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Assessment of the Landfill of the Thi-Qar Refinery and Propose the Alternative Landfill

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Abstract

Oil sludge is one of the most significant wastes generated in the petroleum industry. A potentially contaminating waste product, with a high content of hydrocarbons and heavy metals. This study is to evaluate the effect of petroleum crude oil contaminated soil and groundwater using MODFLOW Flex software. Existing landfills are non-conforming to the environmental conditions. Despite the fact that there are various techniques used for waste disposal, landfill is the most common mode for the disposal of waste in Iraq. landfill site selection criteria are quite complex process and it depends on several regulation and factors. In this study landfill site selection is performed using Geographic Information System (GIS) for (TOR). Existing landfills in (TOR) are non-conforming to the environmental conditions. In order to determine landfill site, several criteria were examined such as urban centers, land use, airports, pipes, power lines, railways, roads, slope, streams, surface water, industrial areas, oil pipes, liquid gas pipes, soil types are prepared. Each map layer was prepared using GIS and the final suitable map was created by overlay analyses of each criterion map. According to the results, a suitable landfill site was obtained in the study area.

Keyword: Oil sludge**,** MODFLOW Flex**,** Arc GIS, Landfill site, Site selection criteria.

1. Introduction

One of the serious and growing potential problems in large urban areas is the shortage of land for waste disposal. Although there are some eﬀ orts to reduce and recover the waste, disposal in landfills is still the most common method for waste destination. Many landfills are designed for 20 or 30-year lifespan and still require post closure monitoring up to 30 years to ensure the environmental health. An inappropriate landfill site may have negative environmental, economic and ecological impacts. Therefore, it should be selected carefully by considering both regulations and constraints on other sources. In this study, candidate sites for an appropriate landfill area in the vicinity of TOR are determined by using the integration of geographic information systems .

The operations in petroleum industry can generate a large amount of oily wastes. Petroleum sludge is a complex mixture containing different quantities of waste oil, wastewater, sand, and mineral matter. Petroleum industries are responsible for the generation of large quantities of sludge, which is a major source of environmental pollution. Oily sludges are hazardous wastes according to Environment Protection Act and Hazardous Wastes Handling Rules. Sludges generated by petroleum industries accumulate in crude oil tanks, refinery products tanks, desalters, and elsewhere during oil production and processing. The composition of oily sludge is very complex. It comprises of oil in water, water in oil emulsion and suspended solids1. Oily sludge contains toxic substances like aromatic hydrocarbons, polyaromatic hydrocarbons and high total hydrocarbons content [1]. It is difficult to be hydrated due to its high viscosity. It is a hazardous solid waste. It basically comprises of about 55.13% of water, 9.246% of sediments, 1.9173% of asphaltenes, 10.514% of wax and 23.19% of light hydrocarbons and also a high concentration of heavy metals for instance vanadium is 204 ppm, Fe is 0.6% and nickel is 506 ppm. which makes the oily sludge harmful for the environment and organisms, which need to be dealt with, for environmental protection[2]. Landfill has historically been the major form of waste disposal in TOR as a means of disposal is a method that is centuries old. The location not suitable and degradation of landfill produces both gaseous emissions and losses to the surrounding soil/water leachate, and the potential for landfills to impact on the environment and human is well known. In contrast, modern landfills must be lined, have suitable treatment facilities for leachate, and they must control gaseous emissions .

2. Study Area and Methodology

TOR is located to the south of Thi-Qar governorate. It lies approximately between laterals 00º N 32º from the north and 36º N 30º from the south (and between longitude E 47º 12 from the east and E 45º 36 from the West) latitudes 32˚6', 32˚31'N, and longitudes 44˚29', 45˚12'E longitude, the total area of the study area is $72km^2$. All the data pertaining to these parameters were taken from the relevant agencies. In this study, integration of GIS and (MODFLOW Flex) was used and applied to study area to simulate landfill site to study effect landfill on study area.

The landfill sites in TOR (as well as in most of Iraq's governorates) were selected using the traditional method which non-specific accurately a mostly random, depending on some initial criteria in a static form and without attention to the dynamic analysis, and as an entrance for the development of the environmental database and investing the information contained in study area and by focusing on the aspect of disposal waste as one of the most important aspects, this study will find an alternative method in the process of selecting landfill sites in the governorate involving more criteria (like the different aspects of the database and other information) and by using GIS technology where these many criteria are used in the form of several maps and analyzed to selection of sites). There are no proper planning standards for selecting landfill. Municipal bodies must develop site selection plans and implement the long-range planning according to select siting criteria. The simulate depends on the information, data and site survey are collected for study area. Fig.1 shows the contaminant concentration distribution with time.

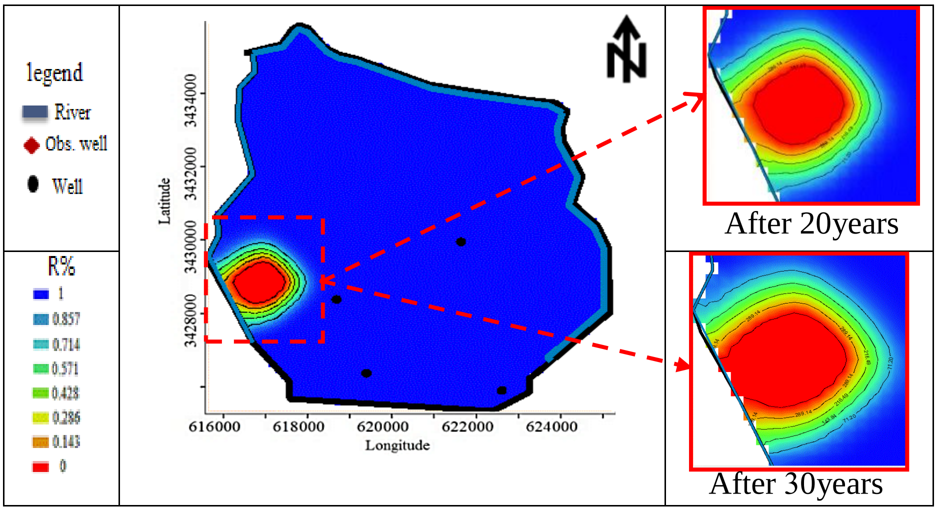

Fig. 1: Contaminant concentration distribution without barrier after (20, 30) years.

The landfill of TOR are unsuitable site according environmental conditions and standards regarding the selection of a suitable site for landfill. Because the increase of liner leakage due to the deterioration of the clayey soil liner and location landfill closes from kandak River. The direction of plume is directed from TOR toward kandak River. So the main contaminated source for groundwater and surface water can be considered it. A simulation results reveals that polluted area increase with an approximate linear increment with time as shown in Fig.2.

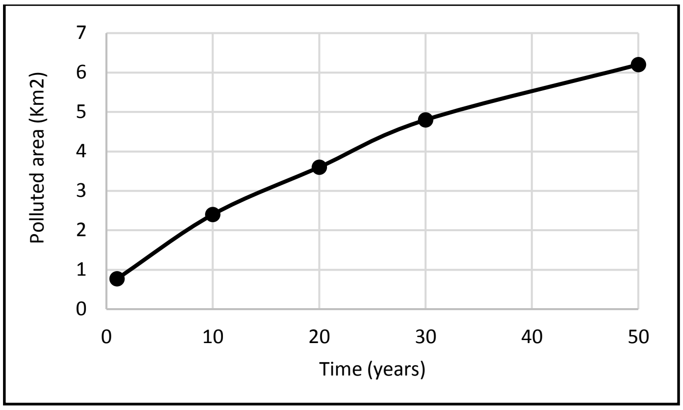

Fig.2: Polluted area variation with time.

3. Groundwater and surface water sampling:

Water, a natural resource which has been used for different purposes, namely for drinking, domestic, irrigation and industrial, mainly depends on its intrinsic quality [3]. Groundwater samples from the surface layer are collected from groundwater well bimonthly in the two season period. Groundwater analyses of common inorganic and organic parameters (COD - chemical oxygen demand, total oils, DOC - dissolved organic carbon) are tested as shown in Table1 and 2. Comparison of the data determined in the river shows that water exceeded permissible limits, not only with respect to organic matter and sulphate, but also manganese and other, in few occasions. It is expected that an increase of the water-level should result in an enhancement of the contaminant transport from the landfill, as upper, more contaminated aquifer layers come into the contact with groundwater (the difference between upper and lower water-levels is 2.5-3m). Namely, the vertical distribution of various contaminants in the soil below the landfill showed a sharp decrease of the concentration for most of the parameters in the layer which represent the upper reach of the groundwater level. Where the concentration of inorganic and organic parameters used in assessing groundwater quality also influences the suitability of water for irrigation purpose. According classification of [4] as shown in Table 3, the chemical test results refer that groundwater and surface water unsuitable for irrigation water and drinking water. Eleven water parameters were determined and compared with the Iraqi standards and WHO standards (2004).

Table 1: Chemical test of groundwater at wet and dry seasons [5].

Name test	Value (-)	Value (+)	WHO 2004	Iraqi Standard
PH	7.5	6.9	6.5-8.5	6.5-9.2
	7.8	6.7		
Ec μs\cm	3003	5997	2000	2000
	1366	4415		
T.D.S (ppm)	2130	4450	500-1500	500-1500
	954	3110		
turbidity	336	310	0-50	0-25
	131	127		
DO	60	63	<5	<5
	82	85		
Cl^{-1} (ppm)	1470	1485	-200	200-600
	487	688		
Hco_3^{-1}	230	235	20-200	-
	142	152		
So_4^{-1} (ppm)	183	193	200	200-400
	382	391		
No3 -1 (ppm)	290	298	0-45	40
	450	457		
Ca^{+2} (ppm)	1230	1114	25-75	75-200
	320	310		
Mg +1 (ppm)	420	402	50-125	50-150
	260	255		

TH (ppm)	336	310	250-500	500
	131	127		
Na^{+1} (ppm)	1620	1110	-200	200
	560	353		
K^{+1} (ppm)	360	247	12	-
	289	181		

Table 2: Chemical test of surface water at wet and dry seasons [5].

Name test	Value	Value	WHO 2004	Iraqi Standard 1998
PH	-	7.9	6.5-8.5	6.5-9.2
	+	7.6		
Ec µs\cm	-	20525	2000	2000
	+	12301		
T.D.S (ppm)	-	14368	500-1500	500-1500
	+	8611		
turbidity	-	78	0-50	0-25
	+	79		
Cl^{-1} (ppm)	-	8900	-200	200-600
	+	6511		
Hco_3^{-1}	-	360	20-200	-
	+	375		
So_4^{-1} (ppm)	-	1218	200	200-400
	+	1213		
No3 -1 (ppm)	-	879	0-45	40
	+	901		
Ca^{+2} (ppm)	-	2170	25-75	75-200
	+	1699		
Mg +1 (ppm)	-	1877	50-125	50-150
	+	2190		
TH (ppm)	-	918	250-500	500
	+	926		
Na^{+1} (ppm)	-	9684	-200	200
	+	6735		
K^{+1} (ppm)	-	1668	12	-
	+	1111		

- **(+) signal refer water at wet season and (-) signal dry seasons.**

Table 3: Classification of Don (1995) for irrigation water [4].

EC µs\cm	T.D.S (ppm)	SAR	Na%	pH	Water Quality
250	175	3	20	6.5	Excellent
251−750	175-525	3-5	20-40	6.5-6.8	Good
751−2000	525-1400	5-10	40-60	6.8-7.0	Permissible
2001−3000	1400-2100	10-15	60-80	7-8	Doubtful
>3000	>2100	>15	>80	>8	Unsuitable

4. Suggested Criteria for Selecting Landfill Sites

Landfill siting is an extremely difficult task to accomplish because the site selection process depends on different factors and regulations. There are a number of criteria for landfill site selection. These are environmental criteria, political criteria, economical criteria, hydrologic and hydrogeological criteria, topographical criteria, geological criteria, availability of construction material and other riteria. Each criterion will be classified [6] as:-

- **Economic Criteria:** Economic factors of landfill siting often include the costs associated with acquisition, development, and operation of each site [7].

- Costs of the land depend on the land prices, which can differ for each location.
- Costs for the access of the landfill depend on the condition and the presence of roads close to the landfill. If reconstruction of actual roads is needed, the costs will increase. Because of that road network is an important factor to locate a landfill site.
- Transport costs are determined by the transport distances from the source of waste generation. The other factors affecting transport costs are the need for waste transfer stations and the possibility to use railways.
- Economic factors must be considered in the siting of landfills, which include the costs associated with the acquisition, development, and operation of the site [8]
- **Hydrologic (Hydrogeological Criteria)**
- **Surface water:** The landfill site should not be placed within surface water or water resources protection areas to protect surface water from contamination by leachate. Safe distances from meandering and non-meandering rivers should be achieved to prevent waste from eroding into rivers and major streams. A landfill should not be located at least 300 feet (91.44 m) from any meandering stream. The buffer zone is determined as 500m for rivers or lakes and up to 250m swamp areas [9]. Current and planned future uses of groundwater and surface water shall be identified within 1km of the landfill site. After considering the identified uses of groundwater and surface water. In order to protect surface water and ground water, the landfill allocation should not be placed within water resources protection areas and safe distances from tangled and no tangled rivers should be achieved. Therefore, landfills should be placed farther than 1000 ft. (304.8 m) up gradient from water wells [10]. The necessary buffer zone for the stream sewer determined as 300 m on both sides [9]. Fig 3. A shows classes for surface water and groundwater (Arc GIS 10.4.1)
- **Groundwater:** To protect subsurface drinking water, landfills should not be situated over high quality groundwater resources. Fresh groundwater (total dissolved solids>1000 mg/l) should be avoided or protected with a compound liner system and monitoring wells [11]. Since potential leachate, leaks will travel down low gradient. T.D.S (total dissolved solids) in study area wells are measured, it found equal > 4454 mg/l). Also, landfill shall be located in areas where groundwater table is expected to be within 2m below base of the landfill. In study area, groundwater table located 2.5- 3m below base of the landfill. Table 4 shows groundwater quality and landfill suitability. Fig. 3, B shows hydrogeology map (surffer v13 software).

Table 4: Groundwater quality and landfill suitability [11].

Groundwater Quality (TDS in mg/l)	Suitability
Over 10000	High
1000 to 10000	Moderate
Under 1000	low

- **Topographical Criteria:** The topography of an area is an important factor on site selection, structural integrity, and the flow of fluids surrounding a landfill site because it has important implications for landfill capacity, drainage, ultimate land use, surface and groundwater pollution control, site access and related operations [12]. Fig. 4 shows topography of the study area.
- **Geological Criteria:** The geology of an area will directly control the soil types created from the parent material, loading bearing capacity of the landfill's foundation soil, and the migration of leachate. Rock and its structure type will determine the nature of soils and the permeability of the bedrock. Geologic structure will influence the movement of leachate. The movement of leachate and rock slope failure can be influenced by geologic structure of dump layer. The best location, for area and trench landfills, are flat rolling hills that not underwent to floods [13].
- **Environmental criteria:** are very important because the landfill may affect the surrounding biophysical environment and the ecology of the area [7].
- **Land slope:** [14] have suggested that the appropriate slope for constructing a landfill is about 8-12% because too steep of a slope would make it difficult to construct and maintain while too flat of a slope

would affect the runoff drainage. Slopes above 12% created high runoff rates for precipitation. With higher runoff rate and decreased infiltration, contaminants are able to travel greater distances from the containment are. Fig. 5 shows classes for slope area.

- **Social- economic criteria**
- **Airports:** The suitable distance from landfill site about 3km buffer around airport according to airport and airplane types [15]. In study area, buffer Zone of airport and airplane locate outside boundary case study.
- **Roads network:** Landfill location must be close to roads network in order to facilitate transportation and consequently to reduce relative costs. Buffer zone of 500m is acceptable for roads around landfill site, despite that, the distance greater than 1km from roads and highways should be avoided because the expensive cost of constructing road networks[14]. Fig. 6 shows classes for main roads.
- **Schools, Hospitals and Markets**: The suitable distance from landfill site about 100m buffer around Primary and Secondary schools, health centers and District hospitals, and markets according to [16].
- **Railways:** Al-Anbari [16] adopted 500m around railways as buffer zone.
- **Settlement Areas:** Settlement areas were subdivided into two layers. First layer consists of residential areas; while the second layer was for industrial areas.

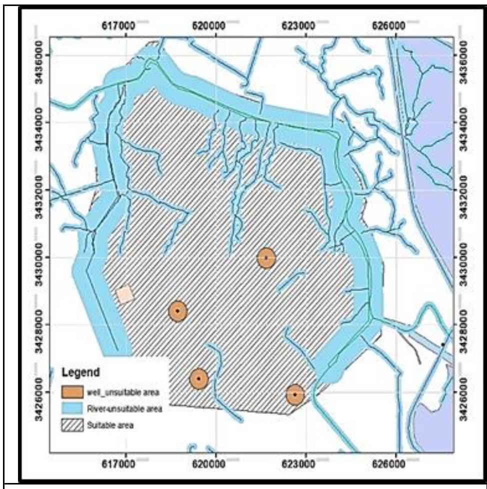

Fig. 3, A : Classes for surface water and groundwater (Arc GIS 10.4.1)

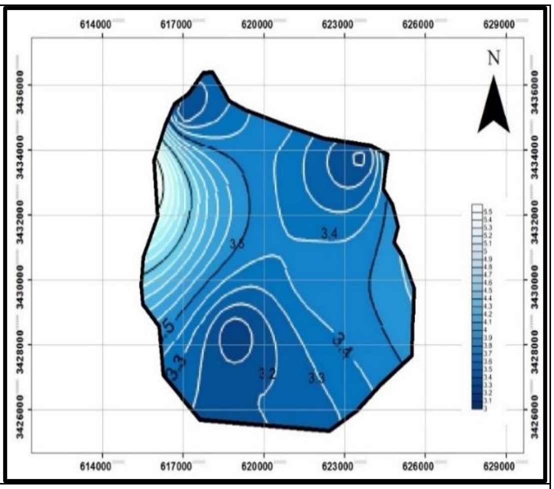

Fig. 3, B: Hydrogeology map (surffer v13 software).

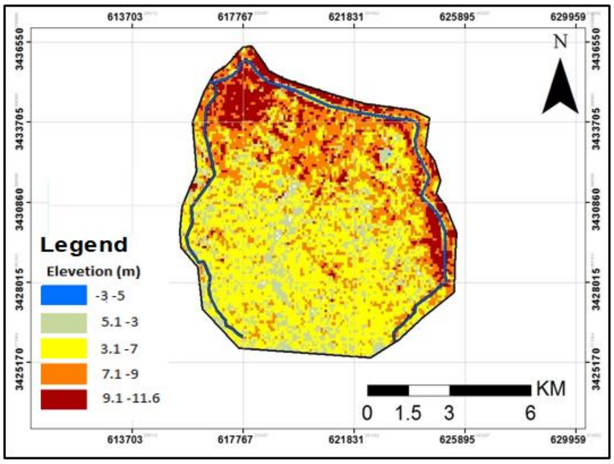

Fig. 4: Topography of the study area (Arc GIS 10.4.1).

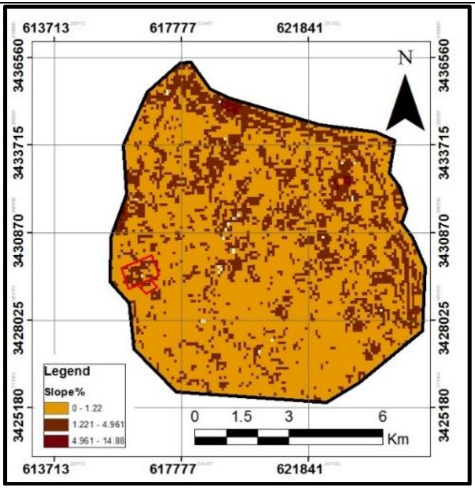

Fig. 5: Classes for slope area (Arc GIS 10.4.1)

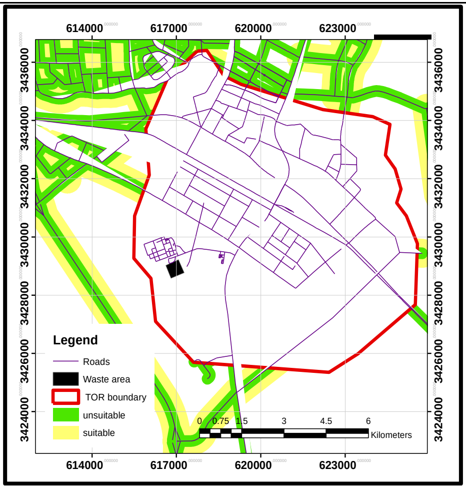

Fig. 6: Classes for main roads (Arc GIS 10.4.1)

The buffer distances for towns and villages within a population greater than 500 people were determined as 1000m. As far as all other identified centers of population it was assumed to be 500m and for private residences, businesses, social and community buildings as 250m [9] . Gisi [17]suggested 1500m distance from sensitive lands as cemeteries, historical sites and religious sites. Fig.7 shows Classes for residential areas.

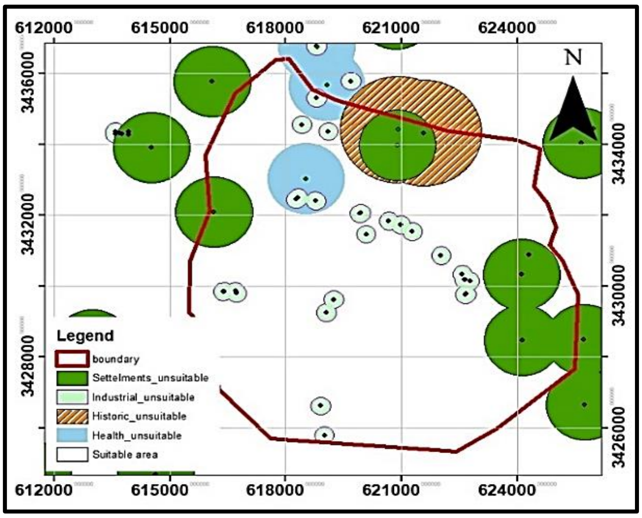

Fig.7: Classes for residential areas (Arc GIS 10.4.1).

4. Results

The site selection involves creating a study area map to input the data layers as shown in (Fig. 8) is indicated that the major and minor criteria used in landfill site selection process, then creating permissible area map for landfill sites in study area.

Superposing all of the raster type layers including geomorphologic, hydrologic, humanistic and land use criteria in land suitability, the final zoning of appropriate, fairly appropriate and inappropriate districts have been identified. Conspindering relative priority of all criteria in corsipinding with others, a specific landfill is selected. Criteria Analysis of the study area using Arc GIS 10.4.1 software as shown in Fig. 10 , The optimal site are selected because this area are planed to use it as a landfill area in future as shown in Thi-Qar master plan (Fig. 9). Costs for the reach of the landfill will be low because of network roads are close to the landfill.

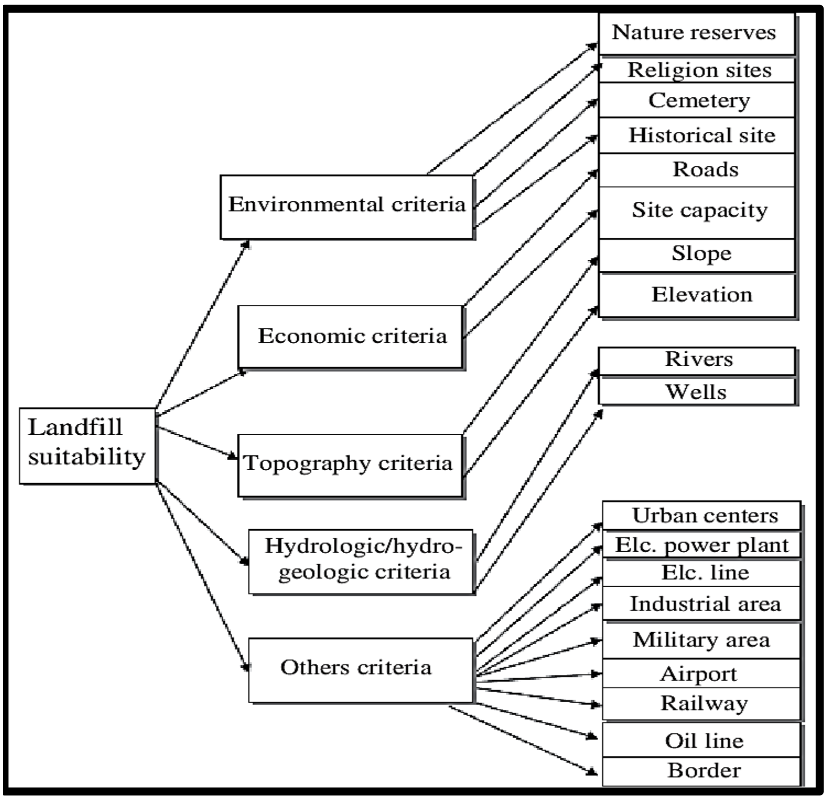

Fig: Major and Minor Citeria Used Iandfill Site Selection Process

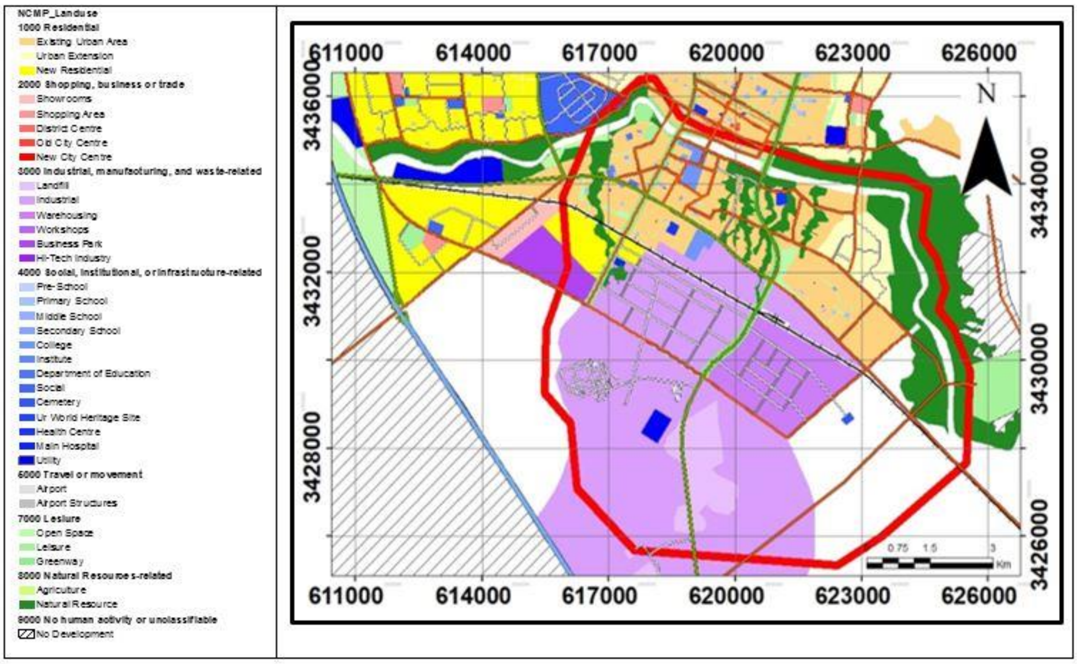

Fig. 9: Thi-Qar master plan using Arc GIS 10.4.1 software.

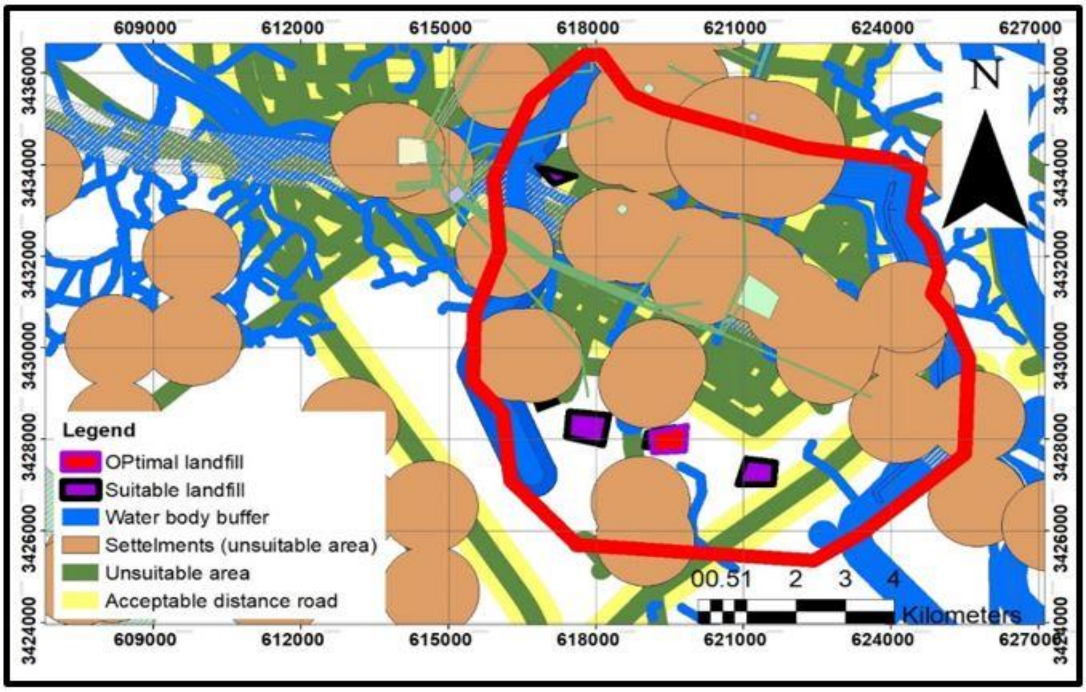

Fig. 10: Criteria Analysis of the study area using Arc GIS 10.4.1 software.

5. Conclusion

- The surface and groundwater of the study area is not suitable as drinking water to exceed the chemical and physical properties in standard specifications
- The water of these sample cannot be used for agriculture and irrigation by increasing the concentration values when compared with Standard limits.
- A number of attempts have been made to site suitability for landfills, whereas factors considered inland fill site selection are: vacant land, agriculture land, residential, industrial, airport, railway, ponds, river and play ground. This study provides an integrated GIS based on landfill site selection criteria at case study that can be the best possible solution to such kind of land suitability problems.

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تقيم صلاحية موقع مطمر مصفى ذي قار النفطي واقتراح الموقع البديل

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الخلاصة

المخلفات النفطية هي واحدة من أهم النفايات المتولدة في صناعة البترول. يحتوي على نسبة عالية من الهيدروكربونات والمعادن الثقيلة. تهدف هذه الدراسة إلى التنبؤ بحركة نقل المخلفات النفطية في طبقة المياه الجوفية باستخدام برنامج MODFLOW Flex. ومن خلال المحاكاة وجد ان مطمر (TOR)غير مطابق للشروط البيئية. مطمر النفايات هو أكثر الطرق شيوعًا للتخلص من النفايات في العراق، ومعايير اختيار موقع مطمر النفايات هي عملية معقدة للغاية، وتعتمد على العديد من الضوابط والعوامل. في هذا البحث، يتم اختيار موقع بديل لطمر المخلفات باستخدام نظام المعلومات الجغرافية.(GIS) لغرض تحديد موقع الطمر، تم فحص العديد من المعايير مثل المراكز الحضرية، واستعمالات الأراضي، والمطارات، والأنابيب، وخطوط الطاقة، والسكك الحديدية، والطرق، والمنحدرات، والجداول، والمياه السطحية، والمناطق الصناعية، وأنواع التربة. تم إعداد كل طبقة خريطة باستخدام نظام المعلومات الجغرافية وتم إنشاء الخريطة المناسبة النهائية وتحديد الموقع الأمثل لطمر المخلفات اخذين بالاعتبار كلفة النقل وبما يتناسب مع التخطيط المستقبلي لاستعمالات الأرض.

الكلمات الدالة: المخلفات النفطية، MODFLOW Flex، مصفى ذي قار النفطي، برنامج Arc GIS، معايير اختيار الموقع. المطمر النفطي.