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# Application Of Low Cost Materials In Dissolved Solids Removal

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## ABSTRACT

To improve desalination techniques that low energy consuming and more environment friendly technologies, local materials tested combined in order to have their advantages in achieving the optimum removal ratio and the best system application.

System consisted of three units ,each tested different sandwich textile material in three runs to determine different purpose ,sandwich panel consisted of (textile-bentonite-textile) of (cotton “natural”, geo-textile “artificial” and, mixed-textile) cases each filled with 4cm layer of powder bentonite , which are local available materials in the Egyptian market.

Sandwich textiles worked as filter media with (1 ,4 ,and 8) layers application in order to estimate stability , suitability , workability ,and durability of each material, under the same synthetic water prepared in the lab with concentration of ≈ (5 gm/L) as a simulation to brackish water.

Working hours of the system determined to be 1.5 hours ; to produce 3L with rate of filtration (1.74 $L/min/m^2$) ,moreover the best application was for the (geo-textile sandwich) material specially when (8 layers) of material used in removal ratio , workability ,and durability.

Experimental work revealed success of tested materials in desalination process with promising removal efficiency, but need more work to improve system workability in order to reduce the amount of washing water between cycles.

## KEY WORDS

Low cost materials, Local materials, Sustainable techniques, Desalination, Brackish water, Treatment, Brine wastewater, Dissolved salts.

## 1. INTRODUCTION

Fresh water resources reduction comparing to human needs increase out of activities such as: (domestic, industrial, agricultural, and construction), Moreover fresh water resources pollution out of variable elements that difficult its direct use, were all motivations to find alternative resources to get fresh, drinkable water with low (cost, energy consumption, and environmental risks).

Spread shed of saline water that extends to about 97% of world water resources in different forms (seas, oceans, lakes, etc.); inspired people to find ways of how to desalinate this form of water into fresh water.

High cost and environmental risks resulted out of desalination technologies used; inspired researchers to improve techniques that made capacities of desalination plants can afford cities with their water demand, with low energy consumption, and less chemical substances usage.

This study tested low cost materials ability to remove salts from water with low energy consumption, and with low amount of produced waste.

## 2. LITRATURE REVIEW

Salinity is the total concentration of all dissolved salts in water, as water can be defined as “brackish water” when the inorganic salt contents reaches between (2000 mg/L) and (15000 mg/L), “saline water” is the term of water salt content reach above (15000 mg/L), and “high saline water” is the form of saline water which salts concentration reaches above (35000 mg/L). Major sources of saline water are: sea water, Agricultural irrigation runoff that produce dissolved salts like: (nitrogen, active phosphate phosphorus, organics, and sodium chloride), and Industrial effluents such as the (aquaculture in coastal areas, the nuclear industry, agriculture and food-processing, petroleum and natural gas extraction, mining currieries, pharmaceuticals, and leather manufacturing industrial) **[1]**.

Brackish water is a potential fresh water resource with lower salt content than seawater. Underground brackish water is relatively abundant, occupying more than half of the total groundwater storage. **[2]**

The treatment methods and technologies of saline water are mainly divided into physical, chemical, biological, and a combination of these technologies, while Physical and chemical technologies are widely used in high-salinity wastewater treatment, primarily including evaporation, membrane techniques, such as (RO and Nano-filtration (NF), ion exchange, advanced oxidation processes and electrochemical techniques) However, physical and chemical techniques are associated with some disadvantages, such as high operational costs and difficulty in achieving the expected treatment results , on the other hand the biological treatment technologies have the advantages of low operational cost, obvious treatment effect and no secondary pollution **[1]**.

Thermal technologies utilized for desalination are based on evaporation (mechanically or naturally) and crystallization, it depends on separation of one component from others presents in the liquid phase and carried out by creating a new phase ,this technology developed into forms such as: **[3]**.

Thermal technologies include: Multi stage flash distillation (MSF), Multi effect-evaporation (MED), Multi- effect distillation (MFT), and Vapour compression distillation (VC).

Membrane technology consists of several processes, but the major difference between them is the ion size, process depends on passage allowance through membranes, it divided into reverse osmosis, electro dialysis, and membrane distillation.

Membrane techniques in forms such as: Nano-filtration, ultra-filtration, microfiltration and filtration mainly used in the pre-treatment stages of desalination in order to remove large particles, bacteria, ions and for water softening **[3]**.

Freezing process is a physical successful method where the dissolved salts present in the inlet water are excluded during the ice forming, technique depends on washing the ice crystals formed before the total freezing in order to remove salts that present into the or cover the ice particles, then de-ice the crystals to get fresh water. **[4]**.

Ion exchange process is an effective chemical technology used for water desalination using charged materials which have the ability to exchange one type of cation (or anion) immobilized on the solid surface for another type of cation (or anion) present in solution. Same as the behaviour of sodium chloride solution that has the capability to accept and release ions, resulting in the complete 'demineralization' of a (NaCl) solution. This process can be reversed by regenerating the cation exchanger with an acid, and the anion exchanger with a base **[4]**.

Biological desalination process is also new technique that remain under research, but with very promising results reach to (95%) in removal ratio and excess sludge reduction.

Algae used in this process to produce different purposes fresh water especially in industrial saline wastewater desalination, also for sea water desalination with low cost demands, easy operation, and friendly for environmental concern. **[5]**

The Middle East and North Africa are currently equipped with 4826 plants, with an installed capacity equal to ($45.32 \times 10^6$ $m^3$/day ) by (47.5% of the world's installed capacity) [4*].

It is noticed that the increase of desalination plants in Egypt, where the produced water amount turned into (150,000 m3/year). Most of the plants work on seawater, but an increase of installed plants number use brackish water as raw water by water capacity of the small with ranges between 500 and 10,000 $m^3$/d. **[6]**

Bentonite pores structure and material hydraulic properties it is used as water proofing material and for groundwater protection. In order to work as barrier to keep surroundings away from geo-chemical damage. **[7]**

Studies revealed that salt solutions decrease the swelling ability of bentonite to develop, As series of experiments have been made with different simulation situations to determine the reaction of bentonite on swelling field using real ground-water with different ranges of salinity levels picked from different depths and locations, Results came in the same way every time that swelling ability of bentonite decrease when using saline water. **[8]**

## 3. MATERIALS AND METHODS

The study target was to minimize cost of total desalination operation by applying different low cost materials, materials tested with lab scale pilot consisted of three PVC units supported with water and air valves for inlets and outlets of each unit as shown in figure (2).

Decision was taken to use combined materials as sandwich panel technique resulted on the experimental works on each material separated test on removal efficiency impact.

Each sandwich panel layer consisted of local textile (cotton, mixed textile, and geo-textile) sewed and filled with bentonite with depth of (4 centimeters) and diameter equal to the circular diameter of the unit as illustrated in figure (1), in order to estimate the ability of the used material to desalinate water.

**Figure (1) Bentonite, Cotton-textile, Geo-textile, and Mixed-textile**

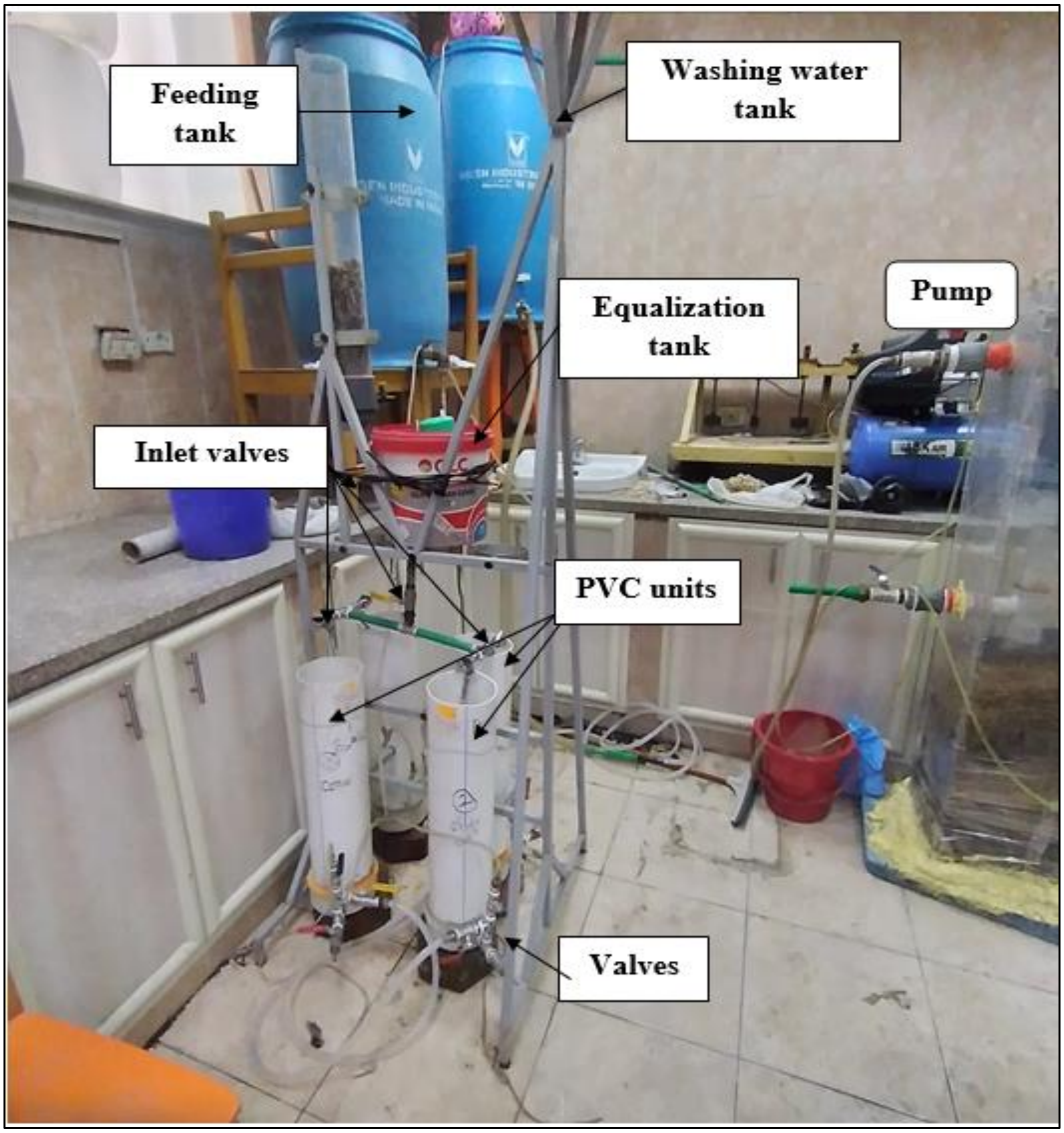


**Figure (2) Pilot**

## 3.1. ESPIREMENTAL WORK

Expiremantal work and measurements were made at sanitary engineering lab at faculty of engineering, Ain Shams University under the same synthetic saline water prepared to be a simulation of brackish water.

The main purpose of this experiment is to check (stability, suitability, workability, and durability) of each material used; that worked as filter media.

Experimental work made in three runs as shown:

### 3.1.1. Run I Experimental Work:

Unit's media content:

a. Unit (1) media consisted of (1 layer) of geo-textile case filled with (4 centimeters) of powdered bentonite.
b. Unit (2) media consisted of (1 layer) of mixed artificial and natural textile case filled with (4 centimeters) of powdered bentonite.
c. Unit (3) media consisted of (1layer) of cotton textile case filled with (4 centimeters) of powdered bentonite.

Steps of the run:

a. Fill each unit with different media as mentioned.
b. Mix tap water with dissolved table salt with concentration of ≈ (5mg/L) to simulate brackish water.
c. Adjust the inflow and outflow to be equal to 2 L/hour.
d. Measure the salinity content of the outflow effluent.

### 3.1.2. Run II Experimental Work:

Unit's media content:

a. Unit (1) media consisted of (4 layers) of geo-textile case filled with (4 centimeters) of powdered bentonite.
b. Unit (2) media consisted of (4 layers) of mixed artificial and natural textile case filled with (4 centimeters) of powdered bentonite.
c. Unit (3) media consisted of (4 layers) of cotton textile case filled with (4 centimeters) of powdered bentonite.

Steps of the run:

a. Fill each unit with different media as described.
b. Mix tap water with dissolved table salt with concentration of ≈ (5mg/L) as a simulation of brackish water as the first run procedure.
c. Adjust the inflow and outflow to be equal to (2 L/hour).
d. Wash media with compressed air for a minute through the air valve at the bottom of every unit the open the inflow washing water valve till the unit is completely filled with water.
e. Measure the salinity content of the outflow samples.

### 3.1.3. Run III Experimental Work:

In this run (8 layers) will be used with the concept of using double layers used in second run, also to raise the number of cycles to study the relation between cycles of media and durability of each media.

Steps of the run:

a. Fill each unit with 8 layers of textile (cotton – geo-textile – mix of natural and artificial textile) case filled with (4centimeters) of powdered bentonite.
b. Mix tap water with dissolved table salt with concentration of ≈ (5mg/L) as a simulation of brackish water as the first run procedure.
c. Adjust the inflow and outflow to be equal to (2 L/hour).
d. Wash media with compressed air for a minute through the air valve at the bottom of every unit the open the inflow washing water valve till the unit is completely filled with water.
e. Measure the salinity content of the outflow samples.

Notice that all measurements were made with salinity meter shown in figure (3).


**Figure (3) Salinity meter [9]**

## 4. RESULTS AND DISCUSSIONS

Run I applied (1 layer) of the three sandwich textiles each in a different column under the same raw, synthetic, saline water prepared in the lab with concentration of (4.69 ppt) for (5 working days) 8 working hours each; in order to check stability, and suitability for desalination process.

The following tables (1), (2), and (3) show effluent salts concentration and removal ratios as well for the three different materials used.

**Table (1) Geo-textile salts concentration and removal ratio for run I**

| DAY 1 | | | |
|---|---|---|---|
| Influent concentration is (4.69 ppt) | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 2.6 ppt | 44.56 % |
| | 1.0 | 3.15 ppt | 32.84 % |
| | 1.5 | 4.56 ppt | 2.77 % |
| | 2.0 | 4.71 ppt | -0.43 % |
| DAY 2 | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 5.17 ppt | -10.23% |
| | 4.0 | 5.15 ppt | -9.81% |
| | 8.0 | 5.38 ppt | -14.71% |
| DAY 3 | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 5.22 ppt | -11.30% |
| | 8.0 | 5.12 ppt | -9.17% |

| DAY 4 | | | |
|---|---|---|---|
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 5.14 ppt | -9.59% |
| | 8.0 | 5.22 ppt | -11.30% |
| DAY 5 | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 5.19 ppt | -10.66% |
| | 8.0 | 5.31 ppt | -13.22% |

**Table (2) Mixed-textile salts concentration and removal ratio for run I**

| DAY 1 | | | |
|---|---|---|---|
| Influent concentration is (4.69 ppt) | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 3.51 ppt | 25.16 % |
| | 1.0 | 4.18 ppt | 10.87 % |
| | 1.5 | 4.68 ppt | 0.21 % |
| | 2.0 | 4.7 ppt | -0.21 % |
| DAY 2 | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 4.97 ppt | -5.97% |
| | 4.0 | 5.15 ppt | -9.81% |
| | 8.0 | 5.29 ppt | -12.79% |
| DAY 3 | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 5.22 ppt | -12.58% |
| | 8.0 | 5.15 ppt | -10.66% |
| DAY 4 | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 5.27 ppt | -12.37% |
| | 8.0 | 5.22 ppt | -11.30% |
| DAY 5 | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 5.25 ppt | -11.94% |
| | 8.0 | 5.35 ppt | -14.07% |

**Table (3) Cotton-textile salts concentration and removal ratio for run I**

| DAY 1 | | | |
|---|---|---|---|
| Influent concentration is (4.69 ppt) | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 3.44 ppt | 26.65 % |
| | 1.0 | 4.12 ppt | 12.15 % |
| | 1.5 | 4.58 ppt | 2.35 % |
| | 2.0 | 4.62 ppt | 1.49 % |
| DAY 2 | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 5.13ppt | -9.38% |
| | 4.0 | 5.25 ppt | -9.81% |
| | 8.0 | 5.34ppt | -12.79% |
| DAY 3 | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 5.22 ppt | -12.58% |
| | 8.0 | 5.15 ppt | -10.66% |
| DAY 4 | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 5.21 ppt | -11.09% |
| | 8.0 | 5.19 ppt | -10.66% |
| DAY 5 | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 5.30 ppt | -13.01% |
| | 8.0 | 5.36ppt | -14.29% |

Comparing result of first run on the three types of textiles showed that the removal efficiency decreased by time, beside that as time flow the media became saturated with salts that removed by the first hour that was very clear in removal ratio results in run tables (1), (2) ,and (3) when the percentages came out in negative values, as a result of salinity level that exceeded the salinity index of the influent then the media needed to be washed or replaced.

From results of the first run it was revealed that the most efficient material was "geo-textile" material that achieved (44.56%) of removal in the first half an hour comparing to the removal ratios of mixed textile and cotton which was (25.16%) and (26.65%) respectively; made geo-textile the most efficient material used.

Here after in tables (4), (5), and (6) results of run II illustrated when (4 layers) of the tested materials used in (2 cycles) of loading:

**Table (4) Geo-textile salts concentration and removal ratio for run II**

| Influent concentration is (4.78 ppt) | | | |
|---|---|---|---|
| Cycle 1 | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 0.929 ppt | 80.56 % |
| | 1.0 | 2.55 ppt | 46.65 % |
| | 1.5 | 3.68 ppt | 23.01 % |
| Cycle 2 | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 0.912 ppt | 80.92 % |
| | 1.0 | 2.59 ppt | 45.82 % |
| | 1.5 | 3.6 ppt | 24.6 % |

**Table (5) Mixed-textile salts concentration and removal ratio for run II**

| Influent concentration is (4.78 ppt) | | | |
|---|---|---|---|
| Cycle 1 | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 0.752 ppt | 84.27 % |
| | 1.0 | 2.36 ppt | 50.63 % |
| | 1.5 | 3.6 ppt | 24.69 % |
| Cycle 2 | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 0.968 ppt | 79.75 % |
| | 1.0 | 3 ppt | 37.24 % |
| | 1.5 | 4 ppt | 16.32 % |

**Table (6) Cotton-textile salts concentration and removal ratio for run II**

| Influent concentration is (4.78 ppt) | | | |
|---|---|---|---|
| Cycle 1 | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 0.869 ppt | 81.82 % |
| | 1.0 | 3 ppt | 37.24 % |
| | 1.5 | 3.4 ppt | 28.87 % |
| Cycle 2 | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 0.983 ppt | 79.44 % |
| | 1.0 | 3.15 ppt | 34.10 % |
| | 1.5 | 4.12 ppt | 13.81 % |

Results of the second run also approved that the removal ratio increased by applying (4 layers) as an effect of increasing the removing surface area that followed by adsorption and filtration action upgrade.

Efficiency reached (80.56%) for geo-textile discs, (84.27%) for mixed textile discs, and (81.82%) for cotton discs in the first 0.5 an hour with incensement by (55%) comparing to (1 layer) used of each media.

In the first hour results analysis showed that removal ratio of geo-textile discs reached (46.65%) ,however the efficiency of removal for mixed textile layers was (50.63%) , and for cotton discs it was (37.24%) ,For 1.5 hours results percentages came as (23.01%), (24.69%), (28.87%) for geo-textile, mixed textile, and cotton textile sandwich panels respectively.

After washing medias with (6.18 L) of tap water for about 3 min. and apply the technique of cyclic load the results were nearly the same with very small variations for geo-textile disc which were not the same happened for cotton and mixed textile layers which resulted huge differences in results for example in the first hour after one cycle removal ratio of mixed textile media has break down by (13.39%).

Tables (7), (8), and (9) show results of run III when (8 layers) of the tested materials used in (3 cycles) of loading:

**Table (7) Geo-textile salts concentration and removal ratio for run III**

| Influent concentration is (4.80 ppt) | | | |
|---|---|---|---|
| Cycle 1 | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 0.92 ppt | 80.83 % |
| | 1.0 | 2.44 ppt | 49.17 % |
| | 1.5 | 3.55 ppt | 26.04 % |
| Cycle 2 | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 0.96 ppt | 80.00 % |
| | 1.0 | 2.5 ppt | 47.92 % |
| | 1.5 | 3.6 ppt | 25.00 % |
| Cycle 3 | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 1.03 ppt | 78.54 % |
| | 1.0 | 2.83 ppt | 41.0 % |
| | 1.5 | 3.75 ppt | 21.88 % |

**Table (8) Mixed-textile salts concentration and removal ratio for run III**

| Influent concentration is (4.80 ppt) | | | |
|---|---|---|---|
| Cycle 1 | | | |
| Efflue nt | Time consumed (hrs) | concentration | Removal ratio |

| | | | |
|---|---|---|---|
| | 0.5 | 0.543 ppt | 88.69 % |
| | 1.0 | 1.99 ppt | 58.54 % |
| | 1.5 | 3.3 ppt | 31.25 % |
| Cycle 2 | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 0.992 ppt | 79.3 % |
| | 1.0 | 2.89 ppt | 39.7 % |
| | 1.5 | 3.9 ppt | 18.75 % |
| Cycle 3 | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 2.9 ppt | 39.58 % |
| | 1.0 | 4.38 ppt | 8.75 % |
| | 1.5 | 4.52 ppt | 5.83 % |

**Table (9) Cotton-textile salts concentration and removal ratio for run III**

| Influent concentration is (4.80 ppt) | | | |
|---|---|---|---|
| Cycle 1 | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 0.62 ppt | 87.08 % |
| | 1.0 | 2.74 ppt | 42.92 % |
| | 1.5 | 3.05 ppt | 36.46 % |
| Cycle 2 | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 1.26 ppt | 73.75 % |
| | 1.0 | 3 ppt | 37.50 % |
| | 1.5 | 3.96 ppt | 17.50 % |
| Cycle 3 | | | |
| Effluent | Time consumed (hrs) | concentration | Removal ratio |
| | 0.5 | 2.7 ppt | 43.75 % |
| | 1.0 | 4.55 ppt | 5.21 % |
| | 1.5 | 4.62 ppt | 3.75 % |

As the result of third run it divided into three cycles: First cycle results showed a little increase in removal ratio but when it came to the second and the third cycle it gave an indication in durability of each material which made the geo-textile material the most efficient media in the experiment situations

From results illustrated in the past charts, it was very clear that the best material in workability and durability within washing cycles was (geo-textile sandwich panel) in the situations of the experiment.

## 4. CONCLUSION

From the results and discussions of the experiment; conclusion can be presented in the following points:

- The promising removal ratio results of the first 0.5 hour when using (1 layer) of sandwich panel media extended to be 1.5 efficient working hours when using up to (4 layers) in the second and third runs.
- The most effective material was geo-textile sandwich panel layers comparing workability and durability parameters with removal ratio reached (80.83%) in the first 0.5 hour, (49.17%) for the first an hour, and (26.04%) for 1.5 working hours.
- Optimum system working hours was 1.5 hours.
- The effective bentonite layer depth was 4 cm each; in order to avoid pores clogging.
- The produced amount of desalinated water every 1.5 working hours was (3.0 L) with (1.74 L/min/$m^2$) rate of filtration.
- System results was promising, but need improvement about the resulted amount of water comparing to the washing water needed in back wash process.

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