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Geospatial Implications Assessment of Zahrat Al Finjan Solid Waste Landfill, North of West Bank, Palestine

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Abstract

Finding suitable sites for landfills is one of the most difficult tasks in solid waste management. The sanitary landfill site selection must address social, environmental and technical concerns. This work aims at assessing the geospatial implications posed by the current Zahrat Al Finjan (ZF) landfill disposal site, located in the north of the West Bank in Jenin districts. GIS-based assessment was employed for different criteria including geology, soil, slope, land use, and stream network. This paper focuses on the assessment of ZF landfill potential environmental impacts on groundwater, sensitive ecosystems, rural areas and land use. The existing soil mantle at the landfill site consisting of clay and marly clay is influenced natural attenuation of the leachate infiltration. Nevertheless, uncontrolled accumulation of the leachate and the absence of a properly treated collection system pose potential contamination risk to shallow groundwater aquifer in the future. Also, gas produced from the landfill is not vented and so leaves from the cover and poses fire risk, and as dissolved in the leachate causes unpleasant odors. Spread of flies, mosquitoes, bird droppings, rodents and spread of stray dogs are other negative impacts of the poorly operated landfill. Monitoring systems and recommendations are proposed in this paper.

Keywords:
Landfill assessment,
Zahrat Al Finjan,
Geospatial implications,
Environmental impacts,
Land use,
Geographical Information System (GIS),
West Bank,
Palestine.

1. Introduction

The management of solid waste is among the issues of major concern in protecting and preserving the environment. Municipal solid waste management is a problem that is experienced by all countries in the world. It is considered as one of the most serious environmental and social problems challenging municipal authorities in developing countries (Berisa & Birhanu, 2015). Waste was an early problem of mankind, and a growing one that is of major concern to every nation of the world (Allende, 2009). It is an issue mostly witnessed in urban areas as a result of high surge in population growth rate and increase in per capita income, thus posing a danger to environmental quality and human health (Javaheri et al., 2006). The most common problems associated with improper management of solidwaste include diseases transmission, fire hazards, odor nuisance, atmospheric and water pollution, aesthetic nuisance and economic losses (Jilani, 2002).

Developing countries just started to establish such agencies and institutions to take care of this field (Al-Khatib et al., 2007, 2010; PAEA, 2006). On the Palestinian side, the years of conflict have presented huge challenges to the Palestinians efforts to manage in a sound manner the environmental situation. Unfortunately, the management of solid waste in Palestine has never been achieved on an environmentally sound basis. It suffered from great ignorance during the Israeli occupation era when the Israeli Civil Administration was responsible for providing the Palestinian communities with the basic infrastructure services. In that period, the policy of the Israeli Occupation Authorities aimed at serving their interests with no attention paid to both the environment and the quality of services provided to the Palestinians. The peace negotiations between the Palestinians and Israelis reached to a mutual recognition of the Palestinians need to protect the environment and utilize natural resources on a sustainable basis. This has resulted in the transfer of some powers and responsibilities to Palestinians in this regard. Both parties agreed as well to cooperate and share the responsibility of preventing damage to the environment (Areej, 2005).

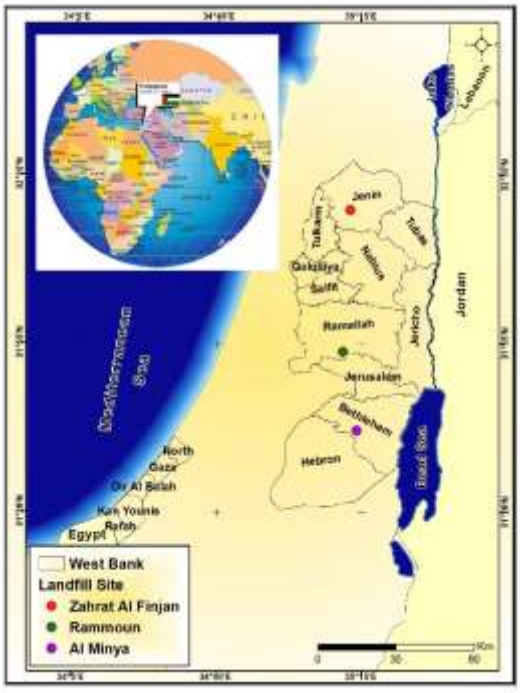

Figure 1 *Location map of Zahrat Al Finjan landfill site, districts of West Bank, Palestine*

In 1994, the Palestinian National Authority (PNA) established the Environmental Planning Directorate (EPD) followed by the development of the Palestinian Environmental Strategy (PES). In the PES, wastewater and solid waste management are recognized as two of the most urgent environmental priority elements that need to be addressed in order to resolve the pressing environmental problems. In the year 2010, a steering committee from several Palestinian ministries submitted the National Strategy for Solid Waste Management in Palestine (NSSWM) for the period 2010-2018. The NSSWM put several policies for prohibiting the random landfilling and adopting the use of three regional sanitary landfills to serve all Palestinian communities in the West Bank (Figure1) and one for Gaza strip (Abdalqader, 2011). These are Zahrat Al Finjan (in the north), Rammoun (in the middle), and Al Minya (in the south) of the West Bank.
This study aims at assessing the geospatial implications posed by the current Zahrat Al Finjan (ZF) landfill disposal site. The evaluation criteria used are; geology, soil, slope, land use, and stream network mapped by the Geographical Information System (GIS). This work focuses on the assessment of ZF landfill potential environmental impacts on groundwater, sensitive ecosystems, rural areas and land use.

2. Materials and methods

2.1. Study area

Zahrat Al Finjan area is located in northeastern part of the West Bank between Arraba and Ajja towns of Jenin Governorate (Figure 1 and 2) at a distance of 18 km to the south of Jenin city, 26 km of Tubas, 23 km north of Nablus, 24 km east of Tulkarem and 50 km northeast of Qalqilyia (Saa'di, 2009).

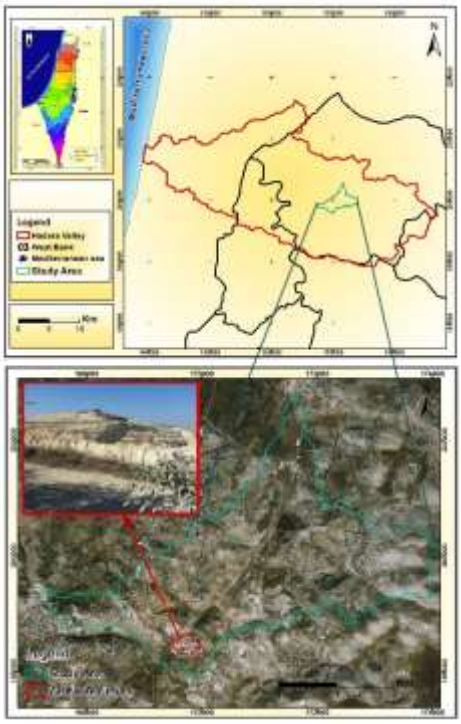

Figure 2 *Study area map*

The site is also located within a distance of 2 km from major Nablus-Jenin road. It is spread over a land area of about 240,000 m^2; 90,000 m^2 out of the area used as waste cells. The landfill was completely conducted and operated in June 2007, and was designed to landfill municipal solid waste from Jenin and Tubas governorates. Currently, it is receiving wastes from Tulkarem and parts of Nablus, Ramallah and Al-Bireh governorates (Shtayyeh, 2012), with landfilling operation capacity of 1000 ton/day from north and middle West Bank governorates (PIU, 2007).

2.2. Leachate and solid waste composition

Leachate is a polluted liquid that drains from the base of the landfill. It varies widely in composition (organic and inorganic compounds) regarding the age of the landfill and the type of waste that it contains (Papadopoulou et al., 2007). The general composition of waste landfilled and served in ZF site (Eid, 2007; Saadi, 2009; Hinde, 2010; Al-Subu, 2015; Sawafta, 2015) is as follows: organic matter and food (34-62%); paper and cardboard (10-16%); plastic and rubber (10-15%); glass (2-9%); metals (2-19%); textiles (8-10%) inert matter (4%); and wood (2%). Out of which organic matter produces large amount of leachates. The nature of leachate depends upon the nature of solid waste buried, chemical and biological processes responsible for the decomposition of waste material, and water content in total waste (Fatta et al., 1999; Mor et al., 2006).

The proposed daily operation of ZF as planned in the final report from Project Implementation Unit (PIU, 2007) is that wastes are spread by bulldozer and compacted by compacters so that the maximum depth of the waste in daily cell is 2.5 m. Perforated pipes network collects the leachate and convey it to the lowest level at waste cells to be pumped to the leachate pond. Also, channels were constructed around ZF to collect stormwater to minimize the possibility of its mixing with the waste. But however and due to some operational drawbacks, the winter storms are mixing with the waste and the leachate and drain downstream to the nearby streams (Figure 7). As such, the polluted stream flow might be infiltrated and put the water quality in the shallow groundwater aquifer in the region at risk.

2.3. Geology and soil

Figure 3 shows the main lithologic units of the study area, the schematic map of the geology is characterized by the following categories of geological features (Abed &Wishahi, 1999): Alluvial and marl soil; Alluvium Formation (Holocen- Middle Eocene), Chalk with Limestone Formation: laminated marl, chalk, reef limestone and chert (Senonian- Paleocene), and Jerusalem Formation: limestone and dolomite (Turonian). The area is dominated by mixed lime with clay texture soil types (Figure 4). The existing types of rock units and soil cover in the study area are influenced natural attenuation of the leachate infiltration.

2.4. Slope

Slope is one of the key criteria in landfill siting because it can reduce or increase stability of landfills (Kirimi & Waithaka, 2014). Figure 5 and 7 show the topography slopes down to the northeast and spreads out to the southwestern borders, with a few numbers of steep sided valleys and streams. The study area is almost located on a flat land with gentle slopes. A steep slope is neither recommended due to high erosion rates and difficulty in leveling and poses sliding of the waste deposits to the adjacent wades.

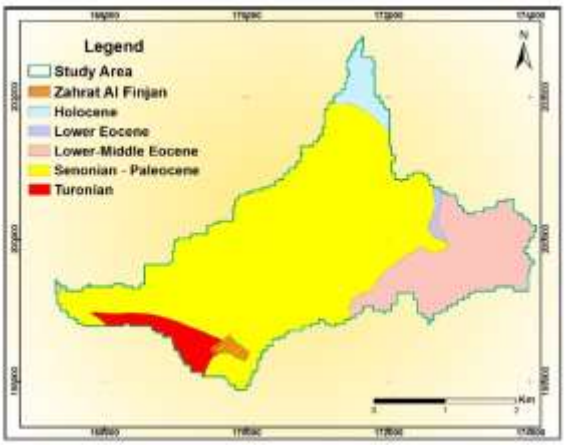

Figure 3 *Geology map, main geological formations (Abed & Wishahi, 1999;* GeoMOLG, *2016)*

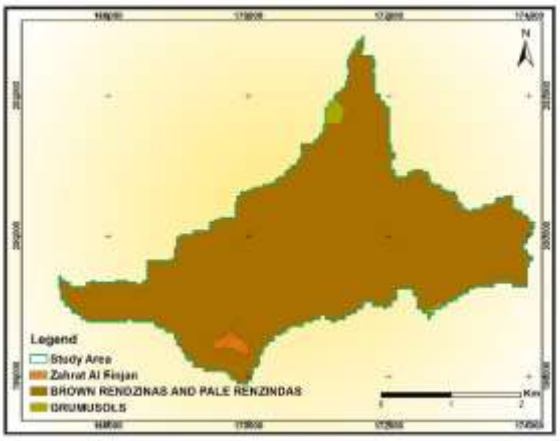

Figure 4 *Distribution of soil stratigraphy (Abed &Wishahi, 1999;* GeoMOLG, *2016)*

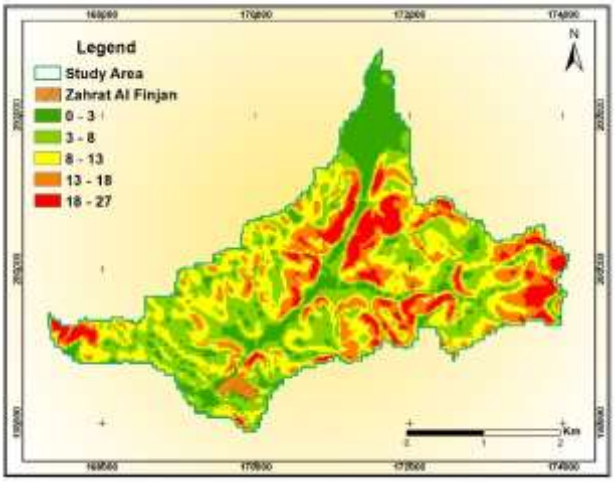

Figure 5 *Slope map showing areas of high and low slope gradient (*GeoMOLG, *2016)*

2.5. Climate and hydrology

The West Bank climate may be broadly described as a Mediterranean arid to semi-arid type, varying from hot and dry in the summer to wet and cold in the winter, with short transitional seasons. The rainy season usually extends from October to April. Rainfall is concentrated over a short period, with more than 80% of the annual rainfall commonly occurring in winter (Shadeed, 2013). In general, rainfall is characterized by its high variability, both temporally and spatially. In the study area (Figure 2), average annual rainfall is estimated at about 600 mm.

Surface water wadis will be of high vulnerability to contamination from the landfill due to the generated leachate. The site is located in the headwaters of Hadera-Massin catchment. The issue of critical concern is the ultimate fate of the contaminants generated from the site that will likely get into the nearby wadis in the upper part of the catchment and drains all the way downstream (Figure 7).

2.6. Land use

Adequate information about land use and land cover is important in order to make decisions to overcome the problems in areas of uncontrolled development. Five land use/ land cover classes were mapped in the study area namely: field crops, natural forest, orchards, scrublands, and built-up areas (Figure 6 and Table 1). Furthermore, land use types such as forests, field crops, and scrubland which form most of the study area would be considered an appropriate indicator of land use suitability for future development. In solid waste disposal sites, urban areas should not be too closed.

Table 1 *Land use/ land cover classes*

	Land Use	Area /km²	%
1	Field Crops	2.90	25.3
2	Natural Forest	0.15	1.3
3	Orchards	3.22	27.2
4	Scrublands	4.33	36.1
5	Urban	1.20	10.1
		11.80	100

Source: GeoMOLG, *2016*

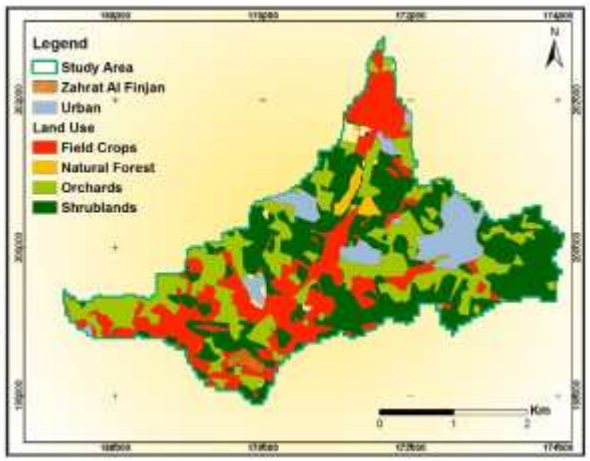

Figure 6 *Map of land use\ land cover (*GeoMOLG*, 2016)*

3. Observation and discussion

Important factors in the natural attenuation of leachate constituents in the groundwater body are the soil stratigraphy and type of rock formations beneath the landfill base (Longe & Enekwechi, 2007). The soil stratigraphy of ZF landfill consists of clay and marly clay (Figure 4). The lithology is capable of protecting the underlying groundwater quality from leachate contamination. The soft sedimentary rocks (chalky marly limestone) forming the subsurface geology of ZF landfill site (Figure 3), are also suitable for an attenuation landfill if properly constructed and operated. ZF was planned and designed to be a sanitary landfill (PIU, 2007), but in fact, it is far away from being a sanitary one. This is because it is poorly operated; uncontrolled accumulation of the leachate and absence of suitable collection and treatment system. The improper collection, segregation and disposal practices of municipal solid waste (MSW) produce highly concentrated leachate (Sanjay et al., 2010). Dispersal of leachate poses potential threats to local ecosystems especially to soils and groundwater (Jorstad et al., 2004).

The greatest contamination threat to groundwater comes from the leachate generated from the landfill material which most often contains toxic substances especially when waste of industrial origin are buried. However, ZF landfill was designed to landfill MSW only. Hazardous, toxic infectious and liquid wastes should not be accepted. The leachate is generally characterized by its strong organic load up to 62%. The rest composition of the waste is paper and cardboard; plastic and rubber; glass; metals; textiles inert matter; and wood. Consequently, the leachate production is high, organically complex in nature, and continuously growing. However, the elevated nitrate concentrations in the groundwater, observed from analysis carried out in the West Bank (Anayah& Al-Masri, 2009), greatly coincide with increasing rainfall, particularly in the past few years, and it has also attributed to the agricultural activities along with the high groundwater recharge.

Possible pollution to groundwater wells and springs close to the possibly-polluted surface water wadis may occur through stream–aquifer interaction phenomenon that considerably takes place in the region (Abboushi et al., 2014). Excessive pumping in the vicinity of the wadi will induce a hydraulic head deficit toward the aquifer and any pollutants will most likely get into the aquifer, accordingly. In order to reduce vulnerability to contamination, landfills should not be located near streams or groundwater recharge areas. Figure 7 shows how much ZF landfill is located closed to the stream network of surface water. Moreover, ZF landfill disposal site is situated over the Eocen (Jenin) sub-aquifer as a

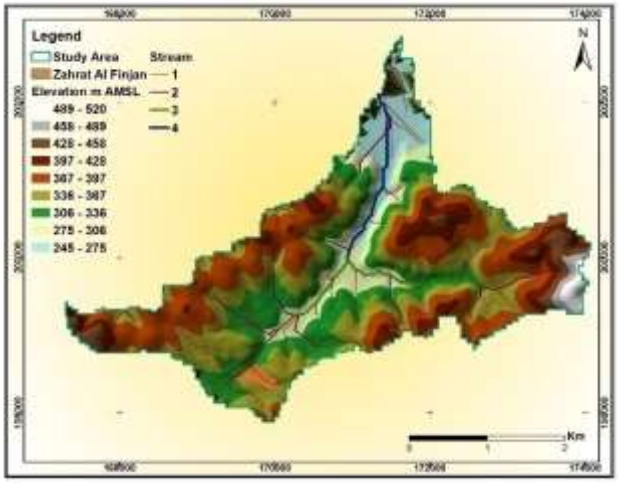

Figure 7 *Topographic map, streams are also shown in the study area (*GeoMOLG*, 2016)*

part of the northeastern groundwater aquifer basin in the West Bank (Abed &Wishahi, 1999). In this aquifer, the geologic subseries formation between Jenin and Nablus region forms part of the shallow aquifers where groundwater wells are normally tapping water table of less than 25 m beneath the area of ZF. This implies a high risk for contaminants to reach the groundwater and thus contaminate the underlying aquifer (Alslaibi, 2009), especially in the absence of a properly collection and treatment system of the leachate. Taking into account the existing storage amount of 35000 m^3

leachate in ZF landfill, accumulated in the base of the landfill during the past nine years waiting for a solution (PIU, 2007).

Decomposition of the organic components of the waste produce landfill gas (Powell, Townsend, & Zimmerman, 2016) mainly composed of methane (CH4) and carbon dioxide (CO2). Out of the general composition of waste landfilled and served in ZF is high amount of organic matter and therefore an estimated amount of 45-50% methane (CH4) gas is expected (PIU, 2007). Gas produced from the landfill containing hydrocarbons is not vented and so leaves from the cover and poses fire risk, and as dissolved in the leachate causes unpleasant odors. The instant effects of MSW decomposition in ZF landfill are stinking smell felt from a distance and breeding of houseflies, vermin, and pathogens. The existing built up and expansion areas in the vicinity of ZF are almost located in a flat land with gentle slope, and fertilized soil, and are thus, suitable for urban and agricultural development (Figure 6 and Table 1), whereas ZF is located at a distance of less than 700 m from the nearest rural area (Figure 8).Unfortunately, the bad smell poses a barrier for any land use development and causes economic losses.

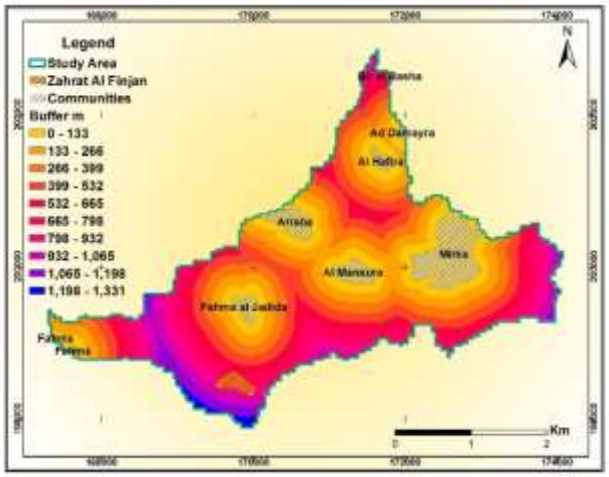

Figure 8 *Buffer map of the urban areas adjacent to the landfill (*GeoMOLG*, 2016)*

On the other hand, serving extra amount of solid waste deposits fromTulkarem and parts of Nablus, Ramallah and Al-Bireh governorates (Shtayyeh, 2012) exceeds the landfilling designed capacity of ZF. The limited area of the landfill does not allow a horizontal expansion for landfilling of the overloaded wastes. Consequently, a daily dramatic vertical expanding of the landfill causes a steep slope of the wastes piles (Figure 9). A steep slope is neither recommended due to high erosion rates and difficulty in leveling and poses sliding of the waste deposits to the adjacent wadis.

Figure 9 *A photo showing the vertical expansion for the landfill*

Recent study aimed at assessing the current operational procedures of ZF landfill was conducted (Sawaftah, 2015), four scenarios were analyzed: separating recycling and reusing paper and cardboard metal, glass and plastic wastes and landfilling the rest; landfilling and composting organic waste; incineration of all wastes excluding metals (metals will be separated and recycled); incineration, composting and landfilling. Studying the feasibility of the above mentioned scenarios, and implementing the proper ones (Musleh & Al-Khateeb, 2010; Soufan, 2012; Hijawi, 2015) will minimize the generation of leachate, and thus will eliminate the current geospatial implications and any potential environmental serious impacts in the future.

4. Conclusion

ZF landfill is poorly operated system; therefore, it is causing environmental and social problems to the neighboring communities. The absence of any kind of waste and leachate treatment has worsening the situation. Moreover, the landfill site is found along a drainage system of the town and is not located in a reasonable distance from the residential areas, whereby it has been posing both social and environmental problems such as nuisance, diseases, and wild animals: spread of flies, mosquitoes, bird droppings, and spread of stray dogs, rodents would affect the public health. Planting poplar trees near ZF

landfill will create a feeling of freshness and exceed the quantity of oxygen as well as wind break trees.

A groundwater flow model with particle tracking has to be conducted to get sensible evaluation of the fate and transport of possible contaminants emerging from the landfill site to the beneath groundwater aquifer system. In addition, degassing system in the landfill must be constructed to mitigate the migration of landfill toxic gas to the atmosphere or through the soil to the groundwater. In addition, monitoring system should carry out chemical analysis for the leachate and groundwater samples in the vicinity areas. Geoelectrical investigation of ZF landfill study area is highly recommended and can be helpful in mapping areas of contaminated soil and groundwater.

ZF landfill was designed to serve Jenin and Tubas governorates. Exceeding the capacity by landfilling waste from extra four governorates (Tulkarem, Nablus, Ramallah and Al-Bireh) has increased the daily social suffering, and the expected negative environmental impacts. New solid waste sanitary landfills in the eastern and western parts of the West bank should be selected and established in the very near future. Moreover, ZF landfill site is designed only for non-hazardous solid waste. Therefore, hazardous wastes should not be dumped in this site; monitoring and testing measures should apply in regular basis, especially under the current critical political situation in the Palestinian Territories. The researchers are strongly alarming the Palestinian decision makers for the adverse effects of the existing unsecured landfills and the open randomly distributed dumping sites.

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تقييم آثارالموقع الجغرافي لمكب نفايات زهرة الفنجان شمال الضفة الغربية، فلسطين

اختيارالمواقع المناسبة لمكبات النفايات يعد من أصعب المهام في إدارة النفايات الصلبة. فتحديد أماكن لإنشاء مكبات نفايات صحية يجب أن يراعي ويأخذ بالحسبان تحقيق شروط اجتماعية وبيئية وتقنية. تهدف هذه الدراسة إلى تقييم الآثار الناجمة عن الموقع القائم لمكب زهرة الفنجان (ZF) للتخلص من النفايات الصلبه في شمال الضفة الغربية. بدايةً يقدم البحث وصفاً للمكب وطبيعة النفايات وعرضاً لخصائص منطقة الدراسة من تكوينات جيولوجية وأنواع تربة، ومعالم طبوغرافية وتصنيف لاستخدام الأراضي، وجريان للمياه السطحية وذلك باستخدام تكنولوجيا نظم المعلومات الجغرافية ال (GIS). ومن ثم يتناول مناقشة وتقييم الآثار المحتملة لمكب نفايات زهرة الفنجان على المياه الجوفية والنظام البيئي والمناطق الريفية واستخدام الأراضي. فرغم أنه يغطي منطقة الدراسة طبقه من التربة الطينية والمارلية الطينية التي تقلل من تسرب عصارة النفايات الى باطن الأرض إلا أن عدم وجود نظام تصريف فعال وتغيب وجود أي تقنيه لمعالجة العصارة يزيد من احتمالية تلوث المياه الجوفية خاصة لوجودها على أعماق ضحلة. كما أن عدم توفر نظام تجميع للغاز الناتج من المكب يؤدي الى تطايره إلى طبقات الغلاف الجوي مشكلاً خطر نشوب الحرائق، ويسبب الجزء الذائب منه في العصارة إلى انتشارالرائحة الكريهة. إضافة إلى أن انتشارالذباب والبعوض والقوارض والكلاب الضالة يزيد من الآثار السلبية على البيئة والتجمعات السكنية المجاورة والتخطيط لاستخدام الأراضي. بعد مناقشة ظروف الموقع الجغرافي للمكب وتقييم آثارها البيئية والاجتماعية قدمت الدراسة عدد من الاقتراحات والتوصيات كطرق للقضاء أو للتقليل من هذه الآثار.

كلمات مفتاحية:
مكب نفايات،
زهرة الفنجان،
الموقع الجغرافي،
استخدام الأراضي،
نظم المعلومات الجغرافية (GIS)،
آثار بيئية،
الضفةالغربية،
فلسطين.