. During the selection of the landfill siting criteria, the political constraint is not considered and the financial/economical constraint will be considered in the further study. The AHP decomposes the complex decision problem into simpler decision problems which provides easiness during decision making. Furthermore, it uses pair wise comparisons for determining the weights of the criteria by which two components are considered at a time which resulted in the reduction of complexity. The pair wise comparison for the determination of weights is more suitable than direct assignment of the weights, because one can check the consistency of the weights by calculating the consistency ratio in pair wise comparison. It has been understood that GIS analysis is not a substitute for field analysis; however, it does identify areas that are more suitable and directs efforts to these areas rather than areas that are unsuitable or restricted by regulations or constraints. The use of GIS during the study provides objective zone exclusion based on a set of screening criteria and effective graphical representation. At the end of the analyses, a number of candidate sites are identified. These sites generally satisfy the minimum requirements of the landfill sites. Among these candidate sites “potential landfill” sites are selected.

References

- [1] Bhide, A. D., Sundersan, B. B., 1983. Solid Waste Management in Developing Countries. Indian National Scientific Documentation Center, New Delhi, India.
- [2] Bhushan, N., Rai, K., 2004. Strategic Decision Making: Applying the Analytic Hierarchy Process. Springer-Verlag, New York, 172.
- [3] Central Pollution Control Board (CPCB), New Delhi, 1999. Development of site selection methodology for land filling – A case study for Bangalore, Hazardous Waste Management Series, HAZWAMS/22/2002–03, 12.
- [4] Central Public health and Environmental Engineering Organization, 2000. Manual on municipal solid waste Management, first Edition, 418-438.
- [5] Dipanjan, S., Vinod, T., and Onkar, D. 1997. “Ranking potential solid wastes disposal sites using geographic information system techniques and AHP.” National Seminar on Applications of GIS for Solving Environmental Problems., Chennai, 98–106.
- [6] Kreith, F., 1994. Handbook of Solid Waste Management. McGraw Hill, New York, USA.
- [7] Kum, V., Sharp, A., Harnpornchai, N., 2005. Improving the solid waste management in phnom Pench city: a strategic approach. Journal of Waste Management 25 (1), 101–109.
- [8] Saaty, T. L. 1980. The analytic hierarchy process. McGraw Hill, New York, USA. 287
- [9] Sener, B., Su“zen, M. L., and Doyuran, V., 2006. “Landfill site selection by using geographic information systems.” Journal of Environmental Geology., 49, 376–388.
- [10] Sumathi, V. R., Natesan, U., and Sarkar, C., 2008.” GIS-based approach for optimized siting of municipal solid waste landfill.” J. Waste Management., 28(11), 2146-2160.
- [11] Tchobanoglous, G., Theisen, H., Vigil, S.A., 1993. Integrated Solid Waste Management, Engineering Principles and Management Issues. McGraw-Hill, New York, USA.