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Performance Comparison of Various Filters Media in Water Treatment (Statistical Study)

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Abstract

In this research, a bench-scale filter is designed and constructed in order to compare the performance of different media namely, sand, crushed marble stone and crushed red brick. The filters are operated under various operating conditions such as filter depth, raw water turbidity, pretreatment, effective size and uniformity coefficient.

These filters are operated under conventional and direct filtration modes with different doses of alum. Statistical methods had been used to determine the best media using Duncan multiple range test.

The result showed the superiority of crushed red brick media in the removal of turbidity and total bacteria. The results also indicated that filters operated under direct filtration mode show better performance than that operated under conventional filtration mode. The pH of treated water show slight increase for the two modes of filtration.

Keywords: Filter media , Red brick, Marble stone, Sand filter.

مقارنة أداء أنواع مختلفة من الأوساط في معالجة الماء (دراسة إحصائية)

الملخص

تم في هذا البحث تصميم وتصنيع ثلاث مرشحات لاوساط ترشيح مختلفة (الرمل والحجر المرمر المكسر وطابوق احمر مكسر) لغرض مقارنة ادائية الاوساط المختلفة. تم تشغيل هذه المرشحات تحت ظروف تشغيلية مختلفة مثل سمك المرشح وعكورة الماء والمعالجة الاولية والحجم المؤثر ومعامل الانتظام. كذلك تم تشغيل هذه المرشحات ضمن الطور الاعتيادي والطور المباشر باستخدام جرع شب مختلفة.

جرى تحليل النتائج إحصائيا باستخدام اختبار دنكن لاختيار الوسط الأفضل. بينت النتائج المختبرية ان الطابوق الاحمر المكسر اظهر قدرة عالية في إزالة العكورة والعدد البكتيري الكلي. لقد تقاربت نسبة الازالة للاوساط الثلاثة حيث كان الفرق يترواح (١-٤)%. كذلك بينت النتائج ان هناك زيادة في الرقم الهيدروجيني للماء المرشح اضافة الى زيادة قيمة التوصيل الكهربائي.

الكلمات الدالة: أوساط الترشيح، الطابوق الأحمر، حجر المرمر، الرمل.

Introduction

Filtration is on of the most important step in treating municipal waters to clarify it, providing an important step in the protection of public health. Surface waters tend to be more turbid than ground waters, and contain more microbes, particles of vegetation, and silt. For that reason, the principles of clarification and filtration play a key role in the protection of public health when surface water sources are used. Filtration removed microbes and other suspended solids that could affect subsequent treatment processes or disinfection steps. Of primary significance in relation to public health, almost total removal is needed because remaining particles may shield the pathogens from disinfection.

In its simplest definition, filtration is the process of separating particulate materials from liquid by passing the liquid through porous material. In drinking water production, filtration usually follows sedimentation.

Drinking water filters typically contain a material such as sand, anthracite or activated carbon, called the media through which the water passes. Being the cheapest medium, sand finds a wide spread use in water treatment plants.

Filtration is often thought of as straining of particles larger than the openings of the filter media opening. Filtration efficiency is related to the pore size of the openings of the media. The size of filter media is directly related to pore size. Some other factors affect filtration efficiency are raw water turbidity, filtration rate, extent of back washing, pretreatment..etc.

In the present work, local material namely crushed red brick and crushed marble stone are used.

The aim of this work is to verify suitability of the material as a filtration medium when subjected to prevailing conditions of sand filter.

Literature Review

The process of filtration forms the most important stage in the purification of water. It usually involves allowing water to pass through a thick layer of certain media. The choice of filter medium depend on durability required, desired degree of purification, length of filter run, and easy of back wash [1, 2].

Montgomery used a wide range of media in filtration systems such as sand, anthracite coal, activated carbon,

The aim of the present work is to

garnet. Diatomaceous earth is also employed as a filter medium in certain filtration application [3].

A review of sand filtration in the United States by Logsdom and fox [4] indicated significant improvement in water quality parameters. Total bacteria removal reached 99.4% or more while effluent turbidity reduced to 0.5 NTU and some times as low as 0.1NTU. Any inert, durable granular material of the proper effective size and uniformity coefficient can be used for slow sand filtration. Mostly, this takes the form of sand, which is readily available in most environments, but there are other alternatives where sand is not readily available [5].

Sand being the cheapest filter medium has been widely used in water treatment plants. The specific gravity of the sand ranged between 2.6 and 2.85. Sand used in water treatment plants should be free from clay, silt, loam and other organic matter. It should be hard, resistant as well. The loss by weight after contact for twenty four hours with 40% hydrochloric acid should not exceed 5%, when the HCl acid became 20% it should be less than 2%. Coefficient of uniformity of less than 3 and preferably less than 2 and an effective grain size of 0.6 to about 2 is required. Bricks are one type of ceramic ware, which has a lot of porosity in the rang of (20 -50) % [6,7].

Argaw and kebede used crushed brick and local clay pot to filter water after three days storage. The results showed 89.6% and 74.6% reduction of fecal coliforms in addition, considerable reduction in turbidity and color is obtained [8].

Rao found that crushed stone with D_{10} of 0.47mm is more effective than sand of the same grading. The stone dust used is a byproduct from quarries [9].

investigate the performance of different types of filter media namely sand, crushed stone and crushed red brick.

Materials and Methods

To achieve the goal of this study, a laboratory bench – scale apparatus is manufactured. The apparatus comprises three cylindrical tubes 53 mm diameter and 650 mm high. It is made of glass and provided with a lower value for the collection of treated water and perform backwashing. An under drain system is also provided at a depth of 25 mm from the bottom. Fig (1) shows schematic sketch of the apparatus and explained in photograph (1). Three media types namely sand, crushed marble stone, crushed red brick had been subjected to the same condition of filter depth, raw turbidity, pretreatment. Table (1) shows these operating variables. Effective size, uniformity coefficient for the three media are the same. Table (2) shows the characteristic of media. Figure 2 represents sample of sieve analysis used to determine uniformity coefficient and effective size. Samples of raw water brought from Tigris river by plastic container. Experiments are performed as follows: The media is first washed by introducing tap water from the bottom valve for 5 minutes until water become clear in the top of filter. The second step is pouring 1 liter of distilled water in the filter column to verify the cleanliness. Characteristics of raw water measured according to standard methods. Coagulation is made using Jar test device with the addition of different alum doses (8, 9, 10, 12 and 14) mg/l. Fast mixing is applied by 100 cycle/minutes followed by slow mixing for 20 minutes by 50 cycle/ minutes. Settling is allowed for 20 minutes in case of conventional treatment. In direct mode, fast mixing for 2 minutes by 100 cycle/min followed by slow mixing for 20 minutes by 50 cycle/min. The required analysis performed for raw and treated water include turbidity, temperature, pH, EC and total bacteria.

Results and discussion

The results obtained from this work for thr three media are compared. Each filter is subjected to the same operating conditions. Statistical methods had been used to determine the best media of used filters using Duncan multiple range test to find the effect of the variables included in this study on effluent turbidity and total bacteria. The results were considered significant at $p \leq 0.05$.

Effect of Operating Conditions on Effluent Turbidity.

Tables (3, 4, & 5) includes the results of filtration experiments using different alum doses for different media of 25, 35, and 45 cm thickness.

Table (3) indicates that best effluent turbidity for conventional filtration mode is obtained with alum dose of 8, 9, 10, 12 and 14 mg/l for crushed red bricks and 12 mg/l for sand. Crushed marble stone failed to give the same level of effluent turbidity. These results indicated that crushed red brick and sand of 25 cm thickness are flexible in application.

Table (4) indicates that the best effluent turbidity for conventional filtration mode was obtained with alum dose of 8, 9, 10, 12 and 14 mg/l for crushed red bricks and 12 mg/l for sand and crushed marble stone.

Table (5) clarify that the best effluent turbidity for conventional filtration mode with alum dose of 8, 9, 10, 12 and 14 mg/l for crushed red bricks, while it was obtained with sand when alum dose of 8 & 9 mg/l is used. On the other hand, the same effluent level was obtained with 9mg/l alum only for crushed marble stone.

These results indicated that conventional filtration was flexible in application with crushed red brick for all thickness and all doses of alum. Sand media is the second while crushed marble stone is the last.

Data of Table (6) shows significant improvement in effluent water turbidity with thickness increase for all media types. For 35cm thickness, significant decrease in effluent turbidity was recorded for crushed marble stone only, while at 45cm thickness all filter media exhibited significant decrease in effluent turbidity. The same results are obtained when using 35 & 45cm for different filter media. From these results it is preferable to use a thickness of 35cm.

The best effluent turbidity for direct filtration mode for 25cm thickness is obtained with alum dose of 12 and 14 mg/l for crushed red bricks and sand. The same level of effluent turbidity is not obtained with crushed marble stone Table (7).

The best effluent turbidity for direct filtration mode was obtained with alum dose of 12 and 14mg/l for crushed red bricks, and the same level of effluent turbidity is not obtained with sand and crushed marble stone.

The best efficiency is achieved with crushed red bricks and sand with alum dose of 14 mg/l .The worst result was obtained of effluent turbidity with crushed marble stone.

These results indicated that direct filtration is flexible in application with crushed red brick and sand for 14 mg/l alum dose for 45 cm thickness of the filter media.

These results indicated also that direct filtration is flexible in application with crushed red brick for 12 and 14 mg/l alum dose for 25, 35, and 45cm thickness.

A comparison between the results is given in Table (8) including the type of filter media and thickness. When comparing the performance of filter media thickness, better results are obtained with direct filtration mode when using 45cm thickness for different filter media. From these results it is preferable to use 45cm thickness for both modes and for all filter media.

Effect of Operating Conditions on Bacteria Removal efficiency

The best bacteria removal efficiency for conventional filtration mode is obtained with sand media at 25cm and crushed red brick at 35, 45cm thickness. The same level of efficiency can not obtained with crushed marble stone Table (9). These results indicated that it is flexible in application with crushed red brick and sand at thickness of 25,35, & 45 cm. The results indicated that crushed red brick is very good in removing bacteria and turbidity from influent water.

The best removal efficiency of total bacteria for direct filtration mode was obtained with sand media at 45cm and crushed red brick at 25, 35, 45cm thickness. The same level of efficiency was not obtained with crushed marble stone Table (10). These results indicated that it is flexible in application with crushed red brick and sand at thickness of 25, 35, 45cm.

Figures (3, & 4) compares the removal of total bacteria for all filter media for both filtration modes. The best results was obtained with crushed red brick and sand for direct filtration at 45 cm thicknesses.

pH value

Results of pH value for filtered water for two modes for all thickness

Results of pH value for filtered water for two modes for all thickness more than the other media because of the nature and composition of this media which is formed from clay while sand is formed from mixture of aluminum silicate and some impurities such as metals oxide.

Electrical Conductivity (EC)

The increase in EC for sand filter at all thickness compared with crushed red brick and crushed marble stone indicated that it gives 50% more than the others.

Conclusions

1. Conventional filtration mode was flexible in application with crushed red brick at all thickness and all doses of alum.
2. Improvement in effluent water turbidity for conventional filtration mode increased with the increase of thickness for all types of filter media. A thickness of 35cm gives significant decrease in effluent turbidity for crushed marble stone only, while at 45cm thickness all media exhibited significant decrease in effluent turbidity.
3. The best effluent turbidity for direct filtration mode was obtained with alum dose of 12 & 14mg/l for crushed red bricks.
4. Better results are obtained with direct filtration mode when using 45cm thickness for different media.
5. The best bacteria removal efficiency for conventional filtration mode was obtained with sand media at 25cm and crushed red brick at 35, & 45cm thickness.
6. Crushed red brick is very good in removing total bacteria and turbidity.
7. The best bacteria removal efficiency for direct filtration mode was obtained with crushed red brick and are listed on Table (11). Crushed red brick filter media has an increase in pH sand at thickness of 25, 35,& 45cm.
8. Filters operating under direct filtration mode show better performance in removing bacteria as compared with conventional filtration mode.
9. Simple increase in pH value after water filtration in two modes for all thickness is obtained.

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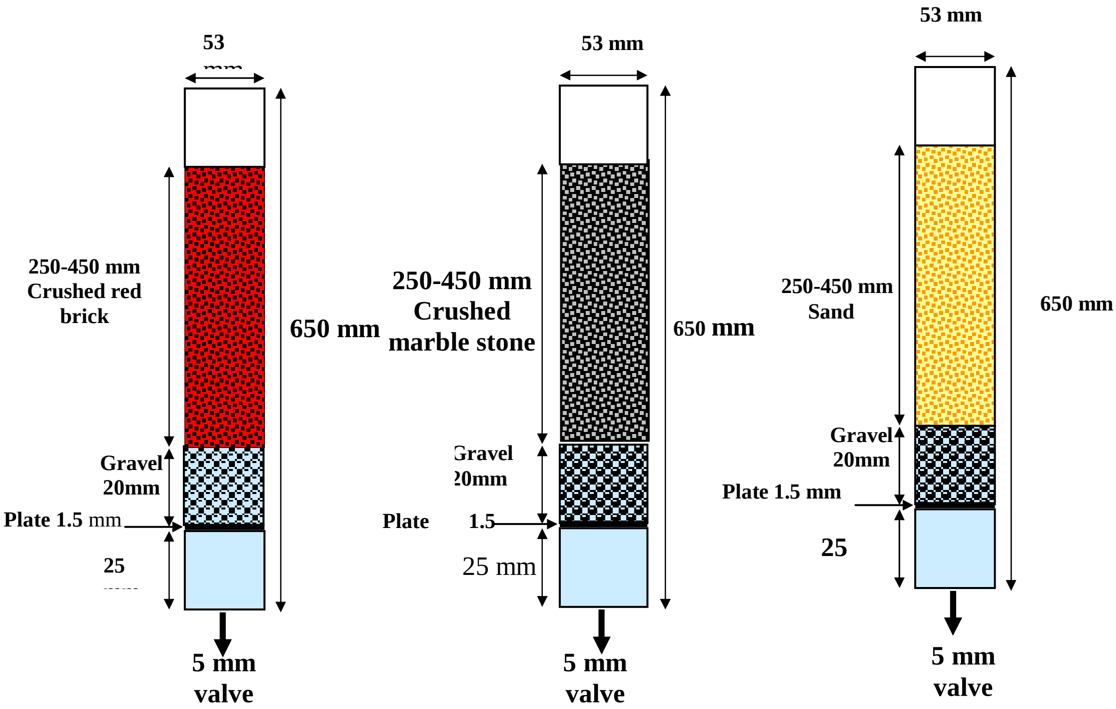
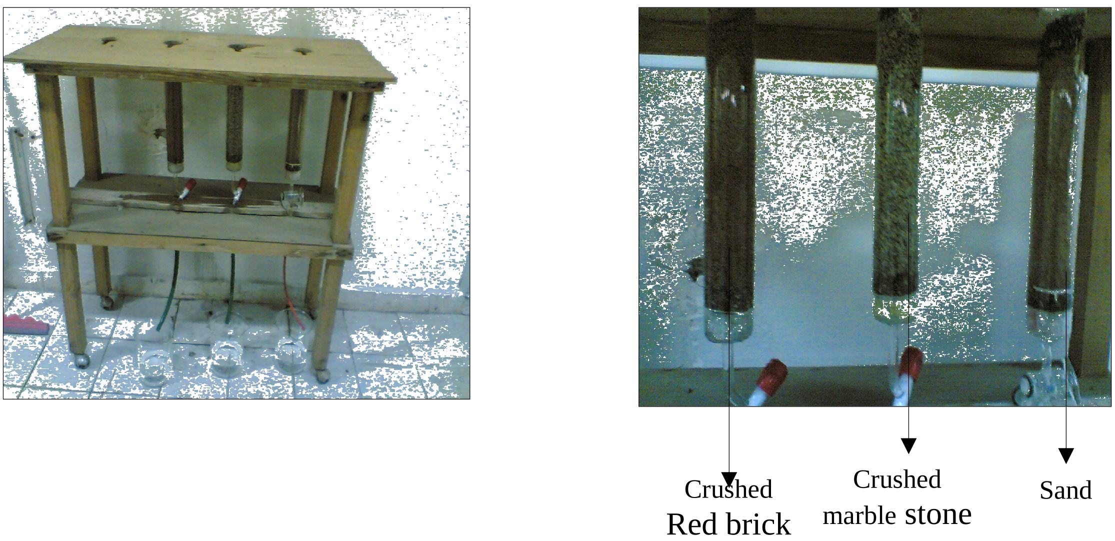


Fig (1) Sketch of a Bench- Scale laboratory Apparatus.



Photograph (1) Laboratory Apparatus

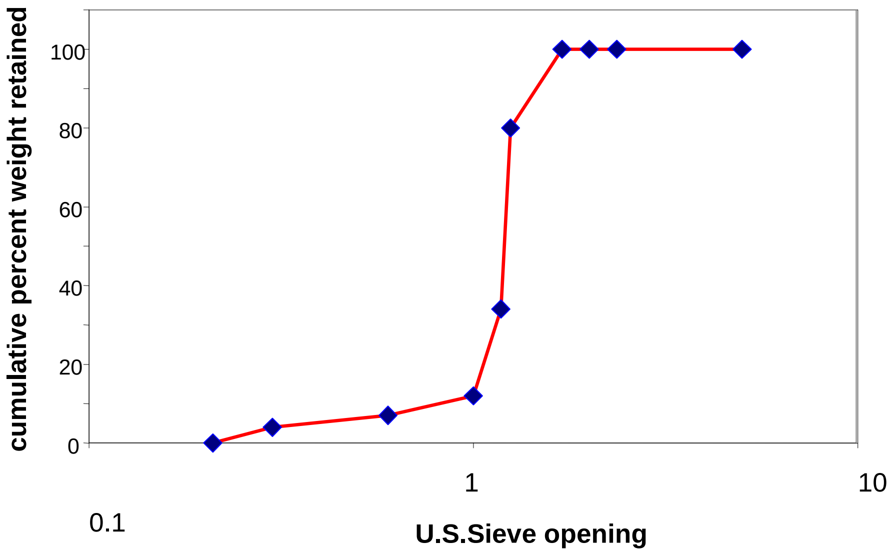


Figure (2) Sieve Analysis for Three material used in This Work

Crushed marble stone

Sand

Crushed red brick

Photograph (2) Grain of Different Media

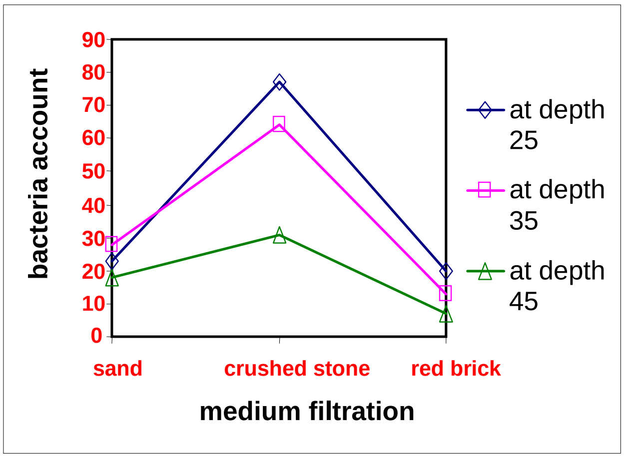


Figure (3) Removal of bacteria for all filter media of Conventional mode

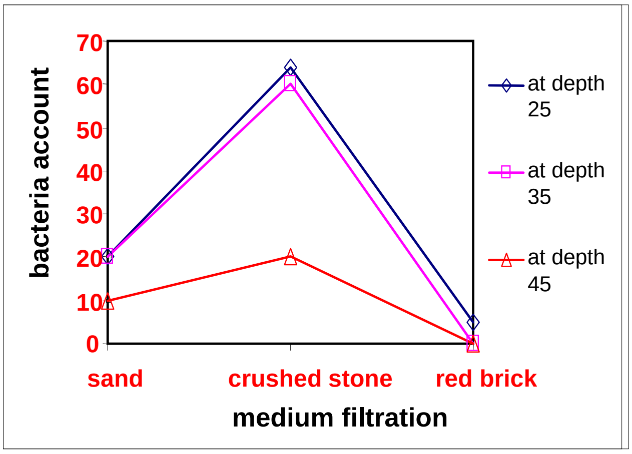


Figure (4) Removal of bacteria for all filter media of direct mode

Table (1) operating Variables

Items	Characteristics
Raw water sources	Tigris river water with turbidity ranging from(6.5-20) NTU
Filter media	Sand, Crushed marble stone, Crushed red brick
treatment	-conventional process (flocculation, solid separation, filtration) - Direct filtration (flocculation, filtration)
Filter depth	filters thickness 25, 35and 45cm.
Coagulants	Alum $Al_2 (SO_4)_3.16H_2O$ with different doses (8, 9, 10, 12, and 14) mg/l in Jar Test.
Temperature	18-20C$^{\circ}$
pH	8.12-8.24
EC	413-432 umos/cm
Filtration rate	2.72 m/h

Table (2) Characteristic of the Media.

materials	**E.S**	**U.C**	**Percent of acid loss< 2%**	**Specific gravity**	**Porosity%**
Sand	0.8	1.3	1.95	2.617	28
Crushed marble stone	0.8	1.3	1.25	2.804	24
Crushed red brick	0.8	1.3	1.78	2.06	30.5

Table (3) Effect of Interaction of Media Type and Alum Dose on Effluent Turbidity, Thickness 25cm.

Alum dose mg/l	Filter media		
	Sand	Crushed marble stone	Crushed red bricks
8	0.38±0.009 b	0.478±0.0009 c	0.352±0.0004 a
9	0.379±0.001 b	0.412±0.0004 b	0.322±0.0009 a
10	0.298±0.0009 c	0.279±0.0004 b	0.272±0.0004 a
12	0.264±0.0009 a	0.277±0.0004 c	0.271±0.00057 b
14	0.258±0.0004 b	0.268±0.0009 b	0.2315±0.012 a

abc means with different letters horizontally and vertically have significant difference at $p \leq 0.05$

Table (4) Effect of the Interaction of Media Type and Alum Dose on Effluent Turbidity Thickness 35cm.

Alum dose mg/l	Filter media		
	Sand	Crushed marble stone	Crushed red bricks
8	0.33±0.009 b	0.374±0.001 b	0.34±0.014 a
9	0.37±0.009 b	0.35±0.009 b	0.31±0.004 a
10	0.28±0.004 c	0.262±0.0009 b	0.25±0.004 a
12	0.264±0.0009 a	0.25±0.0004 a	0.24±0.00057 a
14	0.252±0.0009 b	0.24±0.009 b	0.216±0.0014 a

abc means with different letters horizontally and vertically have significant difference at $p \leq 0.05$.

Table (5) Effect of Interaction of Media Type and Alum Dose on Effluent Turbidity, Thickness 45cm.

Alum dose mg/l	Filter media		
	Sand	Crushed marble stone	Crushed red bricks
8	0.32±0.009 a	0.35±0.09 b	0.31±0.004 a
9	0.31±0.004 a	0.33±0.014 a	0.3±0.009 a
10	0.27±0.009 b	0.26±0.004 b	0.23±0.009 a
12	0.25±0.004 b	0.25±0.009 b	0.21±0.009 a
14	0.24±0.009 a,b	0.25±0.013 c	0.21±0.012 a

abc means with different letters horizontally and vertically have significant difference at p≤0.05 according test.

Table (6) Effect of Filter Thickness and Filter Media Type on Effluent Turbidity.

Media types	Thickness cm		
	25cm	35cm	45cm
Sand	0.3158±0.013 b	0.2992±0.01 ab	0.2768±0.008 a
Crushed marble stone	0.3428±0.019 b	0.2952±0.013 a	0.288±0.011 a
Crushed red bricks	0.2897±0.0099 b	0.2712±0.011 ab	0.252±0.011 a

abc means with different letters horizontally and vertically have significant at p≤0.05 according test.

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Table (7) Effect of Interaction of Media Type and Alum Dose on Effluent Turbidity for Direct Filtration Mode at Media Thickness (25, 35and45) cm.

Thickness cm	Filter media			
	Alum dose mg/l	**Sand**	**Crushed marble stone**	**Crushed red bricks**
25	8	0.54±0.009 bcd	0.785±0.006 g	0.59±0.004 de
	9	0.52±0.009 b	0.71±0.009 f	0.58±0.009 cde
	10	0.52±0.013 b	0.69±0.004 f	0.53±0.013 bc
	12	0.41±0.004 a	0.5445±0.06 bcde	0.4±0.004 a
	14	0.42±0.014 a	0.6±0.004 e	0.41±0.004 a
35	8	0.42±0.013 d	0.62 ±0.008 g	0.42±0.008 d
	9	0.4±0.009 d	0.6±0.004 fg	0.41±0.009 d
	10	0.4±0.008 cd	0.58±0.004 f	0.38±0.008 bc
	12	0.38±0.009 bc	0.54±0.004 e	0.36±0.008 ab
	14	0.38±0.004 bc	0.54±0.009 e	0.35±0.013 a
45	8	0.41±0.004 d	0.6 ±0.008 g	0.4±0.004 cd
	9	0.4±0.009 cd	0.55±0.009 f	0.38±0.009 c
	10	0.4±0.004 cd	0.52±0.009 e	0.38±0.004 c
	12	0.35±0.004 b	0.52±0.004 e	0.34±0.014 b
	14	0.31±0.009 a	0.5±0.009 e	0.3±0.004 a

abcdefg means with different letters horizontally and vertically have significant at $p \leq 0.05$ according test.

Table (8) Interaction of Filter Media Type and Filter Thickness for Direct Filtration Modes on Effluent Turbidity.

Thickness cm	Filter media		
	Sand	**Crushed marble stone**	**Crushed red bricks**
25	0.482±0.013 c	0.6659±0.02 f	0.502±0.019 c
35	0.398±0.005 b	0.576±0.007 e	0.384±0.007 ab
45	0.374±0.009 ab	0.538±0.008 d	0.36±0.008 a

abcdefg means with different letters horizontally and vertically have significant at $p \le 0.05$ according test.

Table (9) Effect of Filter Thickness and Filter Media Type on Removal Efficiency of Total Bacteria

Filter media	Thickness cm		
	25cm	**35cm**	**45cm**
	%		
Sand	91.0931±0.301 a	83.257±0.304 b	81.9309±0.393 b
Crushed marble stone	60.4983±0.478 c	60.4387±0.879 c	54.7124±1.13 c
Crushed red bricks	84.8592±0.332 b	85.8197±0.762 a	85.0494±0.887 a

abc means with different letters horizontally and vertically have significant at $p \le 0.05$ according test.

Table (10) Effect of Filter Thickness and Filter Media Mype on Removal Efficiency of Total Bacteria

	Thickness cm		
Filter media	**25**	**35**	**45**
	%		
Sand	**93.2369±0.515 b**	**93.8742±0.211 b**	**95.403±0.509 a**
Crushed marble stone	**79.3742±0.749 c**	**81.3741±0.537 c**	**89.8801±1.05 b**
Crushed red bricks	**95.6756±0.699 a**	**95.7557±0.81 a**	**96.7905±0.629 a**

abc means with different letters horizontally and vertically have significant at $p \le 0.05$ according test.

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Table (11) pH value of Filtered Water in Two Modes Filtration (Conventional and Direct Filtration) at all Thickness.

Conventional method at 25cm				direct filtration at 25cm			
Media filtration	sand	Crushed marble stone	Red crushed brick	Media filtration	sand	Crushed marble stone	Red crushed brick
At raw water	8.24	8.24	8.24	At raw water	8.23	8.23	8.23
After sedimentation	7.85	7.82	7.84	After coagulation	7.65	7.65	7.65
After filtration	7.79	7.99	10.46	After filtration	8.09	8.18	9.53
Conventional method at 35cm				**direct filtration at 35cm**			
Media filtration	sand	Crushed marble stone	Red crushed brick	Media filtration	sand	Crushed marble stone	Red crushed brick
At raw water	8.12	8.12	8.12	At raw water	8.14	8.14	8.14
After sedimentation use jar test	7.55	7.55	7.55	After sedimentation use jar test	7.77	7.77	7.77
After filtration	7.99	8.14	10.48	After filtration	8.2	8.3	10.6
Conventional method at 45cm				**direct filtration at 45cm**			
Media filtration	sand	Crushed marble stone	Red crushed brick	Media filtration	sand	Crushed marble stone e	Red crushed brick
At raw water	8.14	8.14	8.14	At raw water	8.14	8.14	8.14
After sedimentation use jar test	7.58	7.58	7.58	After sedimentation use jar test	7.75	7.75	7.75
After filtration	8.2	8.24	10.5	After filtration	8.6	8.5	10.64

Table (12) Values of EC of Raw and Filterd Water

Conventional method at 25cm				**direct filtration at 25cm**			
Media filtration	sand	crushed marble stone	Red crushed brick	Media filtration	sand	Crushed marble stone	red crushed brick
At raw water	432	432	432	At raw water	413	413	413
After filtration	٦67	435	453	After filtration	530	417	314
Conventional method at 35cm				**direct method filtration at 35cm**			
Media filtration	sand	crushed marble stone	red crushed brick	Media filtration	sand	crushed marble stone	red crushed brick
At raw water	421	421	421	At raw water	422	422	422
After filtration	789	460	516	After filtration	675	477	530
Conventional method at 45cm				**direct filtration at 45cm**			
Media filtration	sand	crushed marble stone	red crushed brick	Media filtration	sand	crushed marble stone	red crushed brick
At raw water	422	422	422	At raw water	415	415	415
After filtration	893	465	525	After filtration	772	482	535