# Application of GIS in the selection of a suitable site for a Hazardous Waste landfills

**(Final draft)**

**By**

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## Summary

Hazardous waste management is a global environmental problem in today's world. There is an increase in industrial, commercial, residential and infrastructure development due to the population growth and this has negative impact on the environment. Hazardous solid waste management is considered as one of the most serious environmental problems confronting municipal authorities in developing countries. Hazardous waste has high ability of threatening and degrading environmental resources e.g. polluting air through noxious smell, polluting surface and underground water through seepage of deposited and decomposed wastes if not properly managed and above all deterring investments in settlements. On the other hand, waste collection and disposal are very challenging elements in waste management. Site selection for disposal of hazardous waste requires consideration of numerous geographic factors. Use of a Geographic Information System (GIS) can facilitate examination of interaction between site-related factors. In recent years the increases in the popularity of applying environmental criteria in national planning and management has provided a wide range of scientific approaches to determine the best location of hazardous wastes to be land filled. Hazardous waste management is still a problem around the world due to many factors that include: lack of information on the extent of Hazardous waste generated, inadequate data on the number of industries and processes generating the waste e.t.c. Geographical Information System (GIS) is a tool that can provide spatial and non spatial information for Hazardous waste planning and management. Therefore, this term paper deals with determination of suitable Landfill site for the disposal of Hazardous waste generated from Qazvin province (Iran) and surrounding areas using GIS techniques and possible recommendation for applicability in the Kingdom of Saudi Arabia.

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## Introduction

Advancement in recent technological innovations, ease and accessibility has made the application of environmental criteria in national planning and waste management achievable. Hazardous waste management is a global environmental problem in today's world. There is an increase in industrial, commercial, residential and infrastructure development due to the population growth and this has negative impact on the environment. Hazardous solid waste management is considered as one of the most serious environmental problems confronting environmental authorities in developing countries. Hazardous waste has high ability of threatening and degrading environmental resources e.g. polluting air through noxious smell, polluting surface and underground water through seepage of deposited and decomposed wastes if not properly managed and above all deterring investments in settlements. Sitting the best available location for the landfills requires an extensive evaluation process. (Ozeair *et al* 2009). The Environmental planner's analyzes the impacts to minimize economic, environmental, social and health cost. The analysis should generate clear idea for the decision makers to select the best available site to land fill the hazardous waste with minimized adverse environmental impacts. Site selection for disposal of hazardous waste requires consideration of numerous geographic factors. Use of a Geographic Information System (GIS) can facilitate examination of interaction between site-related factors. This term paper focus on the technique applied for a site selection of Hazardous waste land fill using GIS technique and priority processing in Qazvin Province (Iran).

## Criteria's for Hazardous Waste site selection

The hazardous wastes need to be disposed off in a secured manner in view of their characteristic properties such as, toxicity, corrosivity, ignitability, reactivity and persistence. A wide range of health hazards has been attributed to their contamination. An ideal hazardous waste site should meet the following requirements:

- Confirming with the land use planning and zoning of the local area.
- Easily accessible in all weather conditions to the type of transportation that will be used during the operation.
- Having secured safeguards against any potential air, surface water and ground water pollution.
- Acceptability with respect to the sensitivities of the residents
- Located where the operation is not likely to induce adverse impact on the environmentally sensitive resources.
- Large enough to accept and process hazardous wastes during the life of the operation.
- Cost-effective and economically profitable, while complying with applicable rules and regulations.

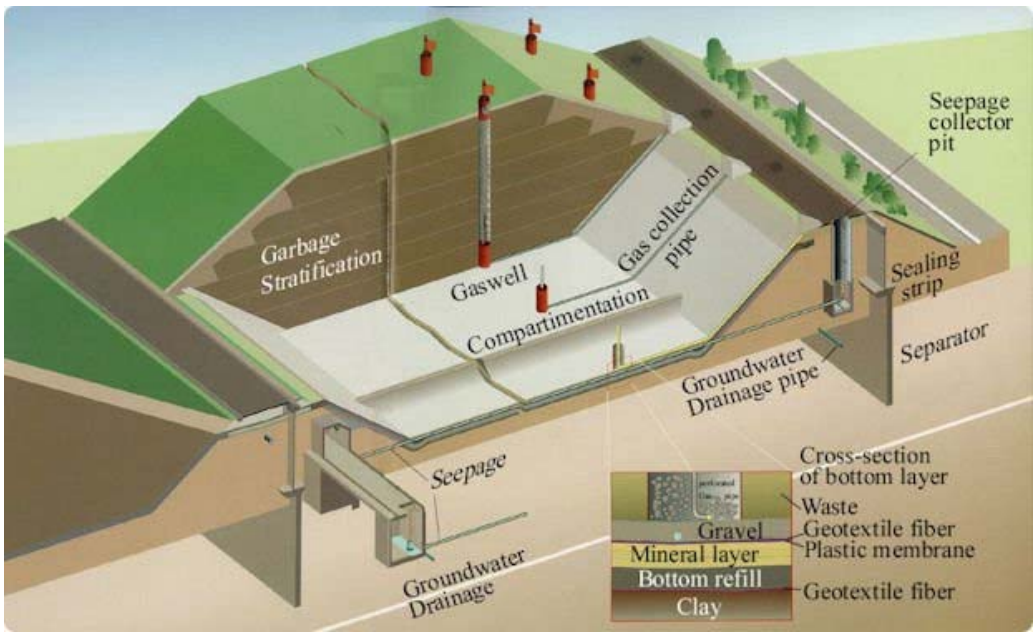

**Figure 3. A typical Hazardous waste disposal site**

## Objective

The following are the objectives of this term paper

1. Understanding the usage of GIS to find and select the suitable site of Hazardous waste landfills
2. Extrapolation of the findings to the current situation in Hazardous waste management in Saudi Arabia
3. To recommend suitable practice for regulation purposes.

## Study Area

This study was conducted for Shahid Rajaee power plant which is located at western central part of Iran 100 km off Tehran (Fig. 1). The province is bounded by Alborz, Rameneh, and Kharghan mountains while agricultural and industrial applications are the main land uses within the area.


**Figure 1 Word Map Showing Power Plant Location**

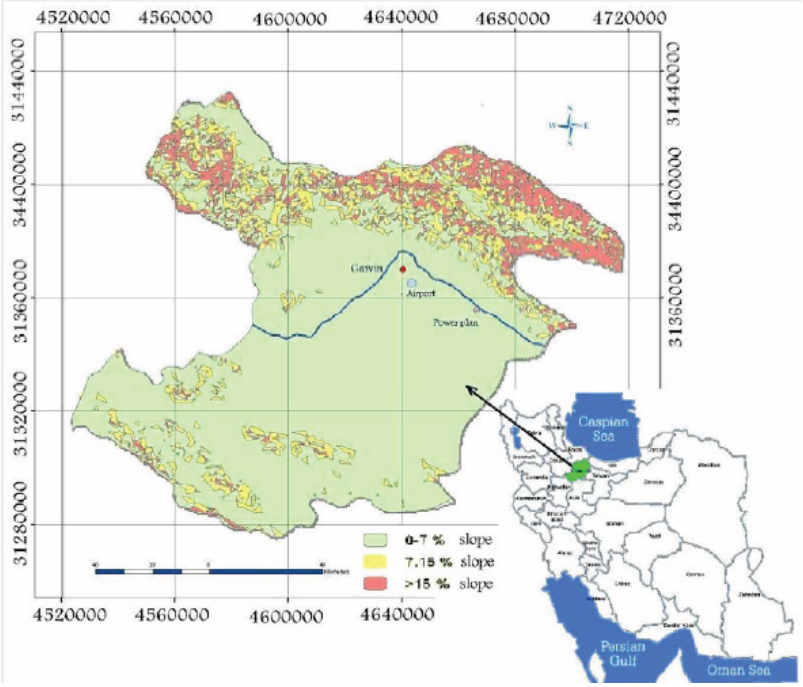


**Figure 2 Location of Qazvin province and its land slope characteristics**

## Methodology of study

The authors of the paper under review utilized GIS to create the digital geo database as a spatial clustering process and easily understood way for landfill sitting in Qazvin plant, Iran. The methodology utilizes GIS to evaluate the entire region .

| | |
|---|---|
| 1. Physical Criteria | • Topography<br>• Soil and geology characteristics<br>• Climate |
| 2. Environmental Criteria | • Vegetation maps<br>• surface and ground water characteristics<br>• specific environmental zone<br>• Residential zones |
| 3. social-economical Criteria | • Accessibility<br>• distance to residential areas<br>• distance to water resources |
| 4. Technical Criteria | • Applicability<br>• Waste transport |

## GIS TECHNIQUES

The final site selection map is prepared by using over layer technique based on the selected criteria and sub-criteria. This technique is an approach that includes various features of the study region (Geology, Topography, Soil, Climate, Etc.) that makes joint comparison possible through GIS software. For developing of the digital GIS database, large varieties of maps in two scales were used as separated information layers. The methodology consists of the following steps:

(a) Development of a digital GIS database, includes all information layers in 1:250,000-scale maps

(b) Development of a digital GIS database includes detail information layer of some zones in 1:25,000-scale maps.

Political segmentation map, map of mines and industrial zones, maps of residential areas and archeological sites, specific environmental areas map, vegetation map, road and rail road map, land slope map, soil characteristics map, groundwater and surface water maps, depth of groundwater, isothermal and isohyets maps, land use maps, channel and wetland location maps, major infrastructure systems maps, seismic activity map, highway and airport location maps in appropriate scales were the maps that were used for the development of the GIS database in the province.

## Landfills Sitting Techniques

Several authors reported different types of techniques that are used for landfills sitting which include

- Combination of GIS and multiple criteria analysis (MCA): Multi Criteria Analysis (MCA) is a tool that has been developed for complex multi criteria problem(s) within

decision making. The method(s) include qualitative as well as quantitative aspects of the problem(s) in the decision making process. (WaterWiki.net)

- Multi-Criteria Decision Analysis (MCDA) or Multi-Criteria Decision Making (MCDM**)** is a discipline aimed at supporting decision makers faced with making numerous and sometimes conflicting evaluations. MCDA aims at highlighting these conflicts and deriving a way to come to a compromise in a transparent process. (Wikipedia.org)

- Utilization of GIS and Priority processing. Data processing in which the operations performed are determined by a system of priorities. The author used GIS method as a sophisticated spatial statistics method, giving some efforts for the analysis of results to highlight some better sites. Priority processing through comparing to ideal condition also provides an efficient way to identify the best site between the primary selected candidate sites.

## Results

Based on the Iraninan Environmental legislations the author divided the screening of the sites into two phases. In the first phase, the author was able to evaluate and eliminate all areas that fails to comply with the set regulation restricting areas for the purpose of landfilling. This process enables the author to reduce the large study area of Qarvin region to more suitable area. Three different parts of the Qazvin province in Abyeck, Takestan and Khoramdasht zones were candidate for more detailed evaluation. In the second phase using available 1:25,000 scale maps candidate areas were evaluated in more detailed. Finally based on minimum needed volume for landfills, 17 sites were identified for hazardous solid waste land

filling in the Qazvin province. For further evaluation, priority processing was selected for the second phase

## *Priority Processing*

The most important factor in selecting proper site for landfilling for Hazardous materials is the vulnerability of these sites to contaminate groundwater. Leakage of the waste either from outside or from semi liquid waste which leads to percolation of these hazardous materials to soils and aquifers by toxic materials is the major factors threating human health and environment. From this point of view, DRASTIC method (USEPA waste management technique), MPCA, socioeconomic, technical and Iranian legislation/standards where considered in evaluating all the candidate sites.

DRASTIC is an empirical method that was developed by the US Environmental Protection Agency (US EPA) for evaluating the pollution potential of groundwater systems on a regional scale. Probably the most widely used ground-water vulnerability mapping method is **DRASTIC**, named for the seven factors considered in the method: **D**epth to water, net **R**echarge, **A**quifer media, **S**oil media, **T**opography, **I**mpact of vadose zone media, and hydraulic **C**onductivity of the aquifer.

Table 2. Parameters and their assigned weights in DRASTIC method.

| Number | Parameters | weight |
|---|---|---|
| 1 | Depth to water table | 5 |
| 2 | Net recharge | 4 |
| 3 | Aquifer media | 3 |
| 4 | Type of soil | 2 |
| 5 | Topography | 1 |
| 6 | Impact of the vadose zone | 5 |
| 7 | Hydraulic conductivity | 3 |

DRASTIC index number which reflect the pollution potential for the aquifer is based on these seven parameters. These factors was normalised to scale from 1-10 and then multiplied by their respective

weights to reflect the importance and influence for each factor on the groundwater. On the hand, MPCA method (Minnesiota pollution control agency ),in this method, six determinative factors and seven conditional factors where selected for siting the landfill which is illustrated in table 3.

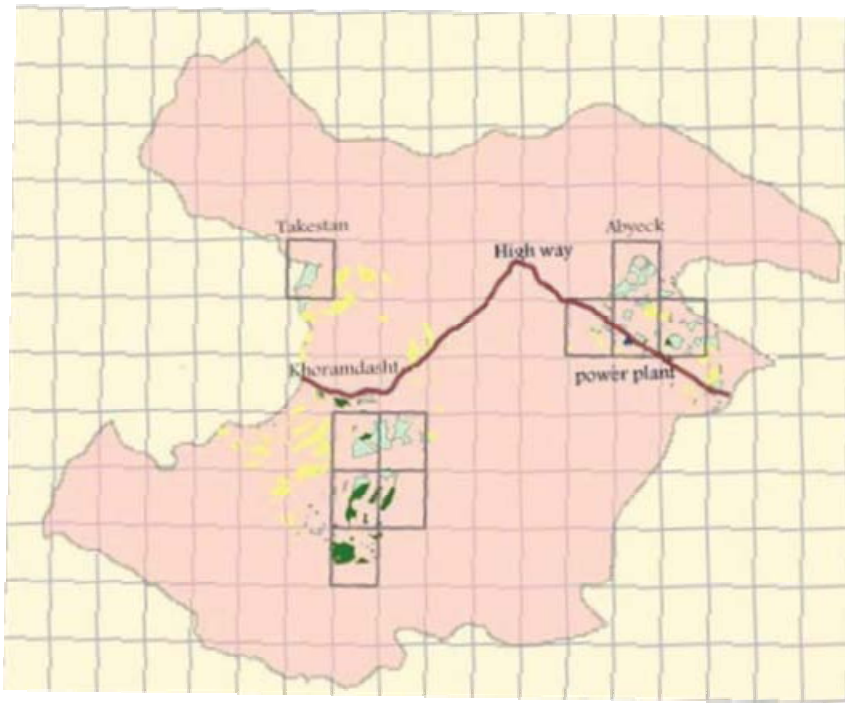


Figure 3 . Candidate areas in Phase 1 site selection processes.

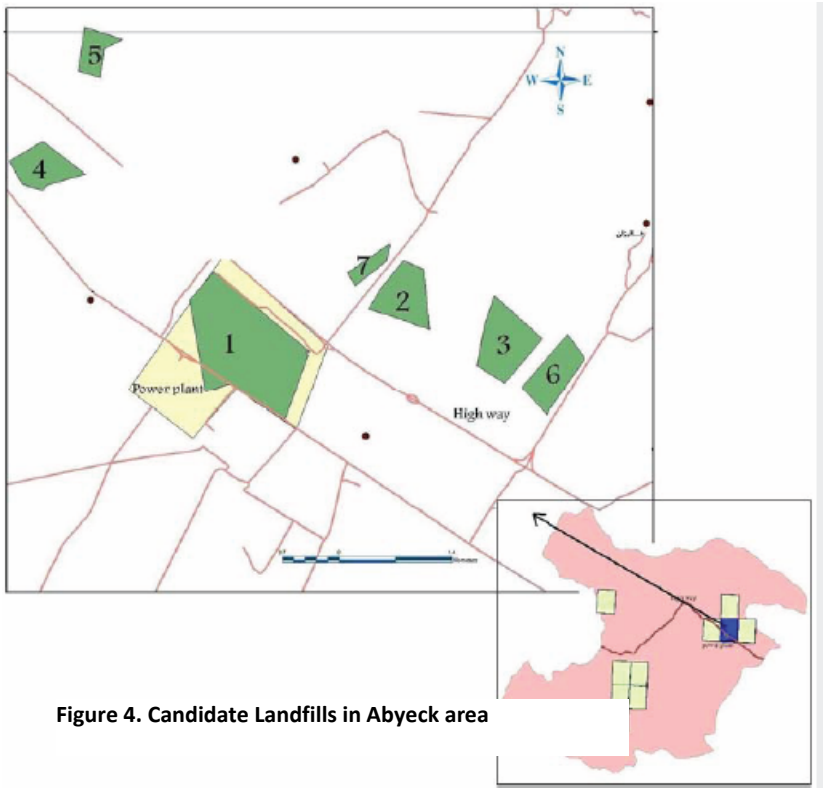


**Figure 4. Candidate Landfills in Abyeck area**

Table 3. Six determinative and seven conditional factors of MPK method

| Number | Determinative Criteria | Conditional Criteria |
|---|---|---|
| 1 | Minimum 305 meters distance from any lake or pool | Minimum 305 meters distance from road, parks and residential area |
| 2 | Minimum 92 meters distance from any river or channel | No threat to any water resources pollution |
| 3 | Distance from area with 100 year retention period flood | Avoiding from area with high erosion and drainage |
| 4 | Avoiding from wetlands | No threat to drinking water storage |
| 5 | Do not cumulate birds in sensitive area around airport | No threat to ground water resources contamination |
| 6 | Distance from area with limestone ground and caves | Constructed with enough precaution consideration |
| 7 | - | Feasibility of monitoring and sampling of ground water |

Table 4. Social, Economic, Environmental-Technical criteria and their assigned weight in the developed method

| Social-Economical criteria | | |
|---|---|---|
| Number | Title | Weight |
| 1 | Distance from waste generation source | 5 |
| 2 | Easily owning | 4 |
| 3 | Distance from residential area | 4 |
| 4 | Easily access | 3 |
| Environmental - technical criteria | | |
| Number | Title | Weight |
| 1 | Depth of ground water level | 5 |
| 2 | Ground water monitoring feasibility | 3 |
| 3 | Rain fall and run off | 3 |
| 4 | Soil type | 4 |
| 5 | Seismic activity | 4 |
| 6 | Distance from mines and industrial areas | 3 |
| 7 | Distance from sensitive environmental areas | 3 |
| 8 | Land Slope | 3 |

Table 5. Ranges and scores for the two sub criteria

| Distance from waste generation source | |
|---|---|
| Distance(km) | Score |
| <2 | 10 |
| 2-5 | 8 |
| 5-15 | 6 |
| 15-30 | 4 |
| 30-60 | 2 |
| >60 | 0 |
| Slope | |
| Rang (%) | Score |
| 0-3% | 10 |
| 3-7% | 7 |
| 7-10% | 3 |
| >10% | 0 |

Based on local hydrogeological and socio-economical characteristics for the area under this study, a new method was developed which is the combination of DRASTIC and MPCA methods, to quantify the potential vulnerability of ground water. Ranges and scores for criterial and subcriterial are presented in tables 4 and 5.

Table 6. Calculation used for determination of utilitarian in site 1,9,14 in three locations

| Social-Economical criteria | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Title | Site 1 | | | Site 9 | | | Site 14 | | |
| | weight | score | utilitarian | weight | score | utilitarian | weight | score | utilitarian |
| Distance from waste generation source | 5 | 10 | 50 | 5 | 0 | 0 | 5 | 0 | 0 |
| Easily owning | 4 | 10 | 40 | 4 | 5 | 20 | 4 | 5 | 20 |
| Distance from residential areas | 4 | 5 | 20 | 4 | 2.5 | 10 | 4 | 2.5 | 10 |
| Easily access | 1 | 10 | 30 | 1 | 6 | 18 | 1 | 6 | 18 |
| Environmental -Technical criteria | | | | | | | | | |
| Depth of ground water level | 5 | 10 | 50 | 5 | 10 | 50 | 5 | 7 | 35 |
| Ground water monitoring feasibility | 3 | 10 | 30 | 3 | 5 | 15 | 3 | 0 | 0 |
| Rain fall and run off | 3 | 3 | 9 | 3 | 6 | 18 | 3 | 6 | 18 |
| Soil type | 4 | 10 | 40 | 4 | 10 | 40 | 4 | 5 | 20 |
| Seismic activity | 4 | 7 | 21 | 4 | 10 | 30 | 4 | 10 | 30 |
| Distance from mines and industrial areas | 3 | 10 | 30 | 3 | 0 | 0 | 3 | 5 | 15 |
| Distance from sensitive environmental areas | 3 | 7 | 21 | 3 | 7 | 21 | 3 | 3 | 9 |
| Land Slop | 3 | 10 | 30 | 3 | 10 | 30 | 3 | 7 | 21 |
| Total Score | | | 371 | Total Score | | 252 | Total Score | | 196 |

Table 7. Score of each site among each site.

| Site | Abyeck zone | | | | | | | Khoramdasht zone | | | | | | Takestan zone | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |
| Score | 371 | 324 | 308 | 288 | 288 | 294 | 304 | 186 | 252 | 242 | 196 | 205 | 252 | 196 | 195 | 174 | 186 |

At the end of Phase two, Priority processing between primary candidate sites, indicates site 1 as the most approprate landfilling of Hazardous solid waste generated from the power plant in Qazvin province.

## Discussion and Conclusion

In developing countries, site selection of Hazardous waste landfills is considered one of the most challenging problems that require extensive efforts in other to locate and manage an appropriate place for landfilling.

This paper used a multidisciplinary approach based on GIS screening map and priority analysis to develop a GIS database and maps with two scales (1:250000 and 1:25000). By utilizing the combination DRASTIC and MPCA methods, it was possible using priority processing to select the most appropriate site.

Saudi Arabia due to the expansion in industrial and urbanization developments need to develop secure landfills to store all hazardous and toxic materials and utilize similar methodologies presented in this study to prevent any contamination on the much dependable groundwater.

GIS is one of the most efficient tools that should be utilized by specialist to study and formulate appropriate landfill site selection application, which will facilitate decision makers in the technicality of landfill selection processes.

## Reference


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4. Ozeair and Saeedi (2009). Site Selection of a Hazardous Waste Landfill Using GIS Technique and Priority Processing, a Power Plant Waste in Qazvin Province Case Example. ENVIRONMENTAL SCIENCES Vol.6, No.4, Summer 2009. 121-134