

Locating Landfills in Arid Environment

Nadhir Al-Ansari¹

Abstract

Protection of the environment from solid waste hazards is becoming a serious problem. Different laws and legislations had been put into practice for this purpose. The effect of solid waste in developing countries with limited financial and natural resources and high population growth rate is more severe. To overcome these difficulties, prudent management system for solid waste is required. Furthermore, solid waste disposal site should be selected using scientific criteria to prevent any harmful effect on local communities and the environment.

Criteria for solid waste disposal dump site for arid and semi-arid regions should be selected in accordance with well-known international requirements that suit the local conditions. These criteria can be used to select the best suitable solid waste dump site using remote sensing and geographic information system techniques. The selected sites are harmless to human life, natural resources and the environment. The same can be achieved when dumping hazardous solid waste. In all cases however, priorities of the site selection criteria should meet the existing geological, meteorological and environmental conditions.

Keywords: hazardous waste, landfills, clay-based isolation, erosion protection, climatic impact, location.

1 Introduction

Human activities (Industrial, domestic, commercial and construction) and animals generate solid waste in many forms. Some of the waste fall out of the commercial use i.e. can not be utilized. Parts of this waste (specially the industrial part) are considered hazardous to the environment and natural resources. With continuous population growth and increase of standard of living, solid waste is increasing in tremendous amounts. This fact enforced a major problem facing the world.

¹Lulea University of Technology.

The problem is more serious in third world countries where 80% of the world population live [1,2] and due to the lack of financial resources. It is believed that about 10% of each person's production life is lost as a result of waste related diseases [1]. These facts led to an increasing awareness of solid waste hazards on an international level. Consequently, legislations and laws developed since the mid of the twentieth century (e.g. UN conference in Stockholm, 1972; Earth Summit in Rio de Janeiro, 1992, in Aldiab, 2000). It is noteworthy to mention that improper solid waste management will causes air, soil and water pollution. The overall objectives of such measures are to ensure sustainable development and management of waste in sound manner to minimize its effects on human and the environment.

2 Municipal Solid Waste (MSW)

Solid waste source and type is generally related to the use and place. There are number of classifications for the solid waste. Generally, we can divide the solid waste into: residential, industrial, commercial, institutional, construction and demolition, municipal services, process and agricultural (Table 1).

The composition of the waste is influenced by several factors such as geographical location, standard of living, energy source and weather. It also varies in low, middle and high income countries (Figure 1).

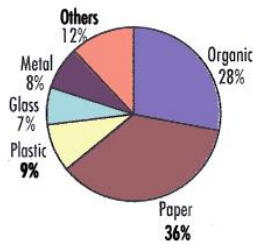
Low and middle income countries have high percentage of organic matter in MSW ranging from 40 to 85 % of the total. Paper waste in high income countries is usually higher than it is in low and medium income countries.

Table 1: Source and type of Solid Waste [3]

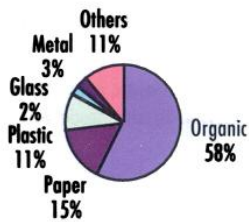
Source	Typical waste generators	Types of solid wastes
Residential	Single and multifamily dwellings	Food wastes, paper, cardboard, plastics, textiles, leather, yard wastes, wood, glass, metals, ashes, special wastes (e.g., bulky items, consumer electronics, white goods, batteries, oil, tires), and household hazardous wastes
Industrial	Light and heavy manufacturing, fabrication, construction sites, power and chemical plants	Housekeeping wastes, packaging, food wastes, construction and demolition materials, hazardous wastes, ashes, special wastes
Commercial	Stores, hotels, restaurants, markets, office buildings, etc.	Paper, cardboard, plastics, wood, food wastes, glass, metals, special wastes, hazardous wastes
Institutional	Schools, hospitals, prisons, government centers	Same as commercial
Construction and demolition	New construction sites, road repair, renovation sites, demolition of buildings	Wood, steel, concrete, dirt, etc.
Municipal services	Street cleaning, landscaping, parks, beaches, other recreational areas, water and wastewater treatment plants	Street sweepings; landscape and tree trimmings; general wastes from parks, beaches, and other recreational areas; sludge
Process	Heavy and light manufacturing, refineries, chemical plants, power plants, mineral extraction and processing	Industrial process wastes, scrap materials, off-specification products, slag, tailings
All of the above should be included as "municipal solid waste."		
Agriculture	Crops, orchards, vineyards, dairies, feedlots, farms	Spoiled food wastes, agricultural wastes, hazardous wastes (e.g., pesticides)

Current Waste Quantities and Composition

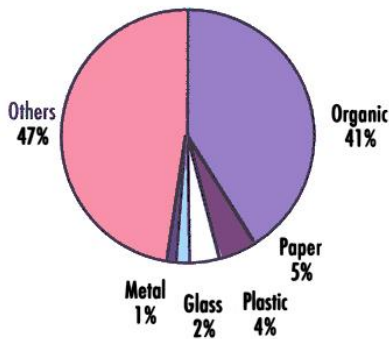
High Income Countries: Current
Total waste = 85,000,000 tonnes per year



Middle Income Countries: Current
Total waste=34,000,000 tonnes per year

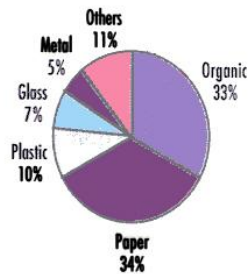


Low Income Countries: Current
Total waste=158,000,000 tonnes per year

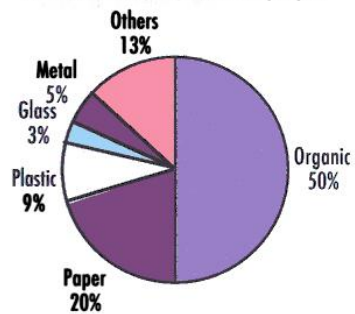


2025 Waste Quantities and Composition

High Income Countries: Year 2025
Total waste=86,000,000 tonnes per year



Middle Income Countries: Year 2025
Total waste=111,000,000 tonnes per year



Low Income Countries: Year 2025
Total waste=480,000,000 tonnes per year

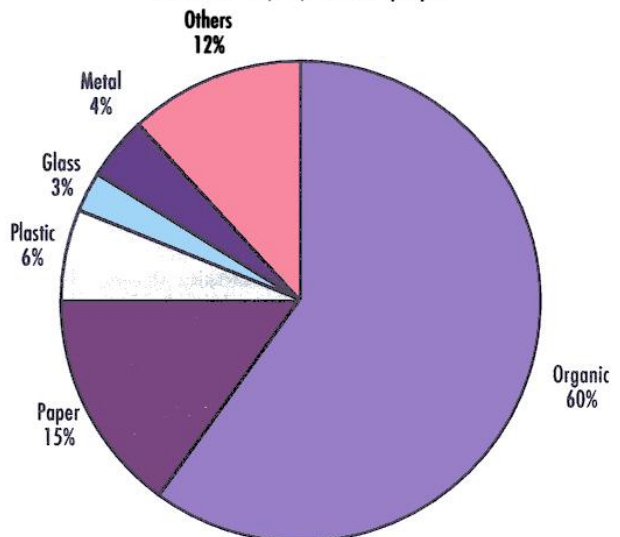


Figure 1: Waste composition of low, Middle and High Income Countries [3]

3 Solid Waste Generation Rates

Waste quantities are closely linked with population density, economic activities and resources consumption (Figure 2). The data given by [3] indicates that the present day MSW generated reaches 277 million tones per year. High income countries generate 30.7% of that waste while 12.2% and 57.1% are generated in middle and low income countries. This figure is expected to increase to 677 million tones in 2025. The percentage of waste generated in high income countries will be 12.7% while it will be 16.4 and 70.9 % in middle and low income countries respectively.

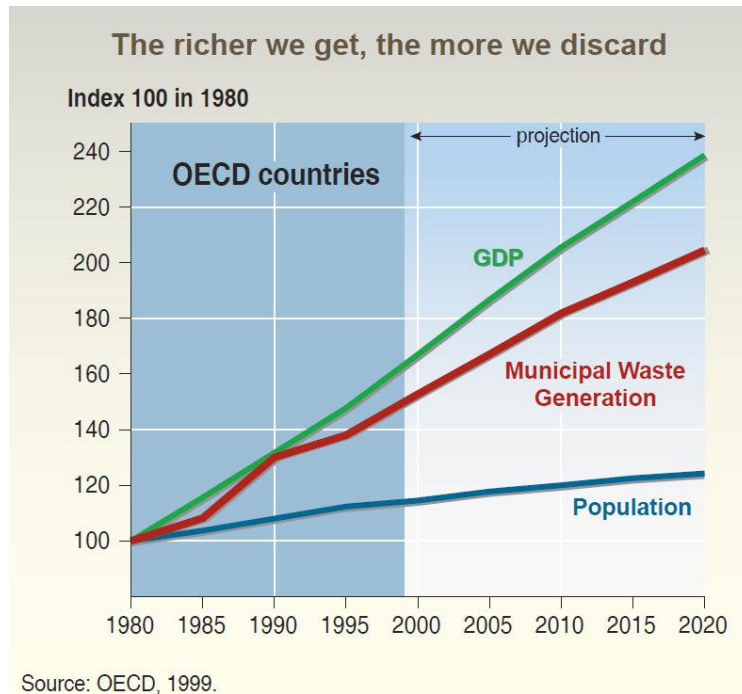


Figure 2: Population growth and GDP relationship with MSW generation.

[3] stated that low income countries has the lowest percentage of urban population and the lowest generation rates (0.4 to 0.9 kg/capita/day) while it is 0.5 to 1.1 kg/capita/day and 1.1 to 5.07 kg/capita/day in middle and high income countries respectively. It is evident that people in rural areas produce less waste compared to urban areas due to their lower per capita income. Developing countries are experiencing high population growth in urban areas compared to rural areas [4]. It has been estimated that, urban to rural migration accounts for 40 to 60 % of the annual population growth in developing countries [5].

Waste composition changes when countries become richer. This is reflected by the increase in the use of paper and paper packing, plastics, multimaterial items and consumer products. In low and middle income countries in Asian, it is believed that the waste production will be tripled in 2025 than it was in the nineties [3]. Low income countries in 2025 will produce twice as much waste (480 million tones) than all middle and high income countries [3].

According to the Organization of Economic co-operation and Development (OECD), SA and Canada produce waste more than other countries. They are followed by Western

Europe, Japan and Korea and Australia and New Zealand (Figure 3). Figure 4 shows how the rate of waste generation varies within the OECD countries. Hazardous waste production is about 150 million tones per year in year 2000 [6] (Figure 5).

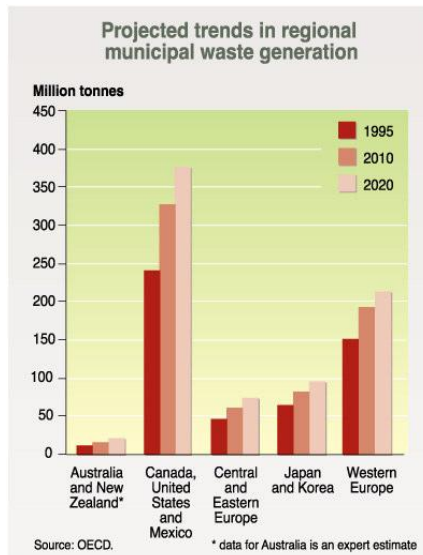


Figure 3: Projected trends in regional MSW generation [7]

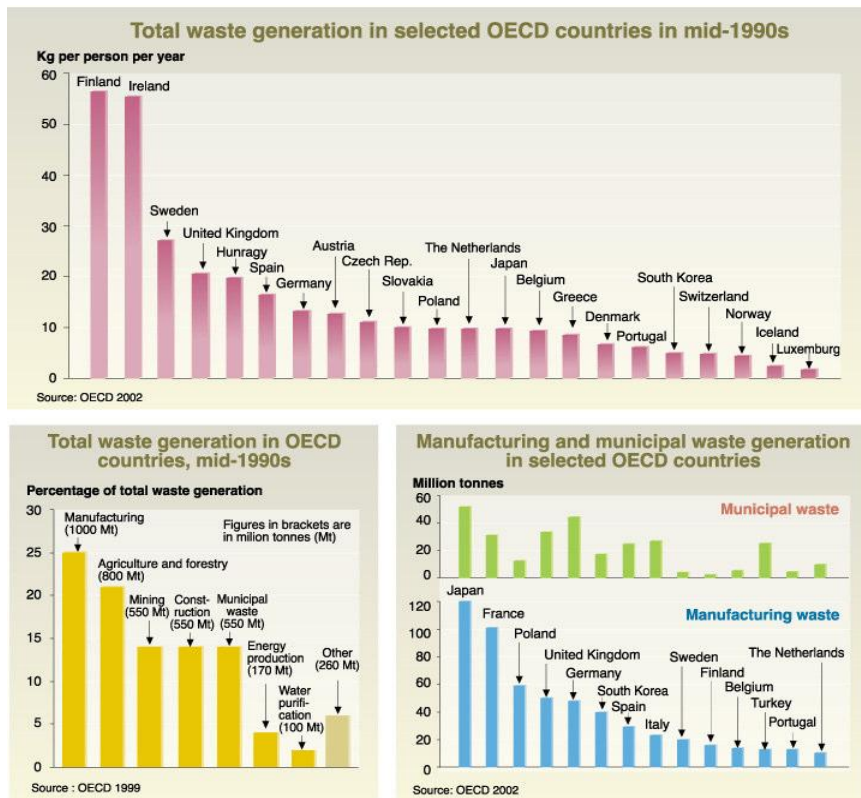


Figure 4: MSW generation within OECD countries.

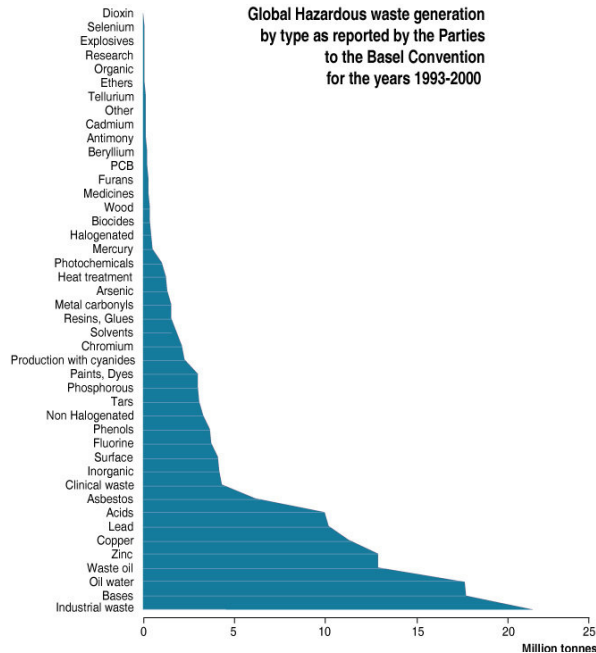


Figure 5: Global hazardous waste generation [6].

MSW management practices vary from place to another. Figure 6 shows the common practices used all over the world. Open dump practices are used in Asia, Africa, South America and Europe. Recycling is relatively higher in North America and Europe; sanitary landfills are more widely used in America.

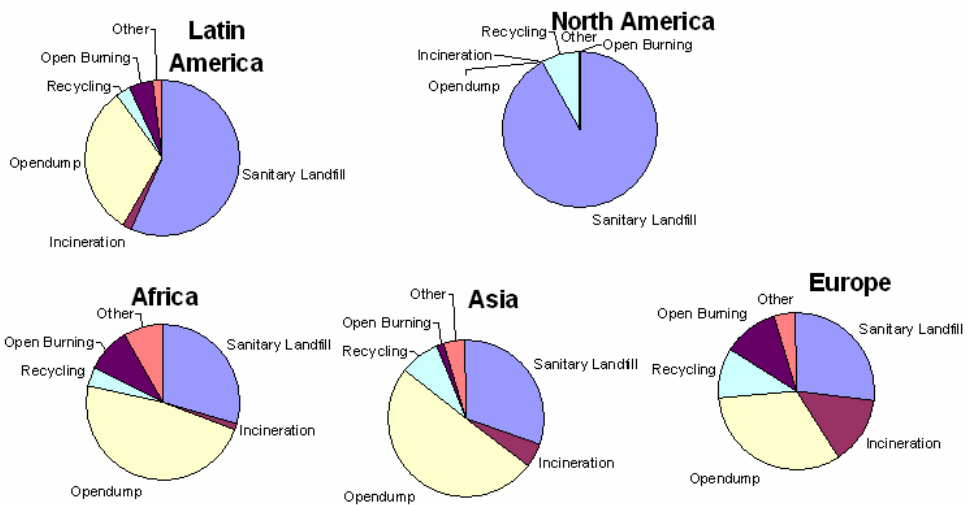


Figure 6: Municipal solid waste management practices [6].

4 Site Selection Criteria

Selecting a landfill site is a difficult task. In doing so, we have to take care of several factors. Among these factors is its effect on humans, environment, water resources, air, and soil as well as other utilities like transportation and power supply. In addition the landfill should have sufficient capacity to meet the current and projected waste to be deposited within at least 10 years. Number of criteria had been proposed for landfill siting [8-12]. The most important points to be recognized in landfill siting are:

1. Distance from Cities and Towns: To minimize the effect of landfill on human health it should be located at least 3 km from the nearest town.
2. Distance from Airports: To overcome birds interrupting aircrafts landing and taking off, it is advisable that the landfill should be at a distance of 3km or more away from the runway.
3. Distance from primary Highways: The land fill should not be very close to highways and this depends on the topography of the area and access roads.
4. Distance from Public parks and recreation areas: The distance of the landfill from parks and recreation areas depends on the topography and the prevailing wind direction.
5. Groundwater: Water table should be deep enough to prevent leakage to groundwater aquifers. The landfill should be away from groundwater recharge areas. In cases of failure, the ground water flow direction should be in such a direction causing minimum pollution.
6. Soil: It is preferable that the existing soil has low permeability (10⁻⁶ cm/s).
7. Flood plain areas: Areas that might be flooded should be avoided.
8. Surface water: The landfills should be at least 200 meters away from streams and stream valleys or lakes.
9. Topography: The land fill is to be located in an area where local drainage is running away from its site. In addition the landfill site should not be located in an area where flash flood might take place.
10. Biodiversity: The site should be located at least 1 kilometer away from protected areas or areas used for breeding or living animals. It is recommended that the site should be away from borrowing animals.
11. Geology: Faulted areas and karsts terrains are to be avoided. Sand dune movements should be studied and landfills are to be located away from such dunes. Areas with rocks having cracks or joints should be avoided, also areas having sinkholes or karsts are to be avoided.
12. Seismicity: The area should be seismically stable. Nearby reservoirs are to be avoided due to possible induced seismicity.
13. Meteorology: Rainfall duration and intensity, temperature, humidity and wind speed and direction must be considered when siting a landfill.

The priorities of the above conditions will vary from place to another depending on the population distribution, meteorological, geological and hydrological conditions.

5 Solid waste in Mafraq, Jordan: Case study

Jordan was selected for the case study because it represent typical arid environment. Site selection criteria in Jordan did not take into account the effect on the environment and natural resources. Examples of such sites are Russaiyfa waste disposal site where it is located on a phosphate mine. This mine in turn is underlain by an important groundwater aquifer. In general all the sites receive untreated medical and industrial waste. In addition, within these sites no liner systems are used. Other sites however, burn the waste in open air (Figure 7) or used as open dump a (Figures 8 and 9). In view of these conditions the Environment Conservation Organization reported the environmental conditions and possible solutions for the existing problems within these sites [13].

Management practices of solid waste are not performed in a prudent way. Recycling and waste selection for reuse is performed by locals (Figure 10) before compaction. As an example 98% of glass bottles are returned back to manufactures. Recycling exercise is becoming more important with time where a number of items are picked and used again in various industries.

Solid waste management and disposal sites in Jordan are poorly operated. These sites are source of potential hazards to the public, natural resources and the environment. Lack of regulations, national waste management policy or guidelines makes the problem worst. In addition, the problem becomes more sever with the lack of financial resources and lack of trained personnel and the absence of any adequate records concerning quality and quantity of solid waste.



Figure7: Burning waste at a dumping Site [13]



Figure 8: Open dump site for solid waste [13]



Figure 9: View of a solid waste dump site [13]



Figure 10: Manual waste selection [13]

5.1 Solid Waste in Mafraq

Mafraq city is located in the northern part of Jordan (long 36 7'30 "E lat 32 15- 32 22' 30" N) about 72 Km north of Amman (Fig 11). Mafraq Governorate covers an area of 26435 square km while Mafraq city area is about 46 square km (Fig 12) which is characterized by its relatively flat topography [14]. The total population of the Governorate in the year 2000 is 232300 while 47105 people live within Mafraq city. The rate of population growth reaches 3.93%. About 40% of the area of the city is used as residential purposes while 52% is used for agricultural purposes. The remainder is used for commercial, industrial public buildings etc.



Figure 11: Map of Jordan.

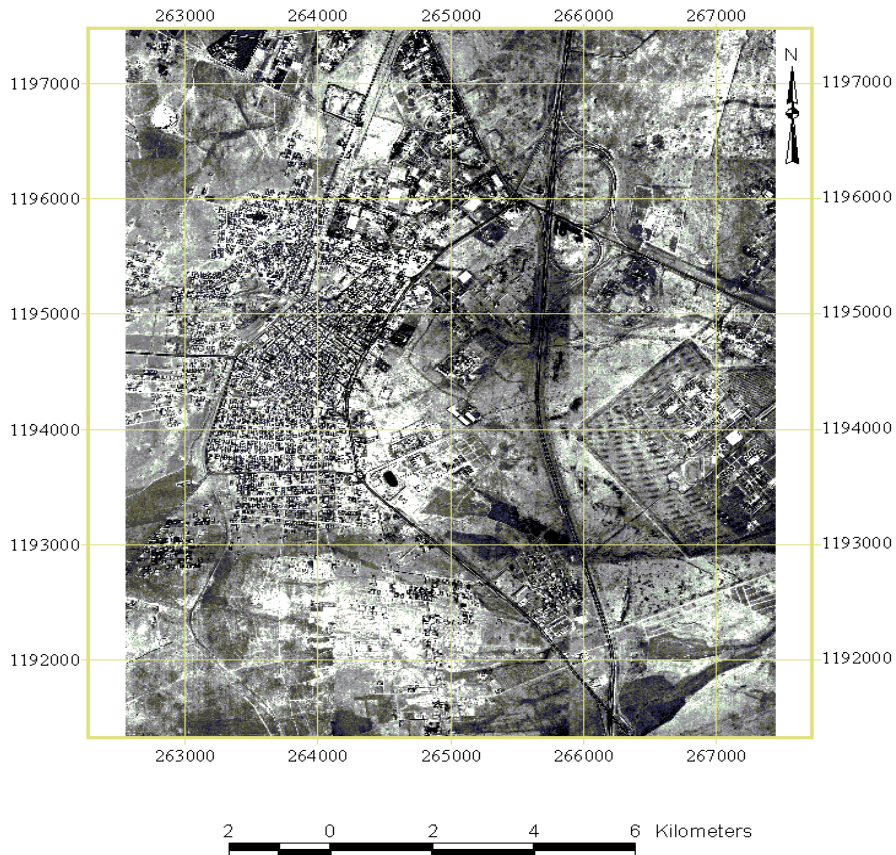


Figure 12: The aerial photography of the Mafrq city.

Eight types of solid wastes can be recognized in Mafrq. They are: residential commercial, industrial, agricultural, housing construction, institutional, municipal and

waste water treatment plants. Within the city daily waste reaches 44tons, and ordinary residential and commercial waste forms more than 80% of the overall average.

Alhusainiyat solid waste disposal site was constructed in 1986 covering an area of 180 donums. The site receives 134 tons of waste daily from 64 villages including Mafrag city. Selection of individual waste is executed manually and the remainder is dumped and covered by 50 cm layer of soil.

Six main villages are situated within the vicinity of the disposal site (Table 2). It was noticed that the site enhanced the existence of different type's harmful creatures, relative to other areas (Table 3).

Table 2: Villages near Mafrag solid waste disposal site

Village	Number families	Percentage inspected
Nuzha	88	20.3
Zuhur	35	10.9
Ruwdhat Basmah	419	18.4
Manshiyat alsaltah	206	19.8
Un al Jemal	271	18.9
Zaatry	216	11.7
Total	1235	1000

Table 3: Type of creatures within the vicinity of Mafrag solid waste disposal site

Type Location	Nuzha	Zuhur	R. Basma	M. Alsultah	U. Jemmal	Zaatri
Insects	33.7%	27.8%	37%	41%	40.9%	47.7
Fly	34%	22.7%	36.1%	34.4%	39.8%	46.3
Mice	10.7%	13.3%	3.8%	8.7%	7.7%	-
Worms	18%	2.9%	15.4%	15.9%	11.6%	6.6%
All above	3.6%	33.3%	7.7%	-	-	-

In addition it was found that these communities suffer from different types of disease (Table 4). Places closer to the site was found to be highly affected relative to other places. During summer the negative effects of the site are more pronounced.

Table 4: Type of sickness distribution near the solid waste disposal site.

Location / Disease	Nuzha	Zuhur	R. Bamah	M. alsaltah	Unm aljemmal	Zaatri
Head ache	10.7%	-	7.7%	40.7%	50%	18.8%
Worms	-	13.3%	-	7%	-	-
Diyoria	-	-	3.8%	-	7.7%	6.3%
Canser	-	6.7%	-	-	-	-
Poisoning	14.3%	-	19.2%	14.8%	15.4%	6.3%
Flu	14.3%	6.7%	-	-	-	-
Sensitivity	-	-	38.5%	3.7%	3.7%	-
Respiration	-	13.3%	19.2%	3.7%	3.8%	-

5.2 Solid Waste Site Selection Using Remote Sensing (RS) and Geographic Information Systems (GIS)

One of the biggest challenges is the proper site selection for solid waste disposal for its direct effect on the community and the environment [15]. For this purpose the United States Environmental Protection Agency set in November, 1993 principle outlines to be considered in this process.

Remote sensing and GIS techniques are very useful tools to be used for solid waste dump sites. For this reason these techniques were used to select the best possible dump site within the vicinity of Mafraq city. This was achieved using 18 aerial photographs (scale 1: 10000) taken in the year 2000 to construct the data layers showing roads and extension of Mafraq city. In addition topographic, geologic and land use maps of various scales were also used. Other data concerning ground water wells, water table depth and meteorological data were obtained from the files of the Ministry of Water and Irrigation. All the maps used were digitized using different software (Auto CAD 14, Arc/ Info 7.2., and 8, Arc View 3.1, Geomedia Professional 4.0 and Arc View Spatial Analyst) and show the results of these maps.

The data used in the analysis were as follow:

- 1- Topographic contours
- 2- Water drainage systems
- 3- Roads
- 4- Geology
- 5- Type of land use
- 6- Ground water levels
- 7- Rain intensity and distribution

All the maps were reconstructed in a "Grid" which is Raster Data composed of vertical and horizontal rows. This will enable Arc View 3.1 (Spatial Analyst) software to analyze the data. The conditions set for the analysis were based on the USA and EU regulations taking into consideration the special conditions related to the studied area. These conditions were:

1. The distance of the dump site should exceed 500 m to the nearest village.
2. The dump site should be close to roads for easy access.
3. The rocks should be impermeable to ensure protection of ground water resources.
4. The dump site should be at least 60m away from faults and joints.
5. Ground water should be deep enough to ensure protection from leaking material.
6. The dump site should be at least 500 meters away from the nearest ground water well to prevent pollution.
7. The area to be used as a dumping site should not fall within the category of agricultural land.
8. The site to be used should be at least 200 meters away from the nearest valley or drainage system to ensure that draining water does not transport the waste dumped.
9. The area to be selected should be nearly flat (slope should be less than 4).
10. Average rainfall should be low on the selected site.

Using the Arc View GIS (Spatial Analyst) different solid waste disposal sites (SWDS) were selected according to the conditions given (Figure 13). The overall selected sites covers an area of about 235 5000 m².

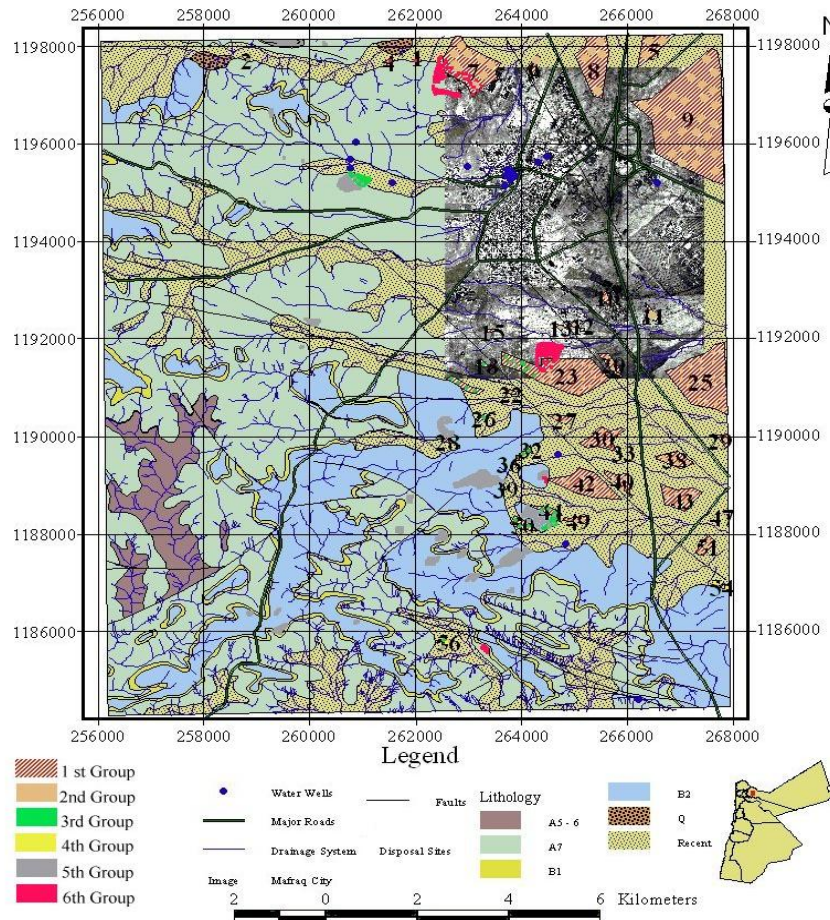


Figure 13: The groups of the suggested solid waste disposal sites within Mafraq city

6 Conclusions

Solid waste management and disposal in most of the cities in developing countries at its present status does not fulfill the required international conditions. Furthermore, high rate of population growth and the movement of people from rural to urban areas will inevitably make the problem more sever. Most of the developing countries are progressively having a higher standard of living. This will also inevitably increases the generation of solid waste. All these factors will cause tremendous increase in generation solid waste in the near future.

To overcome this problem, prudent site selection criteria and management strategies are to be adopted based on scientific knowledge. Local conditions are to be considered when applying such measures due to the effect of local environmental conditions on the criteria to be adopted.

Despite the fact that some disposal sites had been found fulfilling the conditions set by the international community, other conditions concerning the management process should be also fulfilled.

References

- [1] Pearce, D. and Walker, Ch., Sustainable Development, in Baily, R. (ed), *Water and Environmental Management in developing countries*, 1996.
- [2] Jackson, B., *Water and Environmental Management in developing countries*, International Institutions, in Baily, R. (ed), 1996.
- [3] United Nation Department of Economic and Social Affairs (UNDESA), 2010, Trends in solid waste management: Issues, Challenges and opportunities. http://www.uncrd.or.jp/env/spc/docs/01_background%20paper%20PL1_final_draft_8Mar2010.pdf
- [4] World Resources Institute, World Resources: A Guide to the Global Environment, *The Urban Environment*, 1996—97. Oxford University Press, Oxford, United Kingdom, 1996.
- [5] McGee, T.G. and C.J. Griffiths, Global Urbanization: Towards the twenty-First Century. Population Distribution and Migration. *Draft proceedings of the United Nations Expert Meeting on Population Distribution and Migration*, Santa Cruz, Bolivia, January 18—22 (1994).
- [6] Chandak, S.P. Trends in Solid Waste Management: Issues, Challenges and Opportunities, *International Consultative Meeting on Expanding Waste Management Services in Developing Countries*, Tokyo, Japan (18-19 March, 2010).
- [7] Organisation for Cooperation and Development (OECD). 2002, OECD Environmental Data Compendium 2002: Waste. Paris: OECD.
- [8] BCRC, Preparation of a set of tools for the selection, design and operation of hazardous waste landfills in hyper – dry areas, *Regional Center for Training and technology Transfer for the Arab States*, **55**, (2005).
- [9] Tchobanoglous, G., Theisen, H., and Vigil, S.A., *Integrated solid waste management*. Mc Graw-Hill, Inc., New York, 1993.
- [10] Ministry of the Environment, Landfill Waste Acceptance Criteria and Landfill Classification, *Ministry of the Environment*, **33**, New Zealand, (2004).
- [11] McDougall F. R., White, P. R., Franke, M. and Hindle, P., *Integrated Solid Waste Management: a Life Cycle Inventory, second edition*, Blackwell Science, 532. , 2003.
- [12] EPA US-Environmental Protection Agency of United State, *Municipal Solid Waste Landfill Criteria*, (1993). Found at: [wysiwyg://15/http://www.epa.gov/epaoswer/non-hw/muncpl/landfill_techman](http://www.epa.gov/epaoswer/non-hw/muncpl/landfill_techman)
- [13] Chopra M, Reinhart D and Abu-El-Shaar W, US-Jordan Municipal Solid Waste Management Collaborative Research, *FINAL REPORT* ,(2001).
- [14] Al-Ansari, N.A. and Baban, S, *The Climate and Water Resources*, in: Baban, S. and Al-Ansari, N.A, (Eds.), Living With Water Scarcity, Water resources in the Jordan Badia Region, The Way Forward, Chapter 3, Al al-Bayt University Publication, Jordan.(2001).
- [15] Davis M. and Cornwell D., *Introduction to Environmental Engineering, WCB/McGraw Hill Series. Third Edition*. Editor: George Tchobanoglous, University of California, 1998.