Solid Waste Disposal Site Selection for Kandy District, Sri Lanka Integrating GIS and Risk Assessment

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Abstract- Open dumping is the most common method of solid waste disposal in many developing countries including Sri Lankan urban areas. Appropriate landfill site selection is important to minimize negative impacts associated with open dump sites. Landfill siting is an extremely difficult task to accomplish due to strong public opposition and regulations. Developing countries do not have a systematic process for landfill site selection and hence unsuccessful landfill siting leading to environmental degradation is typically the result especially in the developing world. Data were collected from Kandy district, Sri Lanka. Both GIS analysis and semi quantitative risk assessment were used and eight map layers such as surface water bodies, distance from transportation routes and urban areas, land use/land cover, soil, rainfall, population density, elevation were utilized. ArcGIS 9.3 software and its extensions were used as the GIS tool since it is able to perform suitability analysis using Multi Criteria Evaluation (MCE) analysis. Results reveled that about 20% of the area in Kandy district belongs to very high risk area, 40 and 30% were defined as moderate and low risk areas for landfill site selection respectively. The selection of the final municipal solid waste site requires further geotechnical and hydrogeological analyses in order to protect the groundwater as well as surface water. At the end of the analyses, 10% of the candidate areas are suggested however for the selection of the final landfill site further analyses and protective measures are needed in order to ensure the long term sustainability of the environment.

Index Terms- Solid waste, landfilling site, Geographical Information System (GIS), Risk Assessment.

I. Introduction

Unprecedented population growth increases waste generation with rapid urbanization and economic development in urban centres. Improperly managed solid waste is a risk to human health and the environment (Abeynayaka & Werellagama 2007; Balasooriya et al. 2011; Bandara & Hettiaratchi 2010). Management of solid waste has become a major global concern that is increasing day by day (Yahaya & Ilori 2010; Savage et al. 1998). Land filling is the most common and cost effective system of waste disposal method for most urban centres in the developing region (Abeynayaka & Werellagama 2007; Nas et al. 2010). Uncontrolled open dumping and improper waste management causes various problems, including contaminating ground and surface water, attracting insects and rodents, increasing flooding due to blocked drainage canals or gullies and generation of toxic gases (Abeynayaka & Werellagama 2007; Balasooriya et al. 2011; Bandara & Hettiaratchi 2010). All these problems consequence on social, environmental sustainability of the ecosystems.

Large number of impacts are associated with open dumping sites in Sri Lanka (Balasooriya et al. 2011; Bandara & Hettiaratchi 2010). To access those impacts semi quantitative risk matrix was very useful approach. It was developed by Deere et al, 2001. According to it, each risk associated with dumping sites described by identifying the likelihood and consequence of hazard. The impact on public health is the most important consideration, but other factors such as environmental, topographic conditions, hydrology also considered. Each impacts were accessed based on possible, rare, insignificant and major basis. Properly defining likelihood and consequence of the hazard with sufficient assessment, reduce the impacts associated with open dump sites. Lack of data in Sri Lanka, is most critical problem. When data is insufficient to determine a risk is high or low, risk considered as a significant risk. Any areas fall under high, very high areas should not considered as suitable for landfill site selection or may require mitigation measures to avoid those risks.

According to the risk matrix each hazard associated with open dump sites were identified and evaluated according to severity and likelihood, values were decided using CEA landfill guidelines (CEA 2005). It provides general guideline for the landfill site selection. This guideline is cover only the municipal solid wastes. Sewage, hazardous waste including medical wastes and hazardous industrial waste do not consider in the guideline. This guidelines provide a technical guidance to landfill site selection with minimal impacts to the environment. In addition to Sri Lankan guidelines, regional countries guidelines (India, Pakistan, Nepal, Thailand) and EPA landfill manuals also considered. India, Thailand, Pakistan and Nepal are developing countries but in some conditions they are differing from Sri Lanka. For example India has much more land than Sri Lanka. By comparing regional countries guidelines, Sri Lankan

guideline was used in this study, because it is more relax among others.

The impact on public health is the most important consideration, but other factors such as environmental, geology, social, topography, hydrology also considered (Javaheri et al. 2006; Department of Primary Industries, water and Environmnet 2004; Alfy et al. 2010). Each impacts were accessed based on possible, rare, insignificant and major basis. Properly defining likelihood and consequence of the hazard with sufficient assessment, reduce the impacts associated with open dump sites. Lack of data in Sri Lanka, is most critical problem. When data is insufficient to determine a risk is high or low, risk considered as a significant risk. Any areas fall under high, very high areas was considered as not suitable for landfill site selection or may require mitigation measures to avoid those risks.

Geographic information system (GIS) is a strong tool which can integrate in to several methodologies. It efficiently stores, retrieves, analyses and display information according to related method (Nas et al. 2010; Gorsevski et al. 2012; Sener et al. 2011; Guiqin et al. 2009; Donevska et al. 2011). The software ideal for this kind of preliminary studies due to its ability to manage large amount of spatial data from various sources and its saves time.
The objective of this study is to select a suitable site using the Geographic Information System (GIS) and semi quantitative risk assessment matrix at Kandy district a case study.

II. Material and Methods

A.Study Area

Kandy district is located in middle part of the Sri Lanka. Its capital is the city of Kandy, with a population of the district about 1,368,216 (Census report, 2012) and the region occupy 1934 Km^2 of the country's total area.

The climate is tropical, the average annual precipitation varies around 3175 mm and it is located at latitudes $6^0 56'$, $7^0 28'$ N and longitudes $80^0 25''$, $81^0 01'$ E. It has an average temperature range from 21 to 26 ^oC and in dry periods the temperature of the area rises up to 29-30 ^oC. The complex mountainous terrain of different landforms, soil types, geology and altitudinal gradients that range between 462 and 600 m above sea level and slopes varying between 0% and 90% produce a variety of activities, such as agricultural, commercial, industrial and urban land uses.

Most common method of solid waste disposal in Kandy district is open dumping. Improper planning and maintenance of these dump sites affect in many ways to human health and environment in long run.

Figure: 1. Sri Lanka map including Kandy District

B.Methodology

The methodology described in this paper is an efficient approach for a landfill siting process. In this study, eight map layers such as land use, elevation, surface water, distance to roads, and distance to urban areas, soil, rainfall, population density data was collected from the district. Suitable landfill site was analysed by using the GIS together with risk assessment (Table 2). (Deere. et.al, 2001, Bartram. et. al.2009). Based on these data, a risk assessment was carried out with semi-quantitative matrix (Table 1). The findings obtained from this study were used to develop criteria for new landfill site selection.

Table1. Semi quantitative risk matrix

		Severity or consequence				
		Insignificant or no impact – Rating:1	Minor implication impact- Rating :2	Moderate esthetic impact- Rating:3	Major regulatory impact- Rating: 4	Catastrophic impact- Rating: 5
Likelihood or frequency	Almost certain/ Once a day- Rating:5	5	10	15	20	25
	Likely/ Once a week- Rating: 4	4	8	12	16	20
	Moderate/ Once a month- Rating: 3	3	6	9	12	15
	Unlikely/ Once a year- Rating; 2	2	4	6	8	10
	Rare/ Once Every 5 year- Rating: 1	1	2	3	4	5

Risk Score	<6	6-9	10-15	>15
	Low	Medium	High	Very high

Table 2: Typical hazards identification in landfill sites

Hazard Event	Criteria	Hazard Type	Likelihood	Severity	Risk	Risk Rating
Odour and diseases	Landfill within 500m-1km from an urban areas	Social	4	2	8	Medium
	Landfill within 100m from an urban area	Social	4	5	20	Very High
	Landfill >1km from an urban area	Social	2	2	4	Low
	Transportation routes within <300m away from a landfill site	Environmental	4	4	16	Very High
	Transportation routes within >500m away from a landfill site	Environmental	2	2	4	Low
Surface water pollution	Landfill within 500m-1km from an urban areas	Environmental	2	1	2	Low
	Landfill within 500m from an urban area	Environmental	4	3	12	High
	Surface water bodies within <300m landfill site	Environmental	5	5	25	Very High
	Surface water bodies within >500m landfill site	Environmental	2	2	4	Low
Ground water pollution	High elevation(>2000m)	Environmental	5	5	25	Very High
	Elevation between 400m-1250m	Environmental	4	2	8	Medium
	Clay	Geology	2	2	4	Low
	Mixed	Geology	2	3	6	Low
	Sandy	Geology	4	5	20	Very High
	Clean sand/gravel	Geology	4	5	20	Very High
Social/ Environ-mental impacts	Rainfall <500mm	Meteorology	2	3	6	Low
	Rainfall 500mm-1500mm	Meteorology	2	4	8	Medium
	Rainfall >1500mm	Meteorology	5	5	25	Very High
	Population Density 80 -1000Km^2	Social	3	3	9	Medium
	Population Density 1000-3000Km^2	Social	4	5	20	Very High
	Land use- Plantations	Environmental	3	5	15	High
	Land use- Pasture areas	Environmental	4	5	20	Very High
	Land use- Rocky Terrain	Environmental	3	3	9	Medium
	Land use- Bush lands	Environmental	1	3	3	Low
	Land use- Agricultural land	Environmental	2	4	8	Medium
	Land use- Urban Centers	Social	4	5	20	Very High
	Land use- Villages	Social	5	5	25	Very High

According to the risk assessment, buffer zones were assigned as 100 m, 200 m, and 300 m along every existing road by using Arc GIS 9.3 software. 100m and 300m buffer zones were assigned for railway track and values were decided according to the risk assessment.

The location of a solid waste disposal site at a distance less than 100 m from a surface water body causes very high risk; a distance equal to about 300 m causes moderate risk and a distance greater than 300 m causes low risk to the environment. The safe distance between a surface water body and buffer zones were considered to be greater than 500 m.

If a solid waste disposal site is located at a distance less than 100 m from a residential area , it causes very high risk to the residents. If the distance between the residential area and the solid waste disposal site is greater than 1 km, it may impose low risk, while a distance between 400 m and 1 km is considered as to be of moderate risk condition.

The best areas for locating land disposal sites should have a medium altitude. An altitude greater than 2,100 m makes the relevant area not suitable for locating solid waste land disposal sites. Doneveska et al. (2011) considered areas which are 400–1,250 m above sea level, as the most suitable because of being the least less risk areas. An altitude greater than 2,000 m causes a high risk.

Land use map in the area was identified and urban centers, villages, parks and scenic areas were considered as high risk area for landfill site selection. Archeological, histological and protected areas exclude from the consideration (CEA, 2005).

Soil types in the area was considered and values were assigned based on risk assessment. Soil in Kandy district is covered by clay type soil considered as a low risk factor.

Population data in Kandy district was collected from census and statics department and density was calculated. Density higher than 1000Km^2 considered as high risk area and lower than that considered as low risk areas. Low risk areas were considered to be suitable for land disposal.

Meteorological factors are more important in landfill site selection. Rainfall data was collected in twelve meteorological stations (1963- 2011 yrs.) in Kandy district from meteorology department, Peradeniya and developed rainfall distribution pattern of Kandy district by interpolating data by calculating average annual rainfall.

Values were assigned to each layers according to risk assessment and finally overlay analysis was carried out to develop suitability map by using Arc GIS 9.3 software (Figure.2).

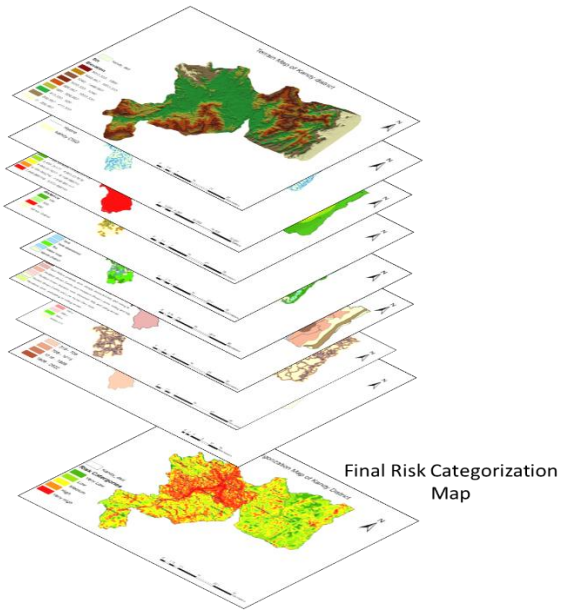

Figure.2. The spatial analysis procedure for landfill site selection

III. Results and Discussion

Selection of potential landfill site is not an easy task and it needs careful evaluation of the study area. For this case study eight criteria were selected according to the CEA guidelines (2005) and the availability of data in Kandy district.

Landfill sites should not be placed too closed to high population density area in order to mitigate conflict against peoples who live in nearby. This prevents health problems, noise complains, odour complains, decreased property values and mischief due to scavenging animals. According to the EPA landfill guideline (Environmental Protection Agency 2006), a landfill site should be located in an area which is at least 500m away from an urban residential or commercial areas. Figure 3, shows the building with buffer zones, and the restricted areas represented by green colour.

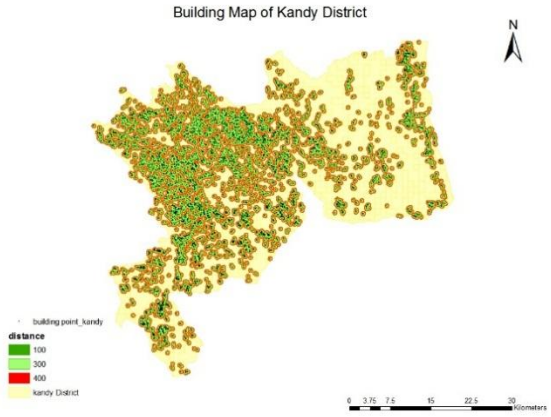

Figure.3. Building Map

Population density of the area was considered as another criterion. Kandy Four Gravest has highest density compared to the other regions. So it is considered as high risk region. Dense population settlements generate most of the waste quantity, it is a very important factor because it defines the operational cost for the waste landfill.

Being a natural resource, surface water is very important as a major human requirement and an agent to keep the ecological balance, Rivers are under risk, since the mixing of leachate with river water leads to river pollution. Older landfills in Kandy district were often sited close to Mahaweli River enhancing the potential for leachate to contaminate ground water as well as surface water. Figure 4 shows the suitability of areas for waste disposal sites according to the surface water distribution of Kandy district. According to the CEA guidelines safe distance buffer zones were created and values was given for each of them according to the risk assessment.

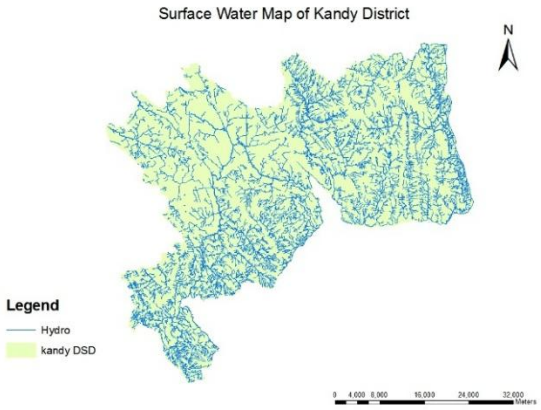

Figure.4. Surface water Map

An optimal landfill soil will have moderately low permeability, a low erodibility potential, and a high cation exchange capacity. Fine grained soils are more suitable for landfills than coarse grained (Şener et al. 2005) However, properties of clays including low drainage rates, shrink/swell potential, and low workability usually reduces a clay soils suitability against soils with a silty clay texture. As, in Kandy district more areas are covered by clay soil, it is considered as low risk area for landfill site selection.

Landfill site located too far away from the existing road network, costs for solid waste collection and transportation will be high. Also it cannot be placed too close due to aesthetic value. Kandy region has a well-developed, dispersed road network system. Buffer zones were created according to the related literature and modified according to the Sri Lankan situation by using risk assessment (Figure.5).

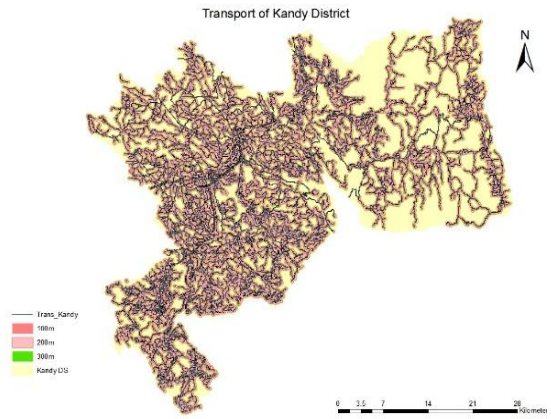

Figure.5.Transportation Map

Land use is considered as important criteria for the landfill site selection, because CEA technical guidelines (2005) exclude some areas as an unsuitable for landfill site selection. Water, urban area, forest were excluded from consideration and barren, shrub lands considered as low risk areas for landfill site selection (Figure.6).

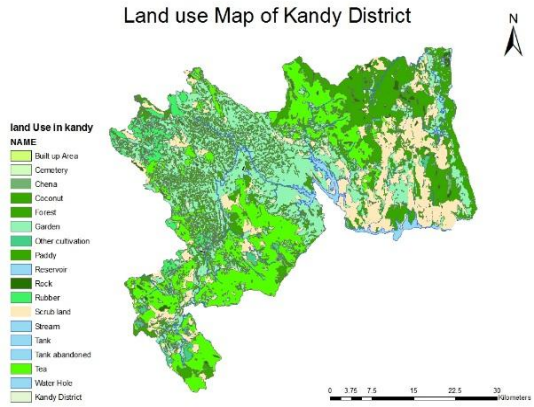

Figure.6. Land use Map

Chemicals in the landfill leach into ground water by precipitation and surface runoff. Precipitation in the area was considered as one of the criteria for this study and interpolate the average annual rainfall in the Kandy district and evaluate using risk assessment.

The elevation map of the study area is divided into four regions, low, medium, high, very high risk areas. The areas with elevations between 400m and 1250m are defined as suitable areas (Sharifi et al. 2009; Ugur & Sener 2010) for a landfill site and the remaining areas as unsuitable.

According to the risk assessment, risk areas were classified in to three categories, low, moderate and high. The identified suitable areas for landfilling are illustrated in Figure.7.

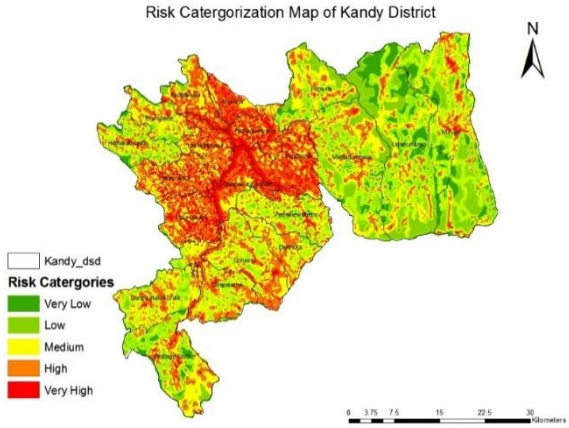

Figure.7. Risk Categorization Map of Kandy District

According to Figure.7, 20% of the area belongs to Kandy district is considered as very high risk area, and need to exclude from landfill site selection. Only 10% of the area considered as very low risk according to risk assessment and those areas suitable for landfill site selection. Rest of 70% belongs to low and moderate risk areas and other factors needs to be considered before use them as landfill site.

IV. Conclusions

This study integrates the use of GIS along with semi quantitative risk matrix method in order to site a landfill site. The GIS tool is a useful for the investigation of separate data sets and the creation of new data sets for visualization.

A landfill siting process requires evaluating many factors and criteria and processing much spatial information. Considering above eight landfill site selection criteria and the data availability, limited area (10%) in Kandy district is defined as suitable for landfill site. Moderate and low risk areas can be modified by using engineering solution in order to use as a suitable site for landfill.

These areas generally satisfy the minimum requirements for the landfill site selection. The selection of the final municipal solid waste site requires further geotechnical and hydrogeological analyses towards the protection of groundwater as well as surface water in order mitigate the impacts caused by landfills.

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