Onshore Subsurface Infiltration Galleries Intake for Reverse Osmosis Desalination Plants: A laboratory Scale Investigation

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Abstract

Intake facility is an important system for seawater desalination plant, quantity and quality of the feed water is greatly dependent upon the type of intake. The proper intake system is the first stage of pretreatment process. Infiltration galleries is based on the concept of slow sand filtration where water passes through a filter bed consisting of deferent layers of gravel and sand to a collecting perforated pipes underneath, these galleries are installed on the beach within the intertidal zone of the beach. For this study different combination of bed depths using four different materials with different grain sizes tested at different water heads which are support gravel(G1) with an average diameter of 10mm, engineered gravel(G2) the average diameter 1.81 mm, Engineered sand (ES) the average diameter 0.74 mm and sea sand (SS) the average diameter 0.32 mm. Results revealed that G1 which characterized by large average diameter, high porosity and shape factor have the lowest impact on water flow and head loss while the last layer of SS have the highest impact on water flow and head loss. The effect of water head is minor. The influence of different bed depths for different media materials was investigated; Particle diameter has the main influence on head loss. Several experiments has been carried out using different combinations of bed depths of the used materials, each was constructed and studied separately to quantify a proper filtration rate. Filtration rate is linearly proportional to water head and Sea sand has the highest head loss among the used materials and any depth of the sea sand more than 20Cm has almost the same head loss and reduces the filtration rate.

Keywords: Seawater reverse osmosis, Intake, beach galleries

Introduction

Libya has very poor water resources. Desalination is the only alternative lift to provide high quality water for municipal and industrial uses. To overcome the deficit in quality and quantity of water, an alternative measure for sustainable development had taken since 1975 by the general electric company of Libya (GECOL) through installing a series of desalination plants along the coast [1], with the increasing demand for water the need for larger desalination plants is increased and consequently huge intake facilities are needed. Now days the reverse osmosis desalination technology is dominating the market, and the need for good pretreatment systems is required. Desalination plant reliability depend on seawater intakes that is capable of providing enough quantity of clean seawater with a minimum ecological impact [2]. On the Libyan coast line there is an extensive growth and accumulation of sea weed   Conventional open channel seawater intakes cause many negative impacts on marine life such as entrainment of marine microorganisms and impingement with screens [3]. Offshore pipe type of intakes is more expensive and have also some environmental impacts such as chemicals used to keep the pipe free of organic growth. Subsurface intake systems are the solution it has no environmental impacts on marine life, it delivers filtered seawater where suspended solids and organic matter are reduced [4].

Subsurface intake yields good quality feed water especially for Reverse Osmosis plants (RO) and it has a positive economic effect on the side of plant operation and maintenance. Subsurface intake can be used only if the geological structure of the site is suitable, where the structure is impermeable to support water extraction [5]. Natural filtration through beach sand reduces bio and organic fouling for RO plants, a column test where carried out and show good results in reducing hydrophilic neutral substances relevant to membrane fouling [6]. Beach galleries system is a kind of slow sand filters installed on the beach within the intertidal zone of the beach and it has the advantage of self-cleaning, the sea waves are working as cleaner swabbing the upper layer of sea sand so it is maintenance free [7]. This system is a modular design where the capacity can be increased by constructing additional galleries. There for reducing the need for physical cleaning and reducing the amount of used chemicals in a desalination plant by feeding higher quality sea water, leads to lower cost of desalted water. Considering the sandy beaches along the Libyan seashore, the subsurface infiltration (beach galleries) can fulfill the target of the ideal intake for small and medium size desalination plants with the advantages of ease of construction and no special submarine machinery are required, non-expensive PVC pipes can be used and low maintenance costs. In this paper an experimental study was performed to measure the infiltration rate and pressure drop through multi-layer of gravel and sand to study the best combination and depth.

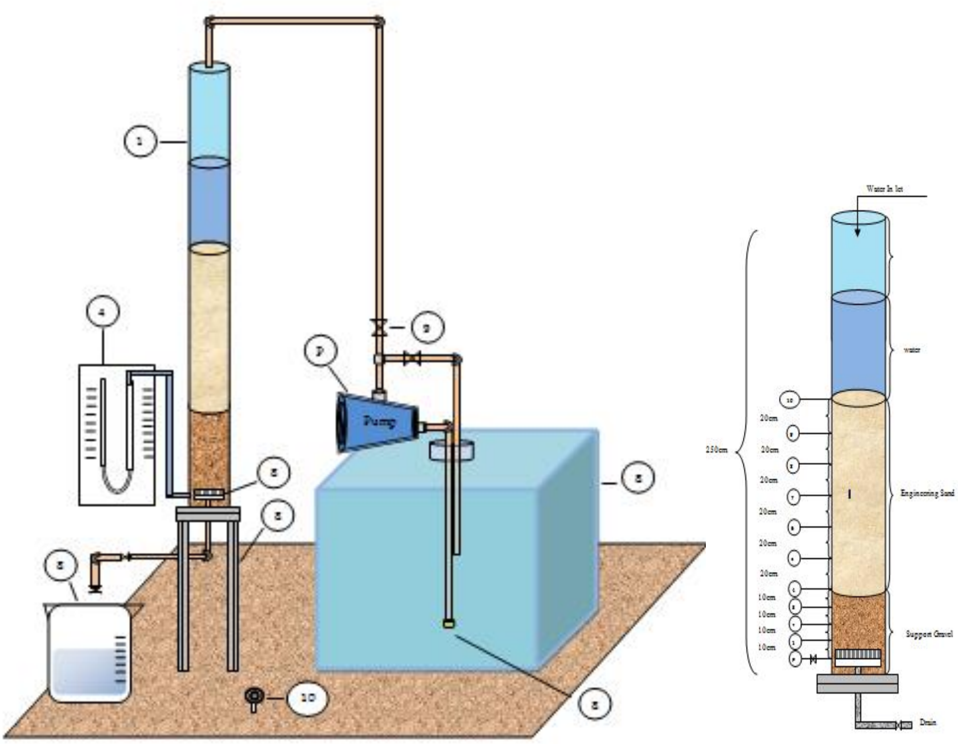
Materials and methods

Using local and available materials a test rig was designed and assembled at Tajoura RO

Desalination plant, the rig takes in account the maximum depth of the collection pipes in the real situation. The rig was operated under the influence of different water heads for each set of filtration materials (beach sand, engineered sand, engineered gravel and commercial gravel). The main objective is to observe and understand the mechanics of filtration, obtaining data of flow rates and head loose through different filtration material layers. A transparent pipe of 10 cm diameter and 2.5 m long was used to support the filtration Column. The used layers are support gravel (G1) with an average diameter of 10mm, engineered gravel(G2) the average diameter 1.81 mm, Engineered sand (ES) the average diameter 0.74 mm and sea sand (SS) the average diameter 0.32 mm, the raw feed water enters at the top of the column and kept at a constant level.

The test rig was assembled as shown in figure (1), so that a continuous flow of feed water is maintained and the flow rate is controlled to keep the required water level above the sand filtrate was collected through slotted T shape collection pipe as shown in figure 2. Measurements of head loose and flow rate are carried out at steady state of water head for each combination of filtration layers using a manometer as shown in figure 3.

Data of filtering material parameters concerning porosity and grain diameters are provided through conducting the required tests such as sieve analysis and porosity measurements.



1- Filtration column 2- Feed water tank 3- pump 4- Mercury manometer 5- Collection pipe(T-shape)
6- Stand 7- Measuring beaker 8- Non return valve 9- Gate Valve 10- stop watch

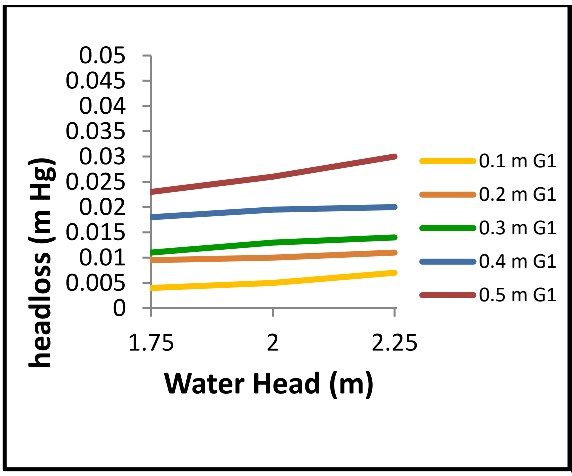
Figure 1: Rig Schematic

Figure 2: collection pipe **figure 3: Multi-layer filtration column**

Results and discussion

The influence of different bed depths for different media materials was investigated closely and its variation are recorded. The experiments were done in such a way that at each run the bed depth of the media is fixed while the water level (water head) is varied in a decreasing manner. Time interval during collecting filtrate is kept the same at each attempted run. Filtration rates and head loss were measured for deferent Water Heads of started from 125 to 225 cm according to filtration column depth. Particle diameter has the main influence on head loss. For small diameter particles, higher values of head loss are recorded. Experimental head loss shows a direct linear proportional trend to water head and depth of material, and inversely proportional to particle size. Each material was studied separately, results revealed that supporting gravel G1 is characterized by large average diameter, high porosity and shape factor therefore low resistance impact to water flow is observed as shown in figure 4, while the engineered gravel G2 which taken to be a sporting layer to control the entrainment of smaller particles of the upper layer results showed that variation on head loss were small enough for bed depths below 30cm as given in figure 5. For the third material the engineered sand ES show high head loss values for bed depths higher than 30 Cm as shown in figure 6. This layer is the support for the last layer of sea sand SS. Figure 7 show that any depth of the sea sand more than 20Cm has almost the same head loss.

Several experiments has been carried out using different combinations of bed depths of the used materials, each was constructed and studied separately to quantify a proper filtration rate. Figures 8 to 10 shows the effect of different combinations and different depths of each material the trend is similar and filtration rate was decreasing with increase of bed depth.



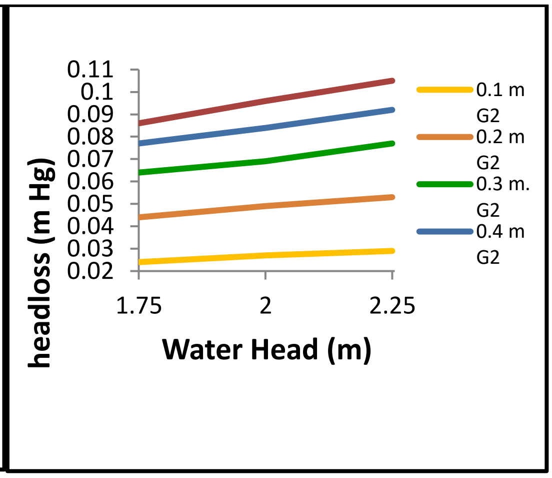
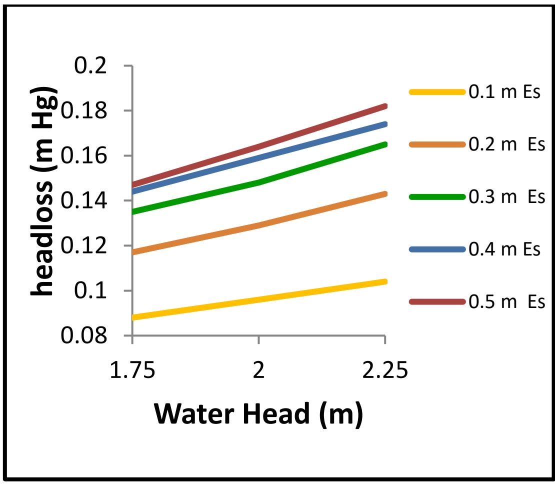


Figure 4: Head loss of G1 Vs water head

Figure 5: Head loss of G2 Vs water head



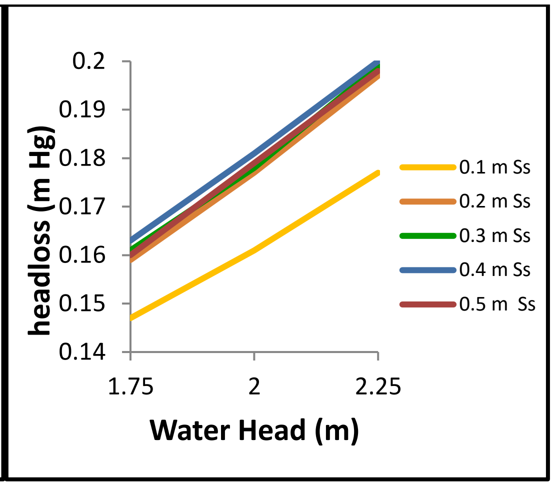
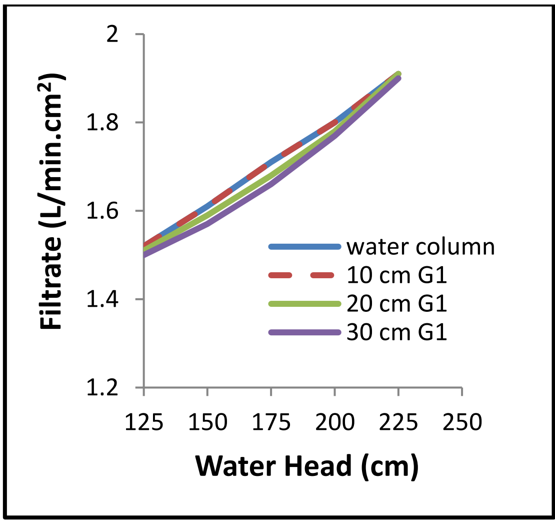


Figure 6: Head loss of ES Vs water head **Figure 7: Head loss of SS Vs water head**

Figure 11show a combinations of the materials under study where the first three layers of material are 30cm G1, 30cm G2, and 40cm ES, where the fourth one is the Sea sand with four different depths 20,40,60 and 80Cm, all runs are carried out to choose the most appropriate combination of materials depths that justifies both enough filtrate with good quality of filtrate in order to satisfy the required condition of feed water to reverse osmosis RO plants. As illustrated in figure 11, it can be noted that the thickness of sea sand (SS) layer have a very big impact on filtration rate as the depth of sea sand layer increased. This experiment was conducted to study the effect of sea sand layer thickness, due to the possibility of change of sea sand layer thickness due to tides and from season to season .



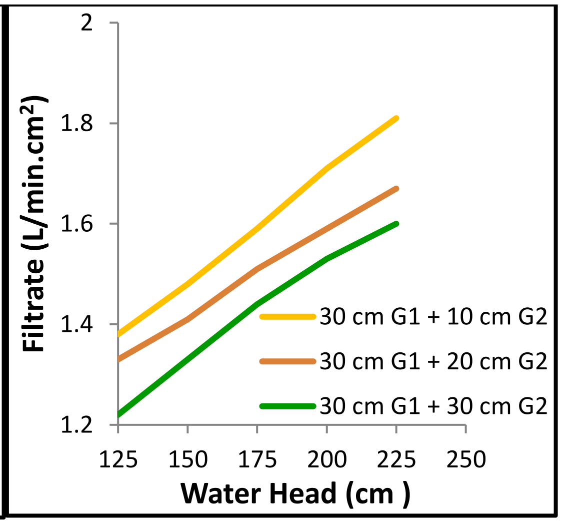


Figure 8: Filtration rate versus water head (G1) **Figure 9: Filtration rate versus water head (G1+G2)**

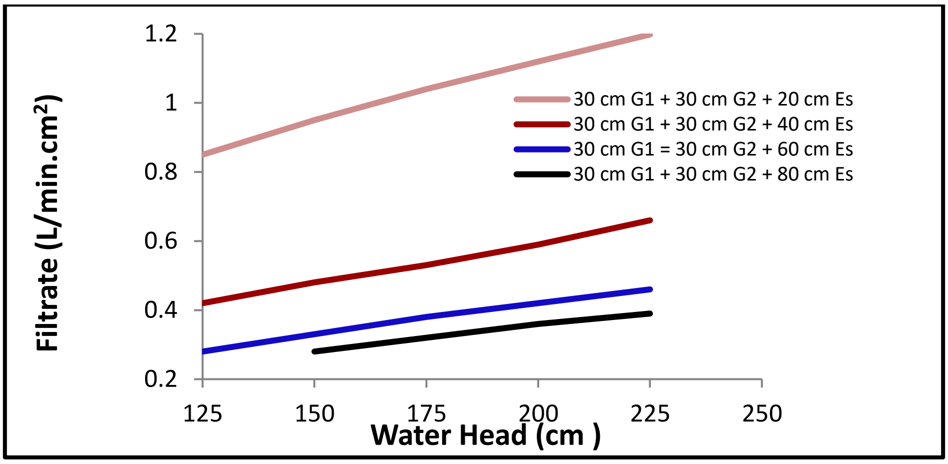


Figure 10: Filtration rate versus water head for (G1+G2+Es)

Considering the minimum amount of filtrate of 0.1 liter per minute for each square centimeter (slots area) of the collection pipe which accounts for 1440 m^3/day m^2, this amount is good enough, beach galleries design is scalable based on the required capacity of Reverse Osmosis desalination plants.

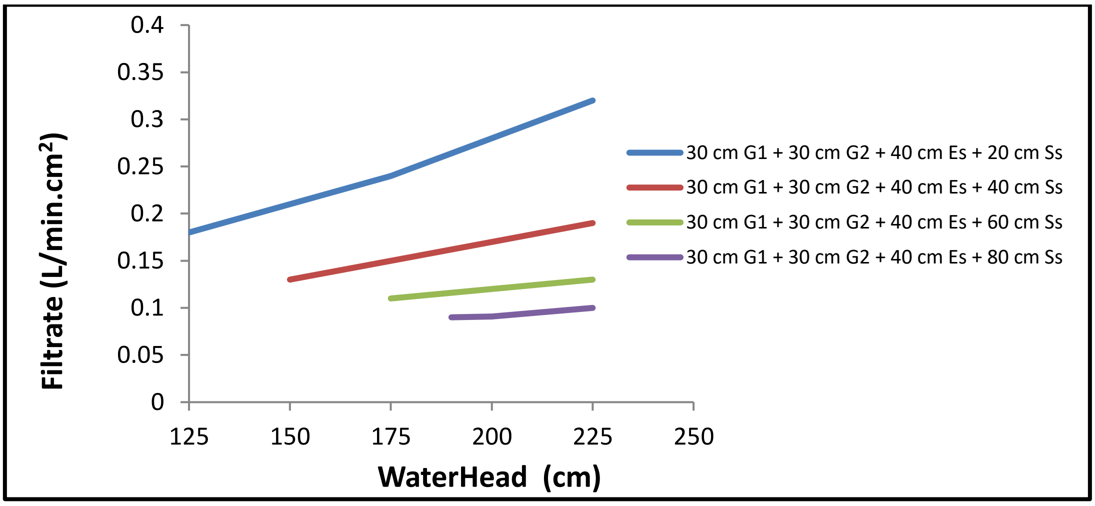


Figure 11: Filtration rate verses water head of Different Ss depths

Conclusion

In this study, a laboratory scale filtration column was constructed to investigate the infiltration galleries for sea water intake system, different bed materials were introduced at different depths. Based on obtained results it can be concluded that filtration rate is linearly proportional to water head and sea sand has the highest head loss as well as low filtration rate with the increase of sea sand layer depth the filtration rate decrease dramatically and any depth of the sea sand more than 20Cm has almost the same head loss, no entrainment of sand was observed due to proper supporting layers of gravel. Onshore Subsurface Infiltration Galleries Intake can supply enough feed for Reverse Osmosis desalination plants.

References

[1] S.A. Kershman, 25 years of experience in operating thermal desalination plants, Desalination 136 (2001) 141–145

[2] Thomas M. Missimer, Robert G. Maliva, Environmental issues in seawater reverse osmosis desalination: Intakes and outfalls, Desalination 434 (2018) 198-215

[3] Thomas Petersa and, Domènec Pintób, Seawater intake and pre-treatment/brine discharge — environmental issues , Desalination 221 (2008) 576–584

[4] T. Pankratz, A review of seawater intake, pretreatment and discharge technologies, in: Proceedings, of the International Desalination Association Seminar on Water Desalination Technologies, Tehran, November 19–20, 2006.

[5] Thomas M. Missimer et al, Subsurface intakes for seawater reverse osmosis facilities: Capacity limitation, water quality improvement, and economics., Desalination 322 (2013) 37–51

[6] Rico Bartak et al, Beach Sand Filtration as Pre-Treatment for RO Desalination, International Journal of Water Sciences.2012

[7] Thomas M. Missimer et al, Use of beach galleries as an intake for future seawater desalination facilities in Florida and globally similar areas, Desalination and Water Treatment, 52 (2014) 1–8