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Modifications added to the existing Government Hafir Type using Geomembrane

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ABSTRACT

In this research a prototype of a hafir is lined-up with HDPE geomembrane. This lined-up hafir was investigated for the dissipation of water to the bottom and to the sides of the hafir. The main objective of this research was to study the effect of lining-up the hafir on the prevention of water from being dissipated to the bottom and the sides of the hafir. Generally, water should stay in hafirs up to the next rain season. This research succeeded to prevent the water dissipation to bottom and sides of the hafir by lining it up with HDPE geomembrane. This research as well set a solution for the reduction of natural evaporation of water by covering the top surface of the hafir by a thin sheet of HDPE with a reflecting material. Some suggestions are mentioned for treating the water chemically and physically so as to be drinkable for man and animal.

INTRODUCTION:

Geomembranes represent the other largest group of geosynthetics and in dollar volume their sales are even greater than those of geotextiles. Their initial growth in the USA and Germany was stimulated by governmental regulations originally enacted in the early 1960 s (Herbert, 1968). The materials themselves are relatively thin impervious sheets of polymeric materials used primarily for linings and covers of liquid- or solid-storage facilities. This includes all types of landfills, reservoirs, canals and other containment facilities. Thus the primary function is always containment functioning as a liquid and/or vapor barrier (Irving, 1966). The range of applications is very great, and in addition to the geoenvironmental area, applications are rapidly growing in geotechnical, transportation, hydraulic, and private development engineering.

Geomembranes are impermeable membranes used widely as cut-offs and liners .Until recent years, geomembranes were used mostly as canal and pond liners. One of the largest geomembranes current applications is at landfill sites for the containment of hazardous or municipal wastes and their leachates. In many of these applications, geomembranes are employed with geotextile or mesh underlines, which reinforce or protect the more flexible geomembrane whilst also acting as an escape route for gases and leachates generated in certain wastes. Some of Geomembranes materials are: (PVC, Polypropylene, Polyethylene, Polyurethane, Butyl Rubber, EPDM Rubber and Elvaloy) , but the most common geomembrane materials are Low-Density Polyethylene (LDPE), High-Density Polyethylene (HDPE) ,Polyvinyl Chloride (PVC) , Polyurea and Polypropylene (PP). Another type of geomembrane is bituminous geomembrane, which is actually a layered product of glass and bitumen-impregnated non-woven geotextile**.** Each geomembrane materials have its welding requirements, special machineries and weld testing regimes (United Nations Industrial Development Organization, 1969). 20 to 40--mil High Density Polyethylene (HDPE) geomembrane material is relatively easy to weld, but when an application requires welding 60 to 80 mil HDPE, certain modifications in welding are helpful towards attaining good results. The objectives of using geomembranes in existing Hafirs are as follows:-

1- Saving water inside the (Hafir) against evaporation and leakage.

2- Using the suitable material to lining the Hafir (High Density Polyethylene Geomembrane).

3- Using the suitable design for the Hafir and installing liner in it.

4- Protecting the water inside the Hafir by making some treatment to make it potable. Three flexible liners like PVC, polyethylene (HDPE, LDPE) and butyl rubber can be used in lining.

A comparison of the advantages and disadvantages between the geomembrane materials:-

The geomembranes	**The advantages**	**The disadvantages**
PVC	1-Available in single or double thickness. 2- Mvailable in various colours. 3-Stretch and easy to fit.	1-They are not resistant to ultraviolet light. 2-Eventually deteriorate.
Polyethylene (HDPE, LDPE)	1-More durable than PVC. 2-Commercially available in a range of densities and qualities. 3- Has an excellent chemical resistance. 4- HDPE geomembranes are best for high wear conditions such as exposed applications. 5- LDPE geomembrane offer extra flexibility.	1-less durable than butyl rubber.
Butyl rubber	1-They are the most durable. 2-Suppliers guaranteed a life of at least 10 years with proper care.	1-More expensive than PVC and butyl rubber.

The advantages of using HDPE geomembranes are as follows:-

1- Long-term durability.

2- Flexibility.

3- Puncture resistance.

4- Optional textured surfaces.

5- Large roll widths and lengths.

6- UV stability.

7- Low temperature flexibility.

8- Thermally welded seams.

9- Flow improvement.

10- Reduced maintenance.

HDPE geomembrane liners may be left exposed or may be protected with a covering of soil or concrete. HDPE geomembrane's UV-stabilized can remain exposed for an extended length of time with no expected decline in their level of performance (Ritchie, 1972). However, most lining system should be protected against damage from rocks, debris, equipment and vandalism.

2. Materials and Methods:-

2.1. Types of Hafir:-

There are three main types of Hafirs, the domestic, the government and the civil engineering hafir**.** A comparison performed by this research about the advantages and disadvantages of the types of hafirs in, the results are stated below:-

The design	**The advantages**	**The disadvantages**
The Domestic's Hafir	1- Very cheap.	1-There is no protection from wrong doing activities of people and animals. 2-There is not any chemical treatment to the water. 3-The water dries out for few weeks after the rain season and that is due to evaporation and leakage.
The Government's Hafir	1-The hafir's body is built leaning from edges to bottom, and that is for: A- Protecting the edges from fall. B- Making it easy for the instruments to get in or out the Hafir. 2-The Hafir is surrounded by two embankments of soil and prickly wire to protect the hafir from the wrong uses of people and animals. 3- The Hafir has an in let well to feed the hafir by water and an out let well to take water from it. 4- The Hafir has wings to reject water when the hafir is being full. 5- Lately an inert filter unit has been used before the out let well to eliminate the turbidity and the microorganisms.	1-The water dries out few months after the rain season and that is due to evaporation and leakage. 2-There is not enough water treatment. 3-The capacity of the hafir is limited, because it depended on the nature of the soil (most of hafirs is 30000 cm3) 4-They build the hafir using only clay soil.
The Civil Engineering's reservoir	1- It has a high efficiency of saving water. 2-Suitable for all kinds of soil. 3-The capacity of the hafir is not limited.	1-It is very expensive. 2- Not easy at construction. 3-High cost of maintenance.

According to the above mentioned comparison it is clear that the Government's hafir is much better than the other two types. Because its advantages are much better than the other two types while the disadvantages could be solved by adding some modifications to the design.

The modifications added to the design of the government hafir by this research were:-

1- Using HDPE geomembrane in lining the Hafir to protect water against leakage.

2- Using HDPE geomembrane with reflecting material to cover the Hafir to protect water against evaporation.

3- Designing a Natural filter inside the Hafir to eliminate the turbidity and designing a Sand candidate to eliminate the microorganisms.

4- Designing a Cistern (tank) to apply chemical treatments.

The lining of the hafir by HDPE geomembrane would make the capacity of the hafir unlimited and the Hafir could be made in any kind of soil.

The New design of the Hafir: The side view of the new Hafir is shown in Figure (1). The specifications of its parts are described below:-

The in-let well: It is a small well (1.75×1×1) m^3, 0.5meters over the surface of earth, covered with a net of steal to eliminate the big sizes of trashes. The main job of this well is to feed the hafir with the water that was collected in it.

The Valve: This was used to stop the flowing of water when the hafir is full.

The Embankments of soil: This was 8meters far away from the hafir, 2meters high and 2 meters wide, surrounding the hafir with prickly wire to protect the hafir from the bad uses of peoples and animals.

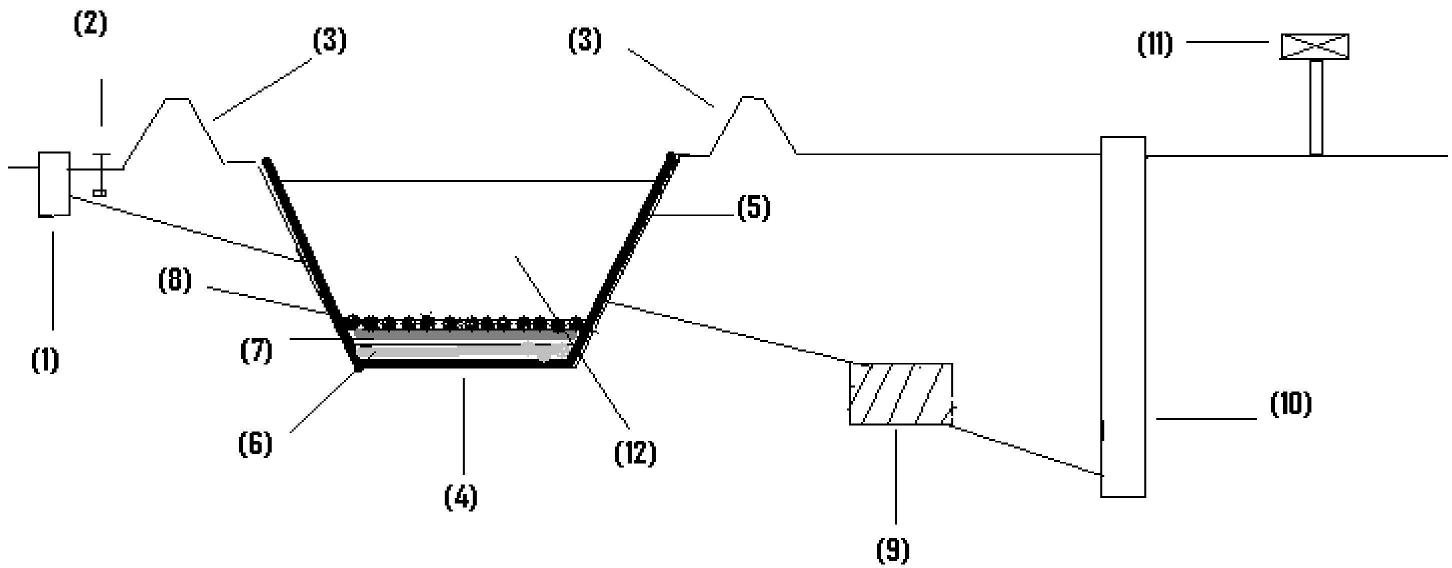
The Hafir's Body: This was a wide crater, dug by modern instruments located in the site and the site is determined by the studies (amount of rain).The hafir is lined with polyethylene geomembrane to protect it from the leakage by sides and bottom. The hafir was then covered by polyethylene geomembrane to limit the evaporation from it. The cover should be higher 1.5m from the hafir to make a suitable aerating. The capacity of the hafir depends on the numbers of people and animals in the village.

The Natural filter (Sand candidate): This was used to eliminate the leaches, turbidity, and microbiological organisms. The capacity of it depends on the numbers of people and animals.

The Out-Let Well: This was a deep well (7×1×1) m^3, 0.5 meters higher from earth. It should be covered to protect it from outside pollution. The people can take the water from the well directly.

The Cistern: This was a tank of water used to make the chemical treatment in it. The capacity of it depends on the consumption of people in one day. It needs a pump to pump the water to it.

The Wings: These were used to deflate the water when the hafir was full, as shown in Figure (2).



(1) In let well
(2) Valve
(3) Embankments of soil
(4) Hafir's body
(5) HDPE Geomembrane
(6) Layer of sand
(7) Layer of small gravels
(8) Layer of medium gravels
(9) Natural filter (Sand candidate)
(10) Out let well
(11) Cistern (Tank)
(12) Water

Figure 4-1-1

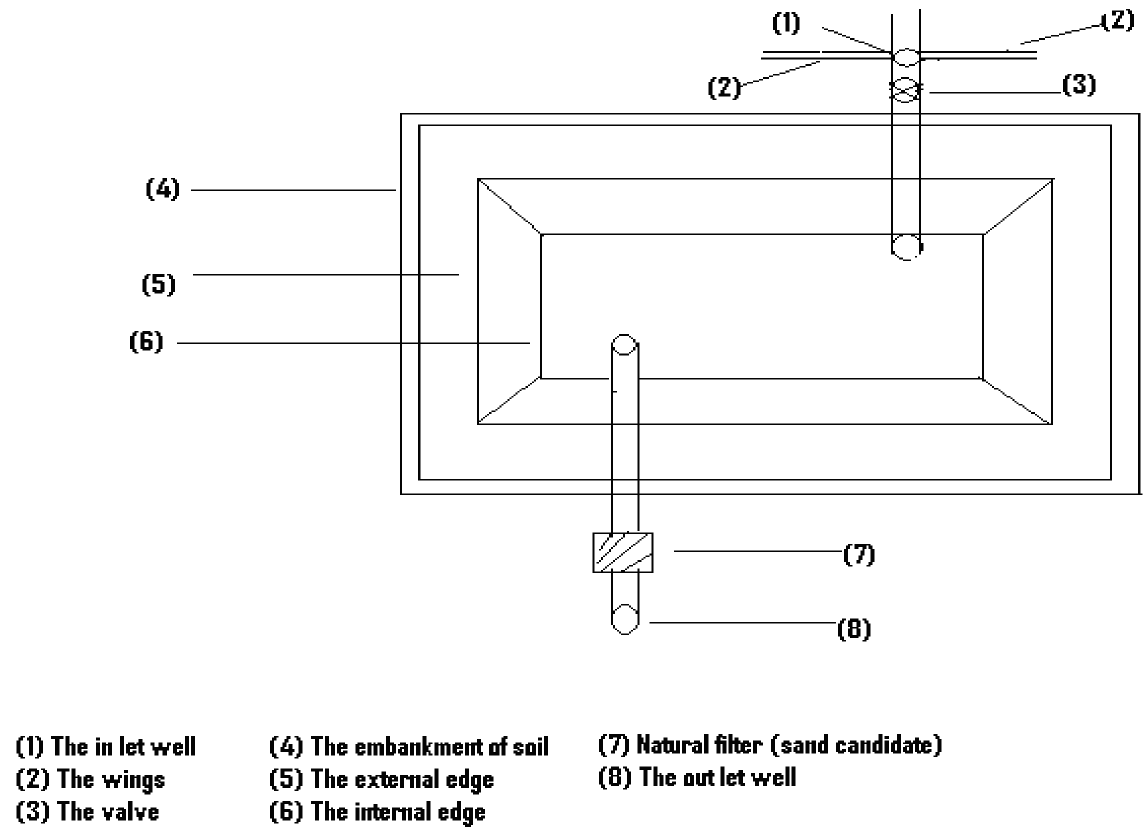


Figure 2: The end view of the new design of the Hafir

The model (Prototype): A prototype was made for this research. It was built leaning from edge to bottom and its dimensions are:

1- The bottom area (cm2) = 50×45

2- The surface area (cm2) = 140×135

3- The height (cm) = 50

This prototype of Hafir was lined by three pieces of HDPE geomembrane welded by heat.

Results and Discussion:-

Three types of tests were made in this research, physical and chemical tests were made for the sample of the geomembrane used in this work and a chemical test was made for the stored water.

The Physical Tests: In this work two physical tests were made, namely the check test and the weather test and the results obtained are stated below:-

CHECK TEST: Physical check tests were made in the laboratories of Sudan University of science and technology and the results obtained are stated in Table (1).

Table 1: The results of the physical check test

TEST PROPERTY	TEST METHOD	VALUE
Thickness, (mm)	ASTM D5199	0.5
Density, g/cm3	ASTM D1505/792	1.0
Weight, g/m2	ASTM D 5187	468
Tensile properties (each direction) Strength at Break, Ib/in Elongation at Break,%	ASTM D638/D6693, Type IV Dumbbell, 50mm/min (30mm gauge length)	78 66.2

WEATHER TEST:

After the check test was made, the sample was put on the roof for three months to make the weather test and the results obtained are shown in Table (2).

T able 2: The results of the weather test

TEST PROPERTY	TEST METHOD	VALUE
Thickness, (mm)	ASTM D5199	0.5
Density, g/cm3	ASTM D1505/792	0.945
Weight, g/m2	ASTM D 5187	468
Tensile properties (each direction) Strength at Break, Ib/in Elongation at Break,%	ASTM D638/D6693, Type IV Dumbell, 50mm/min (30mm gauge length)	58.75 55.14

The Chemical Tests: The main chemical test made in this research was the infrared spectdophotometry test.

The infrared spectdophotometry test: This test was made to show if the membrane contains any stabilizers. Figure (3) shows the results of our sample. Figure (4) shows the results of pure polyethylene geomembrane test and it was taken as a reference to our sample. The results were as follows.

I. The wavelength (2921.20, 2850.81) and (2921.96, 2850.59) were approximately the same in the two tests. They belong to (C-H stretch) group.

II. The wavelength (1467.63) and (1465.80) were approximately the same in the two tests. They belong to (C-H bend) group.

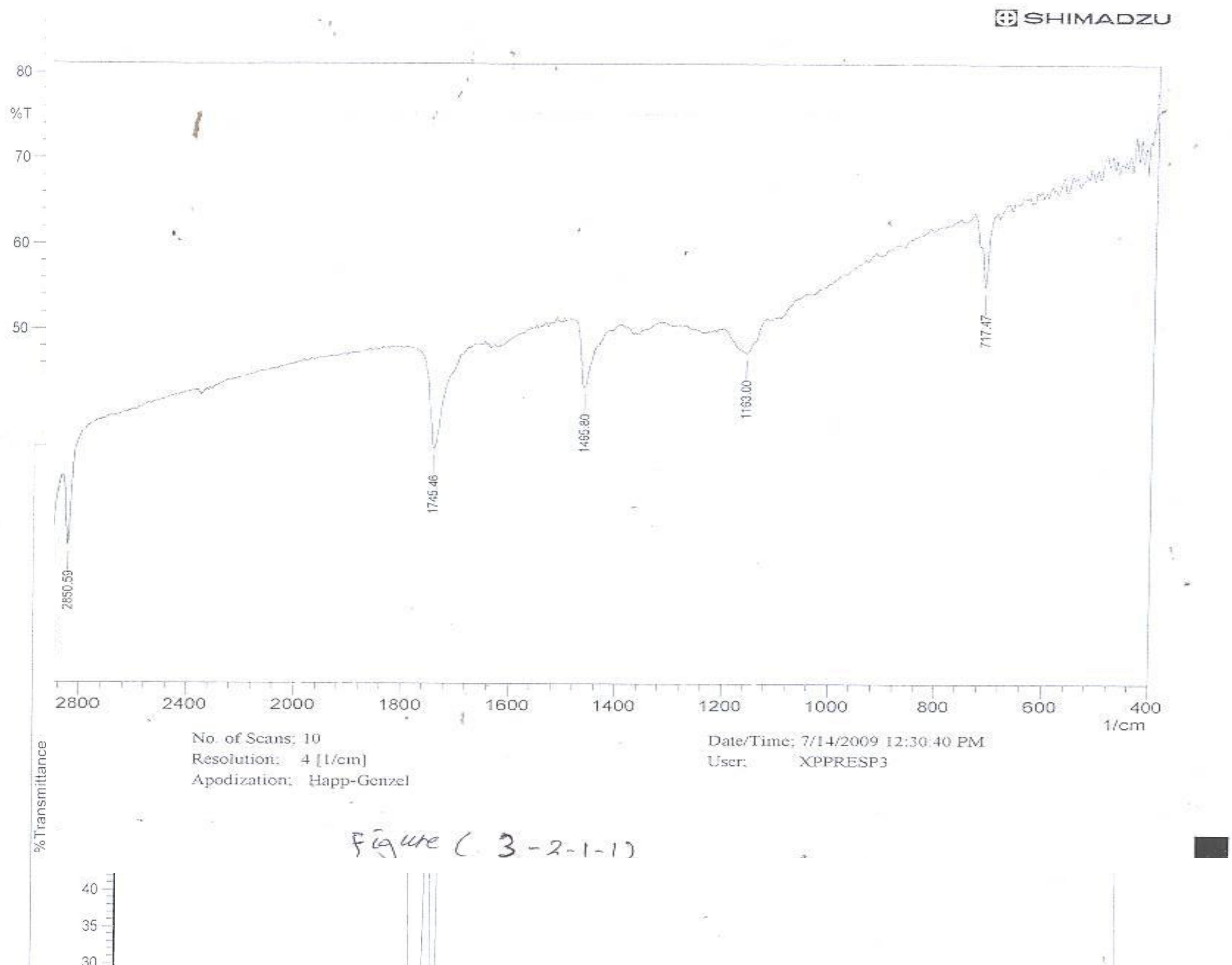
III. The wavelength (725.12) and (717.47) were approximately the same in the two tests. They belong to (C-H bend) group.

IV. The wavelength (3440.77) belongs to (O-H stretch) group.

V. The wavelength (1745.46) belongs to (C=O stretch) group.

VI. The wavelength (1163.00) belongs to (C-O stretch) group.

Figure 3: The results of the infrared spectdophotometry test of the sample used in this work



Chemical tests for stored water (Analysis):

This sample of water was taken from a real Hafir in "Om Dawan Ban" area, after been staying about "6 months". Then the analysis were made for the sample and the results obtained are shown in Table (3)

Table 3: The results of the chemical tests on the sample of the stored water

NO	Parameter	Unit	Max Limit	Sample
1	Appearance	-	Acceptable	Turbid
2	Turbidly	NTU	5	366
3	Color	TCU	15	-
4	Odor	-	-	+ve
5	PH	-	8.5	7.9
6	Temperature	$^{\circ}C$	Accept-able	23.8
7	E. conductivity	$\Omega^{-1}cm^{-1}$	-	2160
8	T.D.S	Lis/cm	1000	1188
9	T.S.S	mg/cm	0	544
10	T. Alkalinity	mg/cm	400	470
11	PH.PH.Alkalinity	mg/cm	-	Nil
12	T. Hardness	mg/cm	180	228
13	Zinc	mg/cm	3	-
14	Hydrogen sulfide	mg/cm	0.05	-
15	Chloride	mg/l	250	205
16	Fluoride	mg/l	1.5	1.84
17	Sulfate	mg/l	250	192.5
18	Ammonia	mg/l	1.5	0.62
19	Nitrite	mg/l	2	0.026
20	Nitrate	mg/l	50	9.68
21	Iron	mg/l	0.3	-
22	Calcium	mg/l	-	20.8
23	Magnesium	mg/l	-	42.24
24	Sodium	mg/l	200	325.5
25	Potassium	mg/l	-	30.15
26	Manganese	mg/l	0.5	0.078
27	Aluminum	mg/l	0.2	-

Key:

1- The shaded areas indicate that the values are over the accepted limits.

2- T.D.S indicates the total salts ratio.

3- T.S.S indicates the total leaches ratio

Observations:-

When the water was put inside the prototype of the new hafir it was noticed that after three months there was no dissipation of water through the geomembrane. As well the evaporation of water became very little after covering the water inside the hafir by a reflecting material. It could be said here that the evaporation of water from the top surface of the hafir is reduced but this amount is not measured during this research.

DISCUSSION:-

The results of the product specifications show that the material contains carbon black, which is used as ultra violet resistant. The results of the check test show that the thickness and the density are in range, but strength at break decreased by 4.9%, and the elongation decreased by 5.4%. The cause of this decrease may be according to:-

(i) The bad storing and transportation which affected the geomembrane.

(ii) The instruments used for the tests did not give the accurate results, because they are old- fashioned and prolong used.

After the sample had been in the roof for three months from May to August the results show that the thickness and the weight did not change, but the strength at Break decreased by 24.4%, and the elongation at Break decreased by 16.7%.These results are considered good, because tests were done during Summer while the temperatures was very high and they were exposed to sun rays for a long period.

The infrared spectrophotometer test shows that the material has an (O-H stretch) group, which contains the "Phenol". The phenol is used as (Antioxidants). In addition, the "Chlorinated phenol compound" is used as a bacterial and fungal attack resistant. These tests show that the geomembrane mostly contains antioxidants, bacterial and fungal attack resistant and ultra violet resistant, which means that it is suitable to be used in the Hafirs. The results of the analysis of water indicate that the water is not suitable for drinking. Therefore physical and chemical treatments can be made by using the followings:-

a- A natural filter (sand candidate) should be used to eliminate the leaches, turbidity, and microbiological contaminants.

b- A suitable aerating process should be applied to deter water fusty.

c- As well as Reversing Osmosis (R.O) device should be applied to eliminate the extra salts.

For better water quality, the following materials can be added to the hafir:-

a- An antiseptic materials like chloride (1g/m3).

b- Materials to eliminate the odor like activated carbon.

c- Materials to eliminate the colour and to improve the taste.

Conclusion

The Sudan has a wide area and it is affluence of rains, but many people are suffering from lack of water especially the shepherds in the dry season. The existing hafirs dissipate water to the bottom and all sides of the hafir.

Water evaporation is responsible of the loss of quite much amount of water. In this research a prototype of hafir was made and the hafir was lined with HDPE geomembrane. The hafir is covered with a reflecting material.

The results show that the use of HDPE in lining hafirs can save the water inside the hafir for extra long time. Covering the surface of water with a reflecting material can reduce vast amounts of water subjected to natural evaporation. This research found that no dissipation of water is found after lining the hafir with the HDPE geomembrane.

Recommendations

The following recommendations are suggested.

1. Workers should be trained especially in welding processes. IF the welding of the HDPE is not efficient, leakage might occur in few days.
2. Chemical laboratories should be equipped with modern equipments for testing geotextile materials.
3. Manufacturing of HDPE should start immediately in Sudan.
4. Much research is needed for this interesting topic.

INDEX:

The Standard Product specifications:-

TESTED PROPERTY	TEST METHOD	VALUES
Thickness,(mm)	ASTM D5199	(0.5)
Density, g/cm3	ASTM D1505/792	> 0.94
Tensile properties (each direction) Strength at Yield, lb/in Strength at Break, lb/in Elongation at Yield,% Elongation at Break,%	ASTM D638/D6693, Type IV Dumbell, 50mm/min (33mm gauge length) (50mm gauge length)	42 82 13 700
Tear Resistance, lb	ASTM D1004	17
Puncture Resistance, lb	ASTM D4833	30
Carbon black content,(%)	ASTM D1603, modified	2.0-3.0
Carbon black Dispersion	ASTM D5596	1/2
Dimension stability, (%)(each direction)	ASTM D1204,(1200C/lb)	+_2
Melt Flow Index g/10min	ASTM D1238 (1900C/2.5.0 kg) (1900C/2.16 kg)	<_3.0 <_1.0
Stress Crack Resistance(NCTL)hr	ASTM D5397, appendix	>_400

REFERENCE PROPERTY	TEST METHOD	VALUES
Oxidative Induction Time (OIT) min	ASTM D3895, (2000C,pureO2,1atm)	>_100
Low Temperature Brittleness 0C	ASTM D746	**-77**
Surface		Double-sided smooth
Roll Width		4.0-7.0

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