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Management of Landfill Locating of Urban Waste

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Abstract

Selection of waste landfill is one of the most important steps in managing urban solid waste. Regarding the landfills' damaging effects on environment, economy and ecology, landfill selection must be done carefully and in a scientific process. Many measures are involved in choosing landfills. This paper aims to describe and review performed procedures. Collection and analysis of data has been conducted through internally and externally valid books, articles and websites. This study evaluates instructions and different methods of locating landfill. And it compares the advantages and disadvantages of each of these instructions. The effective use of geographic information systems (GIS) was explained to combine layers of information for locating.

Keywords: waste, landfill, environmental impact, locating, GIS

Introduction

One of the most important environmental problems that most cities of the country face is the management of industrial, medical and hazardous waste (Sartaj, et al 1386). Waste management is an integrated set of regulations on the control of production, storage, collection, transportation, processing and disposal of waste that best matches with hygienic, economic, aesthetic and environmental requirements desired by the public (Xue et a.2010). Stages in waste management include reduction, recycling and conversion of waste materials (Management and planning Organization, 2001). In all these steps, some of the waste remain that must be buried. Choosing proper landfill is the most important step in waste management (Sener et al. 2006). The problem of selecting the location of the waste has always been an unsolved subject for human. Selecting improper burial place causes water, soil and air contamination in the regions (Department of Environment 2001). Several criteria and indicators are proposed to select a suitable location for the landfill but each of them has limitations and special conditions. In other words, each of the criteria has been built on the basis of scientific fields. So the landfill studies have multidimensional and interdisciplinary structure (Shamsaei of 2003). The ultimate goal of locating is accessing to the most appropriate places to minimize adverse impacts to the environment and natural resources around it. From economical and engineering point of view, it has the best features (Ghazaban 2006). Therefore, we must deal with processing and evaluating data about the laws, factors, regulations, and restrictions (Daneshvar et al.2003). One of the right tools for the analysis of large volumes of information is a geographic information system (Sartaj, et al 1386). Vast capabilities of the system in the management of spatial data, and creation of a platform for decision-making has drawn a lot of attention to the system for locating the burial site (Srtaj et al 2007). In recent decades, many studies, in the field of landfill locating, have been done using geographical information system (Shamsaei fard 2003, Haider zade, 2001, Nir Abadi and Mir Rahimi 2007, Vatalis and Manoliadis2002, Daneshvaret al.2003, Sener et al 2006).

Significance of the Study

Iran's growing urban population with new population centers, lack and or policy-making and assessment of urban different activities and performances based on national comprehensive plan (land use planning) and discharging different types of waste into the environment are crisis factors that in natural environment, have put the quality of sanitation and health of human, particularly in urban areas, at risk. Concerns associated with landfill: (1) the uncontrolled release of landfill gas that can move to the outside of the site and create other possible hazardous conditions; (2) The impact of uncontrolled discharge of gases that cause the greenhouse effect in the atmosphere. (3) The uncontrolled release of leachate that could contaminate groundwater. (4) Reproduction of disease carriers in burial places that are not managed properly. Design and implementation of a modern landfill remove or minimize these concerns. One of the most important steps of carrying out research, as well as the design of landfill waste, is locating and finding a perfect place for burying waste. Several factors are involved in choosing a landfill which, in turn, are important and create restrictions too (Tchobanoglous et al, 1993).

Review of Related Literature

In 2007, Arash Rezai and his colleagues carried out a research titled Landfill Studies and Management of Optimized Disposal of Solid Waste in New City of Hashtgerd. The aim of this study was to determine the best location for the landfill and solid waste management in Hashtgerd. Respective layers include vegetation, land use, topography, geology, soil, slope, elevation, etc. It was prepared using Arc view and PCI GEDMATICA softwares and from 250000/1 50000/1 digital maps. Then, Using local and regional sift method and combining maps, we attempted to produce the final table related to weight of the layers and after overlapping spatial layers, three regions with the highest parameter were chosen. Then, the district located to the south of the city of Hastgered with approximately 163 acres, with the most proper parameter was offered as the best place to bury the waste [http://cong.sbmv.ac.ir] Soomaty (2007) carrying out a research using multicriteria decision making analysis and overlapping analysis, using GIS, found the best waste landfill. The proposed system, in this study, can be updated and adapted to the new information on landfill waste. Several factors were considered in the landfill process, including geology, water resources, land use, sensitive areas, air quality and groundwater quality. Weights determined for each criterion were based on the relative importance and their classification according to the effects. The results of using the system in different locations showed its effectiveness in locating process. [Sabza Andish Payesh Consulting Engineers, 2010]. Cao and his colleagues (2006) investigate the use of a decision-making method of unequally multi-weighted for hygienic solid waste landfill site selection. The factors that were affecting choices included: size and capacity of landfill, strata permeability, the average height difference between the groundwater level and the bottom of the landfill trench, the quality and origin of clay, the quality of burial place, the effect of engineering and design of landfill on the surrounding residential areas, distance to water resources, the cost of construction and transporting water. These factors are weighted based on their importance and relationship among them. By combining these methods with practical experience that was obtained in Jiangsu, criteria, objectives and weights were determined and the process was explained in detail. In this study, we found that the procedure, and the ability to perform simple calculations is a widespread and useful tool for solid waste landfill. And it is a useful, scientific and well-reasoned for choosing solid waste landfill for. [Sabza andish payesh Consulting Engineers, 2010]. Syner and his colleagues (2005) carried out a research using GIS and multi-criteria decision analysis to select suitable sites for solid waste landfill near Ankara. For this purpose, the input map layers included topography, residential areas (cities and villages), roads (motorways and rural roads), railways, airports, wetlands,

infrastructure (pipelines and power transmission lines), slope, geology, land use, floodplains, aquifers and surface water and they were analyzed using a multi-criteria decision making (simple additive weighting and analytic hierarchy process) in a geographical information system. Comparison of the maps produced by this method showed that both methods have adaptive outcomes. The field studies confirmed that the sites were selected according to specified criteria (Sabza andish payesh Consulting Engineers, 2010).

Instructions and Criteria for Solid Waste Landfill Site Selection

Environmental Protection Agency (EPA) of United States

Environmental Protection Agency of Unites States divided solid waste management into three groups that include (1) reducing the amount of waste produced, (2) increasing the cycle of materials, recycling materials such as fabric, paper, plastic and (3) providing appropriate fields of waste management, such as promoting the management of solid waste landfills and improving incinerators design. Important criteria for landfill selection include:

1) Airport: observation of distance of 10,000 feet or 3048 meters from the runway airports turbojet aircraft, keeping a distance of 5000 feet or 1524 meters from the runway of airports with propeller. 2) landfill must be far away from the flood flows with a hundred-year return period . 3) Wetlands: landfills must not be constructed in wetlands 4) faults: landfills should be 60 meters away from the faults. 5) being far away from earthquake prone areas 6) being away from unstable areas (displacement of rocks and karst areas).

Standards and Regulations of British Columbia in Canada

Locating must be done examining all the issues such as water, air and soil pollution, dangers that it has for the wildlife as well as economic and social factors, transport status and access networks.

• The physical boundary of the landfill must be at least 15-50 meters far away from natural landscapes.

• Other duties; landfill distance to the nearest residential area, drinking water wells, drinking water piping, hotels, restaurants and other food establishments, churches and public parks must be at least 300 meters.

• Airport, the distance between the runway and the burial place should not be less than 8 km because of birds

• Water resources; landfill distance to surface water should be at least 100 meters.

• A 200-year flood plain; locating should not be carried out without examining and considering the currents which cause inundation of landfills.

• Unstable areas; landfills must be placed at least 100 meters away from unstable regions (Guam EPA, 2004).

Criteria Provided by the Management and Planning Organization of Iran

1. Natural Water Resources: The distance of the burial place from lakes, and wetlands should be more than 300 meters. The distance of burial place from rivers or streams must be 100 meters. (If this distance is not possible, the landfill can be placed at a distance of 30 meters).

2. Flood lands; burial place or landfills, except for emergency cases, must not be placed in these areas. If the landfill must be located in such areas, ridges of earth must be built beside the creek in order to prevent flood from entering the landfill.

3. Roads; landfills must be at least 300 meters away from the vicinity of roads and highways and they should be hidden by sand ridges and trees.

4. Public parks: landfills shall be at least 300 meters away from these places. Entering and exiting the landfill must be done taking appropriate measures.

5. Hunting and habitat of birds; landfill construction is prohibited in these areas.

6. Wetlands; wetlands shouldn't be selected as landfill.

8. Airports; landfills must be at least 3 km away from the airport.

8 Water wells; landfill must be 400 meters away from water wells. (Management and Planning Organization, 2001)

Instructions provided by the Department of Environment of Iran

1- hydrologic characteristics of the area; all resources of drinking water and distances, located adjacent to the landfill, among these resources must be identified and landfill must be at a distance far from the resource. 2 – A hundred-year return period flood plains; Wetlands must not be selected as landfills, water resources should be a minimum distance of 2000 m. 3 groundwater: in areas where the water level is high, there should be built a layer to a depth of 2 meters (made from silt and clay) and maximum permeability millionths of a centimeter per second. In this case the, cell bottom to the groundwater table is 5 feet away. More or less diameter of the impermeable layer is based on criteria such as leachate generation rate, depth of soil saturation, soil permeability, and based on documents and related studies by Department of Environment Protection experts. 4- Geographic characteristics; it includes maximum and minimum area for at least 10 years. 5 availability; landfill must be at a distance of 5-3 km from the main road. 6 Distance to residential areas, landfills must be placed at a distance of 10-15 km from the city. 7 lowlands and highlands; natural conditions should be considered in choosing a landfill. 8- Geology; landfills must be studied regarding earthquake, faults, underground mines, subsidence and cavities resulting from dissolution and geotechnical studies 9- Climate; landfill shouldn't be in the flow direction of prevailing winds. 10 irrigation and land ecology; landfill must not be placed in unique wetland areas and habitats11- Land use; landfills must not be in densely populated areas or be in conflict with other land uses. 12 social and cultural conditions; landfill must be chosen considering monuments, culture, history, resorts and cemeteries and it must be far from these places. 13 other cases include: the distance of the landfill from the airports must be 8 km and from the agricultural lands must be 500 met (Department of Environment Protection, 2001).

Advantages and Disadvantages of the Instructions

EPA Evaluation Criteria

The advantages of these criteria are: 1. Considering the floodplain. 2 Considering the fault zones and presenting certain distance from every fault. 3. Considering unstable areas. The disadvantage of these criteria are: Failure to consider the distance of the place of landfills from residential areas, water wells, roads, highways, and the ground water that no instruction has been presented about them.

Evaluation of British Columbia Criteria

The advantages of these criteria are: considering residential areas, water wells, hotels, church and the distance from these applications. Also, these criteria have referred to the inundation of rivers in the flood plain. Disadvantages of these criterion are: 1. No detailed description is provided about residential areas. Residential areas include both urban and rural areas 2) British Columbia standards do not pay not attention to areas prone to earthquakes and the danger of faults in the region. (3) Distance from roads and highways is not included in this set of criteria. 4) no restriction has been imposed on wetlands and the risk of contamination of such areas with natural values.

Evaluation of Management and Planning Organization Criteria

Evaluation of the criteria of management and planning organization, and locating resulting from these criteria reflect some advantages and disadvantages of these criteria. In general, management and planning organization criteria have considered many parameters. Observing proper

distance from surface water, examining the status of the 100-year floodplain, paying attention to public walkways, water wells, and public habitat and hunting grounds, distance from roads and highways, lakes and ponds are the strengths of these criteria that some of them have not been referred to in EPA and British Colombia Criteria. One of the major disadvantages of the management and planning criteria is the lack of attention to the distance from residential areas. Other disadvantages of these are: lack of attention to the distance from gardens, agricultural lands and industry and lack of attention to unstable regions such as karst areas. Because karst areas, due to the instability and rapid dissolution, cause leachate to penetrate into the groundwater. Management and Planning Criteria have not considered any restrictions for such areas are. This is one of the major disadvantages of these criteria. Another disadvantage of the criteria is the lack of attention to sensitive areas, areas prone to earthquakes and fault zones. Iran is a disaster-prone country and earthquake occurrence is one of the most important dangers in different regions of Iran. Faults Map of Iran shows the frequency of faults in all regions of Iran. Management and Planning Criteria that are considered as reliable and official criteria in the country have not paid attention to this issue that is one of the most important disadvantages of these criteria.

Evaluation Criteria Based on the Guidelines of the Environmental Protection Agency

Advantages these guidelines include: consideration of numerous parameters and factors, none of the investigated by the criteria of of EPA, British Columbia and the Management and Planning Organization, considering the large distances from natural resources, such as surface water and natural habitat for birds and natural hunting grounds to reduce the negative effects caused by the construction of a landfill on these areas, the attention of the criteria of this organization to the proximity of landfill to the airports and wetlands.

The major disadvantages of this instruction are as follows: 1) the environment organization refers to the danger of proximity of landfills to faults but it does not determine the distance from these faults. (2) This instruction refers only to urban areas and the distance from rural areas is not considered. Also, no exact distance from antiquities, historical places, recreational places and public cemeteries have not been defined. (3) The landfill distance from the city in accordance with the guidelines is 10 to 15 km. In general, in areas where distances between rural and urban areas are small, performing these distances is impossible. (4) the instruction suggests a distance of about 3-5 kilometers from the main road that the includes vast expanse of space surrounding roads and in areas where there are many roads and highways, many restrictions are applied. (5) The Environment Organization has considered the landfill distance from agricultural property about 500 meters but no distance from fruit gardens, trees, scrub, grasslands, forests, particularly forests and grasslands that are worth protecting, is not provided. (6) observing the distance of 1500 m from each well, Therefore, in areas where many wells are drilled for drinking purposes, it is unenforceable, especially around densely populated areas and available land for determining landfill is limited. [Ray Ab Consulting Engineers, 2010].

Solid Waste Landfill Site Selection Methods

There are several methods for selecting locations for solid waste disposal or landfill, each of which has particular importance. There are also some restrictions. The objective of each of these methods is to preserve the environment and prevent pollution. Three common methods locating landfills are:

DRASTIC method

DRASTIC approach has been presented by the United States Environmental Protection Agency and the National Union of wells to assess groundwater pollution potential by hydrogeology.

In this way, different regions with seven c pollutants criteria that influence groundwater pollution are compared with each other. The seven criteria are:

D: depth to water table, R: net recharge, A: aquifer bed, S: soil bed,: T: topography, I: impact of saturation zone and C: aquifer permeability. If we know the weight, boundary and scores for each of the criteria, DRASTIC or pollution potential can be calculated for each site using the following equation. In fact, The DRASTIC method is a tool to compare one place to another place and then a site is selected that its pollution potential is the lowest.

$$D_R D_W + R_R R_W + A_R A_W + S_R S_W + T_R T_W + I_R I_W + C_R C_W = \text{Pollution potential}$$

Capital letters in the equation are DRASTIC criteria and R and W indices are, respectively, the value of a criterion and weight of a criterion.

Regional and Local Screening Method

In Regional and local screening method, three main factors exist. They are: natural conditions, land use and economic factors. These factors are first studied at regional scale and then at local scale. The point for each option of landfill is determined by rating and the table for the weight of each criterion.

Natural conditions

• Landfills should not be constructed on watercourses.

• Landfills should not be constructed in Surface water accumulations (at a distance of 61 meters).

• Areas with high groundwater levels are not suitable for the construction of a landfill, unless the hydraulic trap method is used.

• Areas where it is difficult or impossible to provide heavy clay and use a cover layer are not appropriate to build landfill. These soils must have a minimum coefficient of $1\times10^{9} m/s$ permeability, the soil layers beneath the landfill must be the type of clay - silt with $1\times10^{9} m/s$ permeability and the depth of the landfill must be about 15 meters or more.

• Landfill site must be at least 61 meters away from faults.

• Landslide hazard areas as well as areas of sensitive clays are not suitable for the construction of the landfill.

• Areas with high solubility soils, such as limestone are not suitable for landfill construction.

Land Use

• A minimum distance of 150 meters from landfill for residential, commercial and educational use and a minimum distance of about 80 meters for industrial use is recommended.

• A minimum distance of 3 kilometers from airports must be respected.

• A minimum distance of 300 meters from water wells must be respected.

• Agricultural lands with suitable conditions may be appropriate for landfill.

Economic Factor

Landfill must be built at a suitable distance from the main road (less than 1 km is appropriate)

MPCA Method

MPCA method is composed of the six primary removal factors and seven factors of secondary condition. The six primary removal factors must be observed in selecting the landfill and exclusion of any of these six factors will result in the removal of the place. The next seven factors are conditional, meaning that if these factors are removed by engineering operations, they do not create any prohibition for building the landfill.

Six primary factors are: 1 - a minimum distance of 305 meters must be observed from landfill to lake or a pool of water. 2 - Landfill distance from river or local conduit shall be 92

meters. 3 landfills shall not be located within stream flow return period of a hundred years. 4- Landfill should be selected in marshy areas. 5) Landfill must not create the risk of birds immigration to the local airport. 6 – in areas where limestone caves exist, landfills must not be built.

Choosing MPCA method as the preferred method

Minnesota Pollution Control Agency was established as the agency for controlling pollution in Minnesota to improve the environment in this state and around the world. It has done research and actions in order to protect environment. This organization has done activities such as monitoring environmental quality, providing technical and financial assistance and writing regulations to improve environment. MPCA has signed agreements with Environment Protection Agency of America regarding environment protection, as well as setting standards and rules associated with environmental pollution and environmental quality assessment.

On the evaluation of landfills, the agency has developed guidelines that quickly evaluate landfills with relatively little important data. Criteria required by this method are less than the criteria of other methods. This causes countries with insufficient information on the parameters of their environment to be able to quickly assess the environment and decide for the proper management of critical areas (Sabz Andish Payesh Consulting Engineers, 2010).

The Use of Geographic Information System (GIS) to Locate the Landfill

Experts and decision makers can improve scientific and principle locating of city by using technical and scientific tools like Geographic Information System. They could be aware of the results of decision-making and planning before implementing the plan by computer modeling and remove possible errors and problems before spending executive costs. [www.ensani.ir]. The ultimate goal in most geographic information systems projects is combining data from different sources, to describe and analyze phenomena or create new plans that can ultimately be used in making decisions. Preparing prioritized maps to select a suitable location for the construction of structures or projects such as power plants, dams, landfills, pipelines, power transmission, urban development and evaluation of mineral potential are examples of cases that need to combine different data layers to reach a final map (civilica website, 2012). Using satellite data and GIS in locating urban solid waste disposal is a new method finding landfill. Today, many researchers use GIS to locate a landfill because GIS is able to analyze large amounts of data layers. On the other hand, one of the most important capabilities of GIS that make it particularly distinct from other automated systems is its data fusion capabilities for modeling, locating and determining the appropriateness of the land via land valuation. Since the result of integrating and combining the criteria is choosing the best place to construct public centers. There are different methods to combine criteria that the most important ones are: Boolean logic, index overlay, fuzzy logic, the logic of probability and correlation coefficient. Valuing each criterion is implemented in different methods such as hierarchy analysis process, the Delphi processing, proportion or ratio estimation, indicator weights, logistic regression and neural network (Www.sid.ir).

Conclusion

Locating a suitable landfill or correct locating is most effective and most important step to develop a satisfactory plan for landfill. If possible, urban solid waste landfill should be determined during the preparation of the comprehensive plan of urban development and its land should been bought. In this regard, benefiting from geographic information systems analysis using Arc View software is extremely effective and since the output of such systems is shown visually on the map, thus, it reinforces perceptions, interpretations, and subjective inferences and makes decisions

optimized [http://cong.sbmv.ac.ir]. Geographic information systems with the ability to use various functions and extensive ability to change and manipulate data, extensive ability to combine different data layers and the possibility of using satellite imagery and the results of the interpretation of these images is a unique tool to perform the evaluation operation. Without the use of GIS, maybe it was impossible to quickly and carefully conduct these studies. Finally, GIS with its diverse capabilities will lead us to reduce costs and quickly achieve the desired goal (www.nigcdist8.ir).

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