Step-By-Step Design and Calculations for Water Treatment Plant Units: A Recent Study

Shuokr Qarani Aziz¹* and Jwan Sabah Mustafa²

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ABSTRACT

This work presented the design steps and calculation for each unit of the water treatment plant (WTP), due to its crucial role domestically and drinking purpose. It also illustrated and designed the procedures of the water processing units by estimating water demand and designing the unit process. The objectives of this work were to evaluate the water demand for a certain community and to present design steps and calculations for the required units of a WTP. The design of the WTP units was applied to Greater-Zab River water for the selected location in Erbil City-Iraq. The quality and quantity of the Greater-Zab River water at various times were statistically analyzed and presented. The units of the treatment processes involved intake, coagulation, flocculation, sedimentation, adsorption (optional), filtration, disinfection, storage, and pumping. The calculations and detailed drawings of the units were displayed, the average discharge and population used for the WTP design were 60,000 m³/day and 200,000, respectively. Besides, the calculation required some of the parameters to be estimated as field data, which were taken into consideration. The outline results of each unit of the WTP were tabulated. The quality and quantity of the surface water source affected the WTP design.

It can be concluded that this work can be used as a source for designing other WTP units. A number of factors such as the age of WTP, maintenance, economical and political situations, technical problems, and water demand had a great impact on the removal efficiency of the WTP units.

Keywords: Design; river water; treatment plant; greater zab; water demand; quality.

1. INTRODUCTION

Water treatment processes are applied to surface water sources. Typically, a water treatment plant (WTP) comprises intake, pumping, pre-sedimentation (in some cases), coagulation, flocculation, clarification, adsorption, filtration, disinfection, storage, and pumping to treat water for consumption [1-4]. The designs of a unit or some units for WTPs are available [5-10]. However, forecasting the population size, estimating water demand, and step-by-step designing and drawing WTPs in one published work are currently unavailable. The objectives of the current work were to determine water demand for an individual community, design WTP units on river water step by step, and illustration the required calculations and details of the WTP units.

2. MATERIALS AND METHODS

Information about the quality and quantity of Greater-Zab River water were collected [11]. Statistical Package for the Social Sciences (SPSS) was applied for the statistical analysis for both quality and quantity of Greater-Zab River water. Statistical analysis for the obtained data was presented. Water demand was calculated based on the literature [3,10]. Step-by-step design and calculations for the WTP units such as intake, coagulation, flocculation, sedimentation, adsorption (optional), filtration, disinfection, storage, and pumping were given. Results from the design of WTP units were outlined and the removal efficiencies of the WTP units were illustrated as well. Details are shown in the following sections.

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2.1 Water Demand

Calculations and designs should be applied to a natural river to obtain accurate and realistic results for a WTP design. Therefore, the current work was applied to the Greater Zab River in Erbil City, Iraq (Figs. 1 and 2). The data about the Greater Zab River water were obtained from the Ministry of the Municipality and Tourism Directorate of Water in Erbil City, KRG, Iraq [11]. The Greater Zab River is one of the main tributaries of the Tigris River, which is one of the large rivers that originated from Turkey and has a length of approximately 392 km [12].

A population of 200,000 and an average water consumption of 300 liter per capita per day (LPCD) were proposed to design an appropriate WTP. The selection of the proposed value of 300 LPCD was based on previous studies [3,13]. The minimum and maximum average consumption were suggested as 40% and 180%, respectively [10]. The discharges can be calculated as follows:

- Average discharge ($Q_{avg}$) = $200,000 \times 300$ LPCD = 60,000,000 L/day = 60,000 m$^3$/day = 0.694 m$^3$/s
- Minimum discharge ($Q_{min}$) = $60,000 \times 0.4 = 24,000$ m$^3$/day = 0.278 m$^3$/s
- Maximum discharge ($Q_{max}$) = $60,000 \times 1.8 = 108,000$ m$^3$/day = 1.25 m$^3$/s

Fig. 1. Greater-Zab River on the map
2.2 Water Quality

The quality of the Greater Zab River water is summarized in Table 1. Water quality parameters, such as pH, electrical conductivity (EC), total dissolved salts (TDS), chloride (Cl\(^-\)), alkalinity, Ca\(^{2+}\), Na\(^+\), K\(^+\), Mg\(^{2+}\), nitrate (NO\(_3^-\)), and SO\(_4^{2-}\), remained within the allowable limits recommended by WHO standard [11]. Turbidity and hardness surpassed the permissible levels of 5 NTU and 200 mg/L based on WHO standards. Water treatment processes are essential for the Greater Zab River water to adjust all drinking water quality parameters to their acceptable levels to supply potable and safe water to consumers. Table 2 illustrates statistical analysis using SPSS for Greater-Zab River water quality. It can be noticed from Table 2 that the average values of pH, EC, TDS, Cl, Total alkalinity, Ca, Na, K, Mg, NO\(_3^-\), and SO\(_4^{2-}\) are remaining within the allowable limits mentioned by WHO standards [14]. While the parameters of turbidity and total hardness were surpassed the drinking water quality standards [14]. So, treatment processes for Greater-Zab River water are essential [15,16].

2.3 Water Quantity

The quantity of the Greater-Zab River water is indicated in Table 3. Statistical analysis for Greater-Zab River Water quantity is shown in Table 4. The minimum value of Greater-Zab River water flow was 57 m\(^3\)/s which was reported in September 2001. Whilst, the maximum flow of 1182 m\(^3\)/s was reported in February 2006. The minimum discharge of the Greater-Zab River is greater than the maximum water demand of 1.25 m\(^3\)/s (Section 3).

2.4 Design of WTP Units

2.4.1 Units of WTP

The common steps of river water treatment are provided in Fig. 3, and the processes are illustrated in the following diagram.
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*N.R. means non recorded data

Table 4. Statistical analysis for Greater-Zab River Water quantity (m³/s)

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<th>Minimum</th>
<th>Maximum</th>
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2.4.2 Intake

The basic function of the intake structure is to help safely withdraw water from the water source and to discharge this water into the withdrawal conduit (normally called intake conduit) through which it flows up to a WTP [13,16-17]. The water is diverted through a raw water gravity pipe into the wet well (intake).

The average discharge (Q avg.) used in the design of the intake is described as follows:

\[ Q_{avg.} = \frac{0.694}{4} = 0.17 \text{ m}^3/\text{s} \]

When four pipes were used to convey raw water,

Q per one gravity pipe = \(\frac{0.694}{4} = 0.17\text{ m}^3/\text{s}\).

Velocity inside the gravity pipe = 1 m/s.
Area \( A \) = Discharge \( Q \) / velocity \( v \)

\[
A = \frac{0.17 \text{ m}^3/\text{s}}{1 \text{ m/s}} = 0.17 \text{ m}^2
\]

\[
A = \frac{\pi D^2}{4}
\]

\[
A = 0.17 \text{ m}^2
\] (1)

Diameter \( D \) of each raw water gravity pipe = 0.47–0.5 m
No. of wells = 4, circular wells were preferred

Detention time \( t \) = 20 min, [13]

\[
\text{Discharge} \ (Q) = \frac{\text{Volume} \ (V)}{\text{Time} \ (t)}
\]

\[
Q = 0.694 \text{ m}^3/\text{s} = 41.67 \text{ m}^3/\text{min}
\]

\[
Q \text{ for 4 wells} = 10.41 \text{ m}^3/\text{min}
\]

\[
V = Q \times t = 10.41 \times 20 = 208.2 \text{ m}^3
\]

The bottom of the well is located at 1.5 m below of lower water level (LWL) [13]

Effective depth of the intake well = 10 m [13]

Fig. 3. Diagram of water treatment processes
Area of the well = 208.2 / 10 = 20.82 m$^3$

To find the diameter of the circular well section:

$$A = \frac{\pi}{4} D^2$$

$$D = \sqrt{\frac{4 \times 20.82}{\pi}} = 5.15 \text{ m}$$

The plan of the intakes is shown in Fig. 4:

![Fig. 4: Plan of the intakes](image)

The design of the suction pipe is as follows:

- $Q = 0.17 \text{ m}^3/\text{s}$
- $V = 1.5 \text{ m/s}$

The cross-sectional area of the suction pipe is $A = \frac{Q}{v} = 0.17 / 1.5 = 0.11 \text{ m}^2$.

$$D = \sqrt{\frac{4 \times 0.11}{\pi}} = 0.37 \text{ m} \quad (\text{Use } D = 0.4 \text{ m})$$

$Q$ back washing $= 1/3 \times Q = 0.17 / 3 = 0.06 \text{ m}^3/\text{s}$.

Velocity of water in backwashing pipe $= 3 \text{ m/s}$ [13]
Cross-sectional area of the pipe \( A = \frac{Q}{v} = \frac{0.17}{3} = 0.06 \text{ m}^2 \)

\[
D = \sqrt{\frac{4 \times 0.06}{\pi}} = 0.28 \text{ m} \approx 0.3 \text{ m}
\]

The detail of the intake is presented in Fig. 5:

**Fig. 5. Detail of one of the wet wells**

On the basis of the provided data from the directorate of Erbil water of the Greater Zab River, we find that the high-water level (HWL) is 6.3 m, the LWL is 3.4 m, and the groundwater level is 290 m.a.s.l. The following criteria are considered:

- Total discharge \( (Q) = 0.694 \text{ m}^3/\text{s} \)

To design one strainer:

- Total discharge / 4 = 0.17 \text{ m}^3/\text{s}
- Velocity through strainer \( (v) = 0.15 \text{ m/s} [13,16] \)

\[
A = \frac{Q}{v} = \frac{0.17}{0.15} = 1.13 \text{ m}^2
\]

If the area of strainers is 50\% of the total area (Fig. 6).

- Gross Area = 2 \times Area of the strainers (holes)
  = 2 \times 1.13 \text{ m}^2
  = 2.26 \text{ m}^2

- Diameter of the hole = 12 mm, [13,16].

\[
\text{Area of one hole} = \frac{\pi}{4} \left( \frac{12}{1000} \right)^2 = 0.000113 \text{ m}^2
\]

\[
\text{Number of the hole} = \frac{1.13 \text{ m}^2}{0.000113 \text{ m}^2} = 10,000 \text{ hole}
\]

To find the strainer diameter

\[
\frac{\text{Gross Area}}{2\pi h}
\]

Height of the rectangular shape strainer with closed end \( h = 1.2 \text{ m} \)
2.4.3 Coagulation

Coagulation is the process of adding a coagulant to water to destabilize colloidal suspensions, and the steps of the design criteria of the coagulation tank in accordance with previous studies [1,17] are as follows:

\[ Q = 0.694 \text{ m}^3/\text{s} = 41.64 \text{ m}^3/\text{min} \]

Using two flash mixers, we determined the discharge for one flash mixer as \( (41.64 \text{ m}^3/\text{min}) / 2 = 20.82 \text{ m}^3/\text{min} \). Use \( t = 1 \text{ min (60 sec)} \), [13,17-18]

Volume of flash mixer (V) = 20.82 m³/min × 1 min = 20.82 m³

Depth of the tank (d) = 3 m

\[ A = V / d = 20.82 \text{ m}^3 / 3 \text{ m} = 6.94 \text{ m}^2 \]

The circular section of the tank was used, and the diameter was obtained using the following equation:

\[ D = \sqrt{\frac{4 \times 6.94}{\pi}} = 2.97 \text{ m}, \text{say 3 m.} \]

At \( T = 20^\circ \text{C} \), dynamic viscosity \( (\mu = 1.0087 \times 10^{-3} \text{ Pa.s}) \) was determined in accordance with previously described methods [13]:

For rapid mixing, \( G > 300/\text{s} \) or more [17,19];

\( G = 1,000/\text{s} \) is proposed to be used in power calculation [13]

\[ V = 20.82 \text{ m}^3 \]

\[ \text{Power} = P = G2\mu V \quad [19-20] \]

(3)

Where \( G \) is the mean velocity gradient (1/s), \( P \) is the power dissipated (watt), \( \mu \) is the dynamic viscosity (Pa/s), and \( V \) is the volume of the tank (m³).
\[ P = (1,000/s) \times (1.0087 \times 10^{-3} \text{ Pa/s}) \times (20.82 \text{ m}^3) \]

\[ P = 21,001.134 \text{ Watt} \approx 21 \text{ kW} \]

To determine the amount of the coagulant (e.g., alum) required per day (kg/day), we used the optimum dosage of alum at 25 mg/L (normally optimum dosage determined by Jar test), and we supposed that the density of alum was 600 kg/m³.

\[ Q = 0.694 \text{ m}^3/\text{s} \times 3600 \times 24 = 59,961.6 \text{ m}^3/\text{day} \]

\[
\text{Amount of alum} = \frac{25 \text{ mg}}{1 \text{ L}} \times \frac{1000 \text{ L}}{1 \text{ m}^3} \times \frac{1 \text{ kg}}{1000 \text{ mg}} \times \frac{5,9961.6 \text{ m}^3}{\text{day}}
\]

\[ = 1,499.04 \approx 1500 \text{ kg/day} \]

\[ = 45,000 \text{ kg/month} \]

Density = mass/volume

Volume of alum = mass / density

\[ = 1,500 \text{ kg/day} / 600 \text{ kg/m}^3 = 2.5 \text{ m}^3/\text{day} = 75 \text{ m}^3/\text{month} \]

The details of one flash mixer are depicted in Fig. 7:

\[ \text{Fig. 7. Details of coagulation tanks} \]

2.4.4 Flocculation

Flocculation is the process of slow mixing that can be achieved in a basin, which is known as a flocculator. It is an essential operation designed to agitate force in fluid and coagulation. The design criteria of the flocculation tank are based on previous studies [2, 19]:

\[ Q = 41.64 \text{ m}^3/\text{min} \]

\[ t = 30 \text{ min} [13] \]

\[ V = 41.64 \text{ m}^3/\text{min} \times 30 \text{ min} = 1,249.2 \text{ m}^3. \]

Using six flocculation tanks (with two parallel tanks) = 1,249.2 / 6 = 208.2 m³
d = 4 m
A = V / d = 208.2 / 4 = 52.05 m²
Then, to find the dimension of one square tank, we use the following:
Area = width × length

Using L = 3 W
A = W × 3W
52.05 = 3 W²
W = 4.17 m

P = G²μV
To find out the power of each of the paddle, we apply the following:

For (G = 60/s) rapid mixing P = (60)² × (1.0087 × 10⁻³) × (208.2) = 756.04 Watt
For (G=40/s) medium mixing P = (40)² × (1.0087 × 10⁻³) × (208.2) = 336.02 Watt
For (G=20/s) slow mixing P = (20)² × (1.0087 × 10⁻³) × (208.2) = 84 Watt

The details of both the plan and side views of the flocculation tanks are illustrated in Fig. 8:

Fig. 8. Plan and Side view of the flocculation tanks

2.4.5 Clarification

Sedimentation, also known as settling or clarification, is the process of removing solid particles by gravity [4,17].

To design a clarification tank, we use the following:

Q = 0.694 m³/s
Using four clarification tanks, we used same numbers in Erbil WTP.
For the design of one tank:
Q per tank = Q / 4 = 0.17 m³/s = 10.2 m³/min
Detention time (t) = 2 h = 120 min, according to the design criteria described [13]
Volume = discharge × time
V = 10.2 m³/min × 120 min
V = 1,224 m³

Depth of the clarification = 4 m, [13]

Therefore:
Area = Volume / depth
A = 1,224 m³ / 4 m
A = 306 m²

To find the diameter of the circular sedimentation tank shape, we use the following:

\[ D = \frac{4 \times A}{\pi} = \frac{4 \times 306}{\pi} = 19.74 \text{ m}, \text{ Say 20 m} \]

To check the settling velocity [19]
Assuming stock’s law is valid:

\[ V_s = \frac{g(G_s - G_w) d_s^2}{18\mu} \] (4)

Where \( V_s \) is the terminal settling velocity of the solid particle (m/s), \( g \) is the gravitational acceleration (m/s²), \( G_s \) is the specific gravity of particles, \( G_w \) is the specific gravity of water, \( d_s \) is the diameter of particle (m); and \( \mu \) is the dynamic viscosity of water (m²/s).

Specific gravity of particles (\( G_s \)) = 2.6
Specific gravity of water (\( G_w \)) = 1
Diameter of the particles (\( d_s \)) = 0.02 mm, [13]
Dynamic viscosity of water at 20° C = 1.009 × 10⁻³ pa/s

\[ V_s = \frac{9.81(2650 - 998.207)(0.02/1000)^2}{18 \times (1.002 \times 10^{-3})} = 3.59 \times 10^{-4} \text{ m/s} = 0.3594 \text{ mm/s} \]

\[ \text{Re} = \frac{V_s d_s}{v} \] (5)

Re = 0.0716 < 1 (stock’s law is applicable).

To design the weir:

(90° v-notch) shape weir (50 mm) depth placed (250 mm) center to center,[13] Weir loading rate (WLR) = \( Q / \pi D \)
WLR = 10.2 m³/min / (3.14 × 28 m)
WLR = 0.116 m³/min/m (167.06 m³/day/m); it is within the allowable range [4, 13,17]

\[ Q \text{ notch} = \frac{Q}{\text{spacing between weir}} = \frac{0.116 \text{ m}^3/\text{min.m}}{0.250 \text{ m}} \] (6)
Height of the water above or bottom of the weir \( (h = 0.041 \text{ m}) \). The details of the clarification are given in Figs. 9 and 10:

\[
Q_{\text{notch}} = 0.029 \text{ m}^3/\text{min} = 0.00048 \text{ m}^3/\text{s}
\]

\[
Q_{\text{notch}} = 0.312(2g)^{0.5} \times h^{2.5}
\]

\[
0.00048 = 0.312(2 \times 9.81)^{0.5} \times h^{2.5}
\]

Where 

\[
V_c = \left[ \frac{8\beta gd(\rho_s - \rho_w)}{f} \right]^{1/2}
\]

\[
V_c = \left[ \frac{8 	imes 0.05 \times 9.81 \text{m/s}^2 \times 0.02 (2600 \text{kg/m}^3 - 1000 \text{kg/m}^3)}{0.03} \right]^{1/2}
\]

\[
V_c = \frac{64.7 \text{mm}}{s} = 6.47 \text{cm/s}
\]

\[
V_s = 3.56 \times 10^{-3} \text{ cm/s} < (V_c= 6.47 \text{ cm/s}), \text{ ok}
\]

\[
V_s = 3.56 \times 10^{-5} \text{ cm/s}
\]
2.4.6 Filtration

Filtration aims to remove the suspended solids that are not removed in the sedimentation unit or when the removal of these particles take a long time outside the basin [2,20] Fig. 11:

![Fig. 11. Plan of filtration units](image)

To design a rapid sand filtration tank:

\[ Q_{\text{avg.}} = 0.694 \text{ m}^3/\text{s} = 2,498.4 \text{ m}^3/\text{h} \]

Using the flow of the filter: \( Q_{\text{filter}} = 7 \text{ m}^3/\text{h/m}^2 \), [9,21]

Area of the filter bed \( A = \frac{2498.4}{7} = 356.9 \text{ m}^2 \), say \( 357 \text{ m}^2 \)

A total of 10 filter units were used, and the area of one filter unit is obtained by \( A = \frac{357}{10} = 35.7 \text{ m}^2 \) The width of 4.5 m of one filter unit was used. Therefore, to find length \( = \frac{35.7}{4.5} = 7.93 \text{ m} \) (say 8 m length and 4.5 wide, \( A = 36 \text{ m}^2 \))

Checking filtration rate:

Total Area = 4.5 m × 8 m × 10 Nos. = 360 m\(^2\).

Filtration rate = \( \frac{2498.4 \text{ m}^3/\text{h}}{360 \text{ m}^2} = \frac{6.94 \text{ m}^3/\text{h}}{\text{h}}, (\text{between } \frac{5 \text{ m}^3}{\text{h}} \text{ and } \frac{7 \text{ m}^3}{\text{h}}), \text{ ok} \)

To design laterals and manifold:

Using the size of the openings at 6 or 12 mm [13]

\[
\frac{\text{Total area of perforations}}{\text{Area of filter tank}} = 0.3% \\
\text{Total area of perforations} = 0.3% \times 36 \text{ m}^2 = 0.108 \text{ m}^2 \\
\text{Total area of laterals} = 2 \times 0.108 \text{ m}^2 = 0.216 \text{ m}^2 \\
\text{Spacing between laterals} = 20 \text{ cm}
\]

To find the number of the lateral = \( \frac{\text{length of one filter unit}}{\text{space between laterals}} = \frac{809 \text{ cm}}{20 \text{ cm}} = 40 \) laterals

Total number of the laterals per filter unit = 2 × 40 = 80 Nos.

Area per lateral = \( 0.216 \text{ m}^2 / 80 \text{ No.} = 0.0027 \text{ m}^2 \)
\[
0.0027 = \frac{\pi}{4} d^2
\]

d lateral = 0.0586 m, say 5 cm

No. of perforations = \(0.108 \text{ m}^2 / 0.0001131 \text{ m}^2 = 954.90 \text{ Nos.}\); Use 960 Nos.

No. of perforations per lateral = 960 Nos. / 80 Nos. = 12 Nos. per lateral

The total area of the manifold = \(2 \times \text{Area of the lateral}\)

\[
= 2 \times 0.216 \text{ m}^2
= 0.432 \text{ m}^2
\]

\[
0.432 = \frac{\pi}{4} d^2
\]

d manifold = 0.742 m, say 75 cm

Total length of the lateral = 450 − (2 × 17 + 5 + 2 × 3.5) = 404 cm

Length of each lateral = 404 / 4 = 101 cm

The details of one filter bed unit are illustrated in Fig. 12:

In this work, the adequate size and uniformity coefficient of the filter media was regarded as 0.5 and 1.6, respectively [9,21] The filter media depth of 50 cm was proposed.

The different supporting layers with 20 and 30 cm were recommended for this filter [13]. The head of water above the filter media is 2 m.

Air and water were proposed for the backwashing process for 15 min. Total backwashing time is 30 min.

The filter run time was assumed to be 24 h.

---

**Fig. 12. Detail of one filter unit**
The section of the filter media is shown in Fig. 13:

![Fig. 13. The section of the filter media](image)

2.4.7 Backwashing

The amount of backwashing water should be less than or equal to the 5% rate of the filtered water [13].

Rate of wash water = \((7 \text{ m}^3/\text{h}/\text{m}^2) / (10 \text{ filter}) = 0.7 \text{ m}^3/\text{h}/\text{m}^2\)

\[ Q_{\text{backwash}} = 0.5 \times 7 \text{ m}^3/\text{h}/\text{m}^2 = 3.5 \text{ m}^3/\text{h}/\text{m}^2 \]

Two filter beds were washed at the same time.

Wash area = \(2 \times 36 \text{ m}^2 = 72 \text{ m}^2\)

Amount of water needed for washing = \(72 \text{ m}^2 \times 7 \text{ m}^3/\text{h}/\text{m}^2 = 504 \text{ m}^3/\text{h}\)

Head of wash water = 10 m

Frictional resistance = 4 m [13]

Total head required = 10 + 4 = 14 m

We used two pumps in parallel, and each pump has a capacity of 700 m\(^3\)/h with a head of 14 m.

2.5 Trough Design

To determine the flow through the trough = \((0.694 \text{ m}^3/\text{s}) / (2 \text{ trough} \times 10 \text{ filters})\)

\[ Q = 0.0347 \text{ m}^3/\text{s} \]

\[ Q = 2.49 b h^2 \]

\[ 0.0347 \text{ m}^3/\text{s} = 2.49 \times b \times (0.15)^{3/2} \]

\[ b = 0.24 \text{ m} \]

Total depth = 15 cm + 5 cm (freeboard) = 20 cm

The details of the trough are shown in Fig. 14.

![Fig. 14. Detail of the trough](image)
2.5.1 Adsorption

Activated carbon is used to remove colors and tastes in water, resulting in the presence of dissolved gases. It is also porous and has many carbon atoms with free valencies. In addition, it is available in granular or powder form. Granular activated carbon has a surface area of 500–1400 m²/g [20,22]. Activated carbon can be applied to treat water in two ways:

As powder feed (during adding alum to mixing basin or after coagulation).

As filter media (instead of sand filter bed [13, 19].

Adsorption isotherm is a mathematical model that describes the distribution of adsorbate species among liquid and adsorbent based on the assumptions of heterogeneity/homogeneity of adsorbents.

Adsorption data are described by Langmuir or Freundlich adsorption isotherms.

2.5.2 Langmuir isotherm

This model is based on the assumption that maximum adsorption occurs when a saturated monolayer of solute molecules is present on the adsorbent surface. The energy of adsorption is constant, and adsorbate molecules do not migrate on the surface plane [20,22-23]. The Langmuir isotherm equation is stated as follows:

\[ q_e = \frac{q_m K_L C_e}{1 + K_L C_e} \]

The constants of the Langmuir isotherm can be determined by plotting \((1/q_e)\) versus \((1/C_e)\), and the above equation is rewritten as follows:

\[ \frac{1}{q_e} = \frac{1}{q_m} + \frac{1}{q_m K_L} \frac{1}{C_e} \]

Where

- \(q_e\) refers to weight of adsorbate (g)
- \(q_m\) is the Langmuir constant (mg/g)
- \(K_L\) is the Langmuir constant (L/mg)
- \(C_e\) is the equilibrium concentration of adsorbate (mg/L).

2.5.3 Freundlich isotherm

This model is an empirical relationship describing the adsorption of solutes from a liquid to a solid surface and assumes that different sites with several adsorption energies are involved [20,22-23]. The equation is as follows:

\[ q_e = K_f C_e^{1/n} \]

The equation in the form of logarithm becomes:

\[ \log q_e = \log K_f + \frac{1}{n} \log C_e \]

Where \((K_f)\) and \((n)\) are Freundlich constants, the characteristics of the system. The settled water in the laboratory should be subjected to kinetic analysis to determine the optimum dosage of the adsorbent.
2.5.4 Disinfection

When the filtered water comes out from the filter unit, bacteria and other microorganisms, which may be pathogenic, may exist. Thus, disinfection is necessary to eliminate bacteria and other microorganisms and consequently prevent waterborne diseases. Disinfection involves a number of methods. The use of chlorine has become particularly common in disinfecting water. It is inexpensive, reliable, and relatively safe to handle [19].

Water demand = 60,000 m$^3$/day

Required chlorine and residual chlorine are 0.36 and 0.2 mg/L, respectively [19].

Chlorine demand = 0.36 mg/L – 0.2 mg/L = 0.16 mg/L

Consumed chlorine = 0.36 mg/L × (1/ 10 6) × 60,000 × 1000 = 21.6 kg/day

The time required to complete the disinfection performed in a storage tank is 0.5 h [13].

\[ Q = \frac{\text{Volume}}{\text{time}} \]

\[ \text{Volume} = Q \times \text{time} \]

\[ \text{Volume} = 60,000 \text{ m}^3/\text{day} \times \frac{1}{24} \times 0.5 \text{ h} = 1,250 \text{ m}^3 \]

Using effective depth of 4 m and length (L) = 2 × width (W)

\[ A = \frac{1,250 \text{ m}^3}{4 \text{ m}} = 312.5 \text{ m}^2 \]

\[ L \times W = 312.5 \text{ m}^2 \]

\[ 2W \times W = 312.5 \text{ m}^2 \]

\[ W^2 = 156.25 \text{ m}^2 \]

\[ W = 12.5 \text{ m} \text{ and } L = 2 \times 12.5 = 25 \text{ m} \]

Velocity = distance / time

\[ \text{Velocity} = \frac{25 \text{ m}}{0.5 \text{ h}} = 50 \text{ m/h} = 0.0139 \text{ m/s} \]

2.5.5 Storage and pumping

When the final stages of the treatment process are completed, water can be distributed by high lift pumps to consumers or stored in storage tanks. Thereafter, it can be used as drinking water based on the required household demand.

The details of the storage tank and the pumping are shown in Figs. 15 and 16:

![Fig. 15. Plan of the disinfection and storage tanks](image)
Fig. 16. Section of the disinfection and storage tanks

Q avg. = 60,000 m$^3$/day = 2,500 m$^3$/h = 0.6944 m$^3$/s
Using $v = 1.5$ m/s, (Metcalf and eddy, 2014)

Two pumps are used; the first pump is working, and the second one is on standby. The third pump is used during maximum demand.

2.5.6 Outline of WTP design

The final output of the design steps of the WTP is summarized in Table 3.

Table 3. Summary of the WTP design outline

<table>
<thead>
<tr>
<th>No.</th>
<th>Unit description</th>
<th>No. of unit</th>
<th>Shape of unit</th>
<th>Dimensions of units</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Intake</td>
<td>4</td>
<td>circular</td>
<td>Diameter=5.15m&lt;br&gt;Depth=10m</td>
<td>Diameter of suction pipe=0.4m&lt;br&gt;Diameter of raw water gravity pipe =0.5m</td>
</tr>
<tr>
<td>2</td>
<td>Coagulation</td>
<td>2</td>
<td>circular</td>
<td>Diameter=3m&lt;br&gt;Depth=3m</td>
<td>$G=300$s$^{-1}$&lt;br&gt;$P=21$KW&lt;br&gt;$t=1$min</td>
</tr>
<tr>
<td>3</td>
<td>Flocculation</td>
<td>6</td>
<td>Rectangle</td>
<td>Width=4.17m&lt;br&gt;Length=3*4.17=12.51m&lt;br&gt;Depth=4m</td>
<td>$G=20, 40, and 60$ s$^{-1}$&lt;br&gt;$P=84, 336..02, and 756.04$ watt&lt;br&gt;$t=30$min</td>
</tr>
<tr>
<td>4</td>
<td>Clarification</td>
<td>4</td>
<td>circular</td>
<td>Diameter=28m&lt;br&gt;Depth=4m</td>
<td>$V_s=0.3594$mm/s&lt;br&gt;$V_c=64.7$mm/s&lt;br&gt;$d_p=0.02$mm</td>
</tr>
<tr>
<td>5</td>
<td>Filtration</td>
<td>10</td>
<td>Rectangle</td>
<td>Width=4.5m&lt;br&gt;Length=8m&lt;br&gt;Depth=3m</td>
<td>Filtration=6.94m/hr&lt;br&gt;Rate=Backwashing=124.92m/hr</td>
</tr>
<tr>
<td>6</td>
<td>Disinfection</td>
<td>1</td>
<td>Rectangle</td>
<td>Width=12.5m&lt;br&gt;Length=25m&lt;br&gt;Depth=4m</td>
<td>Time=30min&lt;br&gt;Consumed chlorine=21.6kg/d</td>
</tr>
<tr>
<td>7</td>
<td>Storage &amp;pumping</td>
<td>3pumps</td>
<td></td>
<td>Q=2500m$^3$/h&lt;br&gt;$V=1.57$m/s&lt;br&gt;$D_{pipe}=0.75$m</td>
<td>Dosage</td>
</tr>
</tbody>
</table>
2.5.7 The efficiency of the WTP

A total of three WTPs were constructed on Greater Zab River. Built-in 1982, Erbil ETP is located on the right side of Erbil- Ainkawa main road [24]. To appraise the performance of the WTP units, we can use the following equation:

\[
\text{Removal Efficiency (\%) = } \frac{C_o - C_f}{C_o} \times 100\%
\]

Where \( C_o \) is the initial concentration and \( C_f \) is the final concentration.

Based on the collected data, the authors obtained the average removal efficiencies of turbidity in flash mixing, sedimentation tank, filtration unit, and after disinfection in the final storage tank in were 15.21%, 59.8%, 72.72%, and 85.21%, respectively [24]. The average turbidity of raw water was 12.62 NTU, whereas the average turbidity of the treated Greater-Zab water in Erbil WTP was 1.86 NTU, which is acceptable for drinking water [24]. Greater values of 4 NTU to 5 NTU and 2.31 NTU to 5.44 NTU for treated water were reported in the literature [25-26]. Issa [27] reported that the turbidity value for the treated water for Khanaqin City WTP was 5.5 NTU which greater than the drinking water standards [14]. The overall efficiency for the Khanaqin WTP was 97.88% [27]. Removal efficiencies for sedimentation tank and filter unit for Al-wahdaa Project Drinking WTP were 46% and 75%, respectively [28]. The obtained results by Mohammed and Shakir [28] were very close to the achieved data by Goran [24]. Age of the WTP, maintenance, economical and political situations, technical problems had a great impact on the removal efficiency of the WTP units.

3. CONCLUSIONS

A typical step-by-step design for WTP units was presented. Procedures, detailed calculations, and drawings were illustrated. The average discharge of 60,000 m\(^3\)/day and a population of 200,000 were used in the design of WTP. The outputs of the calculations and the details of the WTP units were tabulated. The quality and quantity of the surface water source affected the WTP design. Surface water resource such as Greater-Zab River needs treatment due to high concentration of some pollutants. The parameters of each unit and the whole WTP by using the pilot scale should be optimized. Populations should be predicted using various methods to use WTP services without any problems. Based on the obtained calculations and details it is concluded that, the study can be used as a base reference for the future works and to design of any WTP units. A number of factors such as age of WTP, maintenance, economical and political situations, technical problems, and water demand had a great impact on the removal efficiency of the WTP units.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

27. Issa HM. Evaluation of water quality and performance for a water treatment plant: Khanaqin City as a case study. Journal of Garman University. 2018;802-811. DOI:10.24271/garmian.64
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