European Journal of Academic Essays 3 (1): 43-52, 2016
ISSN (online): 2183-1904
ISSN (print): 2183-3818
www.euroessays.org

A new technique of the Use of Saline Water in Irrigation Systems by Innovative Pottery Dripper

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Abstract: The pottery dripper dimensions are designed and Manufactured in three volumes (49, 31.4 and 16.5 cm^3), three nominal porosity (10 , 21 and 31%); then various types of pottery drippers (PD) are tested under three pressure heads (1, 0.75 and 0.5 bar) beside the statistical design is split split plots, and three concentrations of saline groundwater (6154, 7149 and 7154 ppm), from Ras-Sudr Research Station.
The main results of this study showed the following:
For porosity P_1 (10%) of pottery dripper, under operating pressure head 1 bar, the discharge ranged from 0.5 l/s to 1.14 l/s; under operating pressure head 0.75 bar, the discharge ranged from 0.5 l/s to 1.14 l/s; and under operating pressure head 0.5 bar, the discharge ranged from 0.2 l/s to 0.53 l/s. For porosity P_2 (21%) of pottery dripper, under operating pressure head 1 bar, the discharge ranged from 1.69 l/s to 4.11 l/s; under operating pressure head 0.75 bar, the discharge ranged from 1.14 l/s to 3.06 l/s; and under operating pressure head 0.5 bar, the discharge ranged from 0.58 l/s to 1.82 l/s. For porosity P_3 (31%) of PD, under operating pressure head 1 bar, the discharge ranged from 24.1/s to 37.7 l/s; under operating pressure head 0.75 bar, the discharge ranged from 16.8 l/s to 28.3 l/s; and under operating pressure head 0.5 bar, the discharge ranged from 9.5/s to 19.4 l/s. Saline water concentration decreased from 6154 ppm to 5840, 5806 and 5440ppm using the PD with porosity 10, 21 and 31% respectively. Saline water concentration decreased from 7149ppm to 7106, 7013 and 6979 ppm using the PD with porosity 10, 21 and 31%, respectively; and finally saline water concentration decreased from 7863 ppm to 7846, 7778 and 7285 ppm using the PD with porosity 10, 21 and 31 % respectively,

Keywords: Innovative Pottery-dripper, Saline-Water, Drip irrigation, Design, Flow, Pressure, Porosity.

1. Introduction

The Irrigation using the clay pitchers was spread in the history of irrigated agriculture, the The ancient Egyptians are used the pottery pitchers in the irrigation according to the founded archaeology which clear this ecological technology of irrigation in Al-Wadi Al-Jadid Governorate, beside there are many evidences of using the clay pitchers in irrigation in China, India, and Latin America. And now this technique is the most economic and suitable for the dry-land condition under the sacristy water to the good management of dry-land and desert water resources.

The pitchers technique could be successfully employed in places where salinity and alkalinity constitute a problem. Salt deposition in the wall of pitchers does not adversely affect the plant growth as the plants continue to draw water from the pitchers. There is a high degree of correlation between the rate of water diffusion through small pitchers and large pitchers. Use of small-sized pitchers was more beneficial both in terms of water saving and in economic terms when compared to large pitchers, **[1]**. The daily depletion (%) from buried pitchers has slightly decreased with time. Mean daily depletion (%) had also decreased with the increase in salinity of the salt water taken. Salt distribution in soil around the pitcher has increased with the increase in horizontal distance from the pitcher and decreased on moving vertically downwards. Salinity of residual water in pitchers has increased with time showing that these pitchers have the capability to retain water, **[2].** The water diffusion is more consistent with respect to the organic matter-mixed pottery samples rather than the sand-mixed ones. Uniform porosities of organic matter-mixed pottery discs, as evidenced by optical micrographs, further exemplify that. Pots/pottery sheets produced through this process can thus be used to control water release in pitcher irrigation of tree saplings. The pitcher irrigation and subsurface irrigation using clay pipes are concerned. It was proved that subsurface irrigation using clay pipes were particularly effective in improving yields, crop quality and water use efficiency as well as being cheap, simple and easy to use **[3 and 4]**.

All the same, in many parts of the world, plastic drip tubing and emitters are cost-prohibitive, and traditional methods such as clay pipe irrigation remain an important technique for irrigation and water saving. **[5]** Besides, the perforated or porous clay pipe irrigation classified as surface drip irrigation **[6 and 7]**

Pottery dripper was designed and manufactured to allow the use of saline water in irrigation systems. In Egypt, 2 to 3

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thousand million m^3 of saline water are used in the irrigation of about 405 000 ha of land. The main objectives of this study are: (1) inventing a new pottery dripper to reduce saline water concentration; (2) manufacture and evaluate an innovative pottery dripper.

Typical emitter flow rates are from 0.16 to 4.0 US gallons per hour (0.6 to16 L/h), These emitters employ silicone diaphragms or other means to allow them to maintain a near-constant flow over a range of pressures, for example from 10 to 50 psi (70 to 350 kPa). Emitter discharge rates for drip and subsurface irrigation are generally less than 12 liters per hour. Most emitters emit 4 liters/hour (4.0 l/hr) of water. That's about 1 gallon per hour (1 gph). **[8]**

Pottery dripper was designed and manufactured to allow the use of saline water in irrigation systems. In Egypt, 2 to 3 thousand million m^3 of saline water are used in the irrigation of about 405 000 ha of land. The main objectives of this study are: (1) inventing a new pottery dripper to reduce saline water concentration; (2) manufacture and evaluate a pottery dripper.

2. Material and Methods

Pottery dripper (PD) are designed and manufactured from local and environmental materials where the basic component of PD is pottery discs. It is made from various mixtures, porosity, and volumes. The mixtures contain organic matter (saw dust) by 10, 21 and 31% total mix weight. The basic element of mixes is Aswan clay. Pottery discs are used in designing poly-ethylene dripper to protect and service the pottery discs for basic aims (dripping and reducing the saline water concentration). There are two shapes of pottery dripper the first is small pottery pitcher which closed tightly using the rubber cover beside it have a tube connector of polyethylene to fix it in the irrigation lateral hose. Fig.1. While the second pottery is using the polyethylene components (connector, dripper body and rubbers) which protect the pottery media, the last prototype will be evaluated and will be under investigation in this study. The pottery media (discs) were washed by soaking To get rid of salts in pottery discs as a result of the used clay into pottery mixture

In addition to both of two pottery dripper is good to use in surface and subsurface drip irrigation systems. Fig. 1 and 2.

Pottery dripper dimensions are designed in three volumes and three porosity, then various types of pottery drippers are tested under three pressure heads (0.5, 0.75 and 1 bar) and three concentrations of saline groundwater (6154, 7149 and 7863 ppm).

Factor study:

1- Pottery discs porosity, according to organic matter (saw-dust) percentage in pottery mixture (5, 10, and 15% from mixture weight).
2- Pottery discs volumes, (49, 31.4 and 16.5 cm^3) and called (V_1, V_2 and V_3, discs of diameter 3.5, 2.8 and 2 cm, thickness 5 cm.
3- Operation head (0.5, 0.75 and 1 bar), and
4- Three different water concentrations will be used in pottery drippers test (6154, 7149 and 7149 ppm).

Measurements and calculation:

Hydraulic characteristics:

Evaluate pottery drippers flow performance under three operation heads (0.5, 0.75 and 1 bar) and called (H_1, H_2, h_3), where discharge is determined by receiving water application at graded container during a period of time according to **[9].** beside the statistical design is split split plots.

Hydraulic laboratory:

Laboratory experiments were conducted in the laboratory of

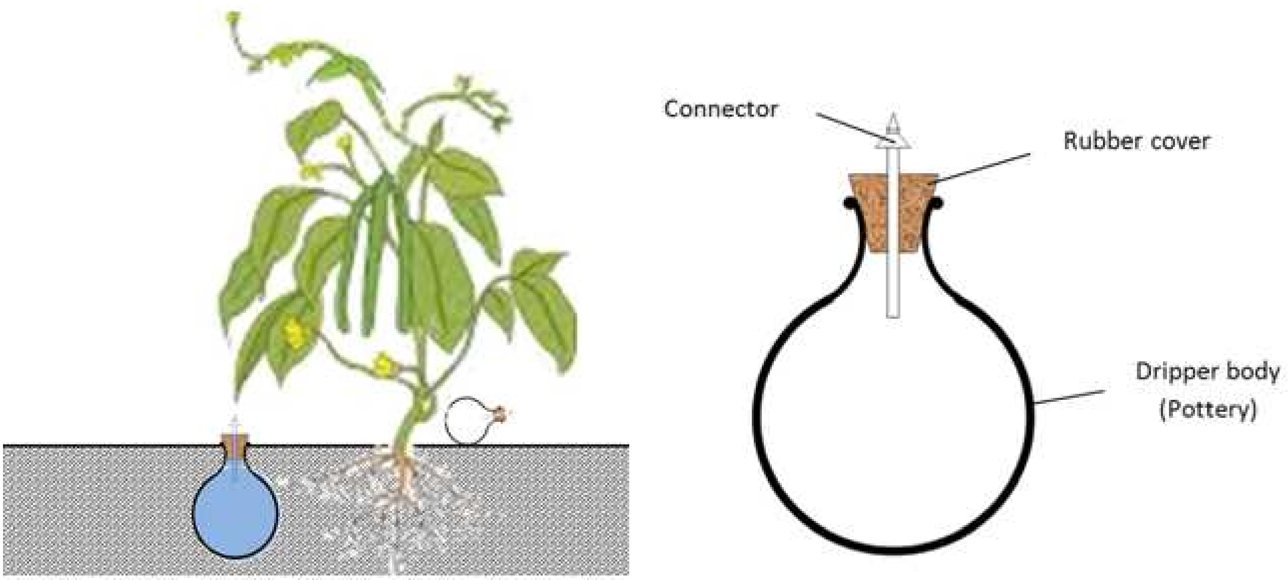

Figure 1: The design of pottery drippers to use the saline water in drip irrigation.

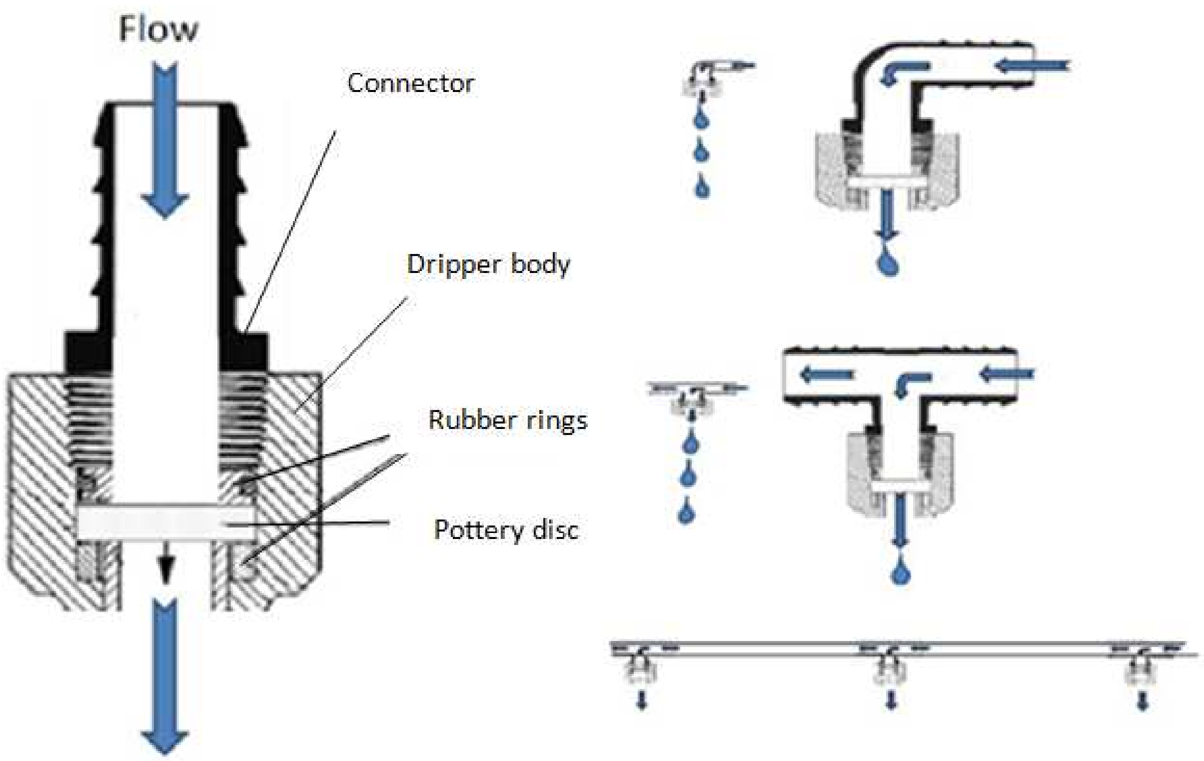

Figure 2: The design and proto-type of innovative pottery drippers to use the saline water in drip irrigation which under the invesgation.

Desert Research Center, to test and evaluate the hydraulic characteristics of pottery drippers (PD) with three disc diameters 3.5, 2.8 and 2 cm, thickness 5 cm. Testing under pressure head ranged between 5- 10 m.

- Experimental apparatus:

The laboratory testing equipment contained an electrical centrifugal pump 1inches /1.5 inches (25-56 m pressure head, 6.6 m3/h discharge, and 1.5kW power), pressure gauges (10cm smallest reading), Manometer, control valves, and water container. Fig. (3).

Hydraulic measurements include drippers discharge and operating pressure head, measurements for various types of designing nozzles were conducted. And received water salinity after pottery dripper was measured by EC Meter and so before pottery dripper.

Physical characteristics:

1- Take a photo of pottery disc surface by optical micrograph and scanning electron microscope (SEM).

2- Determine Water absorption (%), Bulk density (g/cm^3), Drying volumetric shrinkage factors (%), burning volumetric shrinkage factors (%), and Total volumetric shrinkage factors (%).

3- XRD analysis of three types of pottery mixture at X ray lab beside other measurements in National Center for Housing and Building Research, Egypt.

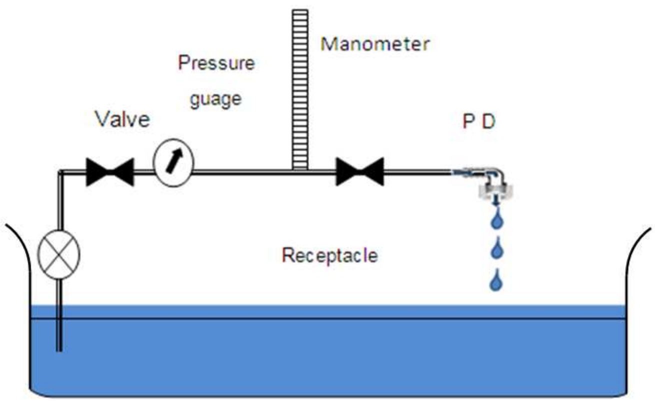

Figure 3: Lboratory apparatus constructed for pottery drippers (PD) expirments.

3. Results

Reducing water concentration versus pottery volume and porosity:

Data as shown in Table (1) clears that saline water concentration is reduced after using pottery drippers. Saline water with concentration C_1 (6154 ppm) is reduced to 5440 ppm. This indicates that the concentration has been reduced from 714 ppm due to the use of pottery with the smallest porosity percentage (10%). Thereupon, water concentration shall decline to 5806 ppm and 5806 and 5840 for pottery porosity 21 and 31 %, respectively.

This is the result of the big volume of pottery discs (49 cm_3). Volume 31.4 cm^3 for pottery discs reduces the water concentration, but not like the biggest volume 49 cm^3, where water concentration declines from 6154 ppm to 5678, 5678 and 5848 ppm for pottery porosity 10, 21 and 31 % respectively. However, the smallest volume of pottery discs (16.5 cm^3) is the least effective in reducing saline water concentration, where water concentration declines from 6154 ppm to 5780, 5831 and 5848 ppm by using pottery discs porosity 10, 21 and 31% respectively. These findings show that that the decline of saline water concentration is directly proportional to the volumes of pottery discs and inversely proportional to pottery porosity percentage, as shown in Fig.4.

Saline water with concentration C_2 (7149 ppm) is reduced to 6329ppm. This indicates that concentration shall be reduced about 650 ppm using pottery with the smallest porosity percentage (10%). Water concentration shall decline to 6363 and 6456 for pottery porosity 21 and 31 % respectively. This applies to the biggest volume of pottery discs (49 cm_3). Volume 31.4 cm^3 for pottery discs reduces the water concentration from 7149 ppm to 6337, 6422 and 6478 ppm for pottery porosity 10, 21 and 31 % respectively. However, the smallest volume of pottery discs (16.5 cm^3) is the least effective in reducing saline water concentration, where the water concentration has reduced from 7149 ppm to 6363, 6556 and 6494 ppm by using pottery discs porosity 10, 21 and 31% respectively. This clearly demonstrates that a reduction of saline water concentration is directly proportional to the volumes of pottery discs and inversely proportional to pottery porosity percentage, as shown in Fig.5.

Saline water with concentration C_3 (7863 ppm) is reduced to 7285 ppm. This indicates that concentration shall be reduced about 578 ppm for using pottery with the smallest porosity percentage (10%).

Thereupon, water concentration shall decline to 7778 and 7846 ppm for pottery porosity 21 and 31 % respectively. This applies to the biggest volume of pottery discs (49 cm_3). Volume 31.4 cm^3 for pottery discs reduces the water concentration from 7863 ppm to 7531, 7829 and 7850 ppm for pottery porosity 10, 21 and 31 % respectively. However, the smallest volume of pottery discs (16.5 cm^3) is the least effective in reducing saline water concentration, where the water concentration is reduced from 7863 ppm to 7616, 7846 and 7855 ppm by using pottery discs porosity 10, 21 and 31% respectively. This indicates that the reduction of saline water concentration is directly proportional to the volumes of pottery discs and inversely proportional to pottery porosity percentage, as shown in Fig.6.

Reduction of saline water concentration is attributed to adsorption of Na^+ on clay minerals found in pottery mixtures. Hence, increasing the clay minerals percentage in pottery mixture shall increase the ability of Na^+ adsorption. And this result agreed with **[3].**

Table 1: Effect of pottery discs volume and porosity on TDS.

C_3 (7863 ppm)				**C_2 (7149 ppm)**				**C_1 (6154 ppm)**			
P_3	**P_2**	**P_1**	**P / V**	**P_3**	**P_2**	**P_1**	**P / V**	**P_3**	**P_2**	**P_1**	**P / V**
7855	7846	7616	**V_1**	6494	6456	6363	**V_1**	5848	5831	5780	**V_1**
7850	7829	7531	**V_2**	6478	6422	6337	**V_2**	5848	5823	5678	**V_2**
7846	7778	7285	**V_3**	6456	6363	6329	**V_3**	5840	5806	5440	**V_3**

Where:

P: Porosity percentage (%), **V:** Pottery disc volume (cm^3), and
C: Saline water concentration (ppm).

Hydraulic characteristics of pottery drippers:

Pottery drippers for (10% pottery porosity and volume 49 cm^3) are tested under operating pressure heads 0.5, 0.75 and 1 bar. The flow rate has increased from 0.75, and 1.5 to 1.95 l/s. With respect to the pottery discs to volume 31.4 cm^3, the flow rate has increased from, 0.53, and 0.97 to 1.41 l/s. For the volume of pottery discs 16.5 cm^3, the flow rate has increased from, 0.39, and 0.755 to 1.12 l/s, Fig. 7.

The increase in the flow rate is associated with an increase in the flow area.The flow area is determined according to the rubber ring inside area, where the last flow rates are appropriate for drip irrigation systems.

Table 2: The impact of Pottery porosity, disc volumes and operating pressure head on drippers flow performance**.**

P	**V**	**H_1**	**H_2**	**H_3**
P_1	**V_1**	0.39i	0.76i	1.12i
	V_2	0.53h	0.97h	1.41h
	V_3	0.75gf	1.50gf	1.95g
Mean		**0.56**	**1.08**	**1.49**
P_2	**V_1**	0.79f	1.46f	2.13f
	V_2	0.99e	1.80e	2.51e
	V_3	1.34d	2.53d	3.72d
Mean		**1.04**	**1.93**	**2.79**
P_3	**V_1**	17.90c	27.40c	37.00c
	V_2	18.20b	27.90b	37.70b
	V_3	19.40a	28.30a	38.30a
Mean		**18.50**	**2.87**	**37.67**
LSD0.05		**0.09**	**0.07**	**0.21**

The Factors which are having the different letters are significantly different from one another.

Where:

P = Porosity percentage (%),
H= Operating head pressure (bar), and
V= Pottery disc volume (cm^3).

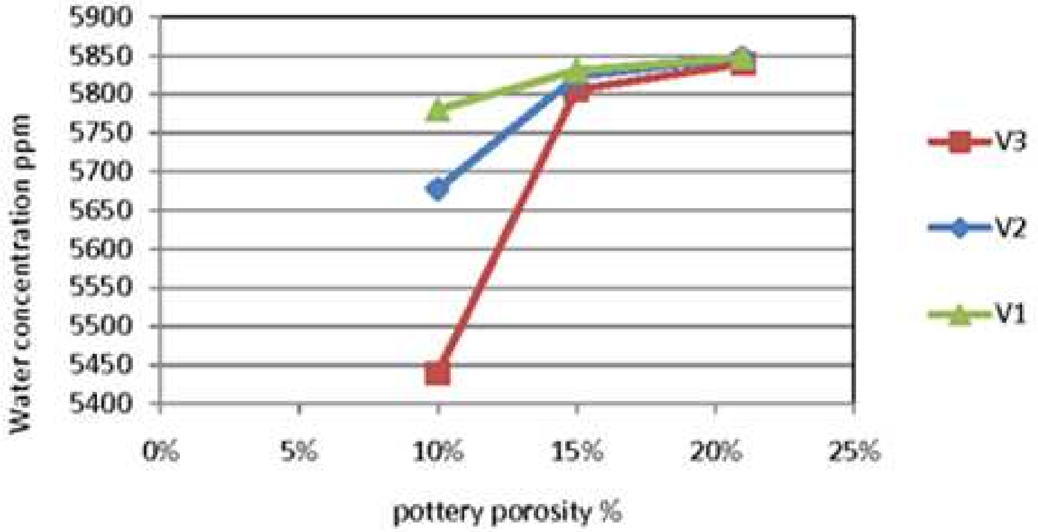

Figure 4: Effect of pottery dripper porosity of total dissolved salts (6154 ppm).

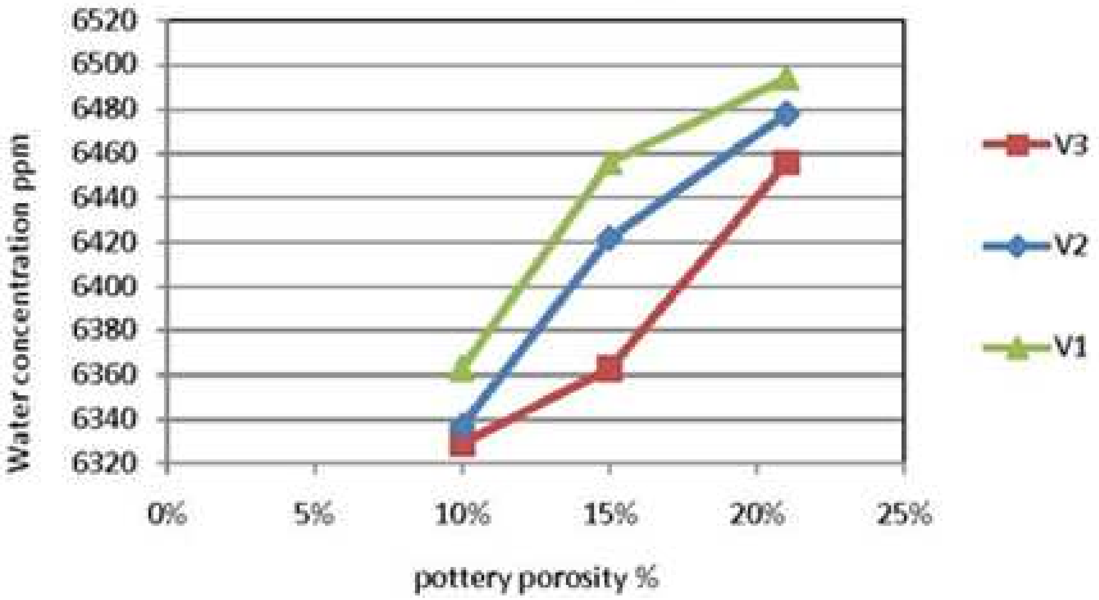

Figure 5: Effect of pottery dripper porosity of total dissolved salts (7863 ppm).

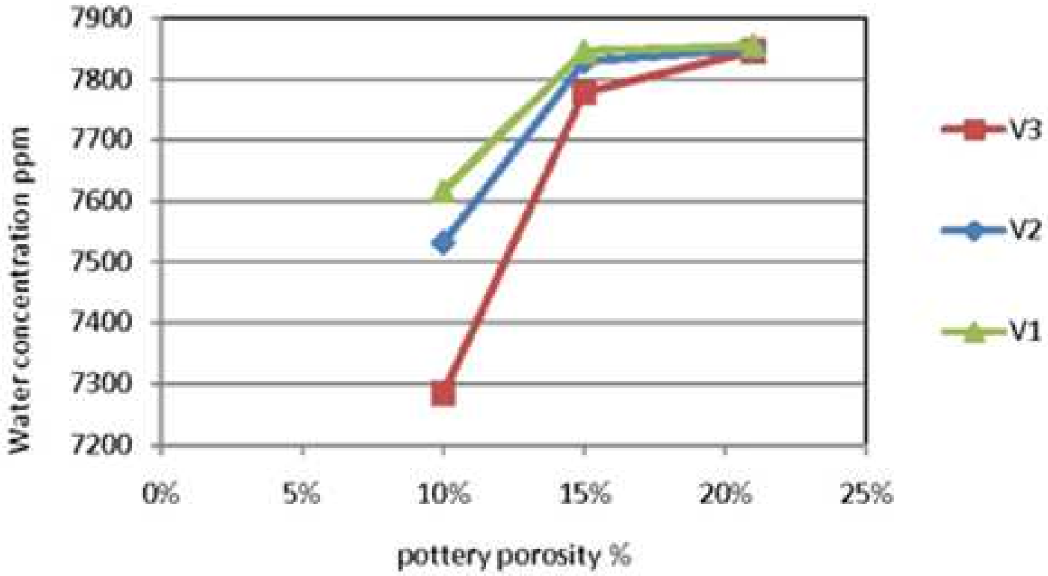

Figure 6: Effect of pottery dripper porosity of total dissolved salts (7149 ppm).

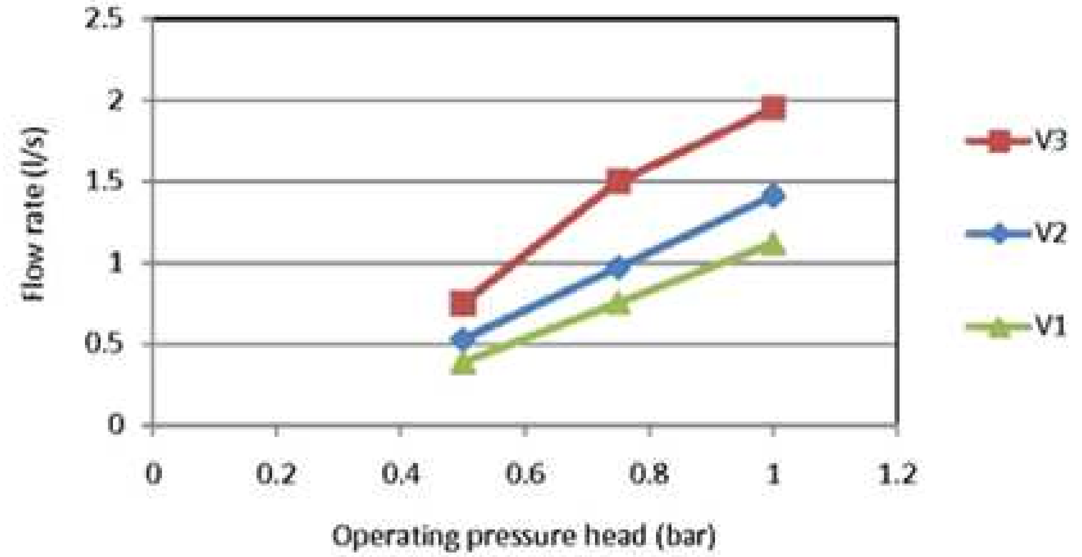

Figure 7: The effect of pressure head on pottery dripper flow rate (porosity 10 %).

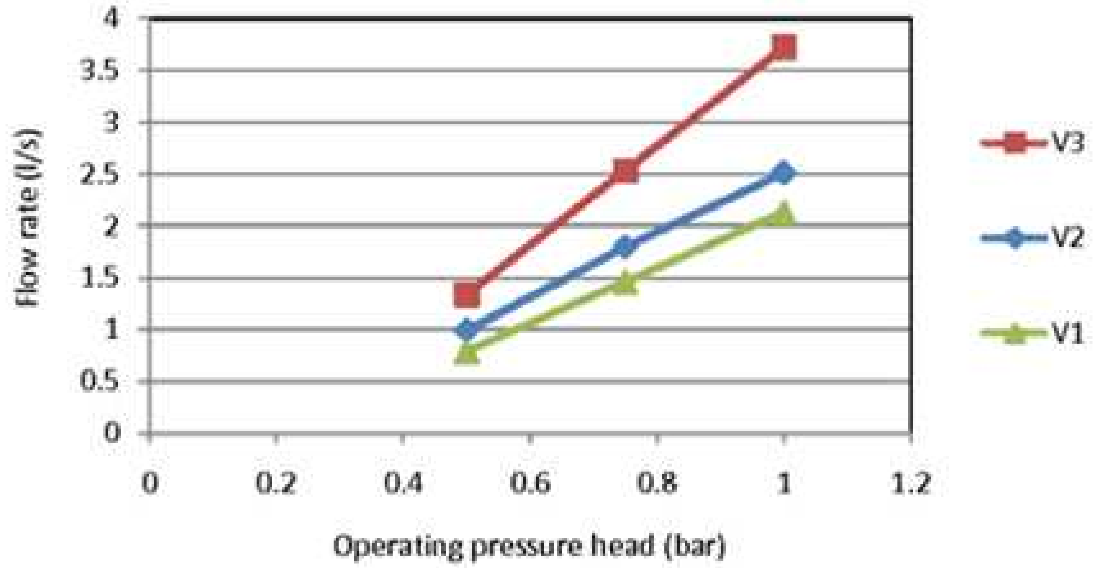

Figure 8: The effect of pressure head on pottery dripper flow rate (porosity 21 %).

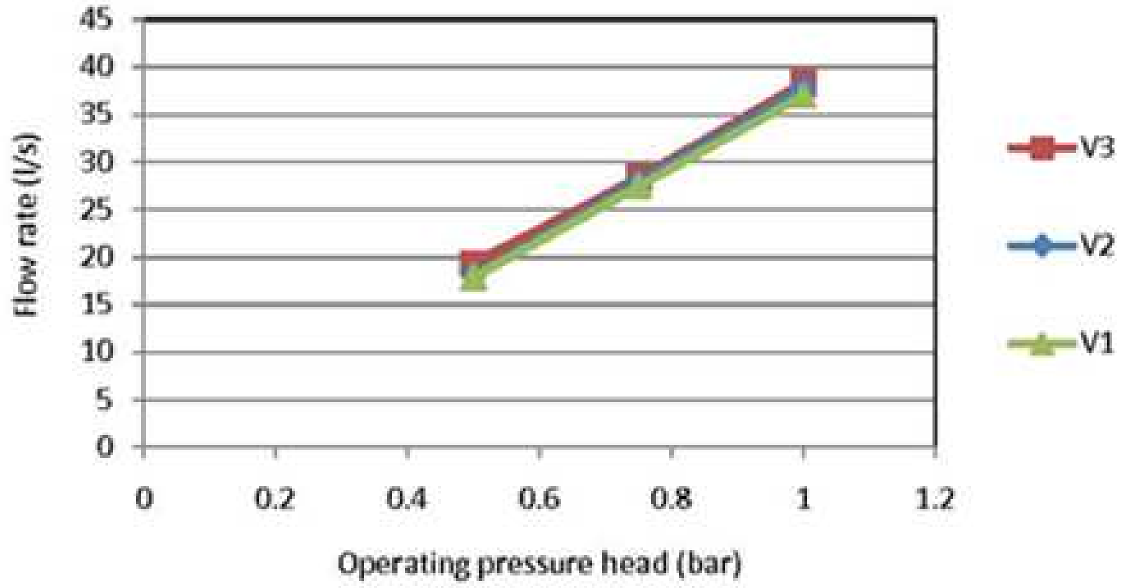

Figure 9: The effect of pressure head on pottery dripper flow rate (porosity 31 %).

Pottery drippers for (21% pottery porosity and volume 49 cm^3) are tested under operating pressure heads 0.5, 0.75 and 1 bar. The flow rate has increased from, 1.34, and 2.53 to 3.72 l/s. With respect to pottery discs to volume 31.4 cm^3, the flow rate has increased from 0.99, and 1.8 to 2.51 l/s. For the volume of pottery discs 19.5 cm^3, the flow rate has increased from, 0.79, and 1.46 to 2.13 l/s, Fig. 8.
The increase in the flow rate is associated with the increase in the flow area. The flow area is determined according to the rubber ring inside area, where the last flow rates are appropriate for drip irrigation systems. Pottery drippers for (31% pottery porosity and volume 49 cm^3) are tested under operating pressure heads 0.5, 0.75 and 1 bar. The flow rate has increased from, 19.4, and 28.3 to 38.3 l/s. With respect to pottery discs to volume 31.4 cm^3, the flow rate has increased from, 18.2, and 27.9 to 37.7 l/s. For the volume of pottery discs 19.6cm^3, the flow rate has increased from, 17.9, and 27.4 to 37 l/s, Fig. 9.

The increase in the flow rate is associated with the increase in the flow area. The flow area is determined according to the rubber ring inside area, where the last flow rates are appropriate for bubbler irrigation systems, and the difference between the three used volumes is so weak. Flow rates versus operating heads, porosity % and discs volume are shown in Table.2.
It is evident that the increase in the flow rate is associated with the increase in Pottery porosity. On the other hand, the efficiency of water salinity reduction decreased, because of the decrease in the percentage of clay minerals, weight in pottery mixture, leading also to a decrease in the cation adsorption process. And this result agreed with **[7].**

Some physical characteristics of pottery discs:

Pottery porosity percentage increases with the increase of sawdust (organic material) in pottery mixtures; pottery porosity is 10%, 21 % and 31% for additional saw-dust 5%, 10% and 15% of mixture weight respectively.

Which indicate the difference of porosity percentage and random shapes of the pottery discs through the use of electronic microscope for pottery disc sections in addition to the optical photo view of the pottery discs that show the quantity of porosity (Black sectors) and clay minerals, sand (pink sectors) This is shown in Figs. 10, 11, 12, 13, 14 and 15.

X RD analysis of three types of pottery mixture:

By analysis three types of Pottery mixture the results are as follows

a) Pottery porosity (P_1):
The mineralogical composition show that the studied sample consists mainly of quartz, albeit and muttile, moreover, illite mineral presets as trace in XRD. Fig. (16).

b) Pottery porosity (P_2):
From the mineralogical composition of the studied sample it can be concluded that quartz, muttile and albeit, are the primary minerals no evidence of precedence secondary mineral moreover, illite mineral presets as trace in XRD. Fig. (17).

c) Pottery porosity (P_3):
The mineralogical composition by XRD show that quartz, mullet and muttile, are the primary minerals represented the main constituted of the studied sample, on the other hand, albite were observed as a secondary mineral. Fig. (18).

Water adsorption for P_1, P_2 and P_3 are 60, 20 and 13%, respectively; and the bulk density is 2.24, 1.7, 1 g/cm^3 respectively. Fig.19. Table.3.

Table 3: Physical characterizes of Pottery disc versus porosity.

Items	**P_1**	**P_2**	**P_3**
Water absorption (%)	60	20	13
Bulk density (g/cm^3)	1.3	0.85	0.75
Drying volumetric shrinkage factors (%)	10.6	10.3	10
Burning volumetric shrinkage factors (%)	1.1	3.8	2.6
Total volumetric shrinkage factors (%)	11.7	17.1	12.6

4. Discussion and Conclusion

Pottery dripper is a new dripper technology for saline water; it can reduce water salinity of 750 ppm. PD is thereupon suitable for using saline water and rationalizing the saline water usage. This study underscores the advantages of both the pottery media (clay minerals) and irrigation nets to conveyance water to plants. A new dripper is used as a filter for small water units. Pottery porosity is a basic factor for reduction of water salinity and also flow rate.
For porosity P_1 (10%) of pottery dripper, under operating pressure head 1 bar, the discharge ranged from 1.2 l/s to 1.95 l/s. For porosity P_2 (21%) of pottery dripper, under operating pressure head 1 bar, the discharge ranged from 2.13 l/s to 3.72 l/s. For porosity P_3 (31%) of PD, under operating pressure head 1 bar, the discharge ranged from 17.9 1/s to 19.4 l/s. Saline water concentration decreased from 6154 ppm to 5840, 5806 and 5440ppm using the PD with porosity 10, 21 and 31% respectively. Saline water concentration decreased from 7149ppm to 7106, 7013 and 6979 ppm using the PD with porosity 10, 21 and 31%, respectively; and finally saline water concentration decreased from 7863 ppm to 7846, 7778 and 7285 ppm using the PD with porosity 10, 21 and 31 % respectively.
It is evident that the increase in the flow rate is associated with the increase in Pottery porosity. On the other hand, the efficiency of water salinity reduction has decreased, because of the decrease in the percentage of clay minerals in pottery mixture, leading also to a decrease in the cations adsorption process. Prototypes of pottery drippers are designed and manufactured from local and environmental material, as one of the models in the Agricultural Waste Recycling Industry.

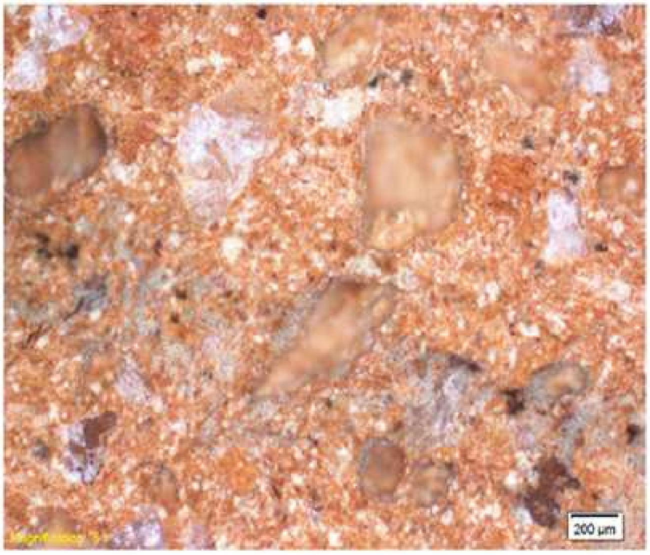

Figure 10: SEM image shows the surface of the pottery disc (P_1).

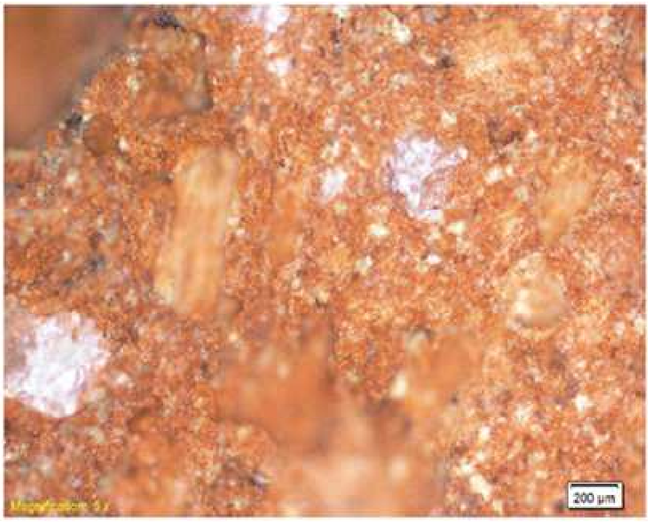

Figure 11: SEM image shows the surface of the pottery disc (P_2).

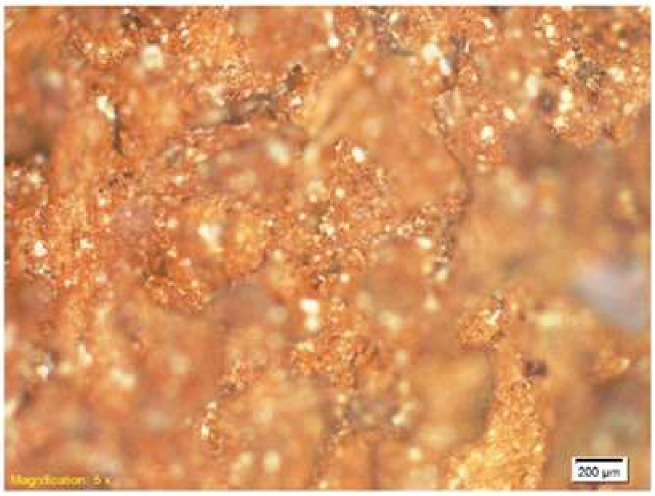

Figure 12: SEM image shows the surface of the pottery disc (P_3).

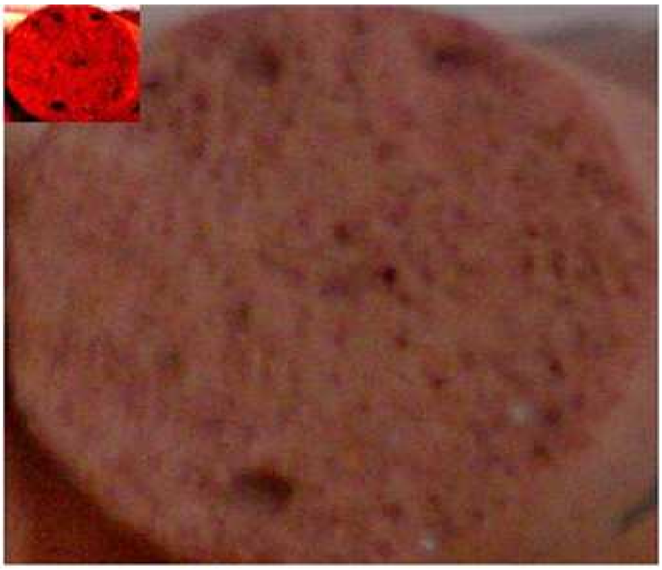

Figure 13: The surface of the pottery disc (P_1).

Figure 14: The surface of the pottery disc (P_2).

Figure 15: The surface of the pottery disc (P_3).

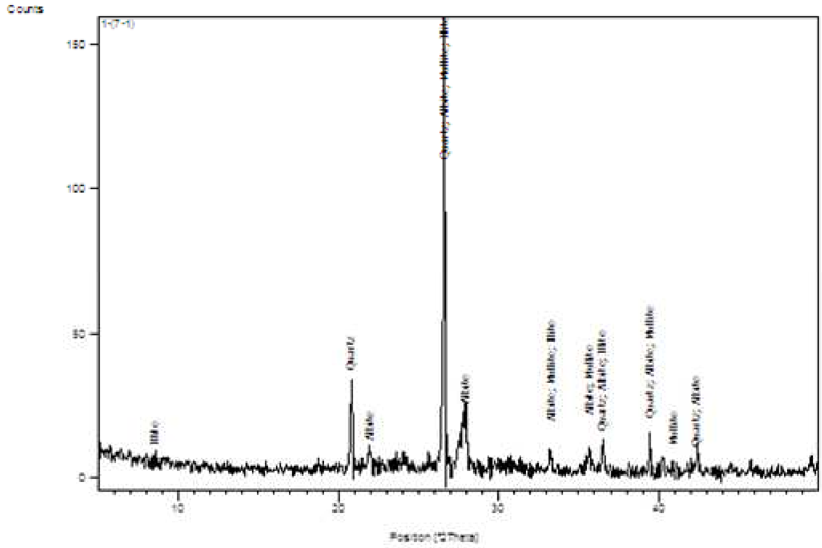

Figure 16: XRD analysis shows the mineralogical composition of the pottery disc (P_1).

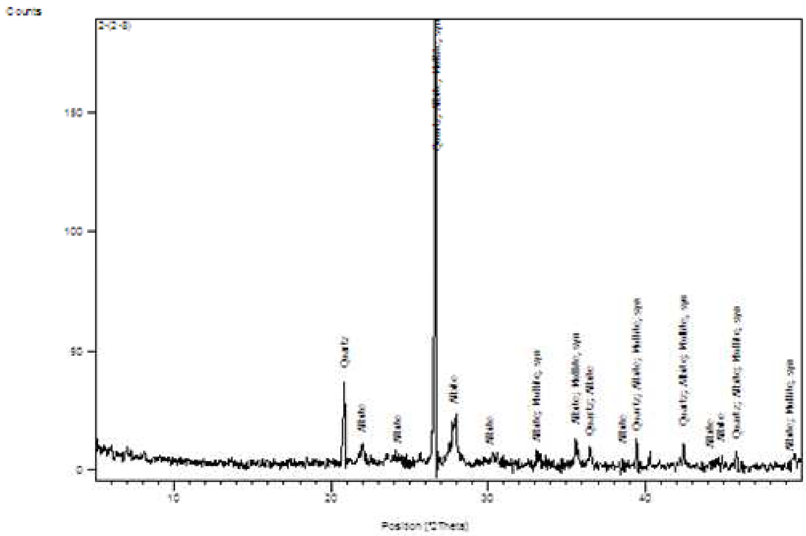

Figure 17: XRD analysis shows the mineralogical composition of the pottery disc (P_2).

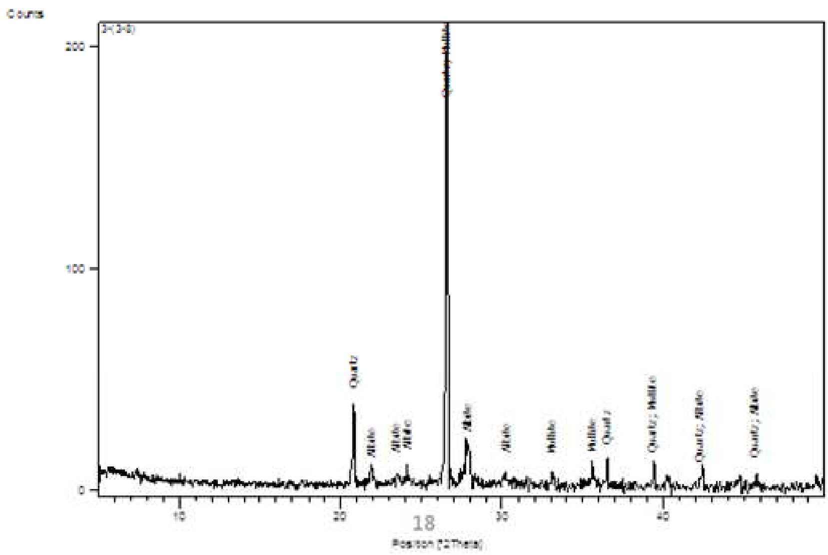

Figure 18: XRD analysis shows the mineralogical composition of the pottery disc (P_3).

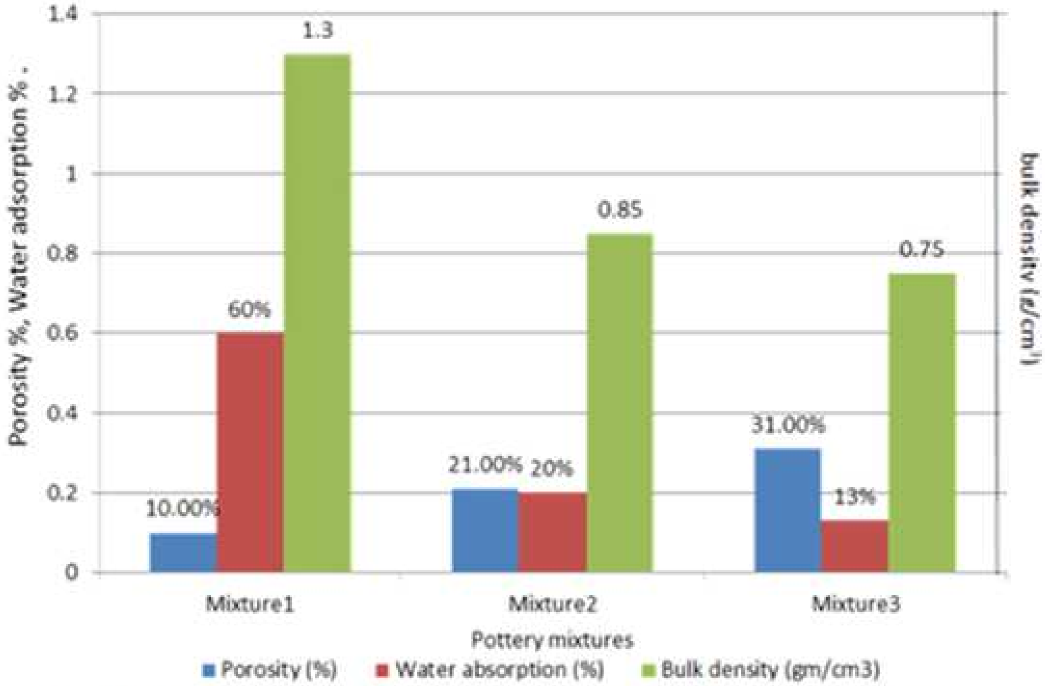

Figure 19: Effect of different organic matter content on pottery discs physical properties.

Acknowledgment

The author is grateful for the Housing & Building National Research Center Institute (HBRC), and the Desert Research Center, DRC, Cairo, Egypt.

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