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Designing a conventional water treatment plant on Orontes River with Around the End Flocculation and horizontal sedimentation basin

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ABSTRACT

In this Research designing the units of a conventional drinking water purification plant facility on Orontes River were made to serve Al-Quser area in Homs city.

The treated water is from a surface water supply with accepted pH, conductivity, temperature and hardness levels according to Syrian Standards No 25 and a mediate total suspended solids continent of 330 mg/L, turbidity between 20 and 200 NTU, and color of 50 º, so the water needed a chemical treatment with coagulants The designing flow was about 0 6 m3/h

The facilities was suggested based on the water characteristics like the following; First, a mechanical flash mixer; Aluminum sulfate was used as a coagulant based on jar test experiments, Round – to – end flocculating basin, and horizontal sedimentation basin, followed with rapid sand filters The last stage was dieselization of the water using chlorine A detailed calculation is described in this work.

Keywords: coagulants, conventional purification plant, around – the – end basin, rapid sand filters, Turbidity.

INtroduction :

Water is the lifeline; it plays an important role in politics and economy of societies. The issue of scarcity of water resources has become an urgent issue in formulating sustainable development policies worldwide due to global economic development and rapid population growth [1,2]. The increase in population over the past few decades has caused real problems due to increased water consumption around the world [3].

The term surface water refers to bodies of water open to the atmosphere, including rivers and lakes. Surface water is one of the main sources of drinking water, but it is often unsafe to use without treatment. [4]. The water source must provide the population with the necessary quantity and quality for a long period in terms of the ability of the purification plants to reach the required quality at the lowest possible costs. [5] Conventional water purification plants include the following processes: Coagulation, Flocculation, Sedimentation, Filtration, and Disinfection. These complex processes are monitored and adjusted in order to provide high quality water for consumers. [6]

Due to the ability of water to dissolve many gases and salts, pure water is almost rare, as it is very difficult to find usable water without prior treatment [7,8]. Natural water contains organic and inorganic substances. Water impurities are classified according to [9,10] mainly to: suspended impurities. Colloidal impurities and dissolved impurities.

Flash mixer:

It consists of a propeller that revolves at high speed by an electric motor, with either a radial-flow or axial-flow impeller, figure 1. The radial-flow impeller provides more turbulence and is better for rapid mixing. This Tank is designed to produce a high level of velocity gradient G; described in equation 1. In order to achieve a good environment for the coagulation process. Chemicals are injected in this basin.

(1)

P: power input, Watt.   Dynamic viscosity, Pa.s. V: volume of water in tank, m3

Fig.1 a: Radial-flow turbine impeller b: Axial-flow turbine [11].

Flocculation Basin:

The objective of this tank is to provide the appropriate environment so that the particles will collide, and grow to a size that will readily settle. appropriate mixing amount must be provided to bring the floc into contact and to avoid their settling in this basin. Too much mixing will shear the floc particles so they finely dispersed. Therefore, the velocity gradient must be controlled. This basin could be of mechanical or hydraulic type, on of the Hydrolic flocculation basin is the around the end tank, represented in figure 4 .

This type of Flocculation basin are used with horizontal precipitators, and its length should be equals to one of the horizontal sedimentation basin dimensions. it is a reinforced concrete tank with barriers of at least 70 cm width per corridor. The speed of the water at the beginning of the chamber is 0.1-0.3 m/sec and the speed of 0.1 m/sec at the end of the chamber. The average depth in the rooms is 2-3 m and the detention is 20-30 minutes.

Sedimentation Basin:

Sedimentation is done in basins that follows slow mixing process; in order to remove suspended substances in water or flocculants formed as a result of the addition of coagulants, as well as under the influence of gravity. The study of the sedimentation process is complex as it is influenced by several factors, including the shape and dimensions of the particles, and the water flow characteristic. This process is done by water leaving in a relatively static mode for a period, in tanks such as sedimentation basins, this process deposits suspended matter and microbes to the bottom. To increase the sedimentation rate, coagulants are added to the water to increase the speed of collection of colloidal particles, and the formation of a colloidal suspension, which is rapidly deposited carrying with it microorganisms and suspended bodies. Water during its movement in the sediments has turbulent properties, i.e. horizontal and vertical components of the speed appear. Therefore, the real value of the plankton speed during the process of sedimentation and the direction of their speed is a combination of the radial combination of the three basic components. the horizontal and vertical 1 components of the speed of the current and the speed of sedimentation of molecules under the influence of their own weight.

This type of sedimentation is used in the plants with flow about 30000 m3/d

Rapid Sand Filtration:

Filtration is the process of passing water through the layer of the filtered material in order to get rid of suspended materials. The passage of water treated by sedimentation and flocculation through a layer of sand or any other material causes the water to lose most of the remaining contaminants. The main filtration material 1 widely used in practical applications of water purification is sand. There are a large number of media used for filtration, but the best of them is sand because of its abundance, cheapness and non-change physical properties with time. [9]

Rapid sand filtrations are rectangular basins built of concrete or gunned. 3 The bottom of the basin is provided with a drainage network topped with a gravel layer, and a layer of sand. The height of the water above the filtration layer ranges between 60-120 cm. Rapid sand filters are used to filter turbid and colored water after treatment with coagulants, as well as to remove water iron and hardness in some other cases. Rapid sand filters are much more quickly than by slow filters. which requires cleaning it, as the experience of investing in filters.

Methods:

Raw Water Data:

This Research aims to optimal design conventional drinking water plant units in urban district in Homs, Syria. Test 1 of the raw water characteristics were taken a long a period of a year, during the months, and after the heavy rain periods. pH levels were between 7.3 – 9.3, Conductivity between 320 and 500 , Chloride levels between 8-50 mg/L, BOD5 between 3-20 mg/L, all the mentioned parameters are within the Syrian Standards levels. [10].

Turbidity levels were high and varied between the sessions, between 10 and 250 NTU, and the Bacterial analyses 1 showed that the water need chemical treatment, Table.1 show the results of some chemical tests of raw water in the sampling stations. Table.2 described some basic parameters accepted levels according to Syrian Standards.

Table.1 chemical tests of raw water in the sampling stations

Station

name

Date

pH

E.coli 100 ml

Staphylococcus aureus

Omiri

7/1/2023

7.6

2×

3360

Rabblah

7/1/2023

8

2×

450

Qanater

7/1/2023

8.4

2×

900

Alnabi Mando

7/1/2023

8.4

10×

500

Omiri

5/5/2023

8.4

1×

400

Rabblah

5/5/2023

8

1×

450

Qanater

5/5/2023

8.1

1×

800

Alnabi Mando

5/5/2023

8.4

25×

460

Omiri

5/9/2023

7.9

7×

500

Rabblah

5/9/2023

7.9

8×

400

Qanater

5/9/2023

8.3

8×

520

Alnabi Mando

5/9/2023

8

9×

480

Omiri

5/11/2023

7.9

7×

500

Rabblah

5/11/2023

8.2

5×

520

Qanater

5/11/2023

8.6

6×

480

Alnabi Mando

5/11/2023

7.9

× 10

600

Alum was chosen as a coagulant to treat the high levels of turbidity. The units for the purification process were chosen as the following. Mechanical Flash mixer, to 4 mix the coagulant with the raw water, flocculation basin; Round – to – End type to provide the time needed to flocs to flocculate, then a horizontal sedimentation basin followed with rapid sand filtration; to complete the purification process. And the last stage is the destabilization process with Sodium hypochlorite NaClO. Figure.2 shows a schematic overview.

Fig.2 The designed Plant Scheme

Table 2. Syrian Standards 4 for drinking water No.25

Unit

Accepted level

Parameter

NTU

1

Turbidity

1500

Conductivity

Mg/L

500

Total Hardness

-

6.5 -9

pH

TCU

15

Color

Mg/L

5

COD

Mg/L

0.1

Residual aluminum

/100 ml

0

E.coli

Each of the treatment units was designed 1 based on the designing criteria described in Table .3

Table.3 Basic Design Criteria for each basin:

Flash mixer

Velocity Gradient

700-1000 sec -1

Detention Time

30 – 60 sec

velocity

0.1 -0.3 m/sec

H/D Ratio

1:1 To 3:1

Flocculating basin

Velocity Gradient

10-100 sec -1

Detention Time

15 – 30 min

velocity

0.1 -0.3 m/sec

Wall thickness δ

15-20 cm

Horizontal Sedimentation basin

Depth

3-5 m

L/H Ratio

10:1

L/W Ratio

4:1 To 6/1

Surface loading rate

1.25 – 2.5 m/h

Detention Time

1.5 – 4 h

Results and Discussion:

Designing Flash Mixer:

A mechanical flash mixer was chosen, 4 the raw water inters the flash mixer with a flow 0.556 m3/sec, and paddles should provide the velocity gradient of 700 sec-1. Flash mixer designed 1 is described in figure.3

Detention time Assumed was 30 sec, then the volume of the tank is

, the depth of the flash mixer was assumed as 2.5 m, and then the diameter was calculated as the following:

H:D ratio = 1.16 : 1 ok

Power required P = G2. ; Assumed velocity gradient = 700 sec-1

⇒ P= 7002.0.001.16.68= 6004.8 watt = 360 watt/m3 =

Impeller diameter = 0.4 × Tank diameter = 0.4 × 2.9 = 1.16 m

Tangential velocity = (impeller speed × impeller periphery /60)

= 150×π×1.16/60 = 9.11 m/sec

Relative velocity = 0.75 × Tangential velocity = 0.75 × 9.11 = 6.83 m/sec

Power requierment = 0.5 ×CD×ρ×Ap×vr3

CD : coffeicient of drags =1.8, ρ: density of water 988 kg/m3 ,

Ap: area of paddles , Vr: relative velocity = 6.83

⇒ Ap= 0.02 m2 ; providing four paddles ; the area of each paddle = 0.005 m2

Fig.3 Mechanical Flash mixer

The width of the flocculation basin usually is designed equal to the total width of the sedimentation tanks; so the next step was designing the sedimentation tank.

1.1 Horizontal Sedimentation Basin:

We assume Four Horizontal sedimentation basin. , the depth of the deposition area is 2.8 m and the continuity of the precipitator between two cleanings is 10 d.

K factor (the factor between 5 horizontal and vertical velocity) is determined from the table.4 according to the L/H ratio; L/H = 15 ⇒ K =10 and α = 1.5

Table.4 K and α factors according to L/H ratio

25

20

15

10

The ratio L/H

13.5

12

10

7.5

K

1.82

1.67

1.5

1.33

Table.5 the values of uo and v 1 according to the type of treatment

Values of v are in mm/sec at values of K

uo mm/sec

Water treatment method

13.5

12

10

7.5

4.7

5.4

6.1

4.2

4.8

5.4

3.5

4

4.5

2.6

3

3.4

0.35

0.4

0.45

For colored water with a concentration of 200-250mg/l for suspensions and treated with chemical solutions

6.8

7.4

8.1

6

6.6

7.2

5

5.5

6

3.8

4.1

4.5

0.5

0.55

0.6

For turbid water with a concentration of suspensions greater than 250mg/l, treated with chemical solutions

1.6

1.8

1.9

2

1.4

1.6

1.7

1.8

1.2

1.3

1.4

1.5

0.9

1

1.05

1.1

0.12

0.13

0.14

0.15

For turbid water not treated with chemical solutions

Using table.5 we choose uo = 0.5 mm/sec ⇒ v =5 mm/sec

Total area of precipitators:

Area of one precipitator:

Length 1 of a single precipitator: The depth of the precipitator area is between (2.5 -3.5) m, given H = 2.8 m:

Display the precipitator:

A single longitudinal barrier is placed inside each precipitator. Thus, the precipitator is divided into two parallel corridors the width of one corridor 3.3.

Size of the sediment collection and condensation area is calculated as the following:

Where:

N: the number of operating precipitators. T: The period 3 of operation of the precipitator between two successive washes (h). m: concentration of suspensions leaving the precipitator, g/m3. The solid concentration of sediments in the depositional part of the sediment (average concentration with height) is 1 related to the turbidity of the initial water and the continuity of the period between two successive sediment releases, it was taken from Table .6.

Cc - the concentration of suspended materials in the precipitator's inlet, and is given by the following relationship:

Where M: concentration of suspensions in primary water, g/m3. K: a factor that follows the type of coagulant. It is taken as 0.55 for alum and 0.8 for iron chloride.

Dc: coagulant dose, g/m3

C: raw water color. B- The amount of undissolved impurities added to the water with lime upon alkalization. B= (1-0.4) × 60; 40: the Concentration of CaO in lime.

Table .6 solid concentration of sediments according to initial of suspended materials

up to 100 mg/L

100 mg/L , 400 mg/L

400 mg/L , 1000 mg/L

1000 mg/L , 2500 mg/L

The average 3 height of the sediment compaction and condensation area is:

1.2 Designing of Round- to –End flocculation basin:

To calculate the volume of basin, a detention 1 time of 15 min was suggested, so the volume was calculated as the continuios equation.

The area of the basin is;

To calculate the Width of corridors (the width should be more than 0.7 m), water inters the basin from the aria of the first corridor, so it could be written as the following:

Assuming the thickness of the walls 0.2 m, the Number of corridors would be:

Say number of corridors: 24

3 The length of a chamber forming the flocculation tank is equal to the length of one aisle:

Energy losses in a chambers: ΔH = 0.15 × ×m = 0.15× ×10=0.135 m

To make sure the mixing is in its right form, velocity gradient should be calculated:

Rapid Sand filters Designing:

Total area of the filters is 5 calculated using the following equation:

T: Continuity of operation of the purification station, v: filtration velocity.

n: Number of filtration washing process per day, assumed once every two days , n=0.5.

w: Washing intensity ; (5 – 15) assumed 6 l/s.m2. .

t2: Filter downtime due to washing, 0.22 h. t3: time of throwing leachate water into the sewage network after the filter washing process, 0.17 h.

Assuming the area of a filter is 43 m2, ⇒ N= 8 filters. B = 4 m , L = 11 m.

- Design of the central channel for raw water distribution, 4 the flow is divided into 5 filters, Qf = 0.556/5=0.11 m3/sec. assuming b = 0.7 m

The flash mixer , flocculation and sedimentation basins and filters are shown in figure.4.

Fig.4 Flash mixer, Flocculation and sedimentation basin and filters

Conclusions:

The objective 2 of this study is to provide a detailed optimal design of a purification plant was studied; the calculations were made to match the standards of each unit, 1 based on the study of the water characteristics. As there was high levels of turbidity, organic matters and Bacterial load that needs coagulant to help removing these particles. Horizontal sedimentation basins were chosen as the flow of the plant 3 is more than 30000 m3/d. and as horizontal basin were chosen; the flocculation basin was of the Round – To – End type; matching the width of the total sedimentation basin. Conventional treatment has usually filters that completes the purification, as after sedimentation tanks the suspended solids my still between 8 to 12 mg/L.

2 CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

DATA AVAILABILITY

The data used to support the findings of this study are included within the article.

AUTHOR’S CONTRIBUTIONS

All authors are contributed equally to bring out this article.

ETHICS

There are no ethical issues with the publication of this manuscript.

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