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THE CHOICE OF THE SUITABLE TREATMENT TRAIN AGAINST RAW WATER CRITERIA

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الملخص العربي
الماء له دور كبير في حياتنا اليومية. الحصول على مياه صالحة للشرب يثير قلق كبير في الوقت الحاضر. ولكن بسبب الزيادة السكانية، زاد تلوث المياه في المصادر المائية السطحية بشكل كبير بسبب الصرف الصناعي. نتيجة لذلك ، يجب استبدال تقنيات تنقية المياه القديمة بتكنولوجيات جديدة للمساعدة في تحسين كفاءة المياه المنقاة. في هذه الدراسة، تم تقييم بعض الأنواع الحديثة لتقنيات الترسيب والترشيح على المياه من ترعة الإسماعيلية. والمقارنة بوحدات التنقية التقليدية مثل المروق ومرشح الرمال السريع. وبينت نتائج الدراسة أن وحدات التنقية الحديثة هذه تحقق نتائج أعلي في كفاءة المياه المنتجة. لذلك يمكن استخدامها جميعًا في إنتاج مياه الشرب النقية في الحدود المسموح بها لمواجهة التلوثات الجديدة بالمصادر.

ABSTRACT
Water has a great role in our daily life. Obtaining clean potable water has a great concern nowadays. But due to increasing population, urbanization, and industrialization pollution of water resources had increased. As a result, the old treatment technologies should be replaced with the new ones to help improving the efficiency of the treated water. In this study, some modern procedures of sedimentation and filtration techniques were evaluated on the Ismailiya Canal raw water samples and were compared with traditional water treatment techniques as clariflocculator and rapid sand filter. The study results revealed that these modern treatment units had a higher removal efficiency and suitable to be used in producing treated water within the permissible limits facing the new pollutants loads in the water resources.

KEY WORDS
Surface Water Resources Pollution, Water Treatment Works, Modern Water Treatment Techniques, Comparison Evaluation.

INTRODUCTION
Water is very important for human's life on earth, an essential resource for the economy, and plays a very important role in the climate regulation cycle.**[1]** Sustaining enough water supply is one of the most important factors for human settlements' development. However, population increment made a large pressure on the limited high-quality surface sources, and the pollution of water with the domestic, agricultural and industrial wastes had driven to spoiling water quality in other sources.
At the same time, water quality legislations have become more restricted and the public becomes more aware of the quality of water. Therefore water quality can't be neglected in developing a water supply.

Water treatment plants are playing a very important role in purifying and supplying water to the people. All sources of water require treatment before being used by people. Water treatment can be known as the processing of water to a certain quality. These quality standards are set by regulatory agencies or by end-users.**[2]** So water treatment plants are designed to remove harmful pollutants from water. and to remove any irritating particles, color or smell that may be presented in water. And this is achieved through different process, each has its own aim that is considered critical to the overall process. Water treatment requires chemical, physical, and sometimes biological processes to remove pollutants.

Conventional water treatment process consists of alum addition, coagulation, sedimentation, filtration, and disinfection. Sedimentation process, is the process of removing water pollutants through settling down by the effect of gravity. Filtration is known as passing water through a porous medium to remove suspended particles. It acts as a second barrier for transferring diseases and disinfection. It decreases the load on the disinfection unit so it helps in increasing disinfection efficiency.**[3]**

The awareness about increasing the environmental pollution around us has opened the way for more effective potable water treatment. This shows the need for clean and improved supply of water. Therefore means have to be explored and done for increasing and improving existing plant capacities.

STUDY OBJECTIVE

This study was conducted in order to determine the best treatment train to meet the water quality in Ismailia canal with different variations using up to date treatment option for both sedimentation and filtration techniques. .

LITERATURE REVIEW

For sedimentation, most of water treatment plants use Clariflocculator as its sedimentation unit. But upgrades can be applied to this system in order to obtain high capacity and efficiency from the existing unit or design smaller footprints.**[4]** These upgrades can be as follow:

Accelerator is developed by Infilco Company [5] and nowadays is a trade-mark of Ondeo-Degremant Inc. **[6]** in accelerator all processes of rapid mixing, flocculation, and sedimentation occur in one unit. This combination has significant benefits like reduced cost and space **[2].**

Plate / Tube settler is dated back to an English patent in 1886. And was used in mining industries to remove heavy metals from slurries. The first developed plate settler was reported by Sweden in the 1960s.**[7]** Adding series of inclined plates/tubes at a certain angle to sedimentation tanks will increase the settling area for solid particles which will increase the capacity of the tank, and help for reducing the footprint for newly constructed units.

For filtration, Often the media used in rapid sand filters was single sand. But the problem appeared after backwashing, which is that the media aligned into different size grades. With larger size at the bottom and smaller size at the top. And this will lead to a filter with a high-efficiency top layer, but with rapid pressure loss. So the appropriate solution to solve this problem is using multi-media beds. The difference in the specific gravity of the media particles means that the large particles will settle slowly after backwashing such that the media will remain segregated **[7]**. A filter can be upgraded to increase its capacity and efficiency. Such that a filter which is originally designed to operate 1.36 L/sec/m² may increase to 2.7-3.4 L/sec/m² by changing media to dual or triple media. Or by capping the upper layer **[8]**

Sand filter capping is the process of replacing the top of sand media with capping material usually anthracite coal to improve the performance of filter similar to (sand/anthracite) filter **[9].** In Mosul water treatment plant in Iraq capping sand filter with 20 cm anthracite coal over a 40 cm sand had increased the plant capacity by two folds, and increased runtimes of the filter by 2-3 folds indicating more clear water production and less amount needed for backwashing **[10].**

Usually, sand had been used as the main media for rapid sand filter due to its availability and low cost. But researches had introduced many media like glass, crushed stones, pumice, and showed their effect on efficiency and head loss compared to the rapid sand filter. Granular activated carbon is used when adsorption and filtration are combined in a single unit **[3].**

A study was done at turkey to compare between both sand and pumice as filter media. It showed that removal efficiency for sand and pumice respectively are 85-90% and 98-99 %. And the head loss for sand and pumice was 460 mm and 215 mm respectively. So results show that pumice has a higher potential of use than sand **[11].**

Usually, media are arranged according to density from top (lighter) to bottom (heavier). Filters usually consist of anthracite coal at the top layer of depths 0.3-0.6 (m) supported on a sand layer of depth 0.15-0.4 (m) **[12]**. The benefit of anthracite coal is that it has high ability to adsorb organic matter and heavy metals **[13].**

In a comparative study between single and dual media filters done in Greece, it was found that dual media filters have greater filtration cycle (about 3 times higher) than single media filter **[14].**

It usually consists of 3 layers of media the top is anthracite coal rested on a sand layer rested on a fine granite layer. The flow of a multi-media filter is from 220-510 m3/m2/day **[15].**

The advantage of triple media filters is that they can filter water at a higher flow rate than mono media filters. (54-58 L/min/ ft^2) compared to 8 L/min/ ft^2. It also can operate at longer times than mono media filters (5 times or more at the same filtration rate). And can achieve a high percentage of water clarity because of the garnite layer that traps very fine particles **[16].**

GAMBELLA water treatment plant was upgraded from capacity 5040 m3/day to 10,000 m3/day. This was done by installing new pumps with higher capacity to the existing intake, adding lamella tubes and sludge scrapers to existing clarifiers, adding more efficient nozzles and changing media to existing rapid sand filter **[17].**

In 2012 BAHARI water treatment plant located in Khartoum was upgraded and its capacity was increased from 190,000 to 300,000 m3/day. This was achieved by constructing a new distribution chamber to centralize the intake of the plant. Replacing old pumps with new ones with higher flow. Execution of new gravity pipelines from and to the new distribution chamber in order to decrease the energy consumption. All clariflocculators have been overhauled and then the installation of lamella settlers was done. And media of rapid sand filters was changed and new nozzles were made to increase the rate of filtration. And new high lift pump station with six pumps was installed. **[18-19]**

In 2001 an old water treatment plant at Kafr El-Sheikh city constructed in 1921 was upgraded to a capacity of 300 l/s instead of 100 l/s, the plant contained one circular and two rectangular plain sedimentation tanks with capacity 60 and 40 l/s respectively and 5 rapid sand filters for treating water. The plain sedimentation basins have been upgraded by dividing each basin into two parts; the first part is assigned for the tapered contact flocculation (TCF) and the second is assigned for plate settlers. All of the existing sedimentation tanks have been upgraded in this way. The capacity of the circular sedimentation tank has been increased to 180 l/s instead of 60 l/s, while the capacity of the rectangular sedimentation tanks increased to 120 l/s instead of 40 l/s. and by replacing the five rapid sand filters with four new others the plant capacity has been increased up to 300 l/s **[20]**

In 1999 a study was done on water from Al-Awir treatment plant to determine the effect of upgrading the existing sedimentation unit with plates and it showed higher removal efficiency compared with the conventional existing one.**[21]**

another experiment was conducted on raw water from Tigris river in Baghdad on a lab scale sedimentation tank with plate settler it was found that the plates increased the hydraulic capacity of the tank with 330% with 7.4 % increment in turbidity removal efficiency.**[22]**

MATERIALS AND METHODS

The study was made at Sanitary engineering Lab at faculty of engineering Ain shams university to determine the study objective for all the applied techniques for both sedimentation and filtration units. Chemical analysis were conducted at the central lab Ain Shams University.

The study used Lab-scale pilots executed for four types of sedimentation units which are Clariflocculator, Plate settler, Accelerator, Accelerator modified with plate settler to determine the optimal performance for each type with the raw water quality.

Lab-scale pilots are executed for four filtration units which are Rapid sand filter, Anthracite Coal filter, Dual media filter, and Triple media filter. To determine the optimal performance for each type with the raw water quality in the chosen water treatment plant.

Different scenarios were operated for the complete pilot to determine the optimum solution that achieves highest water quality.

The scenarios were separated to four scenarios each one operated with one of sedimentation units followed by the four types of filters to determine the optimum case as shown in figure (1).

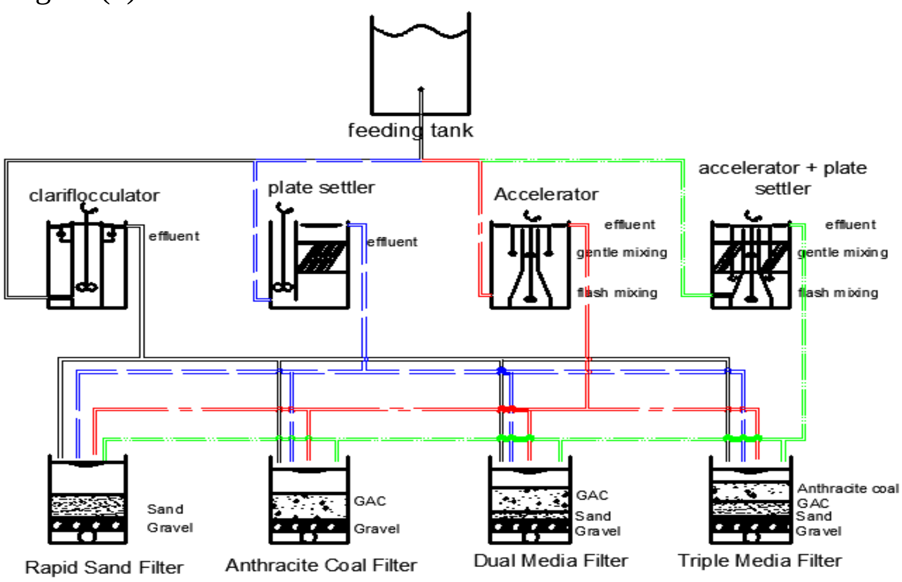

Figure (1) Flow diagram for The Complete Scenarios

First Scenario

First scenario was operating the lab scale pilot with Clariflocculator only followed by the four filtration units which are rapid sand filter, granular activated carbon, dual media filter, and triple media filter. Water was discharged to clariflocculator and settled for 2.5 hours then discharged to the four filters. It was run for five days. TSS was measured for each day after sedimentation and filtration units.

Figure (2) First Scenario Pilot

Second Scenario

Second scenario was operating the lab scale pilot with plate settler only followed by the four filtration units. Water was discharged to the plate settler and settled for 45 minutes then to the four mentioned filters. This was repeated for five days. TSS was measured every day after sedimentation and filtration units.

Figure (3) Second Scenario Pilot

Third Scenario

Third scenario was operating the lab scale pilot with the Accelerator only followed by the four filtration units. Water was discharged to the Accelerator and settled for 1.5 hour then to the four mentioned filters. This was repeated for five days. TSS was measured every day after sedimentation and filtration units.

Figure (4) Third Scenario Pilot

Fourth Scenario

Fourth scenario was operating the lab scale pilot with the Accelerator modified by plate settler only followed by the four filtration units. It was run for two trials with two retention times of 30 and 15 minutes in sedimentation unit then to the four filters. TSS was measured after both sedimentation and filtration units for five days.

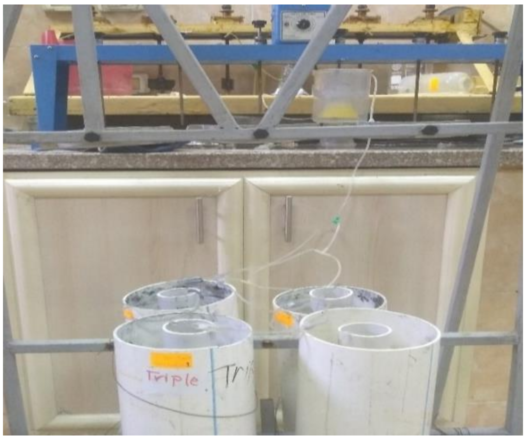

Figure (5) Fourth Scenario Pilot

RESULTS AND DISCUSSION

The results of the experimental tests for the water samples of the four lab-scale scenarios were presented as below. The raw water contained 60 mg/l TSS and the TSS of the samples after treatment were as below.

First Scenario Results Discussion

The efficiency was calculated from the average values which are illustrated in table (1) and figure (6).

Table (1) Results and Efficiency of the First Scenario

	After clarifloccolator (mg/l)	After RSF (mg/l)	After GAC filter (mg/l)	After dual media filter (mg/l)	After triple media filter (mg/l)
Day 1	4.4	2.1	1.6	0	0
Day 2	6.9	2.8	1.2	0.4	0
Day 3	8.1	3.6	3.6	2	0
Day 4	6.8	4.2	2.4	0.4	0.4
Day 5	6.5	5.6	2.4	3.2	0.8
TSS avg.(mg/l)	**6.5**	**3.6**	**2.24**	**1.2**	**0.24**
Overall Efficiency%	**89**	**94**	**96**	**98**	**99.6**

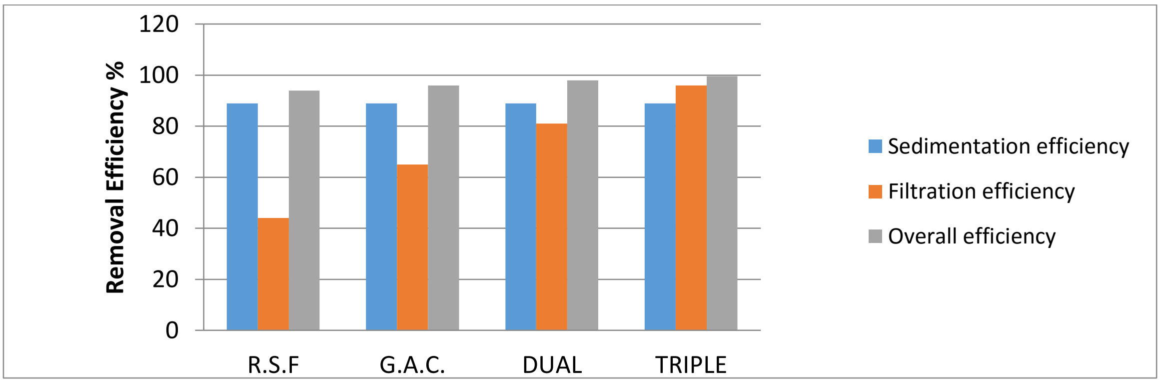

Figure (6) Removal Efficiency for First Scenario

Figure (6) presented the removal efficiency for sedimentation, filtration units and the overall efficiency. As shown in the previous figure the removal efficiency for the sedimentation unit was 89 % and the overall efficiency was enhanced after the four filters as presented. The removal efficiency of mono sand filter was lower than that of GAC, Dual, and Triple media filter which meet the results of all the previous studies.

As known from previous studies, the removal efficiency of triple media filter must be higher than the other filters.**[23]** This is due to the difference in porosity of media along the filter bed. The top layer has high porosity with larger surface area to trap large amount of suspended solids. The bottom layer with small porosoity to prevent small suspended solids from escaping with the filtered water. And the mid layer with medium porosity between the top and bottom layer.

Likewise, the dual media filter has higher removal efficiency than the mono media filter but lower than the triple media filter. The removal efficiency of GAC is higher than the mono sand filter as it has higher porosity which provide larger surface area for trapping suspended solids. But the efficiency after the filters were with lower values than expected this may be due to the incorrect backwashing for them.

Second Scenario Results Discussion

The efficiency was calculated from the average values which are presented in table (2) and figure (7).

Table (2) Results and Efficiency of the Second Scenario

	After plate settler (mg/l)	After RSF (mg/l)	After GAC filter(mg/l)	After dual media filter (mg/l)	After triple media filter (mg/l)
Day 1	6.4	1.6	3.6	0.4	0.3
Day 2	8.4	4	2	0	1.2
Day 3	7.6	1.2	1.2	2	0
Day 4	7.8	0.4	0	0	0
Day 5	8.8	0	0	0	0
TSS avg. (mg /l)	**7.8**	**1.44**	**1.36**	**0.48**	**0.3**
Overall Efficiency %	**87**	**97.6**	**97.7**	**99.2**	**99.5**

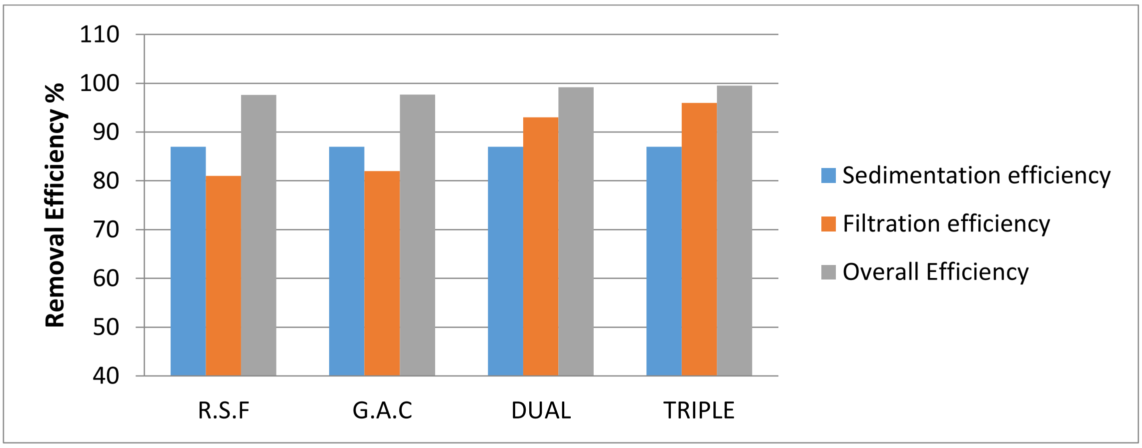

Figure (7) Removal Efficiency for Second Scenario

Figure (7) presents the removal efficiency after plate settler, the four filters and the overall efficiency. As known from previous studies, the removal efficiency after the plate settler is higher than clariflocculator. But this wasn't achieved in this experiment. This may be due to the small size of the lab-scale units that leads to difficulty in controlling the parameters effectively as the short length of the plates may affect the sedimentation efficiency as known from previous studies **[24]**. But overall removal efficiency increased after the four filters with acceptable values.

The removal efficiency for the mono sand filter is lower than GAC, Dual, and Triple filter which meet the results of all the previous studies **[23],** due to the less porosity distribution of the mono sand filter compared to dual, triple media filter. Where in dual and triple media filter, the coarse and light layer with larger porosity and surface area is found at the top of the filter to trap large suspended solids and the fine but heavy layer is found at the bottom of the filter to trap small suspended solids. On the contrary, in mono sand filter the lighter and finer sand particles are found at the top of the filter , and coarser, heavier sand particles are found at the bottom after backwashing. So filtration occur in the top few inches of the filter bed.**[25]**

Third Scenario Results Discussion

The efficiency was calculated from the average values and presented in table (3) and figure (8).

Table (3) Results and Efficiency of the Third Scenario

	After Accelerator (mg/l)	After RSF (mg/l)	After GAC filter(mg/l)	After dual media filter (mg/l)	After triple media filter (mg/l)
Day 1	3.2	0.8	2	0	0
Day 2	5.6	2.4	0.4	0	2
Day 3	5.6	0	0	1.6	0
Day 4	6.4	0	0	0.8	0
Day 5	6.8	2.4	0	0.8	0
TSS avg. (mg /l)	**5.52**	**1.12**	**0.48**	**0.64**	**0.4**
Overall Efficiency%	**91**	**98.1**	**99.2**	**98.9**	**99.3**

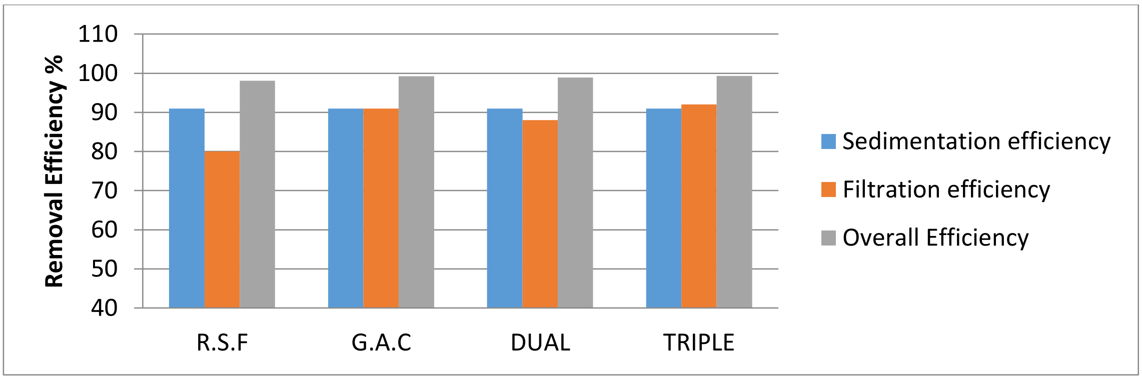

Figure (8) Removal Efficiency for Third Scenario

Figure (8) presents the removal efficiency after sedimentation, filtration, and the overall removal efficiency. The value of the removal efficiency after the Accelerator could be accepted and it was enhanced after the four filters.

As known from the previous studies that the removal efficiencies for the triple media filter is higher than the Dual, GAC and Mono sand filter respectively. And this was achieved in this experiment as shown in the previous figure.

Except for the dual media filter the removal efficiency was lower than GAC filter. This may be due to the following: after backwashing of the filter, the media particles were not distributed uniformly. So some suspended solids escaped with the filtered water. Or some media particles escaped with the filtered water.

Fourth Scenario Results Discussion

For the first trial, the efficiency was calculated from the average values that are illustrated in table (4) and figure(9).

Table (4) Results and Efficiency of the Forth Scenario (first trial)

	After Accelerator and plate settler (mg/l)	After RSF (mg/l)	After GAC filter(mg/l)	After dual media filter (mg/l)	After triple media filter (mg/l)
Day 1	7.2	0	0	0	0.4
Day 2	9.2	0	0.6	0	0.4
Day 3	10.8	5	2	4	0
Day 4	10.4	0	2	0	0.8
Day 5	8.4	0	0	0	0
TSS av. (mg /l)	9.2	1	0.92	0.8	0.32
Overall Efficiency%	85	98.3	98.5	98.7	99.5

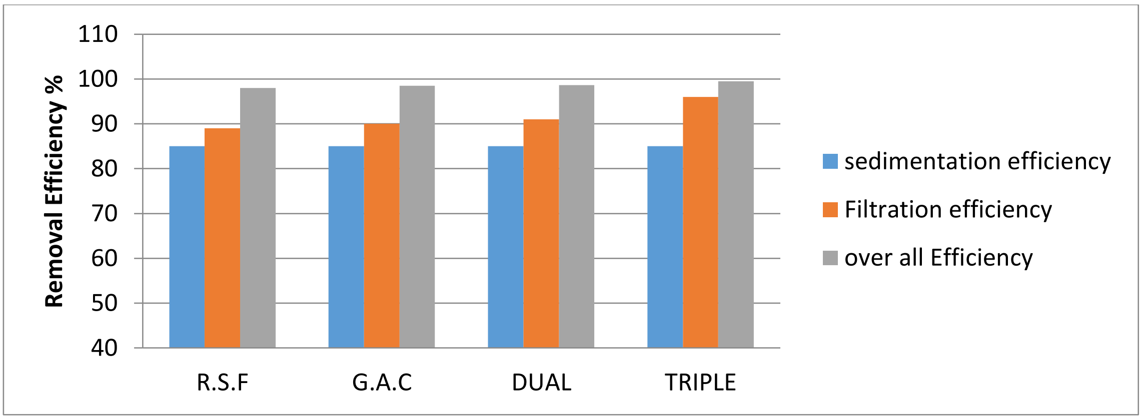

Figure (9) Removal Efficiency for Forth Scenario (trial one)

As shown in figure (9) the efficiency of the Accelerator and plate settler was less than expected. As it was expected to be higher than both accelerator and plate settler. because this system mixed between the increased sedimentation area in the plate settler zone, and the recirculated sludge in the Accelerator zone. But the efficiency might be less than expected due to the small size of the lab-scale units that leads to difficulty in controlling the parameters effectively as the short length of the plates may affect the sedimentation efficiency as known from previous studies.**[24]** or the inaccurate control of timing or alum dose that may affect the results with a large value in that lab-scale pilot.

As known from the previous studies, the removal efficiency for mono sand filter might be lower than GAC, dual, and triple media filter. This was achieved in this experiment as shown in the figure. This is due to the less porosity distribution of the mono sand filter compared to dual, triple media filter. Where in dual and triple media filter, the coarse and light layer with larger porosity and surface area is found at the top of the filter to trap large suspended solids and the fine but heavy layer is found at the bottom of the filter to trap small suspended solids.

In the second trial, the efficiency was calculated from the average values that are illustrated in table (5) and figure (10).

Table (5) Results and Efficiency of the Forth Scenario (second trial)

	After Accelerator and plate settler (mg/l)	After RSF (mg/l)	After GAC filter(mg/l)	After dual media filter (mg/l)	After triple media filter (mg/l)
Day 1	9.6	0	0	0	0
Day 2	8.8	2.4	0	0	0
Day 3	9.6	0	0.8	0	0
Day 4	7.6	0	0	0	0
Day 5	8.9	0	0	0	0
TSS av. (mg /l)	**8.9**	**0.48**	**0.16**	**0**	**0**
Overall Efficiency%	**85**	**99.2**	**99.7**	**100**	**100**

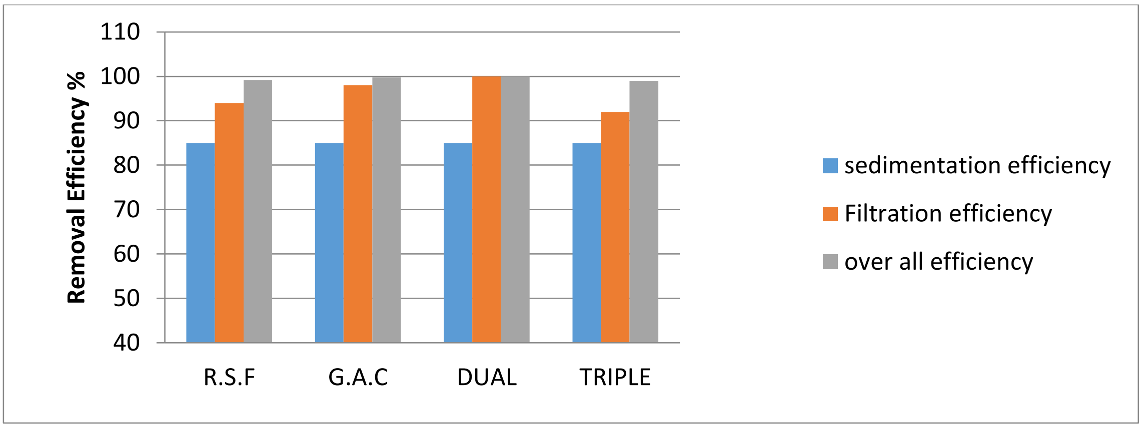

Figure (10) Removal Efficiency for Forth Scenario (trial two)

The removal efficiency after sedimentation, filtration and the overall removal efficiency are presented in figure (10). It was less than expected after the Accelerator and plate settler as mentioned in trial one. But efficiency increased to accepted levels after the four filters.

As known from previous studies the removal efficiency for mono sand filter is lower than that of GAC, dual, triple media filter respectively.**[23]** This was achieved in this experiment as shown in the figure except for triple media filter which must have higher efficiency than the RSF, GAC and dual media filter. But this may be due to the irregular distribution of media particles after backwashing that lead to escaping some media particles or suspended solids with filtered water.

CONCULUSION

From the results of the study the following conclusions are submitted:

1. All types of sedimentation units achieved high removal ratios for TSS.
2. The best sedimentation unit for the applied raw water criteria was the accelerator unit.
3. All types of filter units achieved high removal ratios but the triple mdia one is th only one that achieved the target of effluent water with zero TSS.
4. The optimum treatment train is the Flash mixing followed by the accelerator followed by triple media filter which is deal with the previous studies.

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