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# *ECONOMIC STUDY OF THREE ALTERNATIVES OF WASTEWATER TREATMENT IN BAGHDAD*

[**Dania M Al-lami**, ***Mohamed Tarek Sorour, Medhat Abd Moaty Moustafa, Samia Ahmed Aly*** ]

***Abstract*— Iraq suffers from shortage in water resources due to the increase of population and the extension of agriculture lands and studies have shown that the deficit will reach 73% in 2025. The main water resources in Iraq is the Euphrates and Tigris rivers, which provide more than 98% of Iraq's water demands for the various purposes. Since 1970, Syria and Turkey began building dams on the Tigris and Euphrates Rivers, causing reduction in the flow of rivers into Iraq. Such a problem may be overcome by increasing non-conventional water resources such as reuse of treated wastewater in irrigation. The treated wastewater is preferred to be used in agriculture, where 75% of water consumption. Therefore, the current study focuses on safe reuse of treated wastewater in agriculture to cover the shortage water resources in Iraq.In order to reach the safe use of sewage water, a case study of the Russtmiya wastewater treatment plant in Baghdad has to be chosen according to the guidelines and laws for future using in the cultivation of crops with an economic return. Russtumiya WWTP is selected as a case study, which suffers from over load in 2020. The first step is to design the WWTP using three alternatives; complete mix activated sludge carbon removal (CAS); membrane bioreactor (MBR) process and; complete mix (aerated lagoon). GPS-X program is used to check the design and extract some input data from influent advisor to capdet work program. Finally, the cost analysis of three alternatives is estimated to choose the most suitable and economic design for the plant . The obtained results from cost analyzes for three alternatives, Reveled that the aerated lagoon system was the lowest current value and the unit cost per m$^3$. Economically, the aerated lagoon system is the most cost-effective.***

***Keywords*— *Water resources in Iraq, Wastewater reuse, Reuse guidelines, GPS-X, Cost estimation.***

## *Introduction*

Untreated wastewater is a major risk to human health since it contains waterborne pathogens that can cause serious human illness. Untreated wastewater also destroys aquatic ecosystems, threatening human livelihoods, when the associated biological oxygen demand and nutrient loading deplete oxygen in the water to low levels to sustain aquatic life.

Reuse of wastewater has some benefits such as controlling the level of pollutants that reach the natural water bodies by discharging wastewater also contains high levels of nutrients, and when properly extracted and used, it can reduce eutrophication problems in receiving waters and may ultimately reduce the use of inorganic fertilizers (Aly,2015). Recently, wastewater can be reused in agriculture. Domestic wastewater contains the main nutrients and vital elements for plant growth and soil improvement. Irrigation reuse is also more beneficial, as the level of purification can be reduced. In addition, it saves the processing costs, because of the role of soils and crops as biological remediation facilities .

According to previous studies and expert opinions , Iraq has the maximum available water resources of 64.65 billion m 3 / year and Therefore, Iraq will suffer from water deficit up to 73% in 2025 by 1.4 billon m$^3$/year. The water shortage is expected to continuously increase due to population growth, agriculture expansion, industrial development and rise in the standard of living. Furthermore, the country is facing serious challenge due to plan agriculture. The current study focuses on safe reuse of treated wastewater in agriculture to cover the shortage in water sources in Iraq ,(Nawar J.Hashim,2006) .

In Iraq, about 27 percent of the total urban population lives in Baghdad, this is the largest city in the country. Its population is about 6 million. The Tigris River is the only source of drinking water in it. The sewer network covers about 92 percent of the city. Al-Russtamiya wastewater

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treatment plant is considered one of the oldest stations in Baghdad. It discharges 475 thousand cubic meters per day and feeds the Rusafa part of the capital Baghdad. However, the plant would suffer in the future from the over load of waste water that entering the plant. In this, we propose three ways to design the extension of the plant. The aim of the current chapter is to show the preliminary design concept and the calculations steps based on the guidelines.

The suggest design of three alternatives: conventional Activated sludge with carbonaceous removal (CAS), membrane bioreactor (MBR) and Suspended growth aerated lagoon for Russtumiya WWTP are carried out by using GPS-X of activated sludge process (ASP). The analysis and cost calculation of each design method are done by using the Capdet work (V4). Also, the economic feasibility of reuse of treated wastewater from the WWTP in the agricultural drainage system is evaluated .

Authors Name/s per Affiliation *(Author)*
line 1 College / University Name
line 2: Country
line 4: e-mail address if desired

Authors Name/ **Dania M Al-lami**
Faculty of Engineering / Alexandria University
Egypt

## *2.Materials and Methods*

### *2.1 Description of Russtumiya plant*

Baghdad has three main wastewater treatment plants, namely Alkarkh, northern Al-Rustumiya (3rd expansion) and southern Al-Russtumiya (0, 1, 2) as shown in the figure (1). Al-Russtumiya Wastewater Treatment Plant (3rd expansion) has begun to be in service in1984. The Plant is an activated sludge system which biologically treats compounds of carbon in raw wastewaters. The important constituents of concern in wastewater treatment are: Nutrients (nitrogen and phosphorus), biodegradable organics, suspended solids, pathogens, and heavy metals. Al-Russtamiya wastewater treatment plant (3rd expansion) serves 1500000 capita with an average wastewater inflow of 300MLD.

Figure (2) shows the location of Al-Russtumiya WWTP in Baghdad. The treated wastewater in the plant is discharged to Diyala River. The project is one of Iraq's oldest wastewater projects, providing enhanced services to nearly a third of the population of Baghdad to drain sewage to the Diyala River. The project is located at the Rusafa side .During the last two decades as a result of the economic embargo imposed on the country followed by operations Military after 2003, which included looting the equipment of the project, which led to stop the project and then discharge the heavy water to the Diyala River directly without treatment (Abeer Y. Al-Sakini, 2016). The design capacity of the project is 550,000 ($m^3$ / day). The northern Russtmiya area is more than 400,000 $m^2$. The WWTP designed as two parallel units, Equal in size and each unit consists of two lines of different processing stages Space image. The southern Russtmiya project has an area of 7000 $m^2$ (Muzaffar S. Al Zuhairi, 2007). It was designed as three parallel units of various processing units (old, first and, second).

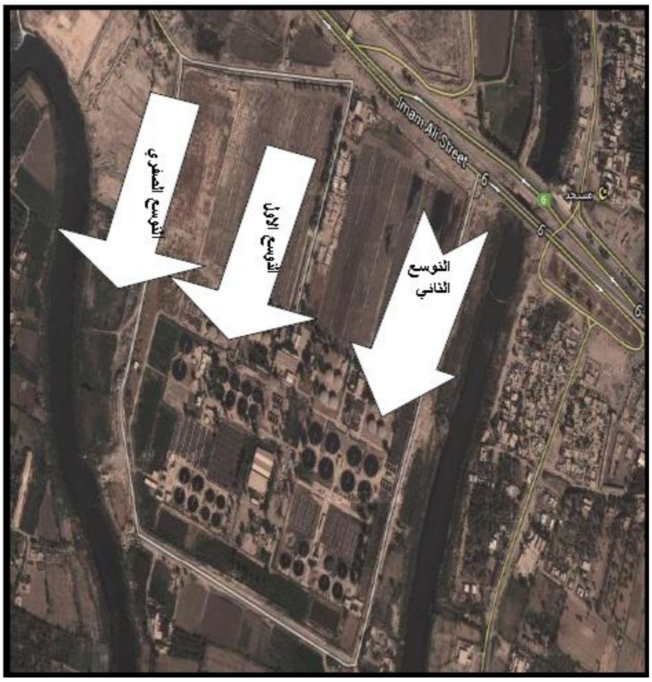


Figure (1) South Russtmiya Plantt, (Abeer Y. Al-Sakini, ,2016)

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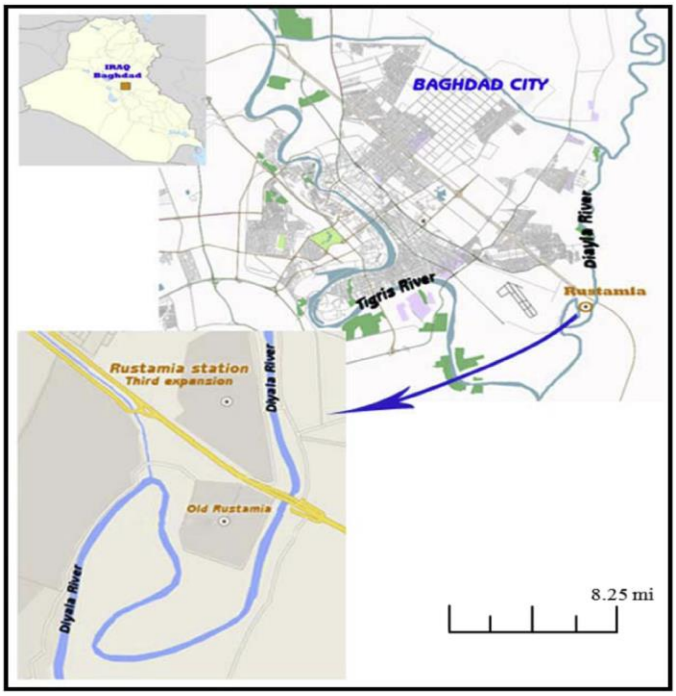


**Figure 2;** Map (1) of Russtamiya WWTP in Baghdad city. ( Zahraw , Abudul Hameed. Al-obiady, 2016)

### *2.2 CapdetWorks Program v (4.0)*

CapdetWorks is the only software tool in the industry to design and estimate initial cost quickly and accurately for construction projects of wastewater treatment plants (Hydromantis Inc., Ontario, Canada). The initial costs of each processing is calculated, initial costs for each alternative treatment process will lead to the most economic decisions.

The cost is calculated in two phases. The first phase deals with the economic comparison of the three alternatives, while the second one deals with the cost of the unit volume of sewage flow. The calculated cost from the program includes the total cost of the project (construction and land costs, planning, design) and the annual operation and maintenance costs. The steps used to estimate the cost were the same as in WWTP casting; data entry, building design.

The required information for the Capdet (v. 4) program are wastewater discharge (maximum, average, minimum), the unit operations and processes that must be included in the treatment group, and the quality of the required liquid waste. Design criteria regarding influent wastewater flow and characteristics for the different treatment layouts were taken as those of the Rustomiya WWTP. These data and information were taken from the previous design calculations and the default values suggested by Capdet Works (Hydromantis, 2018). The cost estimating technique used by the Capdet Works (v.4) requires an input of current unit prices if model accuracy is to be maintained.

### *2.3 Methodology*

Safe reuse of treated wastewater on a case study in Iraq (Russtumiya WWTP) by

- ❖ Proposed three alternatives design for Russtmiya plant for future expected population increase.
- ❖ Cost analysis of three proposed design of WWTP

The three alternatives designs of biological wastewater treatment systems are proposed which namely; conventional activated sludge (CAS), membrane bioreactor (MBR) and Suspended growth aerated lagoon

In the present study, these methods have been assessed for al Russtumiya Baghdad. The design of the three alternatives includes the units of preliminary, primary treatment, and secondary treatment. Due to the constant value of flow rate for the alternatives, the pre-treatment and primary treatment units were assumed to be with same sizing for design calculations. The required equations for designing the three alternatives are mainly obtained from (Metcalf & Eddy, 2003; Park et al., 2015; Judd and Judd, 2010; and Karia & Christian, 2006).

The characteristics of raw wastewater in the case-study are given in table (1).

**Table (1) Characteristics of domestic wastewaters in Russtumiya WWTP.**

| Parameters | Units | average value |
|---|---|---|
| Total suspended solids, SS | mg/L | 185 |
| Biological Oxygen demand ,$BOD_5$ | mg/L | 264 |
| Chemical Oxygen Demand , COD | mg/L | 350 |
| Total TKN | mg/L | 40 |
| Nitrate Nitrogen, N-NO3 | mg/L | 23 |

Report Fedral Board of supreme Audit 2016

GPS-X computer software was used to extracted some parameter such as (Volatile solids, Soluble $BOD_5$, Soluble COD, Soluble TKN, Ammonia nitrogen,) to run capdet work computer program to calculate the cost of the Russtimya WWTP construction. GPS-X software helps to build models of different WWTPs to examine the different scenarios for calculating the parameters required later.

The major costing variables that were used to calculate capital, operation and maintenance costs is shown in table 3. Three complete treatment layouts were built. Each is consisting mainly of pre-treatment, primary treatment and secondary treatment. The secondary includes the completely mixed activated sludge systems (without biological nitrogen removal and with MBR). Figure below 3,4,5 shows the layouts of the different treatment layouts.

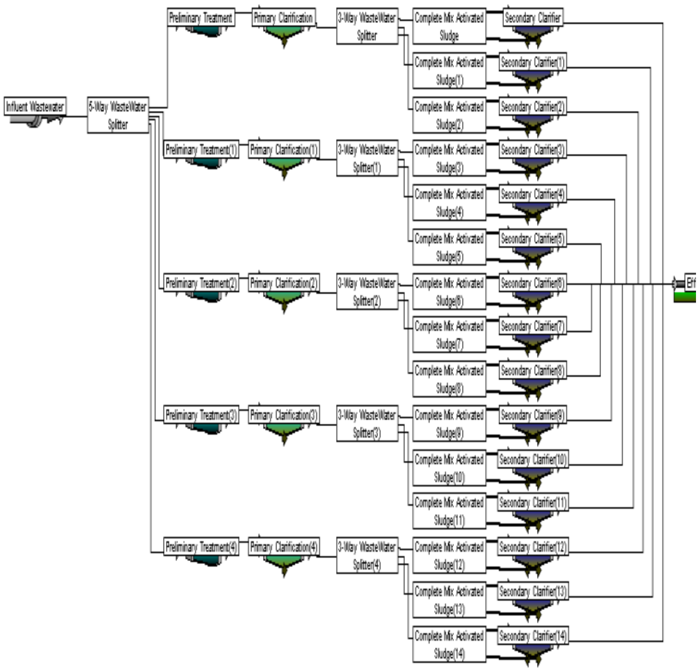


**Figure 3 Compete mix activated sludge without sand filter**

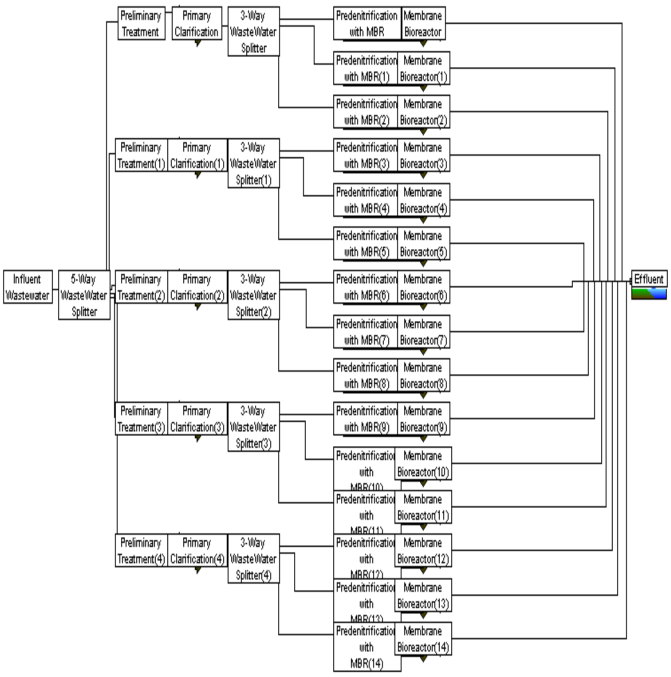


**Figure 4 Complete Mix activated sludge with membrane bio reactor**

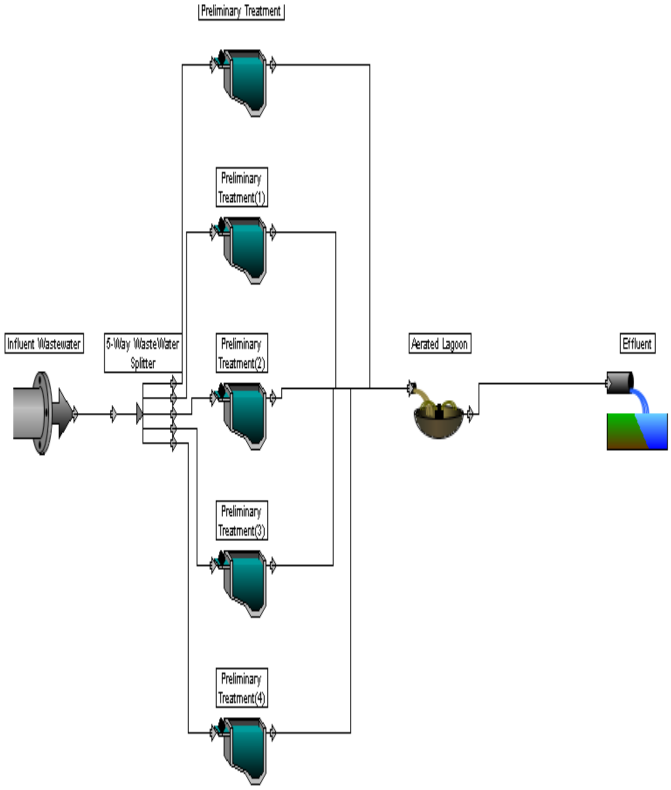


**Figure 5 complete mix Aerated Lagoon**

## *3. Results and discussion*

After design and estimating primary cost of Russtumiya the treated wastewater either be thrown in the river or be used to irrigate crop according to the guidelines.

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The quantity of TWW is ((250000 + 475000) $m^3$/d* 365 day= 264,625,000 $m^3$/y, Two wastewater treatment plants can treat a total of 1.0 × 106 $m^3$/d by secondary treatment. The Russtumia wastewater treatment can treat 5.5 × 105 m3/d and this is the plant that is being considered for production of Reuse of wastewater in this study. The total land area available for agriculture under consideration is 7,045 ha (17,409 feddan) divided into 106 individual farms. This quantity can irrigate many crops as proposed below for each alternative:

• **Restricted irrigation :** The use of low-quality liquid waste in limited areas and for certain crops (wood, feed and fertilizer), restrictions on the soil type, near the irrigated area of the potable aquifer, irrigation method, crop harvesting technique and rate of fertilizer use. It is simple and low cost so farmers should be trained to handle low quality liquid waste such as:

- alternative one(CAS without sand filter ) : secondary treatment due to Iraqi standard
- Alternative three (Aerated Lagoon): The effluent parameters BOD, COD, TSS are complying with Iraqi codes that suggested but the TKN is above it so the irrigation is restricted.

• **Unrestricted irrigation:** Use high-quality liquid waste, rather than fresh water, to irrigate any crop (including raw vegetables eaten) any type of soil such as:

- alternative two(MBR tertiary treatment) the effluent parameters BOD, COD, TSS are complying with Iraqi standard to irrigate All types of landscape(Green belt around the city of Baghdad, irrigation (e.g. golf courses, parks, cemeteries).

### *3.1 Result of Three Alternatives Design of Russtumiya WWTP*

Table (2) summary design of the three alternatives

| The included units for phase one | | CAS | MBR | Aerated lagoon |
|---|---|---|---|---|
| **Pretreatment** | | | | |
| Screening | Number of screening bars | 100 | 100 | 100 |
| | Area of each channel screen,$m^2$ | 10 $m^2$ | 10$m^2$ | 10$m^2$ |
| Aerated grit chamber | Number of tanks | 5 | 5 | 5 |
| | volume of each chamber ,$m^3$ | 239 $m^3$ | 239 $m^3$ | 239 $m^3$ |
| **Primary treatment** | | | | |
| | number of tanks | 5 | 5 | - |
| | diameter ,m | 40m | 40m | - |
| **Secondary treatment** | | | | |
| Anoxic tank | number of tanks | - | 15 | - |
| | volume of each tank,$m^3$ | - | 1,389 $m^3$ | - |
| | MLVSS, mg/l | - | 2,120.3 mg/l | - |
| | F/M ratio,$gBOD_5$/g day | - | 0.9 g/g day | - |
| Aerobic tank | number of tanks | 15 | 15 | - |
| | volume of each tank,$m^3$ | 2,794 $m^3$ | 3,037 $m^3$ | - |
| | MLVSS, mg/l | 3500 | 8000 | - |
| | F/M ratio,$gBOD_5$/g day | 0.31 $kgBOD_5$/kg MLVSS ·d | 0.2 kgBOD 5/kg MLVSS ·d | - |
| | required oxygen kg $O_2$/d | 36,998.17kg $O_2$/d | 28645 9.2 kg $O_2$/d | - |
| | solid retention time day | 6 | 20 | - |
| secondary sedimentation tank | number of tanks | 15 | - | - |
| | diameter ,m | 40m | - | - |
| Immerged membrane | number of membrane tanks | - | 75 | - |
| | volume of each tank,$m^3$ | - | 220.5 | - |
| | Total membrane area $m^2$ | - | 744,053.6 $m^2$ | - |
| | Aeration requirement $m^3$/h | - | 388,824.88 $m^3$/h | - |
| | Design flux, L/$m^2$h | - | 14 L /$m^2$ h | - |

| Cost item | Value | | | | Unit |
|---|---|---|---|---|---|
| | CAS (with sand filter) | CAS (with out sand filter) | MBR | Aerated lagoon | |
| Total project costs | 193,000,000 | 163,000,000 | 458,000,000 | 146,000,000 | $ |
| Total operation and maintenance costs | 468,000 | 459,000 | 884,000 | 127,100 | $/yr |
| Annualized project cost * | 15,806,700 | 13,349,700 | 37,510,200 | 11,967,809.5 | $/yr |
| Annualized project cost + annual O & M cost | 16,274,700 | 13,808,700 | 38,394,200 | 12,094909.5 | $/yr |
| Cost / $m^3$ ** | 0.35 | 0.298 | 0.83 | 0.264 | $ /$m^3$ |

## *3.2 Results of Cost Analysis Program (Capdet Work)*

### *3.2.1 Land Cost*

**Table 3 the required land and cost land of the three alternatives.**

### 3.2.2 Cost of Treated Wastewater per $m^3$ for CAS and MBR.

The estimation of the capital costs, operation and maintenance for all CAS (with and without sand filter) MBR and aerated lagoon systems, by program (capdetwork) a cost analysis was conducted to identify the most cost-effective processing systems such as the cost of the Wastewater Flow Unit The cost of treated wastewater per cubic meter is calculated manually by dividing the total annual project cost and annual operation and maintenance cost by the average planned wastewater flow and the number of days per year as shown in table (4) To estimate the annual project cost, the cost of the project is multiplied by the CRF. The CRF is a factor that combines the current project cost and a series of equal payments at an interest rate (i) (i = 8%) during the planning period (n = 39 years) (Alaa Uldeen A. Arif, 2018)

$$CRF = \frac{i\,(1+i)^n}{\{(1+i)^n-1\}} = \frac{0.08\,(1+0.08)^{39}}{\{(1+0.08)^{39}-1\}} = 0.0819$$ ………………. (1)

**Table (4) The summary cost of treated wastewater per $m^3$ for CAS and MBR.**

| Unit process | Surface area ($m^2$) | | |
|---|---|---|---|
| | CAS | MBR | Aerated lagoon |
| Screen with Grit chamber | 2,000 | 2,000 | 2,000 |
| Primary sedimentation tank | 6,285 | 6,285 | |
| Anoxic tank | | 4,630 | 250,000 |
| Aeration tank | 9,315 | 15,000 | |
| Final sedimentation tank | 18,500 | | |
| Membrane tank | | 5,955.00 | |
| Total surface area | 36100 | 33,870 | 252,000 |
| Add 30% for more space | 46,930 | 44,031 | 327,600 |
| Land cost ($) | 703,950 | 660,465 | 4,914,000 |

* Annualized project cost = project cost x CRF. For i = 8%
**and planning period = 39 years, CRF = 0.0819

$$Cost/m^3 = \frac{(\text{annualized project cost} + \text{annual O \& M cost})\,\$/yr}{(\text{average design flow} * 365)\ m3/yr}$$

(2) (A. Arif,2018)

Table (4) shows that the price per cubic meter to flow 250,000 cubic meters / day of MBR plant is 0.83 $/ $m^3$, CAS with sand filter is 0.35 $/ $m^3$ while the cost of CAS without sand filter and aerated lagoon is 0.298, 0.264 $/ $m^3$. $m^3$so they are the most economic designs .
The obtained results from cost analyzes for three alternatives, Reveled that the aerated lagoon system was the lowest current value and the unit cost per $m^3$. Economically, the aerated lagoon system is the most cost-effective.

## 4. Conclusion

Reuse of wastewater in Baghdad is logical as the wastewater treatment plants are located in the southern portion of Baghdad and there is land available for agriculture at south of Baghdad. Three methods of treatment have been proposed according to the state of the economic situation and climate of Iraq, CAS, MBR, and aerated lagoon. The MBR design method is the best treatment in term of efficiency and quality result and its conformity with requirements of the reuse of treated wastewater. The cost analysis by capdetwork program showed that the cost of treated wastewater for per $m^3$ of flow the CAS, MBR and aerated lagoon respectively were 0.298, 0.83,and 0.264$/$m^3$ .The aerated lagoon gave the lowest current value or unit cost per cubic meter. In accordance with the international guidelines, it is must be add a chlorination unit to the plant to get rid of the bacteria.

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