ENVIRONMENTAL IMPACT ASSESSMENT OF MUNICIPAL SOLID WASTE LANDFILLS: A CASE STUDY FROM JORDAN

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SUMMARY: Landfills have been and will remain the dominant alternative for the ultimate disposal of municipal solid waste. However, landfilling of solid waste was associated with certain adverse environmental impacts. This has created some sort of objection from the public and decision makers' side for setting a new landfill. One tool to gain the acceptance of the public and the decision makers is to conduct an EIA study of the selected site, so as to eliminate and/or minimize the adverse impacts of the site.

This paper is aiming at presenting the Environmental Impact Assessment (EIA) study for Al Ghabawy landfill site of the Jordanian Capital City (Amman), so as to identify the significant adverse impacts and to recommend the necessary mitigation measures. Site visits, survey and scoping session revealed that the most serious issues that might have adverse impacts and required special attention were leachate and gaseous emissions from the landfill. The study analyzed the extent of the above impacts and the required measures to avoid or to minimize them were recommended. Furthermore, operational guidelines, monitoring, and post closure measures were suggested. The procedure followed and recommendations made by this study may serve as guidance for planners and decision makers to conduct EIA for landfills under similar conditions.

1. INTRODUCTION

Landfilling has been used for many years as the most common mean for solid waste disposal generated by different communities (Komilis et al 1999). Despite the intensive efforts that are directed to the recycling and recovery of solid wastes, landfills remain and will remain an integral part of most solid waste management. Solid waste disposed in landfill usually subjected to series of complex biochemical and physical processes, which lead to the production of both liquid and gaseous emissions. As water percolates through the solid waste matrix, leachate produced which contains soluble components and degradation products from the refuse. Green house gases such as methane and carbon dioxide are generated during the stabilization of solid waste organic fraction. Volatile components of the solid waste tend to be emitted into the atmosphere with the evolved landfill gases.

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The contamination of groundwater by landfill leachate has been reported by several researchers (Nixon et al 1997, Shultz and Kjeldsen 1986, Swaney and Kozolosk 1984). Lee and Jones (1993) reported the potential adverse impacts of municipal solid waste (MSW) landfills on those who own or use properties near such facilities. Hirshfeld et al (1992) reported that the property values near MSW landfills are adversely impacted by the landfill for distances of a mile or more from the area where waste deposition occurs. Adverse environmental impacts, public health and socio-economic issues associated with MSW landfills have led to issuance of stricter regulations and increased public opposition to the sitting of such facilities (not in my back yard syndrome) (Ham 1993). As a result, the sitting of a new landfill has become one of the most difficult tasks faced by most communities involved in MSW management. (Tchobanoglous et al 1993).

It is important to convence the decision makers and the public that the selected site is environmentally friendly and its adverse impacts will be minimal. One tool to achieve this objective is to conduct EIA study of the selected site, so as to eliminate and/or minmize the adverse impacts of the site. The objective of this paper is to present the major environmental issues considered in the EIA study conducted for the Al Ghabawi Landfill for the capital City of Jordan(Amman) and to highlight the mitigation techniques recommended to minmize the adverse impacts.

2. CASE STUDY – AL GHABAWI LANDFILL

Amman is the Capital City of Jordan with population of about 1,766,922 in the year 2000. Solid waste management in the city is the responsibility of the Municipality of Greater Amman (MOGA). Until recently, MOGA used to dispose of the solid waste generated by the city at Ruseifeh landfill, which is located at the eastern edge of the city. Due to the location of the landfill in a populated area (Figure 1), and to the unsanitary landfilling process at the site, several adverse environmental impacts were created by this landfill. As a result, MOGA decided to close this landfill and move to a new site. After an overview of several potential sites, Al Ghabawi site was selected to construct the new landfill.

3. METHODOLOGY

The environmental assessment procedure for Al Ghabawi landfill site was conducted in such a way to highlight the key environmental issues and to achieve proper and accurate prediction of potential impacts. To achieve the above objective, the study conducted according to the following sequence:

3. 1. Data collection

Data on the site location, capacity, topography , geo-hydrology, climatology and other information related to the area that will be served by the landfill were collected. These data were obtained from MOGA’s documents, walkover survey to the site, and pictorial recording of certain site features and operations. Data collected were presented in the environmental setting chapter.

3.2. Scope of the study

In order to determine the nature, significance and the extent of the project impacts, a scoping session was conducted. The session was attended by many stakeholders, including representatives specialists from regulatory agencies, NGO's, local communities, proponent, academic and research institutions, media and other stakeholder.

3.3. Impacts identification

Based on the output from the brainstorming at the scoping session, the significance of each impact was evaluated, and the study focused on the most significant ones. The impact magnitude was evaluated by direct measurement, such as, noise from landfill operation and transportation, or using modeling techniques based on the available data such as in the case of groundwater and air pollution, or based on the visual inspection and judgment.

3.4. Mitigation and monitoring measures

After the magnitude of the significant impacts was evaluated. The proper mitigation, management and monitoring techniques were recommended.

3.5. Post closure monitoring plan

After reaching the full capacity of the site, the landfilling process should be stopped and the site must be closed. The closure and post closure monitoring plan is recommended for the site

4. SITE CHARACTERISTICS

Al Ghabawi is located in the eastern area of Amman, at 23 km east from Central Amman and at 17 km from Russifah landfill site as shown in figure.1. The total surface area of the site is about 2000,000 m^2.The selected site is part of Azraq Basin, which is one of the four largest desert basins in Jordan.

The area used to be as a military land, and characterized by an arid nature without any residential, historical, cultural land uses. The site was connected by an access dual carriageway for a distance of about 23 km. The topography of Al Ghabawi is semi-flat with general slope of 1.4% from south east down to northwest The elevation of the site boundaries ranging from 800 - 810m above mean sea level.

The site area itself is characterized by a desert nature and used to be as a military training area. About 2.5 km to the east from the landfill there is a cow farm. Along the access highway, there are some residential communities. The nearest one to the site is Al-Manakher, which is about 7 km from the site. In addition, there are some agricultural activities on both sides of the access road.

As for the seismic activities, the new site at Al Ghabawi and the surrounding area is located within region B, which has 0-5 factor of intensity, and considered as a region with moderate potential of earthquakes occurrences. However, historically there were no earthquakes over the site and surrounding area.

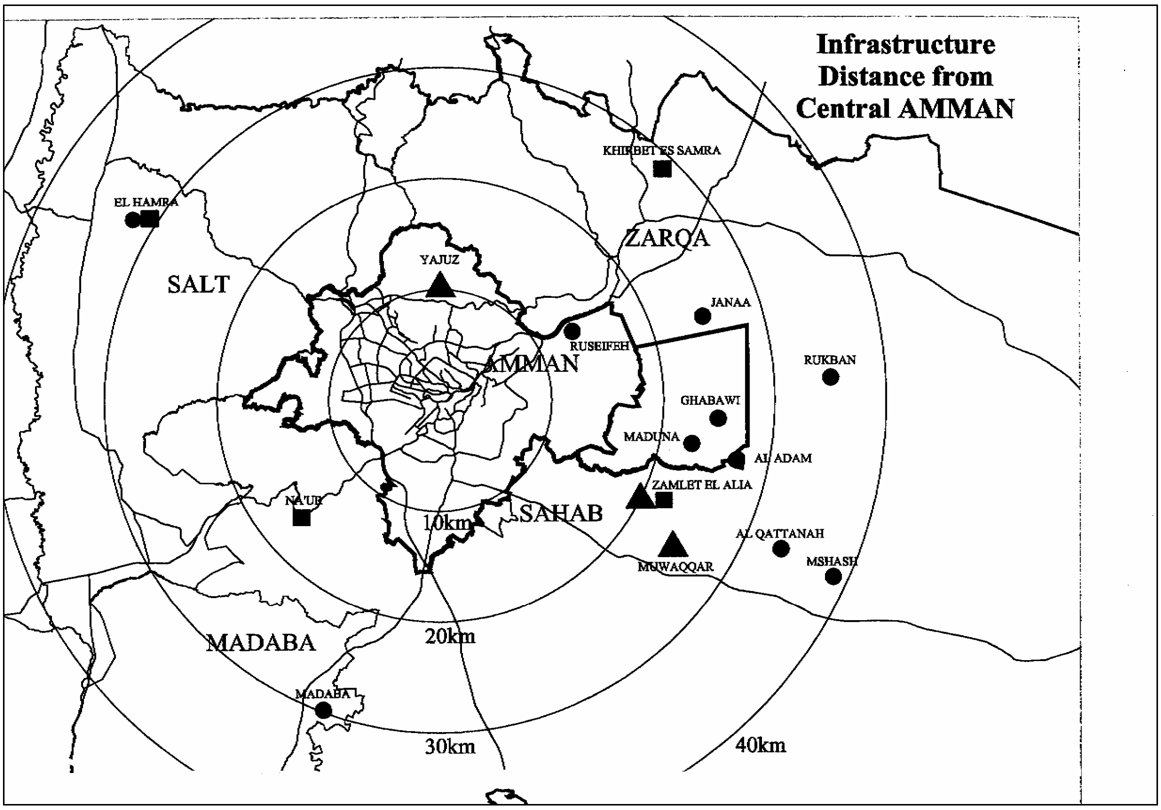

Figure 1. Location of Russaifah (Old) and Al Ghabawi (new) landfill sites with respect to Amman City

4.1 Climate and meteorology

The study area is characterized by an arid climate, which manifests itself by hot dry summers, warm winters, and little rainfall. The region is affected mainly by desert climate with the following characteristics:

- The colder months of the year are January and February, with temperature about 8°C, while the hottest months are July and August, with average temperature 32°C.
- The average precipitation in the rainy months (January to May) is about 60 mm/month, while the average precipitation is less than 1 mm for the period from June to September.
- The lowest evaporation is during January (about 80 mm/month) while the highest is during July (about 334 mm)

The average wind speed in the last 20 years is 9.9 km/hr (2.75 m/s). According to available information the prevailing wind direction (from true North Degree) for the period from 1923 to 1999 is 253 degrees, which means south west direction.

4.2. Geology and soil

The geology comprises the formations and structures existing in the area. To evaluate the geological and hydrogeological characteristics of the site, a geological survey was conducted on site in 1999. Five boreholes were implemented. The vertical receptivity distribution detected 4 zones as follows:

- Top soil with thickness ranging from 0.5 to 1 meter
- Muwaqqar-chalk marl (B3) with thickness from 80-132 meters

- Dry zone of Al-Hisa- Amman and Wadi As Sir formation (A7/B2) with thickness of 108 meters
- Water saturated zone within A7/B2 aquifer system

From hydrogeological point of view, the Muwaqqar chalk marl formation is considered as aquaclude. All the test realized on the site ranged the values of hydraulic conductivity between 10^{-3} – 10^{-7} mm/s. The variation in hydraulic conductivity values is due to the presence of chert lenses within the Muwaqqar-Chalk Marl formation. The presence of fine and very find materials mixed with sand or silty also affecting the value of permeability.

4.3 Ground water

The water saturation zone within A7/B2 aquifer system is one of the main water aquifers in Jordan and it represents the aquifer on the site and surrounding area. The depth of water saturation zone is about 248 m, which is the depth of the groundwater well available at the site.

The flow direction in this aquifer is East-Southeast with a hydraulic gradient of 0.007. The thickness of the water in this aquifer is approximately 40 meters. The analysis of water samples withdrawn from the aquifer by the Water Authority of Jordan, revealed that the water quality is not suitable for drinking purposes as per the Jordanian standards of drinking water (JS 286-2001).

4.4 Surface water

Surface water is limited in Al- Ghabawy area to flash storms occurring during winter. This surface water is not exploited as most of them are either evaporated or percolated into ground. The drainage system over the site has two directions**:**

- to the North-North West towards Zarqa river through Wadi- Janna'a in the north and Wadi Al-Hajar in the North West of the Site
- to the north East toward Zarqa river through Wadi Alghabawi which is laying to the east and turns to the North to Zarqa river

4.5 Biodiversity (Flora and Fauna)

The soil in the region is poor with low annual rainfall, this will results in poor vegetative cover. The vegetation is mostly composed of fleshy and drought tolerant plants that can resists the conditions of hot and dry climate. Vegetation is restricted to the places close to the wadi system where enough soil moisture exists. Figure 2 shows some of the species available on the site..

Most of the fauna species in the eastern desert in general are of Saharo-Arabian origin. Between the soft silt dunes, many varied species have evolved. The majority of the Herpeto-Fauna (Reptiles) of Jordan are found in the Eastern Desert, where a wide range of a wide range of microhabitats exists due to its large area and unpredictable harsh climatic conditions.

The present study was prepared one month after the start of landfilling at the site. During the visits to the site, there were no birds noticed in the landfill area. However, as the filling process will proceed, it is expected that the site will attract several types of birds that will come to the site to look for food**.**

Figure 3. Vegetative cover available on Al-Ghabawi landfill site

5. ENVIRONMENTAL CONSEQUENCES AND MITIGATION MEASURES

Most waste management projects aim at improving the environmental conditions. Nevertheless, a series of potential environmental impacts should be considered, as well as prospective mitigative measures that can reduce negative impacts of waste handling on health and environment. Thus, assessing the possible environmental impacts of the landfill site can help identify which activities, if any, are likely to give rise to significant adverse impacts. These impacts then can be eliminated or minimized through proper mitigation and management techniques.

The output of the data collection and scoping session revealed that, the key areas of potential environmental impacts of the Al Ghabawi landfill site are as follows:

- Ecological impacts
- Hydrology and water quality impacts
- Public health and safety impacts
- Air quality impacts
- Socio-economic impacts
- Noise impacts
- Off- site and on site traffic impacts
- Visual and landscape impacts
- Archeological and Cultural sites

This paper will focus on air and water quality impacts. Impacts were classified as either positive or negative. The potential significance of impacts was then evaluated through brainstorming with a core group of specialists, and through evaluation of baseline data on the surrounding environment, and the specifics of the project. Impacts were classified as to their potential significance. The classification system is based on degrees of impact significance as follows:

- high
- moderate
- minimal
- none

5.1. Air quality Impacts

5.1.1. Gas and odor emissions

Once solid waste dumped into the landfill it will be subjected to series of reactions. Initially the waste is aerobically and the main reaction products are carbon dioxide gas and water. This stage takes several days to week. With the progress of degradation, the oxygen is depleted and the degradation converted into anaerobic. As waste decompose in the landfill, landfill gases will be generated due to the anaerobic degradation of the organic fraction of the waste. Gas will start to be given off within few weeks of the waste deposition and will continue to be emitted even after the site closure. The main components of the landfill gas are methane and carbon dioxide. Both of methane and carbon dioxide are green house gases (GHG's), which contribute to global warming phenomena. In addition, the methane gas is a potentially flammable and explosive gas for a concentration of 15% of the air volume. Furthermore, some of the gases that can be produced as a result of anaerobic degradation are hydrogen sulfide and ammonia. These gases are mainly causing a bad odor in the vicinity of the landfills and it has been reported in studies that the offensive odor can reach for a distance of one mile or more from the landfill site.

At Al Ghabawi site, the odor potential at the site and the surrounding area was measured by nose smelling at various distances from the working face on the site at various intervals during the day. Several persons were asked to stay for a while close to the working face and then move gradually into different directions from the filling place. At every 20 m distance from the working face each person stayed for a while and recorded his feeling regarding the odor. The measurement revealed that, there is a moderate to strong odor in the vicinity of the filling work face, while it is moderate at the edges of the filling cell and it is minimal at the site corners. Outside the site boundaries, no odor could be smelt.

The odor problem, so far, limited to the site boundaries, this is because the filling is just started one month ago. It is expected that odor potential will be increased with time, as more waste will be received on the site and the anaerobic degradation will advance. However, the site location and the design features will contribute to keep the odor level minimal:

- The nearest populated area to the site is about 7 km on the wind side(not down wind) , thus the probability of being affected by odors is very low. (see figure 4)
- The site design includes a gas collection and recovery system, which will lead to prevent the odor and release of GHG's to the atmosphere.

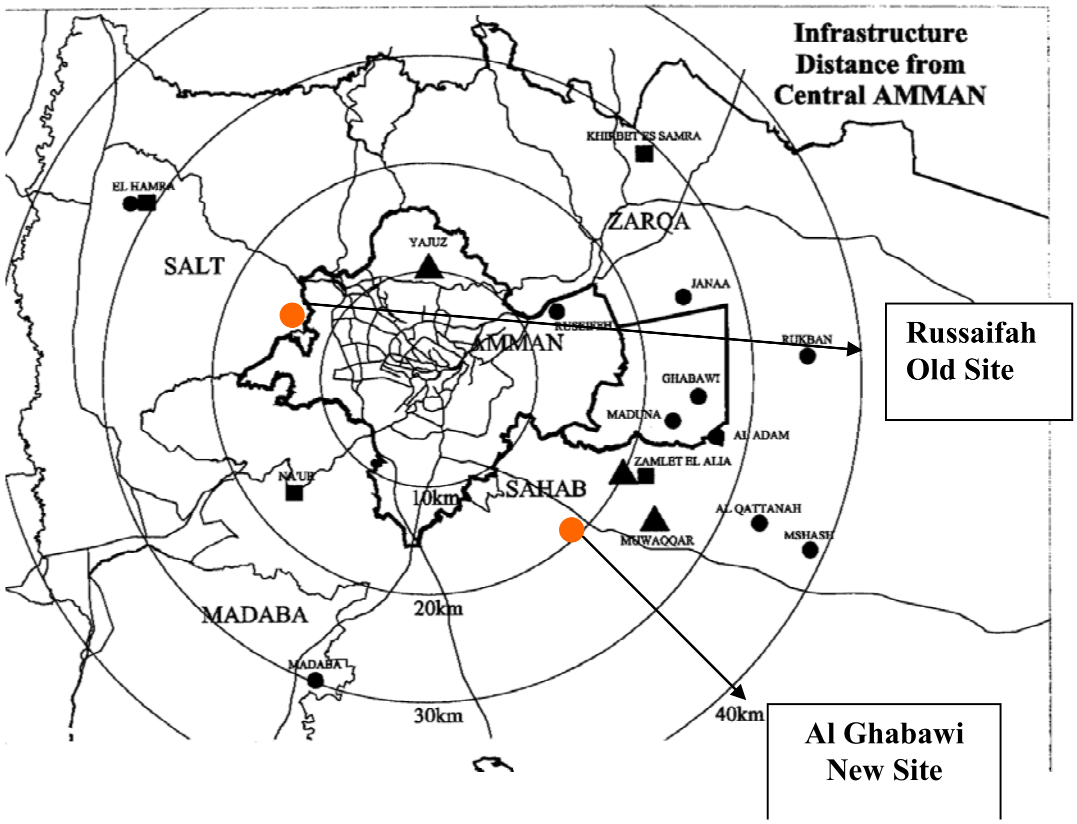

Figure 4 Location of population centers with respect to wind direction at Al Ghabawi landfill site

5.2 Leachate reduction

The problems associated with leachate may be minimized by limiting the amount of water getting in to the solid waste matrix. This can be achieved into a number of simple design and operational measures:

- ensuring surface water does not enter the landfilled areas, or areas prepared for future landfilling by construction intercepting ditches between the working areas and surrounding unused parts of the site.
- ensuring water does not accumulate in the working area where waste is being landfilled
- keeping the open areas at the tipping face as small as practicable
- applying soil cover to the wastes at the end of each working day
- progressively completing and grading areas of the site with a capping layer, as they reach their final design heights

Surface water diversion is an important issue, since it will not only reduce the leachate quantities, but it also removes flooding by surface water which can destabilize waste slopes, resulting in slip failures.

Table 6.2: Leachate calculation for Al-Ghabawi landfill site

	Leachate flow m3/hr	leachate 1000 (m3)	waste water 1000 (m3)	Deposited waste 1000(m3)	Evaporation 1000 (m3)	Surface Runoff 1000 (m3)	Direct Infiltration 1000(m3)	Rainfall 1000 (m3)
Jan	24.92	17.94	13.97	139.7	116.9	3.1	3.968	124
Feb	25.19	18.14	13.97	139.7	122.78	3.255	4.1664	130.2
Mar	23.49	16.92	13.97	139.7	86.76	2.3	2.944	92
Apr	19.94	14.36	13.97	139.7	11.32	0.3	0.384	12
May	19.64	14.14	13.97	139.7	5.09	0.135	0.1728	5.4
June	19.41	13.98	13.97	139.7	0.189	0.005	0.0064	0.2
Jul	19.4	13.97	13.97	139.7	0	0	0	0
Aug	19.4	13.97	13.97	139.7	0	0	0	0
Sep	19.42	13.98	13.97	139.7	0.377	0.01	0.0128	0.4
Oct	20.14	14.5	13.97	139.7	15.65	0.415	0.5312	16.6
Nov	21.62	15.56	13.97	139.7	46.96	1.245	1.594	49.8
Dec	23.67	17.04	13.97	139.7	90.528	2.4	3.072	96
Annual	21.35	184.5			496.58	13.165	16.85	526.6

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