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Research Paper

Develop filtration compact piping unit as pretreatment for ultrafiltration plant

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ABSTRACT:
This study targets to create a new compact unit used as a simple pretreatment unit for the ultrafiltration modules. The used unit targets to reaches the inlet total suspended solids (TSS) concentration for the water source to the allowable TSS concentration to enter the ultrafiltration units which are determined according to the manufacturer.
The experimental works concerned with the filtration process using three types of filtration media (sand, anthracite coal & agricultural waste). The filtration unit is compact consists of a pipe divided into three segments. The effect of the filtration process using mono, dual & triple media measured at different water sources which have a different TSS concentration to evaluate the suitability of using the filtration unit as a pretreatment unit for the ultrafiltration modules according to the inlet water source. The results showed high TSS removal efficiencies with all the filtration processes which make the filtration unit able to work as an effective pre-treatment unit for the ultrafiltration units for all water sources.
KEYWORDS: *Water treatment, Filtration, Compact unit, Pretreatment, Ultrafiltration*

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I. INTRODUCTION

Ultrafiltration plants offered several advantages over conventional plants. The small area required to install the plant, the small-time needs to construct the plant, and the high quality of the outlet water regardless of the source water quality, are some of the advantages of the ultrafiltration plants [1].

Despite the above advantages, Appling ultrafiltration plants in Egypt has the main problem. The problem with the quality of the water source. Unfortunately, water sources in Egypt are exposed to a high level of pollutions which causes poor water quality with high loads on the ultrafiltration membranes. These loads affect the ultrafiltration performance and cause an increase in the rate of backwashing and chemical cleaning which reduce the plant productivity. Also with a continuous flow of this water for long period, the membrane lifetime decreases which causes an increase in the operation costs.

According to this problem, the need for ultrafiltration pretreatment has become a must. But the pretreatment unit must be a compact unit to can save the main benefit of the ultrafiltration plants which is the small area required for the plant installation. More researches needed for the pre-treatment to be able to apply this technology with maximum efficiency and minimum costs.

Physical, chemical, and biological are the different strategies used in pre-treatment processes. The selection of the suitable pre-treatment strategy dependent on many factors such as the feed water quality, membrane properties, and operation conditions [2].

Coagulation-sedimentation (conventional), oxidation, adsorption and bio-filtration are the most common pre-treatment techniques before the ultrafiltration process [3],[4]. This study discusses the use of the filtration process as a pre-treatment technique.

Filtration as a pre-treatment prior to the ultrafiltration membrane refers to the use of packed-bed filters or membranes to remove particles from the feed water to enhance the performance of the ultrafiltration process. The removal action mechanism may be physical sieving or chemical adsorption/deposition according to the used media [5].

II. MATERIALS AND METHODS

The pilot was located at the Sanitary & environmental engineering laboratory at engineering faculty at Ain Shams University. Several trials were made to choose the suitable materials for the pipe and the connected pieces to create the compact unit. The final unit consists of a pipe divided into three segments each segment with 5 cm diameter & 20 cm length to can apply mono, dual & triple filtration processes. This unit is connected by a tank with a capacity of 200 liters as the water source for the unit. Figure (1) shows a schematic diagram of the filtration unit. Figure (2) shows the final shape of the filtration unit.

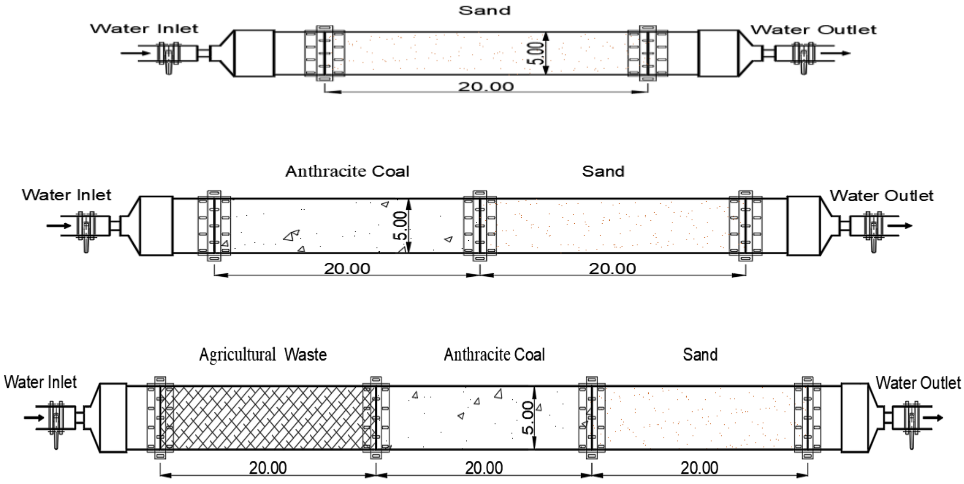

Figure (1) Schematic Diagram of the Filtration Unit

Figure (2) The Final Shape for the Filtration Unit

The experimental works were divided into seven runs. Each run had a different media type for filtration. Sand, anthracite coal, and agricultural waste are the three media types used in this study for the mono, dual and triple filtration process. First run used sand, 2nd run used anthracite coal, 3rd run used agricultural waste as a mono filtration media, 4th run used sand & anthracite coal, 5th run used sand & agricultural waste, 6th run used anthracite coal & agricultural waste as a dual filtration medias and finally 7th run used sand, anthracite coal & agricultural waste as a triple filtration media. Each run was repeated three times with different water sources that had different inlet TSS concentrations. Average TSS concentration for the first water source equal 34 mg/l, for the second water source equal 146 mg/l, and for the third water source equal 468 mg/l.

Samples were taken twice a day from the inlet and the outlet of the unit. Water samples were routinely collected each day of the run and then analyzed to investigate water quality during the examination period. TSS concentration was the measured parameter in this study.

III. RESULTS

Each run was applied for 3 days for each water source. The experimental results for each run illustrated in a table (1)

Table (1) The TSS concentration during the experimental works

Samples	First Quality		Second Quality		Third Quality	
	TSS	Removal	TSS	Removal	TSS	Removal
First run (mono filtration using sand)						
1	16.00	52.94	65.00	55.48	209.00	55.34
2	15.50	54.41	63.50	56.51	191.00	59.19
3	15.00	55.88	64.50	55.82	207.00	55.77
4	15.50	54.41	62.00	57.53	182.00	61.11
5	14.90	56.18	61.00	58.22	185.00	60.47
6	14.65	56.91	59.00	59.59	176.00	62.39
Average	15.26	55.12	62.50	57.19	191.67	59.05
Second run (mono filtration using anthracite coal)						
1	17.00	50.00	68.50	53.08	206.00	55.98
2	17.00	50.00	67.50	53.77	200.00	57.26
3	16.50	51.47	67.00	54.11	199.50	57.37
4	16.00	52.94	65.00	55.48	203.50	56.52
5	15.50	54.41	63.00	56.85	199.00	57.48
6	15.00	55.88	61.50	57.88	195.50	58.23
Average	16.17	52.45	65.42	55.19	200.58	57.14
Third run (mono filtration using agricultural waste)						
1	21.00	38.24	75.50	48.29	228.50	51.18
2	20.50	39.71	76.50	47.60	214.00	54.27
3	21.10	37.94	73.60	49.59	225.00	51.92
4	20.00	41.18	74.50	48.97	213.70	54.34
5	19.70	42.06	72.00	50.68	205.50	56.09
6	19.20	43.53	73.00	50.00	210.00	55.13
Average	20.25	40.44	74.18	49.19	216.12	53.82
Fourth run (dual filtration using sand & anthracite coal)						
1	6.10	82.06	20.00	86.30	54.00	88.46
2	5.90	82.65	20.70	85.82	52.00	88.89
3	4.90	85.59	19.50	86.64	52.50	88.78
4	5.60	83.53	19.30	86.78	51.00	89.10
5	5.50	83.82	20.00	86.30	49.00	89.53
6	5.00	85.29	19.10	86.92	47.50	89.85
Average	5.50	83.82	19.77	86.46	51.00	89.10
Fifth run (dual filtration using sand & agricultural waste)						
1	9.50	72.06	32.50	77.74	95.00	79.70
2	8.60	74.71	32.50	77.74	96.50	79.38
3	8.60	74.71	31.00	78.77	86.60	81.50
4	8.00	76.47	31.30	78.56	75.00	83.97
5	8.35	75.44	30.20	79.32	79.00	83.12

6	7.50	77.94	29.10	80.07	78.00	83.33
Average	8.43	75.22	31.10	78.70	85.02	81.83
Sixth run (dual filtration using anthracite coal & agricultural waste)						
1	9.45	72.21	35.00	76.03	96.10	79.47
2	9.70	71.47	35.10	75.96	94.00	79.91
3	9.30	72.65	34.00	76.71	93.30	80.06
4	9.45	72.21	35.00	76.03	93.40	80.04
5	8.40	75.29	33.00	77.40	92.00	80.34
6	8.20	75.88	31.00	78.77	91.20	80.51
Average	9.08	73.28	33.85	76.82	93.33	80.06
Seventh run (Triple filtration using sand, anthracite coal & agricultural waste)						
1	3.60	89.41	11.50	92.12	22.50	95.19
2	4.20	87.65	10.00	93.15	19.50	95.83
3	2.40	92.94	11.50	92.12	22.00	95.30
4	2.40	92.94	9.50	93.49	19.50	95.83
5	3.60	89.41	8.50	94.18	21.00	95.51
6	1.80	94.71	7.00	95.21	19.00	95.94
Average	3.00	91.18	9.67	93.38	20.58	95.60

IV. DISCUSSION

The data in Table (1) show that for the first water source the average TSS removal efficiency using sand, anthracite coal & agricultural waste as a mono filtration media was 55.12%, 52.45% & 40.44% respectively. The dual filtration results for sand & anthracite coal, sand & agricultural waste, and anthracite coal & agricultural waste were 83.82%, 75.22% & 73.28% respectively. While triple filtration results reached 91.18%.

For the second water source, the average TSS removal efficiency using sand, anthracite coal & agricultural waste as a mono filtration media was 57.19%, 55.19% & 49.19% respectively. The dual filtration results for sand & anthracite coal, sand & agricultural waste, and anthracite coal & agricultural waste were 86.46%, 78.70% & 76.82% respectively. While triple filtration results reached 93.38%.

For the third water source, the average TSS removal efficiency using sand, anthracite coal & agricultural waste as a mono filtration media was 59.05%, 57.14% & 53.82% respectively. The dual filtration results for sand & anthracite coal, sand & agricultural waste, and anthracite coal & agricultural waste were 89.10%, 81.83% & 80.06% respectively. While triple filtration results reached 95.60%.

Figure (3) shows the relation between the Filtration removal efficiency with the different water sources according to filtration media.

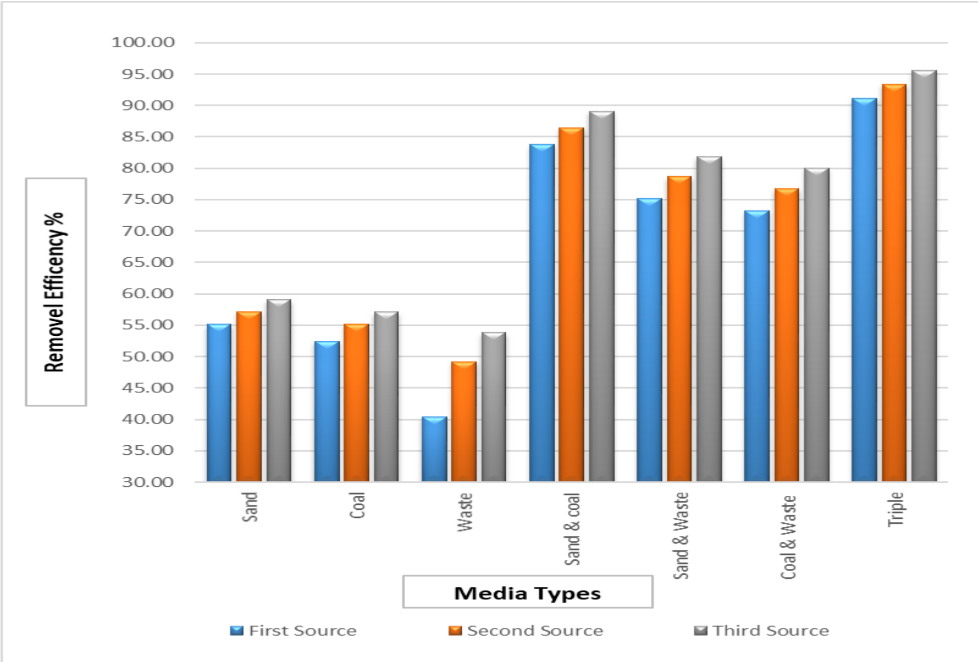

Figure (4) Average TSS Removal Efficiency with Different Water Sources

The data show that, the maximum TSS removal efficiency for all water sources achieved by triple filtration using sand, anthracite coal, and agricultural waste as a filter media and the minimum TSS removal efficiency achieved by mono filtration using agricultural waste as a filter media.

As usually, triple filtration recorded higher TSS removal efficiency than dual filtration and dual filtration recorded higher efficiency than mono filtration and this matches the previous studies about the filtration process. This is maybe due to the difference in media porosity, particle size, and the surface area of the particles.

For mono filtration, sand achieves higher TSS removal efficiency than anthracite coal which means that sand is better than anthracite coal as a filtration media. As known sand has a lower porosity than anthracite coal, this may be the reason for the increase in the TSS removal efficiency of the mono filtration using sand than mono filtration using anthracite coal. Sand porosity around 0.45 and anthracite coal porosity around 0.55 this small difference may be the reason for the small difference in the removal ratio.

Mono filtration using agricultural waste as a filter media recorded the lowest TSS removal efficiency for all water sources. It is maybe due to the high porosity of this media which approve the small particles to pass through the media voids and trap only the large particles. That also explains the increase in the TSS removal efficiency when using agricultural waste to treat water with high TSS concentration.

Dual filtration using sand & anthracite coal recorded higher dual filtration efficiency. On the other hand, dual filtration using sand & agricultural waste and dual filtration using anthracite coal & agricultural waste recorded lower TSS removal efficiencies. This is maybe due to the use of agricultural waste. From the above results can assume that when using agricultural waste as a filter media instead of sand or anthracite coal had a negative effect on dual filtration processes.

Dual filtration using sand & agricultural waste and dual filtration using anthracite coal & agricultural waste recorded similar removal efficiencies almost as the small difference in results recorded for the mono filtration using sand and anthracitic coal.

Also, experimental results show that the TSS removal efficiency for the first water source which has a low TSS concentration is close to the TSS removal efficiency for the second and third water sources which have high TSS concentration, so the inlet TSS concentration almost had a slight effect on the filtration process except when using mono filtration using the agricultural waste. As from the above results using mono filtration by agricultural waste for low TSS water source is not effective as when used to filtrate high TSS water sources which means the efficiency of the agricultural waste as a filter media increase when the inlet TSS inlet increase.

From these experimental results mono filtration recorded removal ratio ranged between 40 to 55 %, dual filtration recorded removal ratio ranged between 70 to 80 % and triple filtration recorded removal ratio above 90%. All efficiencies were suitable to use as a pretreatment unit for the ultrafiltration process. So the choice of filtration type and media for the pretreatment unit will depend on the filter size, media price, and the required washing rate.

V. CONCLUSION

Generally, the results of this study had shown the following specific conclusions: -

1. The suitability of applying the horizontal mono, dual & triple filtration process in a pipe.
2. The system can use as a pre-treatment for the ultrafiltration units for any source of water.
3. Triple filtration using sand, anthracite coal, and agricultural waste achieves the best TSS removal efficiencies.
4. Sand as a filtration media better than anthracite coal & agricultural waste.
5. Anthracite coal & sand have a better effect on the TSS removal efficiency than agricultural waste, especially for the low TSS water sources.
6. Agricultural waste is more suitable to filtrate high TSS water sources than low TSS water sources.

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