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Upgrading of An Existing Compact Water Treatment Plant

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ABSTRACT

Compact Water treatment plants was established to solve the problem of water supply in villages as a quick solution, but with the increase in population and poor maintenance of compact units, the actual production capacity became not equal to the capacity of its design, so the tendency was to remove these units and build new water treatment plants with a high cost and thus do not achieve any benefit from the current units.

This study aims to increase the capacity of El-Warrak compact water treatment plant by developing its hydraulic capacity and maximize its productivity without affect the produced water quality or need more land with minimum possible modifications, by comparison between three types of sedimentation units (tube settler, super Accelerator, super precipitator) followed by three types of filtration units (sand filter, Dual media filter, Triple media filter), After application The removal efficiency of them were within the permissible limits which allows there application.

The technical comparison between the six proposals resulted that the best solution was the proposal which is converting only four plate settlers to tube settlers and & eight rapid sand filters to triple media filters that achieves increasing the capacity of sedimentation unit from 2400 m3/day to 10324.8 m3/day it means increasing the capacity by 4.3 times the old one,

The total cost of vertically upgrading the existing water treatment plant is 28,800,000 L.E while the total cost of removing existing plant and building new one will be 103,850,000 this means that vertical upgrading for the existing plant saves about 72.26 % of the total cost of horizontal upgrading the existing water treatment plant.

Keywords: Water Treatment, Sedimentation, Filtration, Compact units

INTRODUCTION

Water is one of the most important substances on Earth and is essential for the continued existence of life on Earth. The importance of water supply to all people in any country is an important goal. so, the process of water treatment is classified as essential before it is delivered to the consumer as it can contain many harmful pollutants.

Water is treated in water treatment plants. Water undergoes various processes such as coagulation, flocculation, sedimentation, filtration and disinfection. then pumped through the network to consumers.

Each process plays a different role in water treatment. For example, sedimentation removes most of the suspended solids, filtration removes the rest, and disinfection kills all bacteria in the treated water.

Compact Water treatment plants was established to solve the problem of water supply in villages as a quick solution which covers technical and political means, with progress in civilization and natural water pollution increase, the government decided to cover all the country with treated water to improve the health and human life but with the high cost of central water treatment plants the government decided to use compact water treatment plants.

With the increase in population and poor maintenance of compact units, the actual production capacity became not equal to the capacity of the its production, so the tendency was to remove these units and build new water treatment plants with a high cost and thus do not achieve any benefit from the current units, so it was necessary to study the possibility of developing these units and benefiting from them as much as possible.

This thesis aims to optimize the increase of the capacity of an existing water treatment plant vertically without addition of new treatment units to avoid breaking down the plant for a long time and to save the high cost of building a new plant including the land cost and new tanks.

The thesis work was divided into two parts. The first was the experimental lab work, which was done at the Sanitary Engineering lab. at Faculty of Engineering Ain Shams University. Tests related to this lab work were done at the central lab of Ain Shams University, Faculty of Science.

The second part was a mathematical application on an existing water treatment plant, which was Al-Warrak water treatment plant. The experimental lab work was divided into Three scenarios. Each scenario used one of sedimentation unit from tube settler, super accelerator and super precipitator followed by three lab-scale filters (sand filter, dual media filter and triple media filter), the total suspended solids (TSS) were measured at the effluent of the lab-scale sedimentation units and the three filters. Finally, the efficiency of each scenario was calculated to determine its ability to be applied on the existing water treatment plant.

LITERATURE REVIEW

for operation and maintenance needs and also to obtain the investments capital in the water supply system the small water treatment plant that called compact unit is a system for treatment of water of surface or ground sources had appeared for saving both time and money for towns, factories and villages in Europe and USA after the end of the second world war for quick feeding for drinking water. it had been distributed quickly as an easy, fast in construction, cheap and low in O & M requirements system comparing with big conventional plants. [1]

The small communities, villages and towns were always served separately by even compact units or ground water direct source till the end of the fiftieth and the beginning of the sixtieth of the past centenary when the regional planning started to take place depending on a big conventional water treatment site for serving a region include several towns and villages [2].

The regional concepts cannot be economically satisfactory with the long distances between the served communities and for the temporary or securities or private communities as mining or army camps. Also, with the high cost of water transportation and feeding network maintenance an area had been left for the compact treatment unit to live and developed with the society needs [3].

The towns, villages and small communities are almost need the water supply criteria for the absence of the big huge industries that need special requirements and raise the consumption rates. The use for the compact units with these types of inhabited areas was very economic and successfully for both construction and running costs [6]. This met with the reality of the small number of served people, their poorness and disability to raise funds without the governmental assistance. [4]

A design had been made by NOPWASD depending mainly on the designs of the four imported compact units and had been used for locally manufacturing by Eriscom company. Also, now and after the trial success the military factories started to manufacture its compact unit depending also on NOPWASD design. [5]

he main problem the main problem in existing compact units is the use of steel sheets, parts and elbows that in the humid Egyptian weather quickly highly corroded which increase the maintenance needs. [6]

The compact units according to their existing situations are not suitable to be a permanent solution under the reality of the absence of central workshops for manufacturers in each governorate and the shortage in qualified staff for plant operation. [6]

The success of the use of compact units in Egyptian circumstances needs the achieve of enough budgets for operation and maintenance needs, qualified and trained operating staff, good control management for plant operation and the use of good quality materials in construction. [6]

MATERIAL AND METHODS

Our study was applied on two parts. Frist was in the laboratory as experimental work using lab scale pilot and the second part was the mathematical applying on the existing El Warrak plant.

LAB SCALE WORK

it was made by a lab scale pilot (figure (1,2)) in Sanitary Engineering lab, faculty of engineering, Ain Shams university to determine the optimal design and technology for both sedimentation and filtration units.

Several different scenarios were operated for the complete pilot to determine the optimum solution that achieves maximum possible capacity with high water quality. The scenarios consisted from three types of sedimentation unit (tube settler, super accelerator and super precipitator) each one was followed by the three applied types of filters (mono sand media filter, dual sand and AC media and triple sand, AC & activated carbon media filter) with total nine scenarios to determine the optimum solution in both productivity & efficiency.

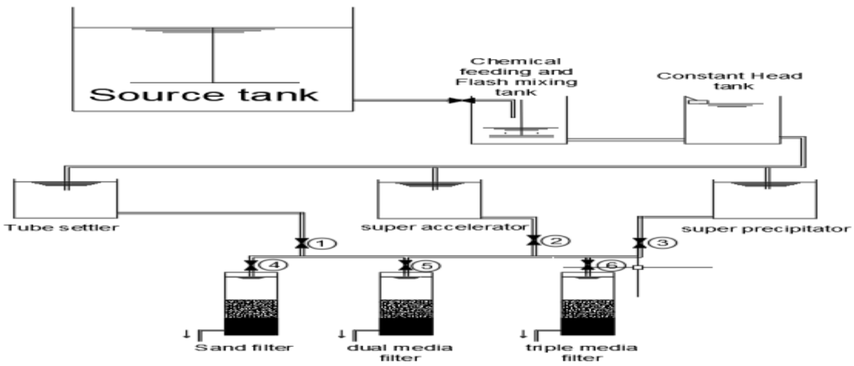

Figure (1) Flow Diagram for The Complete Scenarios

Figure (2) The Used Lab Scale Pilot

RESULT AND DISCUSSION

The lab scale results showed the success of all scenarios to achieve the required efficiency with different flow for each scenario as illustrated in tables (1) & (2).

To determine the best choice for sedimentation unit a comparison between the three applied sedimentation techniques due to removal efficiency, required modification for existing unit and time of execution was made.

The comparison in efficiency was made using the study experimental results that depended on the use of raw inlet water with 70 mg/l as TSS load on the units with alum dose for coagulation 35 mg/l as illustrated in table (1) that is presented the comparison between removal efficiencies for sedimentation units for the 6 days operation period which measured for each unit at same conditions and with same raw water characteristics.

Table (1) Comparison Between Sedimentation Units Efficiency

Sample Location / Date	TUBE SETTLER		Super Accelerator		Super precipitator	
	Residual TSS (mg/l)	Removal Ratio (%)	Residual TSS (mg/l)	Removal Ratio (%)	Residual TSS (mg/l)	Removal Ratio (%)
Day 1	3.27	95.33%	4.41	93.70%	3.41	95.13%
Day 2	3.27	95.32%	3.55	94.93%	3.85	94.50%

Day 3	**3.11**	**95.55%**	**3.90**	**94.43%**	**3.68**	**94.74%**
Day 4	**3.15**	**95.50%**	**3.88**	**94.46%**	**3.55**	**94.92%**
Day 5	**3.15**	**95.50%**	**3.89**	**94.45%**	**3.54**	**94.95%**
Day 6	**3.17**	**95.47%**	**4.30**	**93.85%**	**3.56**	**94.91%**
Average	**3.19**	**95.45%**	**4.01**	**94.27%**	**3.60**	**94.86%**

As shown in table (1) the average removal efficiency for the tube settler was 95.45 % at retention time of 20 minutes, super accelerator was 94.27% at retention time of 35 minute and super precipitator was 94.86% at retention time of 30 minutes the overall efficiency was enhanced after the three filters.

As known the small size of the lab-scale units leads to difficulty of the operation control on the pilot due to the weakness of content compared with actual plant.

Table (2) presents the comparison between removal efficiencies for filtration units for the 6 days operation period preceded by the different applied sedimentation units which measured for each unit at same conditions and with same raw water characteristics which has TSS of 70 (mg/l).

Sample Location / SED. Unit	**DAY NO**	**Mono Sand Filter**		**Dual Media Filter**		**Triple Media Filter**	
		RES TSS (mg/l)	**Removal Ratio (%)**	**RES TSS (mg/l)**	**Removal Ratio (%)**	**RES TSS (mg/l)**	**Removal Ratio (%)**
Tube Settler	**1**	**1.25**	**98.22**	**0.82**	**98.82**	**0.54**	**99.23**
	2	**1.10**	**98.43**	**0.87**	**98.76**	**0.48**	**99.31**
	3	**1.11**	**98.42**	**0.79**	**98.86**	**0.51**	**99.27**
	4	**1.13**	**98.39**	**0.79**	**98.87**	**0.48**	**99.31**
	5	**1.11**	**98.42**	**0.76**	**98.91**	**0.48**	**99.31**
	6	**1.11**	**98.41**	**0.76**	**98.92**	**0.54**	**99.23**
	Avg.	**1.13**	**98.38**	**0.80**	**98.86**	**0.51**	**99.28**

Super Accelerator	**1**	**1.62**	**97.69**	**1.10**	**98.42**	**0.77**	**98.90**
	2	**1.45**	**97.93**	**1.13**	**98.38**	**0.72**	**98.97**
	3	**1.51**	**97.84**	**1.07**	**98.47**	**0.68**	**99.03**
	4	**1.29**	**98.15**	**1.05**	**98.50**	**0.67**	**99.04**
	5	**1.30**	**98.15**	**1.05**	**98.50**	**0.65**	**99.07**
	6	**1.33**	**98.09**	**1.06**	**98.49**	**0.66**	**99.05**
	Avg.	**1.42**	**97.98**	**1.08**	**98.46**	**0.69**	**99.01**
Super Precipitator	**1**	**1.12**	**98.39**	**0.73**	**98.96**	**0.46**	**99.34**
	2	**1.24**	**98.22**	**0.87**	**98.76**	**0.63**	**99.09**
	3	**1.23**	**98.24**	**0.87**	**98.76**	**0.64**	**99.08**
	4	**1.23**	**98.24**	**0.89**	**98.73**	**0.61**	**99.13**
	5	**1.24**	**98.23**	**0.85**	**98.78**	**0.61**	**99.13**
	6	**1.25**	**98.22**	**0.87**	**98.75**	**0.61**	**99.13**
	Avg.	**1.22**	**98.26**	**0.85**	**98.79**	**0.59**	**99.15**

Table (2) Comparison Between Filtration Units Efficiency

From Table (2) which illustrated the removal efficiency for the three applied types of filters, the results coup with the literature review for such types of filters, but the decrease of removal efficiency than it should be was because of the lap scale pilot that neglect some parameters as media depth, instability of the bad distribution of the back-wash water in the pilot due it is lab scale size and personal equation errors in the measuring.

FINICAL COMPARISON BETWEEN UNITS

The applied prices of upgrading each unit for the application on the existing plant were taken according to the material prices in the bulletin of February 2023 of building materials prices issued by the Egyptian Ministry of Housing, Utilities and Urban Communities **[7]**.

FINICAL COMPARISON BETWEEN SEDIMENTATION UNITS

As table (3) illustrate, Changing plate settler with tube settler increasing the capacity of sedimentation unit from 2400 m3/day to 10324.8 m3/day it means increasing the capacity by 4.3

times the old one, the required time for modification for this unit is 20 days and its replacement cost will be 400000 L.E , Changing plate settler with super accelerator increasing the capacity of sedimentation unit from 2400 m3/day to 5760 m3/day it means increasing the capacity by 2.4 times the old one, the required time for modification for this unit is 50 days and its replacement cost will be 600000 L.E and Changing plate settler with super precipitator increasing the capacity of sedimentation unit from 2400 m3/day to 6316 m3/day it means increasing the capacity by 2.84 times the old one, the required time for modification for this unit is 60 days and its replacement cost will be 650000 L.E , note that there is 4 compact units in this plants which means the final cost will be 4th this cost

Table (3) Comparison Between Sedimentation Units application

Comparison face / Applied Unit	Upgrading Max Capacity (m3/Day)	Capacity Increase Ratio	Time for Modification of Sed Unit (days)	Cost of unit Modification (L.E.)
Tube Settler	**10324.8**	**4.3**	**30**	**300000**
Super Accelerator	**5760**	**2.4**	**50**	**500000**
Super Precipitator	**6316**	**2.84**	**60**	**550000**

FINICAL COMPARISON BETWEEN FILTRATION UNITS

Table (4) illustrates that the application results on the existing filter units with the three types showing the time of application taking place and the cost inclusive existing filter body inhabitation. Even the mono sand filter is the lower in cost and less time of upgrading but it's also the lower efficiency, the deference with the dual and triple media filters with mono media filter is so small that raise the weight of the efficiency and filtration rate increase than the cost increase.

Generally, from the settling unit comparison and the filtration unit comparison the best scenario to maximize the productivity with minimum modification is the applying of tube settler followed by Triple media filter that achieves 4.3 the existing capacity.

Table (4) Comparison Between filtration Units application

Comparison / Applied Unit	**Time for Modification of Sed Unit (days)**	**Cost of this unit Modification L.E**
Sand filter	**5**	**11884**

Dual media filter	**8**	**15966**
Triple media filter	**10**	**19106**

APPLICATION ON THE EXISTING EL WARRAK WTP

The experimental work study results were applied on the existing El Warrak WTP by replacing the plate settlers inside the sedimentation tanks with tube settlers and the mono sand filter media with triple media filter. The results of modifications on units detailed dimensions were illustrated in here after.

Figure (3) The Existing plant

Figure (4) Existing Plant First Part

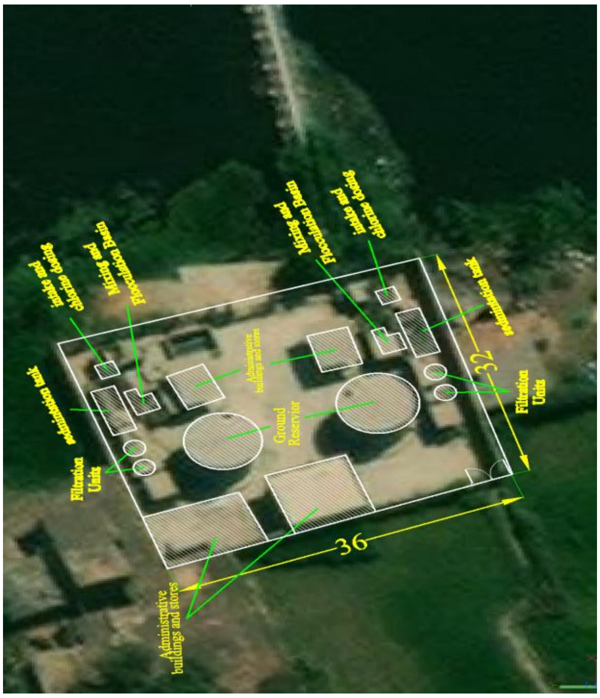

Figure (5) Existing plant Second Part

UPGRADING PLATE SETTLER TO TUBE SETTLER

The existing sedimentation tank contained plate settlers as mentioned in chapter 3. These plate settlers replaced by tube settlers to give the max productivity as mentioned in this chapter as flowing:

volume of sedimentation unit = 5.95*2.6*2.3 = 35.851 m3

Retention time 20 min

Q = R.T * Volume = 24/ (20/60) * 35.851 = 2581.2 m3/day

SLR (surface loading rate) = 200*2.3*5.95 = 2737 m3/day

take Q = 2581.2 m3/day

with the following properties and dimensions.

vertical length of tube = 100 cm

inner width of tube = 2.5 cm

outer width of tube= 3.2 cm

inclined angle of tube = 60 degree

area of tube ellipsoid = 15.909 cm

area of tube ellipsoid + half gaps between pipes = 20.256 cm

No of required tubes = sed unit area / (area of tube ellipsoid + half gaps between pipes).

=230 x 430/20.256= 4883 tube = 493 tube/m2

S.L.R for Tubes = 2581.2 / (.1586*4883) = 3.33 m^3/ m2/day =

UPGRADING SAND FILTER TO TRIPLE MEDIA FILTER

The existing filters are 8 pressure sand filters with diameter of 2m and height of 2m to serve 4 sedimentation units we are going to cheek if we need more filtration units and changing these filtration units to pressure triple media filters.

Cheek on existing units' number:

Triple media filter surface loading rate (235-590 m3/m2/day)

Actual flow for the 8 triple media filters = Q/A

=2581.2*4 / (8*3.14*1^2) = 411 m^3/m^2/day **(SAFE) (no need to add units)**

Applying requirements

Required amount of gravel = 3.8 m3

Required amount of sand = 8.8 m3

Required amount of GAC = 5 m3

Required amount of anthracite coal = 3.78 m3

After making these modifications there will be no need for any other modifications except replacing old pumps with new pumps which achieve the new efficiency and building the two new ground storage tank in each site with 1800 m3 capacity.

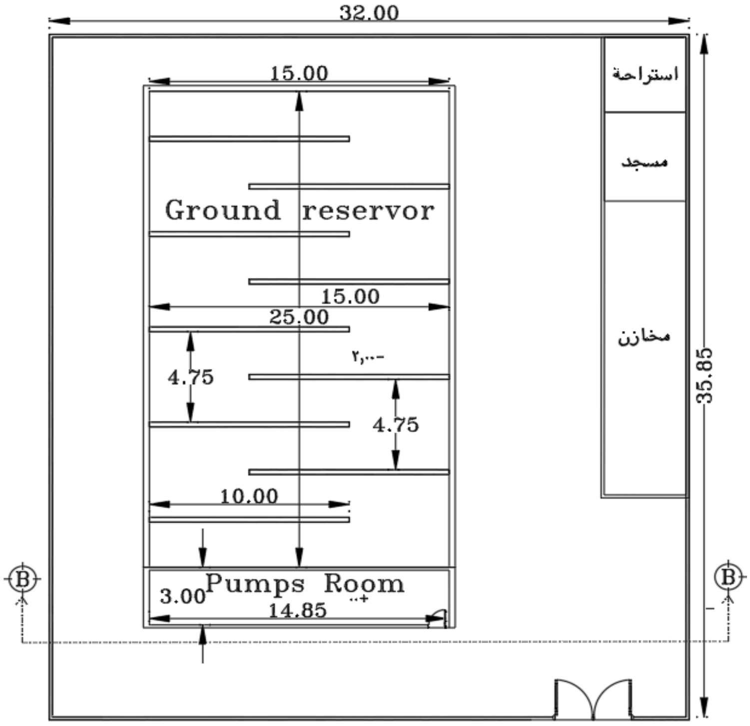

Figure (6) Frist Floor of Proposed WT Plant Plan

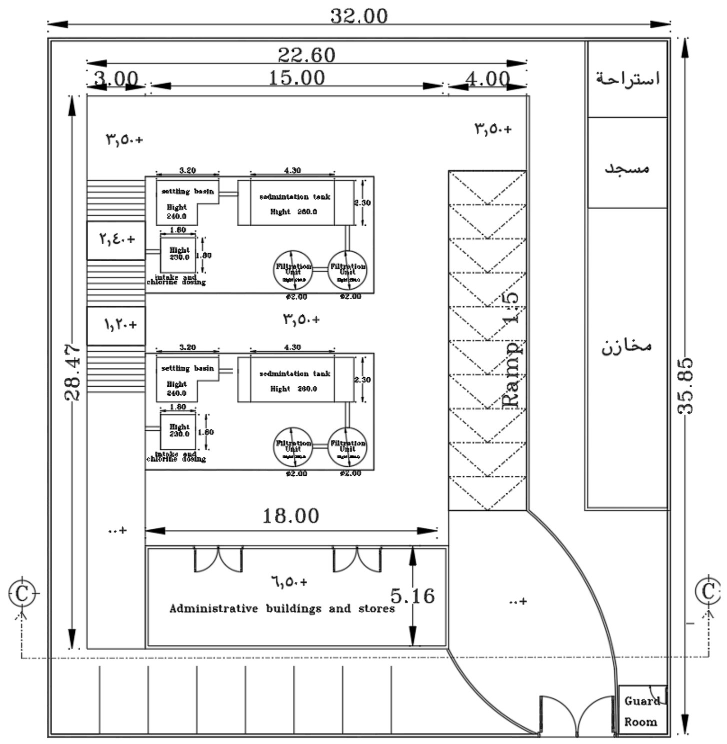

Figure (7) Second Floor of Proposed WT Plant Plan

As shown from previous calculations This scenario application leads to increase the existing plant from 2400 m³/day to 10324.8 m³/day. Nearly 4.3 times the existing one.

The development will be in phases, where the first phase for a period of 4 months will begin with the second part of the station, and the first part will continue to work until the production of treated water does not stop, then the second part will be operated and the development of the first part will begin for a period of 4 months as well.

COST OF MODIFICATION APPLICATION ON EXISTING PLANT

Table (5) illustrated the estimated cost for the upgrading the existing plant using tube settlers and triple media filters instead of plate settlers and mono sand media filters. Prices are calculated according to material prices in the bulletin of February building `materials prices issued by the Egyptian Ministry of Housing, Utilities and Urban Communities published in February 2023 **[7]**.

Table (5) Estimated Cost for Upgrading the Existing Plant

UNIT	SPECIFICATIONS	COST in 10^3 L.E
Removal of existing plant cost	Removing all old buildings and storing them till modification	**600**
intake and low lift pump station	8 new pumps with q of 110 m3/hr. (replace the existing old four pumps and add 4 stand by pumps)	**1,600**
for replacing plate settler to tube settler	removing plate settlers, maintenance (sandblasting, painting) Adding tube settlers	**1,600**
replacing old filters pumps	8 new pumps with 110 m3/hr.	**1,200**
replacing filter media	removing existing media maintenance (sandblasting, painting) adding new media (gravel + sand + anthracite coal + GAC for the 8 filtration units	**1,800**
building 2 new ground	2 concrete ground reservoirs each with capacity of 1800 m3	**12,000**

reservoirs		
service buildings	2 new service buildings for stores, lab. and administration rooms 2 new service buildings for workshop, electricity room, labors rest room, clinic and mosque	**3,000**
land scape and fence rehabilitation	2 new gates with guard room 8 new guard towers fence rehabilitations road pavement and landscape	**3,000**
total upgrading cost		**24,800**

MODIFICATION DISCUSSION

As illustrated from previous calculations the best scenarios is to upgrade the existing four plate settlers with four tube settlers and the eight sand filters to eight triple media filters with building new two ground reservoirs with capacity of 3600 m3, now we are going to compare the proposed modification with the case of removing old plant and building new one according to the material prices in the bulletin of February building `materials prices issued by the Egyptian Ministry of Housing, Utilities and Urban Communities **[7]**

Table (6) Comparison Between the Results of Modifications with The Cost of Removal and Building New Plant with the Same Capacity

Comparison	**THE RESULT of MODIFICATION**	**REMOVING OLD PLANT and BUILDING NEW PLANT**
Land needs	No need for additional area As the needed area equal to the existing available area of plant = 2294.4 m2	We need to duplicate existing area with approximate. COST = **3,250** x 10^3 L.E
COST of Civil & Mechanical Works In 10^3 L.E	As mentioned in table (5) = **24,800**	Removal cost = **600** Civil work of new plant = **50,000** Supplies and mechanical equipment = **50,000**
Time Required for	**8 months**	**15 months**

Modification		
Total Cost	**24,800**	**103,850**

As illustrated in table (6) removing of old plant and building new one with the same capacity and caricaturists will need to duplicate the existing area and will cost 4.18 times the proposed modification ant it will take 7 months more than the proposed modification to be applied.

CONCLUSION

From the previous study, the following conclusions could be illustrated:

All the applied scenarios in the lab scale had succeeded in producing the potable water according to the drinking water limits in all cases the difference in produced water quantity was noticeable between them depending on the applied technology.

The technical comparison between the six proposals resulted that the best solution was the **proposal** which is converting only four plate settlers to tube settlers and & eight rapid sand filters to triple media filters that achieves increasing the capacity of sedimentation unit from 2400 m3/day to 10324.8 m3/day it means increasing the capacity by 4.3 times the old one,

The total cost of vertically upgrading the existing water treatment plant is 28,800,000 L.E while the total cost of removing existing plant and building new one will be 103,850,000 this means that vertical upgrading for the existing plant saves about **72.26 %** of the total cost of horizontal upgrading the existing water treatment plant.

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