

DEVELOPMENT OF AN INTEGRATED GIS BASED METHODOLOGY FOR THE SELECTION OF SOLID WASTES DISPOSAL SITES FOR KHULNA CITY

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Abstract: Solid waste management system is a global concern today. As sustainable management of the environment is necessary to keep a safe and livable world for the next generation, the continuous process of environmental degradation must be stopped or at least minimized immediately. Improperly managed or unmanaged solid waste can create adverse impact on environment through air pollution, water pollution, land contamination etc. It is really a serious threat to the environment. In order to minimize the impact, environmental consideration is incorporated in solid waste management system in developed countries but it is a new practice in developing countries. This paper examines a GIS based location finding approaches combined with multi-criteria evaluation for solid waste dumping for Khulna city in Bangladesh. It attempts to develop a methodology that can be applied in finding suitable sites for solid waste disposal for most of the major cities.

Keywords: Solid Waste, Site Selection, Multi Criteria

Introduction

Solid waste management, an indispensable part of our modern life on this planet, has become increasingly complicated since its earliest days. General awareness of our environmental problems has led to the development of pollution control technologies and more stringent legislation and strategies on waste handling and disposal to minimize the environmental impact associated with solid wastes. Waste dumping is an important part of waste management system, which require much attention to avoid environmental pollution. In context of Bangladesh waste disposal and management is in a bad shape in urban areas. Since urban inhabitants generate huge amount of municipal solid waste daily and population density is high. Only major cities have some sort of garbage disposal system. In the major cities in Bangladesh, per capita production of solid waste is 0.5 kg/day but only 0.2 kg of waste per capita is carried to the final disposal (Enaetullah, 1995 and Miah, 1998). The rest are disposed off locally. This view of the major cities of any country obviously exhibits the poor waste management situation of that country.

To minimize the adverse impact, efficient management of solid waste is essential. Solid waste management incorporates collection, disposal and recycling of domestic and commercial waste. Collection of solid waste from individual house or collection points culminates in a dumpsite that makes the sites selection for waste dumping so crucial factor for proper management of solid waste. Because, inefficient and improper dumpsite may cause huge transportation cost, environmental pollution and make the whole waste management activities more expensive. In selection of appropriate dumping sites different aspects like environmental, social and economic etc. are needed to be considered. Among these the environmental aspect has to be emphasized most. Because any improper dumping site can effect the surrounding settlements, ground water and air by different pollutants created from wastes and thus can make the surrounding environmental unsuitable for living.

This study has attempted to develop a standard methodology for solid waste disposal site selection, which can be applied in any urban area, especially for developing countries. Another important output of this study is the allocation of some suitable solid waste disposal sites for Khulna city by using the developed methodology, which can be used by the concern waste management authority according to the need.

Solid Waste: Quantity and Characteristics

Solid wastes are all the wastes arising from human and animal activities that are normally solid and that are discarded as useless or unwanted. The definition of solid waste encompasses all those wastes, which are neither wastewater discharged nor atmospheric emissions. Solid waste is the term now used internationally to describe non-liquid waste materials arising from domestic, trade, commercial, industrial, agricultural as well as from public services (Enaetullah, 1995). The term solid waste as used in this study is all - inclusive and encompasses the heterogeneous mass of throwaways from residences and commercial activities and public services.

Quantity and characteristics of generated wastes depend upon different factors such as food habits, cultural traditions, socio-economic and climatic conditions. Nature of wastes is a function of relative consumption and production activities within countries, and also depends on the stage of economic development. Refuse characteristics and quantity vary not only from city to city but in the same city itself, from area to area and seasonally (Bachmann, 1985). In Bangladesh, all major cities, generate same level of solid waste and their quantity and composition of generated domestic wastes are shown in Table 1 and Table 2.

The physical composition of waste components varies widely with the location and season of the year. The main constituent of wastes generated from both domestic and commercial areas is food waste. So the

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decomposable organic matter is high (84.37%) in wastes of such sources (Table 1). As a result proper and prompt management action is needed to dispose such wastes to prevent pollution because these food wastes can be decomposed and create pollution within only a few hours.

Table 1. Physical Composition of Solid Wastes

Constituents	Residential area % by dry wt.	Commercial area % by dry wt.
Food waste	84.37	79.49
Paper	5.68	7.22
Plastics	1.74	1.48
Cloths	1.83	1.59
Glass, Metal and construction wastes	6.38	10.22
Total	100%	100%

Source: Enaetullah, 1995 and Miah, 1998

Table 2. Chemical Composition of Solid Wastes

Constituents (%)	Wastes from disposal site	Domestic wastes	Market wastes	Mixed wastes
Moisture Content	47-55	45.3	53.6	95.3
Fixed Residue	52.2-59.7	57.52	55.6	83.37
Organic Carbon	--	22.6	25.7	21.84
Organic Nitrogen	0.4-0.6	0.41	0.36	0.39
Phosphorus	0.0-0.05	0.05	--	0.94
Potassium	0.0	--	--	--

Source: Enaetullah, 1995 and Miah, 1998

Suitable Solid Waste Disposal Option in Context of Developing Countries

Most developed countries do not have the financial, technological and material resources constraints necessary to adopt the highest standards and the most advanced established principles for liquid and solid waste disposal. However, developing countries usually lack these resources, and may be unaware of the dangers of inadequate practices in waste disposal.

The vast majority of towns in middle and lower-income countries continue to use open dumping as their principal disposal method. The method is neither safe nor hygienic (EPA, 1983a). It is no longer realistic to simply remove the health risks posed by wastes from urban streets and accumulate them in a nearby suburb or rural area. No amount of careful collection or treating of wastes will reduce the hazards to health or the environment from disposal if the final resting place is an open dump. Also, even the most advanced waste technologies produce residues that need to be landfilled. Therefore, since it is the essential end point for every waste management system, it is important to operate it in a best possible way, with whatever resources are available locally. Otherwise, local administrative bodies will continue to live under the delusion that for a healthy life only the health and environmental concerns from waste collection need to be addressed.

It is sobering to realize that there are around 30 higher-income countries (about 15% of the total) in the world where 'sophisticated landfill' disposal designs and operating techniques are employed. In the remaining approximately 170 countries (about 85%) 'subsistence landfilling' is practiced (Ali, 1997), either through open dumping onto waste ground or into watercourses, or through back yard burial at individual homes and isolated settlements which are becoming great threat against environment and public health. So in such countries where certain methods of disposal are prohibitive, such as composting, incineration or sophisticated landfill due to economic, systematic and infrastructural constraints, controlled dumping may be suitable which can progressively be replaced by engineered landfill (Blight, 1995).

Methodology for the selection

Selection of solid waste disposal site is really a hard task in context of present world, where huge quantity of waste has become dangerous threat to the environment and public health (Campbell, 1998). Improperly managed or unmanaged wastes may cause acute adverse effects on environment. To minimize such impact of solid wastes, disposal of solid waste need to be emphasized much, because pollution is mainly occurred in this stage of solid waste management system. In this site selection process, social, economic and mainly environmental factors need to be considered. The aim of this study is to develop a GIS integrated methodology to select proper disposal sites. Khulna city has been considered as a case study in this study. As example, the methodology has been applied on this city and the developed methodology has selected some suitable sites by using information of wide aspects. It is expected that this methodology will be capable of identifying suitable disposal sites for any other city, if the process follows similar steps with proper data set.

Overall Process of the Selection

The overall methodology of the study can be presented precisely by the following flowchart (figure 1). Data collection and converting to digital format constitutes the major components of the study. Criteria were developed based on the availability of the data. Spatial analysis was performed using different tools in GIS

to differentiate the non-compensatory locations (where it should not be) and the suitable location (where it should be). In spatial analysis BUFFER, UNION, INTERSECTION and NETWORK-ALLOCATION operations have been performed.

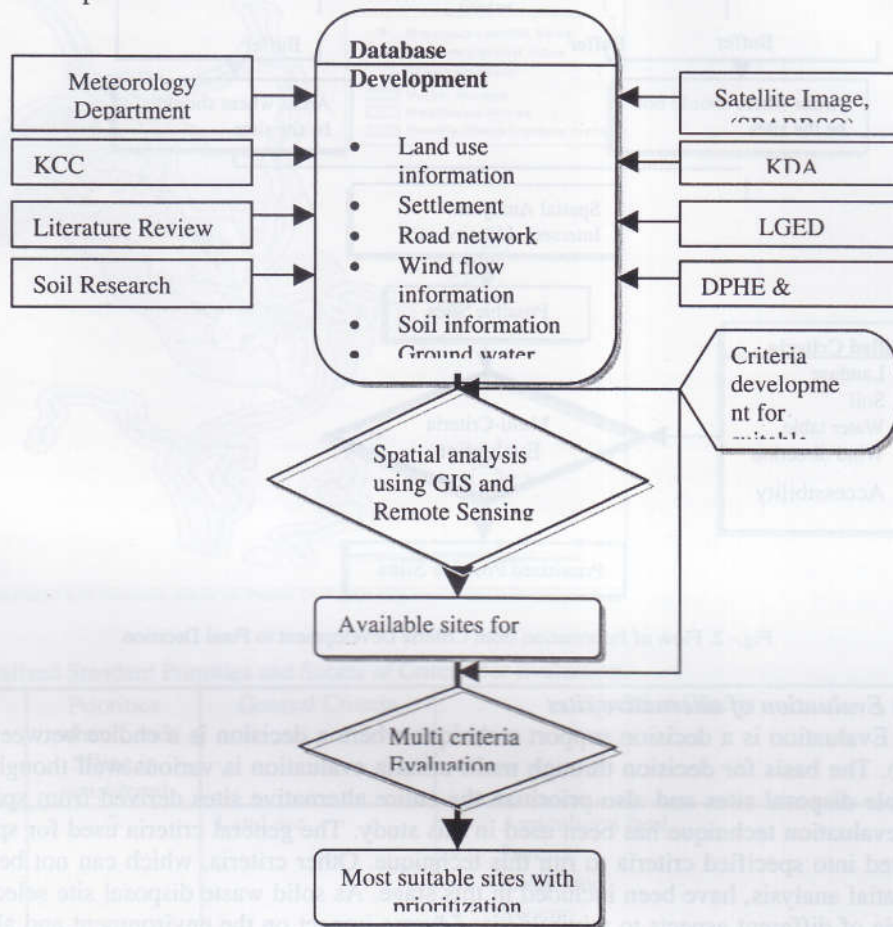


Fig.- 1. Generalized Methodology for Selecting Disposal Site Selection.

Development

Before selecting suitable disposal sites it is necessary to decide where it should not be. After that, among the available area a relative evaluation can decide the proper site. To get available area some general criteria have been developed. These criteria have been developed to make answer of the two broad questions-

- Where the disposal sites should not be?
- Where it should be?

For example disposal sites should not be near to any settlement or any water body, but any disposal site needs to be within a specific distance from major roads to minimize waste transportation cost.

General Criteria

The general criteria by which possible disposal sites have been identified can be listed as below:

Criteria for selecting the areas where disposal sites should not be:

- Within 1 km. from any settlement
- Within 500 meters from water bodies
- Within 2 km. from the city

Criteria for selecting the areas where disposal sites should be:

- Within 5 km. from the boundary of the city
- Area with good accessibility

The listed criteria have been used for spatial analysis and have been specified into more specific criteria for multi-criteria evaluation. In multi-criteria evaluation stage, some other specific criteria have been used which will be discussed later.

Incorporation of criteria for decision-making

The flow of information from collection to final decision through criteria development and different processes are as follows (fig.- 2):

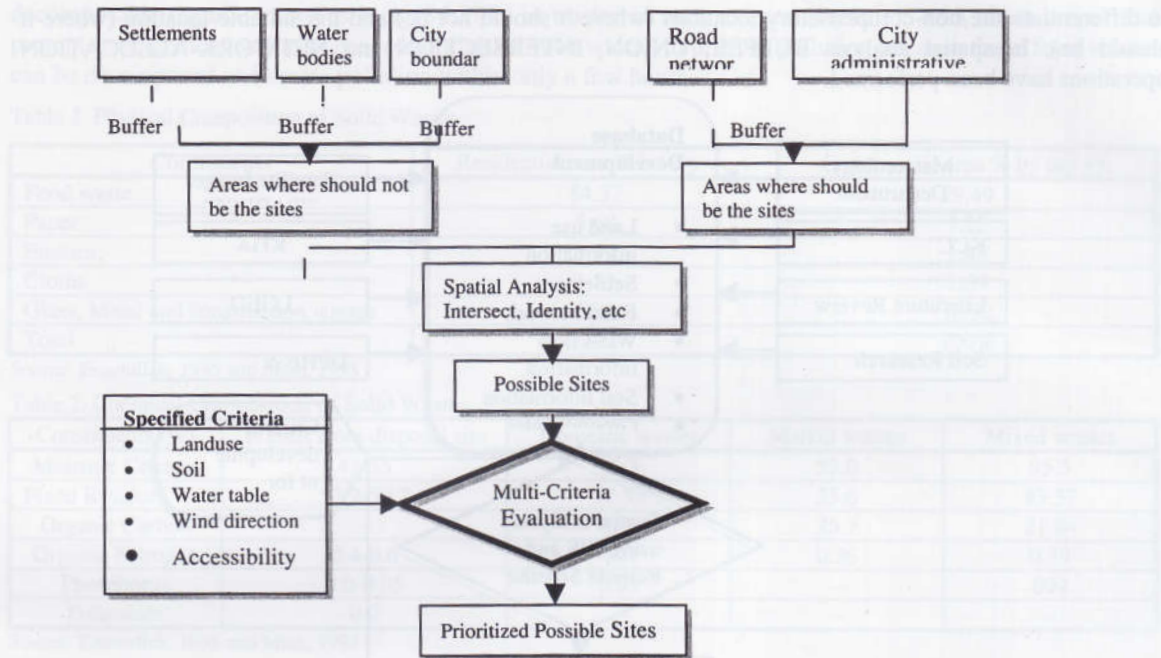


Fig.- 2. Flow of Information from Criteria Development to Final Decision

Multi-Criteria Evaluation of alternative sites

Multi-Criteria Evaluation is a decision support technique where a decision is a choice between alternatives (Sharifi, 1995). The basis for decision through multi-criteria evaluation is various well thought criteria. To get best possible disposal sites and also prioritize the entire alternative sites derived from spatial analysis, multi-criteria evaluation technique has been used in this study. The general criteria used for spatial analysis have fragmented into specified criteria to run this technique. Other criteria, which can not be incorporated properly in spatial analysis, have been included in this stage. As solid waste disposal site selection needs to consider criteria of different aspects to minimize its adverse impact on the environment and also to make it socially and economically viable, possible sites should be evaluated by this technique.

As the aim of the study is to develop an integrated method for disposal site selection, all the required criteria for such selection need to be incorporated in this study though it may not be included in the case study due to lack of sufficient data. Some of these criteria are more important for selecting the sites for open dump and some are for landfill. Because different procedures are involved in two different methods, such as land filling require excavation of earth and in this method there is a chance of ground water pollution through lechate formation and infiltration. So depth of ground water table is more important consideration for land filling but such is not applicable for open dumping. On the other hand, as the possibility of air pollution is high for open dump as the wastes remaining uncovered in such dump, so such dumpsite must be far away from any settlement, but it may not be required for land filling (EPA, 1983a and EPA, 1983b). Considering all these factors the criteria and their priorities are given in Table 3.

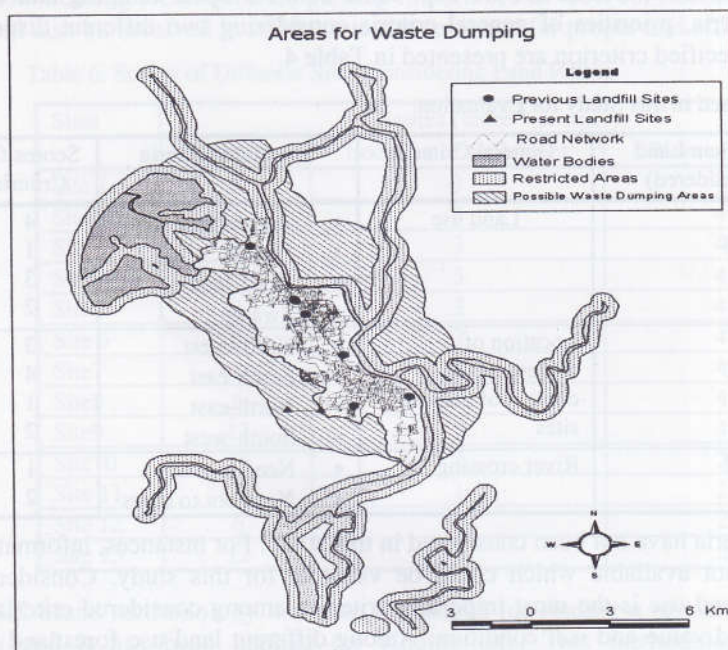
Weight for each criterion has been assigned by direct ranking. Ranks are assigned in their ascending order of importance. For example, in landuse criteria, agricultural land has given rank order '4' and '1' for forest. It indicates, agricultural land is preferred for site selection compare to forest.

Application of Developed Methodology

This section has attempted to describe the results when the developed methodology has been applied on Khulna City Corporation (KCC) area.

Available Disposal Sites from Spatial Analysis

Buffer operation has extracted the areas in which disposal sites should not be allowed or to which these should be restricted. Coverages gained by buffer operation then overlaid by 'UNION' overlay operation to get only those areas where it is suitable to locate disposal sites. UNION overlay is chosen because it is suitable for overlaying two polygon layers (Start and Estes, 1990). By imposing the location map of dumpsites on the coverage of available areas it has shown that only the presently used dumpsite of the city is located in such area (map 1).



Map 1: Restricted and Available Areas for Waste Dumping

Table 3: Generalized Standard Priorities and Scores of Criteria for Evaluation.

Priorities when open dumping is considered	Priorities when Land filling is considered	General Criteria	Specified Criteria	Scores for Criteria
7	7	Land use	<ul style="list-style-type: none"> • Agricultural land • Forests • Grass land • Swamp 	4 1 3 2
4	4	Accessibility	<ul style="list-style-type: none"> • Exist • 500 meters road construction • (500-750) m. road construction • (750- 1000) m. road construction 	4 3 2 1
1	6	Depth of water table	<ul style="list-style-type: none"> • 100 meter above water table • 200 meter above water table • 300 meter above water table 	1 2 3
6	1	Distance from settlements	<ul style="list-style-type: none"> • (0.5- 1) km • (1-1.5) Km. • More than 1 km. 	1 2 3
5	2	Location of settlements in context of disposal sites	<ul style="list-style-type: none"> • North-west • South-east • North-east • South-west 	3 4 1 2
3	5	Soil condition	<ul style="list-style-type: none"> • Clayey-silty Gravel • Clayey-silty sand • Silt • Clay 	1 2 2 3
2	3	River crossing	<ul style="list-style-type: none"> • Need to cross • Not need to cross 	1 2

Land cover/land use map derived through satellite image classification is then overlaid on the finally gained coverage to fragment the available chunk of land according to different land cover. Land use is an important criterion for site selection. The available areas have been evaluated by multi-criteria evaluation based decision support system. The criteria are: landuse, location, travel impedance etc.

Multi-Criteria Evaluation (MCE) of Different Selected Sites

For the available site a MCE has been performed. Two sets of criteria has been developed: general criteria which satisfies the major objectives of a site and specified criteria which are rather options of general criteria

with different weight value to decision. Both criteria set are kept same both for open dumping and land filling. The general and specified criteria, priorities of general criteria considering two different disposal methods and scores defined for each specified criterion are presented in Table 4.

Table 4: Priorities and Scores of Criteria Used in this Study for Evaluation.

Priorities (when open dumping is considered)	Priorities (when Land filling is considered)	General Criteria	Specified Criteria	Scores for Criteria
3	3	Land use	<ul style="list-style-type: none"> • Agricultural land • Forests • Grass land • Swamp 	4 1 3 2
2	1	Location of settlements in context of disposal sites	<ul style="list-style-type: none"> • North-west • South-east • North-east • South-west 	3 4 1 2
1	2	River crossing	<ul style="list-style-type: none"> • Need to cross • Need not to cross 	1 2

Due to lack of sufficient data some criteria have not been considered in this study. For instances, information on water table, soil types etc were not available which could be valuable for this study. Considering environmental and economic aspects land use is the most important criterion among considered criteria as land use is directly correlated with land value and soil condition. Among different land use forestland has given lowest score for its great environmental importance. Swampy land has also given low score as disposal site on such low land causes land and water contamination through 'lechte' formation.

Wind direction has incorporated in the study by considering the location of settlements in context of disposal sites. As waste is covered in land filling, this criterion has given less weight when land filling is considered because there is low chance of air pollution (table 4). In the concern area wind direction in summer is from south-west to north-east and in winter low speed wind directed from north-east to south-west. So the disposal site having settlement in north-east has given lowest score as pollutants from such site can directly be conveyed to nearest settlement.

As per these criteria and their priorities the scores of each individual site in context of open dumping and land filling are given in Table 5 and Table 6 respectively.

Table 5. Scores of Different Sites Considering Open Dumping

Sites	Scores (score * priority)			Total Scores
	Land use	Location of settlement	River-crossing	
Site 1	6	6	1	13
Site 2	3	6	1	10
Site 3	6	6	1	13
Site 4	6	6	1	13
Site 5	3	6	1	10
Site 6	6	6	1	13
Site 7	6	6	1	13
Site 8	3	6	1	10
Site 9	12	6	1	19
Site 10	12	2	2	16
Site 11	3	2	2	7
Site 12	6	2	2	10
Site 13	12	2	2	16

The results derived from multi-criteria evaluation are presented in Map 2. 'Site 9' is found best suitable both for 'open dumping' and 'land filling'. This site has received higher weight because of its location with respect to Khulna city and distance from it (map 2). Location 11 (site 11) on the other hand, is least preferred. This is because of its closeness to settlements and present landuse. Presently, most of the area in 'site 11' is forest, which is least preferred in selecting site for waste dumping (table 3).

Conclusion

A standard solid waste management system is an important element of public health and environmental protection. Its purpose is to provide hygienic, efficient and economic collection, transportation, and disposal of solid wastes without causing pollution to atmosphere, soil or water. Careful identification of present and future waste disposal problems is necessary to establish the objectives of proper management. Different tools and techniques are being developed for solid waste disposal site selection in developed world. GIS and

Remote Sensing techniques are gaining importance as tools for decision support in site selection. Such tools should also be involved in solid waste site selection for proper and efficient area selection.

Table 6. Scores of Different Sites Considering Land Filling

Sites	Scores (score * priority)			Total scores
	Land use	Location of settlement	River-crossing	
Site 1	6	3	4	13
Site 2	3	3	4	10
Site 3	6	3	4	13
Site 4	6	3	4	13
Site 5	3	3	4	10
Site 6	6	3	4	13
Site 7	3	3	4	10
Site 8	6	3	4	13
Site 9	12	3	4	19
Site 10	12	1	2	15
Site 11	3	1	2	6
Site 12	6	1	2	9
Site 13	12	1	2	15

A GIS based methodology has been developed for finding a suitable location for the solid waste disposal sites and it has been applied for Khulna city. This methodology considered economic, social and environmental aspects in selecting the location for open dumping and land filling. It can be applied for selecting sites for solid waste disposal of the major cities in Bangladesh. The available sites are further evaluated using multi-criteria evaluation. This study does not only propose some locations for waste dumping rather it explains why a particular area has been selected and why no. by changing the criteria, weight and analytical tools the general methods could be applied in other site selection processes.

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