Feasibility of LLW & ILW-SL Landfill In AL-Tuwaitha Site_Iraq

Hussein saadi A. AL-Daffaie, Y. K. Bind, Emad S. Shamsaldin

Abstract_ The present study is the effort of investigating the safe disposal of radioactive waste to save the people of Iraq from the bad effect of radioactivity. Iraq has suffered from many destructive wars in recent past in the year of 1991 and 2003. Lots of radioactive wastes were generated as a consequence of these wars. Radioactive wastes are divided in three categories Low-Level Radioactive Waste (LLW), Intermediate-Level Radioactive Waste (ILW) and High-Level Radioactive Wastes (HLW). HLW have life span of more than 10000 years hence it is quite difficult to find any site for safe disposal of HLW wastes since it needs to be buried in deep mines whereas it is relatively easy to isolate LLW and ILW wastes in manmade repositories. This paper assesses the suitability of AL-Tuwaitha site, which is small town located south of Baghdad city to be used as the sits for confining the radioactive wastes. The suitability of location of site from geotechnical and geological point of view was studied from three and six borehole data's respectively. It was found from the study of selected area that site is suitable for the construction of hazardous waste landfill.

Keywords: Low- Level Radioactive Waste, Intermediate-Level Radioactive Waste, High-Level Radioactive Wastes, Landfill.

I. INTRODUCTION

Iraq has suffered from many destructive wars in recent past as a consequence of these wars million tons of hazardous waste was generated. Although many types of waste were produced as a result of these wars however we can divide the most hazardous wastes in to two major categories. These are the radioactive and chemical wastes as in [1]. The earlier one produced while destroying Iraqi nuclear program on different locations in Iraq. The latter one was produced during destruction of chemical factories supported by Iraqi Ministry of Defense as an understanding of inventing chemical or biological weapons.

Radioactive wastes are divided in three categories depending on their life span of radioactivity. These are Low- Level radioactive waste (LLW), Intermediate-Level radioactive Waste (ILW) and High-Level radioactive Wastes (HLW), ILW have vast range of life ranging from 300 to more than 10000 years hence they again classified into short lived and long lived waste and denoted by ILW-SL and ILW-LL respectively. Amongst with physical exposure to living organism, soil with radioactive contaminants needs also be isolated from groundwater. LLW and ILW can be disposed on surface or at shallow depths by making landfills which is the main theme of discussion of this research paper. However, HLW have stretched life span say 10,000 or more than that. Hence, they used to be disposed in deep geological mines since it is hardly possible to make any disposal system that may last for this great span of time as in [2]. For this purpose Al -Tuwaitha located twenty kilometers to the south-east of Baghdad city was considered for the construction of the landfill. Al -Tuwaitha is also known for its closeness to the confluence point of the river Tigris and Diyala. Estimated distance of Al - Tuwaitha is around one kilometers east of the Tigris River and 3.5 kilometers south of the Diyala River. The reason of selection of this place as potential disposal hazardous waste site is its use as a Centre for nuclear enrichment plant in its recent past. Keeping in mind the above discussed information, the present study is carried out to investigate the geological and geotechnical aspects of the study area for the construction of landfill and to propose the design which is most appropriate for isolating radioactive wastes.

Many researchers have recently explored the possibilities of construction of hazardous landfill in Iraq as in [1]-[5].and other places as in [6]-[11].

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II. CLASSIFICATION AND COMPONENTS OF LANDFILL

The proper design and suitable location are the two most important factors that need to be considered under the notion of development of reliable disposal system. In the absence of adaptation of inappropriate measures pertaining to above said criterion it will be very difficult to restraint the hazardous wastes to expose with living organisms. Therefore, before proceeding discussion on suitable location, it is also very important to give a brief discussion on existing systems of hazardous waste landfill and its main components so that most appropriate design may be selected.

From the study of existing literature it was found that presently three types of system is in use for the hazardous waste landfill. The adoption of any concept relies on the geology, hydrogeology and various other aspects that will be discussed in the subsequent literature. These are the surface concept, underground concept and partially subsurface concept. All above concepts contains three main components of landfill that are important from the design point of view. These are the final cover, bottom cover and the leaching removal and collection system (LRCS). In addition to above a liner is also provided in final and bottom cover system.

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A. *Advantages and drawbacks*

A drawback of surface concept is the exposure to weathering and erosion that might endanger its integrity and function in near future. Similarly underground concepts also have a drawback to come in contact with groundwater in cases of rise of water table in rainy season. To avoid said problems the concept of partially subsurface landfills are adopted. However, selection of any concepts depends on specific requirement and geology of the area.

II. TRENCH OR VAULT CONCEPTS

Direct burial of radioactive wastes is avoided in hazardous wastes landfill. Therefore, two new concepts are being used now a days to give maximum protection to the environment. This system is known as trench concept. In this system wastes is placed in layers and a barrier is laid above each layer. This barrier could be made of natural or engineered materials. Two techniques are generally adopted to confine wastes in trenches. First is by making reinforced concrete vaults and second is by use of concrete or steel drums. These vaults are then barricaded by natural (clay barrier) or engineered materials (concrete) to isolate the wastes from surrounding enviornments. The principle can be as in Fig. 1.

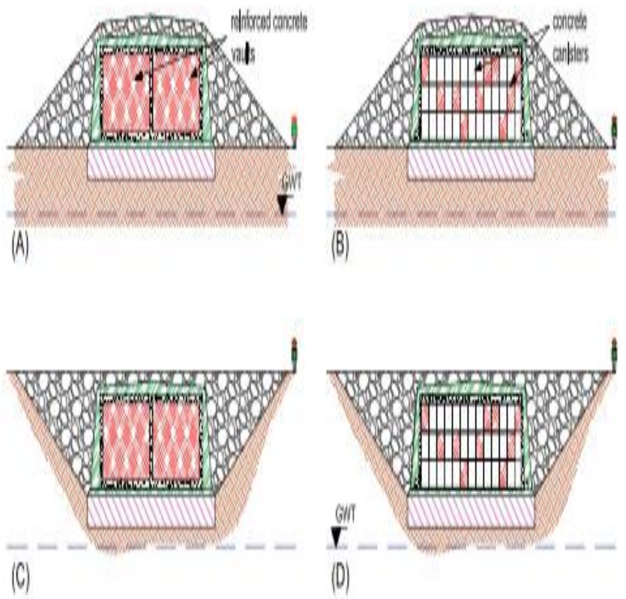

Fig 1: The trench disposal concept, Courtesy [1].

III. COMPACTED CLAY LINERS (CCL)

It has already stated that three components of a landfill are the final cover, bottom cover and the leaching removal and collection system (LRCS). Both final and bottom cover system comprise the clay liner which is the most important component of landfill.

Usually clay soil is preferred as liner material due to its low permeability. Also these clay liners are compacted 97% or more than its maximum dry density (MDD) to wet side of optima. Various organizations provide the design recommendation for compacted clay liners according to their standards. One of the internationally accepted design criterion is by United States Environmental Protection Agency (USEPA) given below in Table I.

Table I: USEPA recommendations for CCL

S. No	Property	Range / Recommended Value
1	Percentage fines (Percentage passing 75 micron or No. 200 sieve)	20 % - 30 % or greater than this
2	Plasticity index	7 % - 10 % or greater than this
3	Percentage gravel (Percentage passing 4.75 mm or No. 4 sieve)	$\leq$ 10%
4	Maximum particle size	25-30 mm
5	Hydraulic conductivity	$\leq 1\times10^{-9}$ m/s for top CCL $\leq 1\times10^{-10}$ m/s for bottom CCL

IV. RESULTS AND DISCUSSIONS

The investigation of suitability of a location used as potential site for hazardous landfill may be carried out based on various parameters for example climatic condition, geological and hydrogeological condition etc. Although various parameters were undertaken but main emphasis is given to geotechnical and geological aspects since they play major role in deciding the suitability of any site.

It has already been discussed that Al –Tuwaitha located twenty kilometers to the south-east of Baghdad was developed as the main center of Iraqi nuclear facility program by past Iraqi governments. Therefore, to avoid the risk of human exposure of radioactive elements during transportation to dump it on any other location it was decided to use Al-Tuwaitha itself as the potential site for developing repositories to isolate the radioactive wastes. In terms of topography the ground surface of Tuwaitha is flat, surrounded by earthen dykes and is heighted around 30 to 32 m from mean sea level (Fig. 2).

Fig. 2: Location of Tuwaitha Site

A. *Results from Geological Study*

selection of site for disposal of hazardous wastes is dependent on many other factors instead solely relying on its remote location from a urban place. For example roadways, transportation facility and availability of labor is also the important matters. Al-Tuwaitha is located near the capital of Iraq that is Baghdad therefore, it is easy to avail the required building materials and labor in less cost.

The area near Baghdad and Tuwaitha comes in under Mesopotamian plain. As a whole it represents a flood plain which consists of Quaternary deposits. These plains are covered mainly with Holocene deposits. The analysis of these deposits shows existence of alternating sequence of sand, clay, silt and gravel. However the top soil is the constituent's particles of rock of Zagros-Taurus Mountains. The weathering action and flow of Tigris and Euphrates rivers transported and deposited the rock constituent particles in these areas in their geological past. Also Diyala River which is one of the tributary of Tigris River merges in it few miles before the study area.

Baghdad province lies within the unstable shelf of the Arabian plate. The study of lithology of the area was carried out by making six boreholes. The details of lithostratigraphy of wells are shown in Fig. 3.

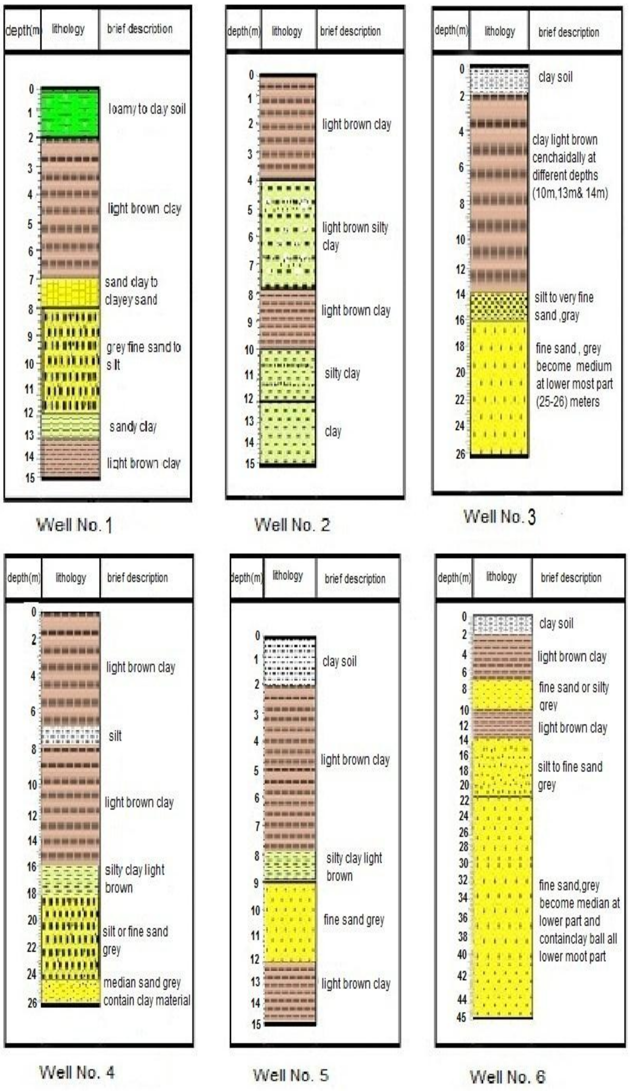

Fig. 3: lithostratigraphy of wells in Tuwaitha site

It shows that four of those wells (1,2,5 and 6) represent two sedimentary cycles while the others two wells (3 &4) exhibit only one sedimentary cycle due to the lack of the top fine sand cycle because of these two well located within the flow of the Tigris River.

The Tigris River deposits comprised of clay and silt which resulting in increase of the clay beds of the lower cycle which reaches to 14-18m in thickness with loss of the fine sand cycle. Indeed, from the study of the six wells in the area, the deposits of the study area consists from one main sedimentary cycle of upward fine-grained sand and clay at the top with thickness reach up to 31m.

B. Results from Geotechnical Study

Total three bore holes were made on the study area for finding geotechnical characteristics of the soil. The boreholes were excavated up to a depth of 10 m. The disturbed and undisturbed samples were collected at the regular depth interval of 50 cm. It was taken care that the samples were collected when and only soil strata changes. Table II shows the soil properties obtained from borehole 1.It may be seen from this Table that almost all depth intervals containing clay soil of medium to low plasticity accept for the depth range of 3.0 to 3.5 which is having silty sand that usually possess no plasticity characteristics. It may also be seen that water table is located at the depth of 3.2 meters from the ground level.

Table II : Geotechnical properties from BH – 1

Type	Depth of sample		Index Property		Partical Size ,Distribution & Hydrometer Analysis					S.P.T. "N" Val.	Symbol
	From (m)	To (m)	L.L.	P.I.	Clay %	Silt %	Sand %	Gravel %	Fine %		
D	0	1			27	58	15	0	85	....	CL
U	1	1.5	43	22						....	CL
SS	1.5	2	36	14						9	CL
U	3	3.5								....	SM
					38	58	4	0	96	......	CL
SS	3.5	4			31	65	4	0	96	21	CL
SS	5.5	6	60	31						15	CH
SS	7.5	8			24	72	4	0	96	15	CL
SS	9.5	10	45	21						19	CL
Bore hole No. 1			Water Table @(3.20) m below ground surface								

It may be seen from this Table that the liquid limit (determined from Atterberg limits test ASTM D4318: 2010d) varying from 36 % to 60 % which is in favor of suitability of soil for landfill purpose because clay soil with high liquid limit takes sufficient time to absorb water. Therefore, in cases of rise of water table or in cases of failure of bottom clay liner or migration of leachates towards the natural soil deposits it may give proper indication before alarming situation reaches.

It may also be seen from this Table that clay fraction varies from 24 to 38%, silt fraction varies from 58 to 72 % and sand varies from 4 to 15 % using particle size and hydrometer analysis (ASTM D422: 2007c). It is clear from here that clay and silt forming major portion of the soil which is also good for suitability of site since permeability of such soils is low which is one of the important requirement for preventing seepage of leachates. The bulk density and dry density of the soil for upper depth that is3-3.5m were 1.973 gm/cc and 1.608 gm/cc respectively. The compression index and swelling index for this strata were 0.195 and 0.042 respectively (see table III).

The void ratio of this stratum is 0.70 initially but after the application of loading of about 1600 kN/m^2 (Consolidation test ASTM D 2435-96) the void ratio reduces approximately to 0.44 which is again the good indication

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of suitability of soil for land fill use since volume of void is highly reducible after the application of loading which intern decreases permeability (Fig 4).

Table III: Data of consolidation test for BH - 1

Data of Consolidation Test/BH.No.1 @depth 3-3.5m				
Bulk density	1.973	Moisture cont.	initial	22.67
Dry density	1.608		Final	23.7
GS	2.72	Void ratio	initial	0.691
Swelling index	0.042		Final	0.555
Effective over burden pressure			60 KN/m²	
Pre-consolidation pressure			100 KN/m²	
Compression Index			0.195	
Swelling pressure			20 KN/m²	

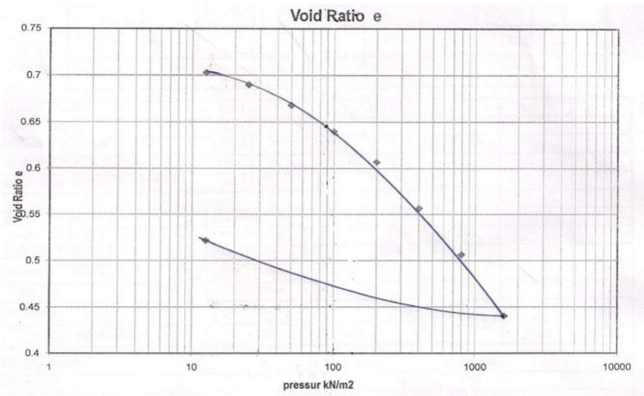


Fig. 4: Consolidation test graph of BH – 1

From the above details, it is clear that although site is appropriate for the construction of landfill however it is necessary to take high precautionary measures since water table is located within shallow depth (3.20 m from GL). Although water present at this depth is salty in nature and is not being used for drinking purposes but in any case of seepage of leachate from the landfill, there will be chances of contamination of groundwater from radioactive elements. This water is also used for irrigation purpose (sometimes farmers of remote area also uses this water for drinking or domestic purposes) which is directly or indirectly hazardous for the civilians. It is also important to select the most suitable landfill looking at the groundwater and soil properties. As states above that water table is located at a depth of 3.20 m therefore it is important to select above surface landfill from this perspective because bottom liner of subsurface landfill is located up to a depth of three or more than three meters which will fell directly in contact of groundwater

Similar soil profile was observed for second borehole (see table IV) also. Most of the soil present below ground level is clay (medium plasticity) in this borehole also that is indicator of soil suitability for landfill use. Exceptionally the soil profile from 2.5 to 3.0 m is inorganic silt (low plasticity) and 3.0 to 3.5 m is silt sand which is non-plastic. Similar to borehole 1 it is important to follow proper construction ethics (design recommendation must be strictly followed) because the sandy and silty layer in this region may create severe problems in case of any failure since ground water table is located at a depth of 3.20 m.

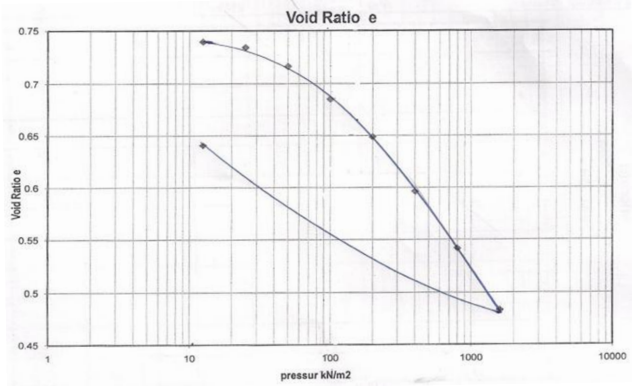
Table IV : Geotechnical properties from BH – 2

Type	Depth of sample		Index Property		Partical Size ,Distribution & Hydrometer Analysis					S.P.T. "N" Val.	Symbol
	From (m)	To (m)	L.L.	P.I.	Clay %	Silt %	Sand %	Gravel %	Fine %		
D	0	1			44	51	5	0	95	....	CL
SS	1	1.5	41	22						10	CL
U	2.5	3	36	15						....	CL
					18	77	5	0	95		ML
SS	3	3.5			23		77	0	23	16	SM
U	4.5	5	41	24						......	CL
SS	5.0	5.5	44	22						9	CL
SS	7.0	7.5			47	52	1	0	99	14	CL
SS	9.5	10	54	30						22	CH
Bore hole No.2					Water Table @(3.20) m below ground surface						

It may be seen from this Table that that the liquid limit of clayey soil is varying from 36 % to 54 % which again good for landfill purpose. It may also be seen from this Table that clay fraction varies from 18 to 47%, silt fraction varies from 51 to 77 % and sand varies from 1 to 77 %. Contrary to borehole 1 in this case silt and sand is found in considerable amount therefore it is again suggested to follow proper construction ethics. To reduce the permeability of silt and sand Bentonite may also be used.

Table V: Data of consolidation test for BH – 2

Data of Consolidation Test/BH.No.2 @depth 4.5-5 m				
Bulk density	1.955	Moisture cont.	Initial	22.17
Dry density	1.601		Final	26.5
GS	2.72	Void ratio	Initial	0.699
Swelling pressure	20 KN/m²		Final	0.641
Effective over burden pressure			75 KN/m²	
Pre-consolidation pressure			100 KN/m²	
Compression Index			0.194	
Swelling index			0.042	



The bulk density and dry density of the soil for the depth of 4.5 - 5.0 m were 1.955 gm/cc and 1.601 gm/cc respectively (see table V).

The compression index and swelling index for these strata were 0.194 and 0.075 respectively and swelling pressure was 80kN/m^2. The void ratio of this stratum is 0.74 initially but after the application of loading of about 1600 kN/m^2 (Consolidation test ASTM D 2435-96) the void ratio reduces approximately to 0.43 which is Similar to the previous borehole (Fig. 5).

Since most of the soil profile was similar to previous bore hole therefore same recommendations are suggested for example it is suggested to use above surface landfill and clay layer should be properly compacted.

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The results last borehole is shown in table VI. This table indicates slight variation in the soil strata since silty sand is not located in shallow depth and is located at deep stratum in between 8 – 10 m. This intern is suitable for the site because clay at upper strata is suitable for landfill construction since natural clay deposit will attenuate the leachate migration.

Table VI : Geotechnical properties from BH – 3

Type	Depth of sample		Index Property		Partical Size ,Distribution & Hydrometer Analysis					S.P.T. "N" Val.	Symbol
	From (m)	To (m)	L.L.	P.I.	Clay %	Silt %	Sand %	Gravel %	Fine %		
D	0	1			31	65	4	0	96	.....	CL
U	1	1.5	42	22	32	65	3	0	97	......	CL
SS	1.5	2	40	19						17	CL
U	3	3.5	38	19						....	CL
SS	3.5	4			40	58	2	0	98	20	CL
SS	5.5	6	44	23						15	CL
SS	7.5	8								7	SM
SS	9.5	10			23		77	0	23	12	SM
Bore hole No.3					Water Table @(3.20) m below ground surface						

TableVI shows that the liquid limit of clayey soil is varying from 38 % to 44 % which is slightly less in comparison to previous boreholes however this range is sufficient for the construction of landfill. It may also be seen from this Table that clay fraction varies from 31 to 40%. Minimum silt (along with some portion of clay) is 23%. Maximum silt content is 65% mostly for the upper strata. Sand content varies from 2 to 77 %. These represents marginal reduction in clay content in comparison to borehole 1 that is insignificant and suggestive of no bad effect on the suitability of soil since sand and silt is located at great depths.

The bulk density and dry density of the soil for the depth of 3.0 – 3.5 m were 2.009 gm/cc and 1.680 gm/cc respectively (see table VII) which is slightly higher than previous boreholes and is good indicator of site suitability. The compression index and swelling index for this strata were 0.176 and 0.042 respectively.

Table VII: Data of consolidation test for BH – 3

Data of Consolidation Test/BH.No.3 @depth 3-3.5 m				
Bulk density	2.009	Moisture cont.	Initial	19.62
Dry density	1.680		Final	23.27
GS	2.69	Void ratio	Initial	0.601
			Final	0.473
Effective over burden pressure			65 KN/m²	
Pre-consolidation pressure			90 KN/m²	
Compression Index			0.176	
Swelling index			0.042	

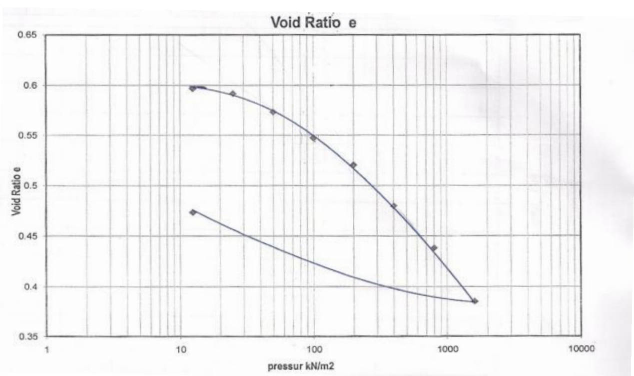

Fig. 6: Consolidation test graph of BH – 3

The void ratio of this stratum is slightly less in comparison to previous boreholes. It was 0.60 in natural state and reduces approximately to 0.37 after the application of loading of about 1600 kN/m^2 (Fig. 6). The low initial void ratio is again suggestive of suitability of site for construction of landfill.

The above results for borehole 3 shows that the soil data from this borehole is highly consistent with the set standards but due to high water table it is suggested to use above surface landfills only in the study area.

C. Hydrogeological of Study Area

The study area is also characterized as flat floor surface ranging from 30 - 32 meters above mean sea level and hence the topography factor has no significant impact on water level and groundwater movement.

Investigation showed that the water table levels are almost same in the six wells in the study area as shown in(see table VIII) and there is movement of flow of water from east to the west towards the well No.2 (fig. 7). It indicates that the groundwater flows towards the Tigris River in dry season (summer) and from the river towards the wells in wet season (winter). The relationship between the main bed water-bearing and the Tigris River led to decrease the total dissolved solids in in this bed.

Table VIII: Type and levels of ground water wells.

Well No.	Type of well	G.S.L. at well	W.T.L	Depth of W.T.
1	Shallow (15m)	32.02	27.8	4.22
2	Shallow (15m)	31.88	27.67	4.21
5	Shallow (15m)	31.59	28.07	3.52
3	Deep (26m)	31.56	27.61	3.95
4	Deep (27m)	31.81	27.79	4.02
6	Deep (45m)	31.57	27.86	3.71

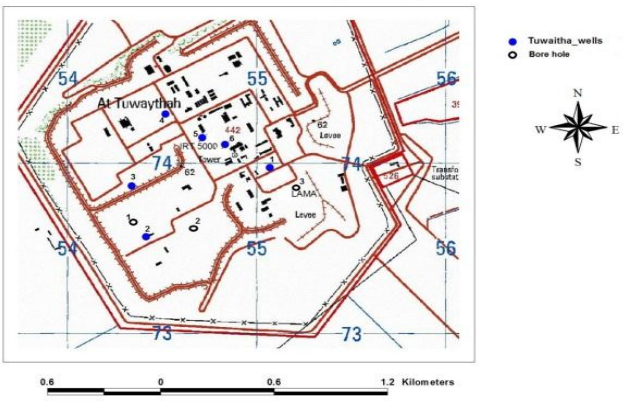

Fig. 7: Location of wells and borehole in tuwaitha site.

From the results of chemical test (Table 4.8) for samples of ground water it may be inferred that

There is large variation in the TDS values of groundwater in the shallow bed from that in the deep bed bearing-water, which indicates that there is no interaction between these two beds because of presence of 4m thick clay deposit between them.

The TDS value in well 5 is generally above of all values of the other wells.

Decrease of TDS with depth in wells 3, 4 and 6 in the deep

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bed, may be due to the interconnection of groundwater in that bed with the surface water of the Tigris River.
The field observations and detail studies of lithostratigraphy of drilled wells in the study area show clearly that the first shallow bed is not continuous but it appears as unconnected lenses as it disappear in the wells 3 and 4. The sources of the water in this bed come from filtration of water from irrigation and sewage of the IAEC and it doesn't represent an aquifer or bed bearing –groundwater.
Quality of groundwater of the second bed (deep) is very good and suitable for irrigation.
Above discussion indicates that selected study area is suitable for above surface NSR since water table is present at shallow depth and there exist chances of rising of water table at season of rainfall.

Table IX: Chemical test for ground water in site.

Well No.	PH	TURB. (NTU)	E.C. Ms/cm	T.D.S. mg/l	T.S.S. mg/l	Cl^{-1} mg/l	Ca^{+2} mg/l	Mg^{+2} mg/l
1	7.8	9.11	12.02	5000	450	4050	567.43	2458.3
2	8.09	31.6	13.53	6000	501	3780	614.37	2949.1
5	7.87	6.34	16.86	7680	761.52	5560	888.76	3823.8
3	7.82	11	2.69	1656	688	799.1	140.28	36.48
4	7.64	0.48	2.86	1330	360.72	880	Nil	699.78
6	9.12	0.24	4.31	1740	300.6	490	Nil	849.73

D. Geophysical Investigation

Geophysical studies were conducted using the method of seismic surface, where they were distributed two lines perpendicular one to other with length of 90 meters, was developed Geophones with distance of 5 meters between the one and the other, one of these lines to measure the P-wave and the other to measure the S-wave, and by using a hammer source of energy at the beginning of the line at zero distance and at middle line and at the end of line in the distance of ninety meters.
The device used in the geophysical investigations (Seismograph: Strata visor-NZ from American geometrics company), (software: SeisImager /2D, SeisImager /SW, involving program e.g. Surface wave analysis wizard) and geophone 10 HZ.

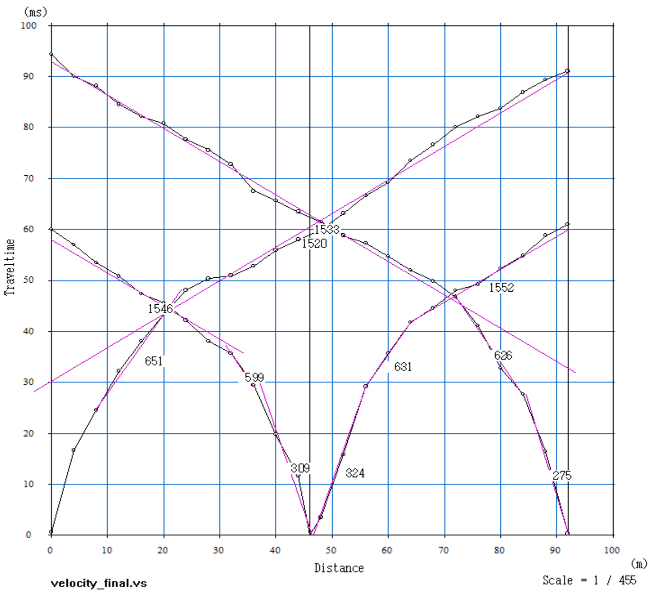

Fig.8: P-wave

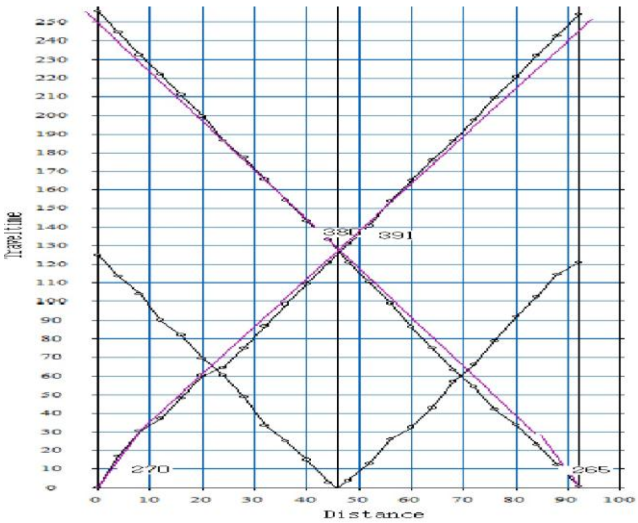

Fig.9: S-wave

Results illustrates that the region is composed of three layers of different velocities of P-wave and S-wave for the depth of less than ten meters. The thickness of first layer is equal to (h_1=2.295 m) and second layer (h2=5.6m) . it is clearly from fig.8 (P-wave) and fig.9 (S-wave) that these layers horizontal and parallel and continuous and also it clearly no any cavities found in this region because no any delay in time of refraction wave, and classification of these layer it is from clay and silty clay. that is meaning this site is suitable to construction of landfill .

E. Design of LLW landfill

As it has already been discussed that above along with trench and vault concepts can effectively be applied for the construction of LLW landfill in the study area. However, there exist some significant advantages of the partially above surface trench concepts that cannot be ignored. For example, the disposal is partially below ground and therefore there are least chances of threat of exposure if located near residential areas. In addition, they do not require any surface barrier to avoid influence of external factors like heavy rainfall and frost that surface disposal requires sometimes. But due to high ground water table it is not possible to recommend the said landfill in selected area.

The proposed design is presented in Fig. 10. It should also be ensured that disposal site fell within an area where wells for drinking water or irrigation water were not present. The edges of landfill were confined by constructing stable and tight embankments or dikes since stress are prevailing at these points.

The top cover of the landfill was given sufficient slope so that precipitation do not infiltrate and amount of water retained on top may be evaporated back to the atmosphere. Construction of drainage pipe systems for collection of percolate is usually not required in DU wastes landfill as well as proper slope on the top cover also decreases the possibility of percolation of rainwater inside the landfill. Therefore, drainage system for removal of leachates is not provided in the proposed design. But for more safety prefer doing it.

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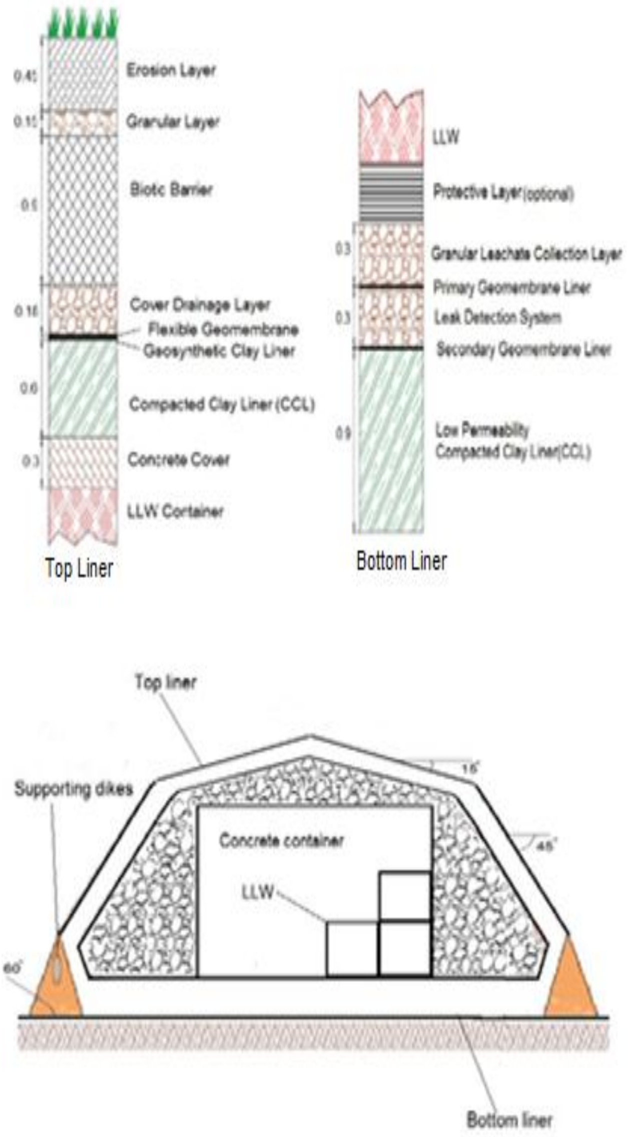

Fig. 10: Design of suggested radioactive waste landfill

F. Design Clay Liner:

Clay is the most important component of soil liners because the clay fraction of the soil ensures low hydraulic conductivity, EPA requires that soil liners be built so that the hydraulic conductivity is equal to or less than 1 x 10^{-7} cm/sec. To meet this requirement, certain characteristics of soil materials should be met.

First, the soil should have at least 20 percent fines (fine silt and clay sized particles). Some soils with less than 20 percent fines will have hydraulic conductivities below 10^{-7} cm/sec, but at such low fines content, the required hydraulic conductivity value is much harder to meet.

At the Tuwaitha site investigations showed that the proportion of fine particles more than 85%, and this means that the soil is very suitable to using as clay liner and within the Internationals specifications for the design.

Second, plasticity index (PI) should be greater than 10 percent. Soils with very high PI, greater than 30 to 40 percent, are sticky and, therefore, difficult to work with in the field. When high PI soils are dry, they form hard clumps that are difficult to break down during compaction.

At the Tuwaitha site investigations showed that the value of the plasticity index in the upper layers of the first five meters does not exceed 20%, and this means that the soil site is very suitable and within the Internationals specifications for the design.

Third, coarse fragments should be screened to no more than about 10 percent gravel-size particles. Soils with a greater percentage of coarse fragments can contain zones of gravel that have high hydraulic conductivities, Soil Tuwaitha site does not contain particles of gravel and thisis a good indicator to ensure no increase in the permeability of the soil .

The material should contain no soil particles or chunks of rock larger than 1 to 2 inches in diameter. if rock diameter becomes a significant percentage of the thickness of a layer of soil, rocks may form a permeable "window" through a layer. As long as rock size is small compared to the thickness of the soil layer, the rock will be surrounded by the other materials in the soil. It is recommended cleaning the top soil layer, if found any trace of pieces bricks or chunks of rock.

Finally, (fig. 11) showing hydraulic conductivity as a function of plasticity index. Each data point represents a separate soil compacted in the laboratory with standard Proctor compaction procedures and at water content about 0 to 2 percent wet of optimum. Hydraulic conductivities are consistently below 10^{-7} cm/sec for soils with PI greater than 10 percent.

As stated above this confirms that the soil of Tuwaitha site has hydraulic conductivity less than 10^{-8} cm/sec and after compaction we can reduce the hydraulic conductivity and also by adding bentonite by certain percentages. Note that the consolidation test showing after applied pressure to samples to 1,600 kN/m^2 decreasing void ratio from 0.7 to 0.48 and this is a good indicator so after the construction of the landfill will guarantee get low permeability

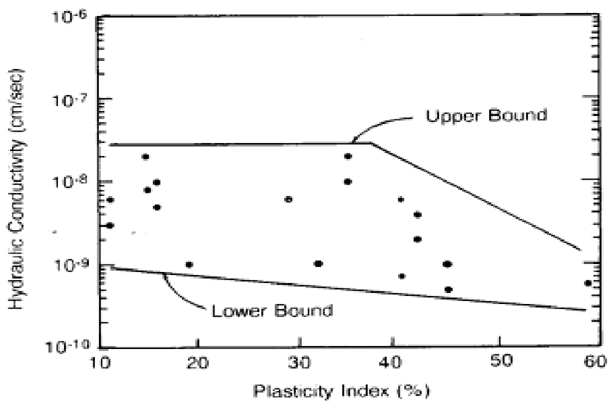

Fig. 11: Hydraulic conductivity as a function of plasticity index (USEPA).

V. CONCLUSIONS

The study was carried out to check the suitability of AL Tuwiatha as potential site for dumping LLW and ILW-SL. Based on geotechnical parameters it was finally concluded that this site is suitable provided certain guidelines are strictly followed. In addition, the design of selected surface landfill (trench concept) is also proposed at the end of results. From the obtained results the following conclusions may be drawn.

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The geological and geotechnical parameters of the selected site obtained from borehole data were in favor of landfill construction as most of the soil profile is made of stiff clay having very low permeability.

The selected design is very suitable for safe disposal of hazardous wastes because higher safety measures were adopted by giving proper reinforcement to the trench system and top and bottom liner system. The slope was also according to the guidelines of international system that ensures easy drainage of rainwater from the top of the landfill.

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