TREATMENT OF GREATER-ZAB WATER BY DIRECT FILTRATION

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ABSTRACT

In this research, a water treatment plant is designed to treat Greater-Zab River water by direct filtration. Direct filtration comprises of intakes, coagulation, flocculation, and filtration is not preceded by in-plant sedimentation of flocculated water. To ensure which season is suitable for using direct filtration process; turbidity values of Greater-Zab water recorded throughout fourteen months, October 2004 to May 2005 and May 2006 to October 2006. Proposed treatment-plant units are designed and summary of design are outlined. Cost analysis of conventional treatment-plants and direct filtration discussed.

Keywords: Direct filtration of water, Greater-Zab River, and turbidity

INTRODUCTION

A primary requisite for good health is an adequate supply of water that is of satisfactory sanitary quality. It is also important that the water be attractive and palatable to induce its use; otherwise, water of doubtful quality from nearby unprotected water sources may be used [1].

Natural waters are rarely of satisfactory quality for human consumption or industrial use and nearly always need to be treated. The level of treatment required will depend on how acceptable the natural water is. Raw freshwater is abstracted from rivers, lakes or underground sources and treat to standards acceptable for human consumption or industrial requirements [2]. Potable water is most conventionally classified as to its source, that is, groundwater or surface water. Generally, groundwater is uncontaminated but may contain aesthetically or economically undesirable impurities. Surface water must be considered to be contaminated with bacteria, viruses, or inorganic substances which could present a health hazard [3]. Generally, in Iraqi Kurdistan both surface and ground water sources are used for different uses. Also in Arbil City both water sources are used for drinking and domestic uses: 1) Surface water, Greater-Zab lie on the North West of Arbil City, Figures1 and 2. It is the only surface water source for drinking and other uses. 2) Groundwater, there are more than 416 drilled wells spread over entire city [4].

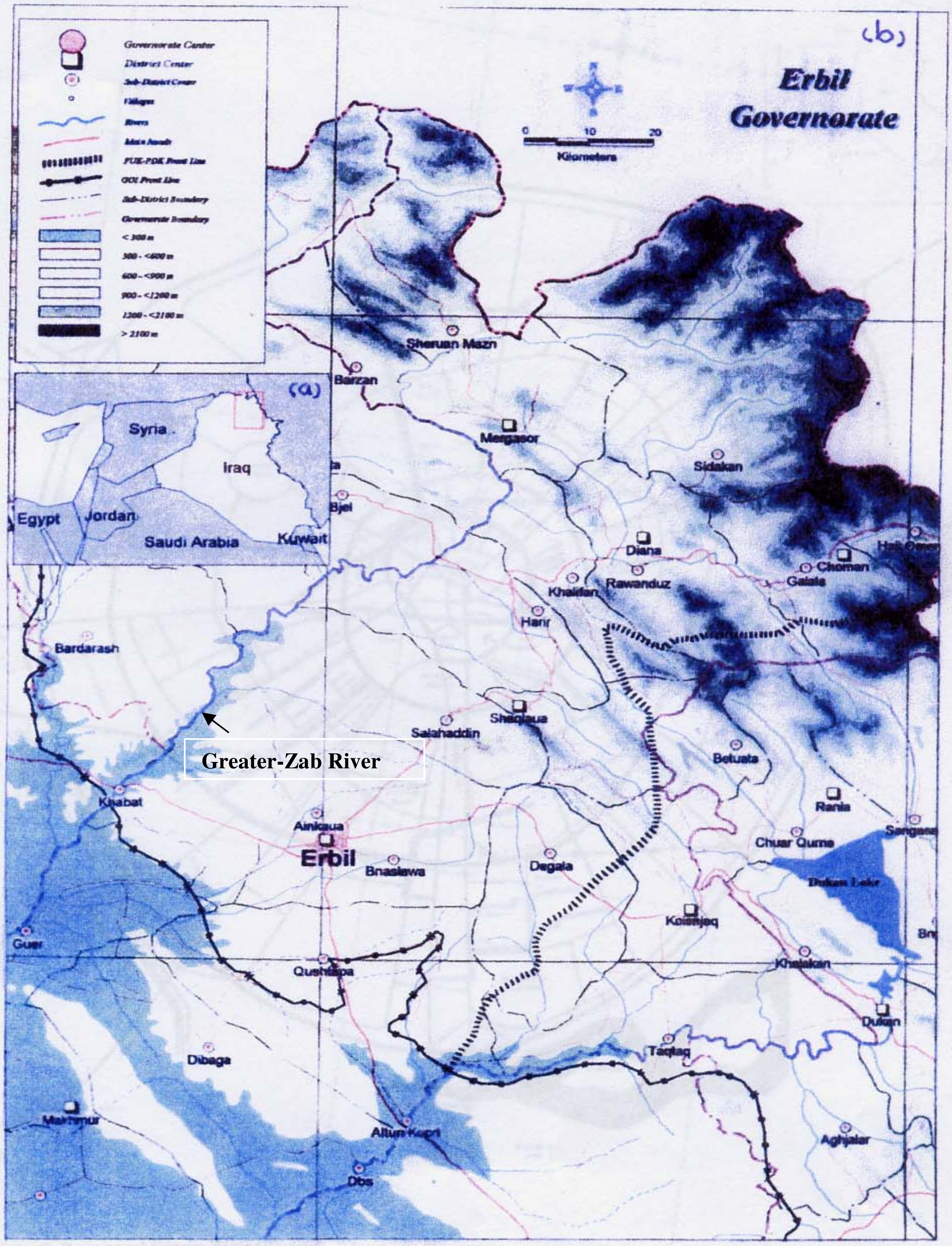

Figure1: a) Map of Iraq, b) Arbil Governorate [9]

Figure 2: Greater-Zab River

Three conventional water treatment plants constructed on Greater-Zab river for the purpose of supplying water to Arbil City: Ifraz (1969), Arbil Water Project (1983), and Third Arbil water treatment-plant (2006).

The conventional method for removing colloidal and other particulates from waters consists of coagulation, flocculation, sedimentation, and deep bed filtration through granular media. The direct filtration process differs from traditional methods of treatment, in the all sides; those occurring naturally, and those added in the course of treatment, must be removed in the filter. The committee on coagulation-filtration of AWWA's water quality division has defined direct filtration, as being any water treatment system in which filtration is not preceded by in-plant sedimentation of flocculated water [5].

For direct filtration of surface water, a work performed by Rashid 1989 for treatment of Tigris river water [5]. Babu and Raveendra tried to treat turbid surface water (15 – 25 NTU) in the laboratory by using seeds of the plant species strychnos potatorum and moringa oleifera contain natural polyelectrolytes as coagulants [6]. A pilot–plant constructed and 100 filter runs conducted to treat Greater-Zab River water by rapid filtration [7].

For preparing a research about treatment of Greater-Zab by direct filtration which this type of study not done in previous, turbidity values of the river water recorded for different periods: October 2004 to May 2005 and May 2006 to October 2006, Table 1. Also flow rates of the river tabulated in the same table during mentioned periods [8]. It can be seen from the collected data that the turbidity values lie within the limit(less than 100 NTU) reported by Rashid 1989[5]; and this agree with [6]. Turbidity ranges from 10.71 to 15.65 NTU recorded by [9]. Minimum and maximum values of turbidities were ranged between 6.88 to 320 NTU [10]. Also Aziz 2006 confirms the present results [11].

Table 1: Values of Turbidity and Flow rate during study period

No.	Month	Turbidity(NTU)	Flow rates ($m^3.s^{-1}$) [8]
1	October 2004	2.6	79.16
2	November 2004	82.8	83.14
3	December 2004	11.6	135.07
4	January 2005	16.2	403.61
5	February 2005	31.1	726.09
6	March 2005	26	1101.21
7	April 2005	44	856..9
8	May 2005	65	610.71
9	May 2006	86	781.86
10	June 2006	9	608.81
11	July 2006	2.5	296.84
12	August 2006	8.3	165.78
13	September 2006	5.3	146.49
14	October 2006	100	154..85

The aims of this study are: 1) Since there is no previous study on treatment of Greater-Zab River water by direct filtration; therefore this study regards the first attempt for this type of treatment. 2) Decreasing cost by up to 30% when compared with treatment of surface water by rapid filtration [5]. 3) Decreasing time for construction water treatment-plant. And 4) operation and maintenance costs are less than for conventional treatment.

INSTRUMENTS AND EXPERIMENT METHODS

Turbidity model, WTW, Turb 550 (Germany) was used for measuring turbidity of the collected samples. Collection of samples and analyzing were done according to [12].

Quantity of water

The proposed treatment plant by direct filtration supposed to serve a community with 100000 populations on Greater-Zab River (such as Khabat District). The quantity of water estimated as 250 litres per capita per day (lpcd) for domestic purposes, commercial, and public uses. Minimum and maximum of the average consumption suggested as 40% and 180 %, respectively. During study periods, flow rates in Greater-Zab ranged from 79.16 to 1101.21 $m^3.s^{-1}$ [8].

Average discharge (Q_{av}) = 250lpcd$*10^5*10^{-3}$ = 25000 $m^3.d^{-1}$
Maximum discharge (Q_{max}) = 25000*1.8 = 45000 $m^3.d^{-1}$
Minimum discharge (Q_{min}) = 25000*0.4 = 10000 $m^3.d^{-1}$

TREATMENT PLANT UNITS

The methods used for treatment of Greater-Zab water are related to the quality of the water during different seasons of the year. Removal suspended particles which causes turbidity in water is the goal of treatment. Annually, turbidity values will decrease during May to October, because generally there is no rain in these months; therefore direct filtration is proposed for treatment of Greater-Zab water, Figure 3.

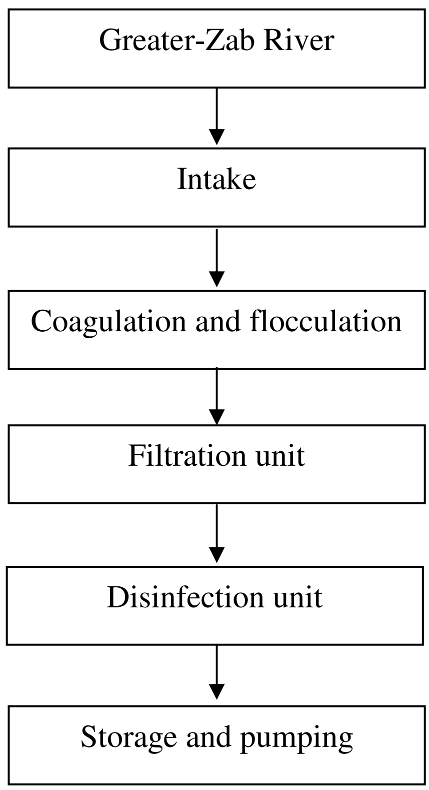

Figure 3: Flow diagram of direct filtration treatment-plant

1- Water Intakes

The first step in the treatment of water is the removal of floating or suspended debris and living organisms, possibly including fish. The simplest screens, used where river, lake or reservoir water is diverted to water works intake [13]. River-water intakes are commonly located in a protected area along the shore to minimize collection of floating debris; lake water is withdrawn below the surface to preclude interference from floating materials [14]. An intake structure is required to withdraw water from a river, lake or reservoir [15]. Intakes consist of the opening, strainer or grating though which the water enters, and the conduit conveying the water, usually by gravity, to a well or sump. From the well the water is pumped to the mains or treatment-plant. River intakes are specially likely to need screens to exclude large floating matter which might injure pumps; other intakes employ vertical gratings of steel bars.

Design of intake comprises the following parts: Wells, suction pipe, screen, and penstocks.

Summary of design:

i- Wells:

- No. of wells = 2 (prefer more than one)
- Detention time = 15 min
- Bottom of the wells is 1.5 m lower than the lowest level of the river
- Diameter of each wells = 4.2 m
- Total height of each well= 8.5 m
- During Q_{av} and Q_{min}, one well will be in use
- During Q_{max}, two wells will be in use

ii- Suction pipes

- Velocity = 1.3 $m.s^{-1}$
- End of strainers above the well = 0.7 m
- Cylindrical strainers are used
- Submerged pumps are used
- For screens, velocity = 0.3 $m.s^{-1}$
- Diameter of suction pipe = 350 mm
- During minimum demand one pipe with 350 mm diameter required.
- During average demand two pipes with 350 mm diameter required.

During maximum demand, four pipes with 350 mm diameter required.

iii- Screens

- Screens area = 0.772 m^2
- Screens diameter = 400 mm
- Height = 620 mm

iv- Penstocks

- Velocity during $Q_{min} = 0.7$ m.s^{-1}
- Velocity during $Q_{max} = 1.4$ m.s^{-1}
- Diameter = 480 mm

Diagram of intake's part is shown in Figure 4.

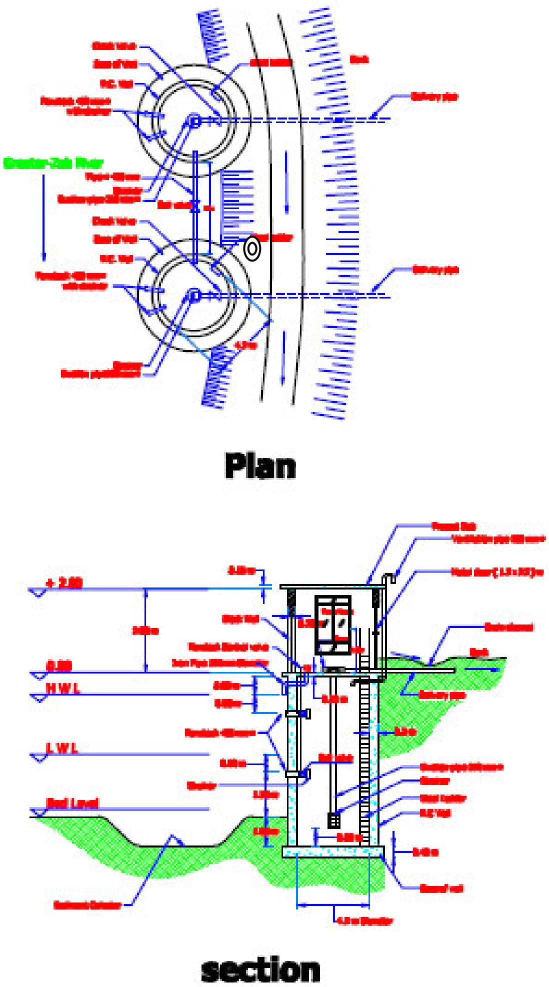

Figure 4: Details of Intake: Plan and section

2- Coagulation

Increasing particle size is advantageous, particularly in cases where a significant fraction of particles are quite small. A problem exists in the fact that particles of colloidal size usually are charged; charges on particles are usually the same. Thus the particles repel each other, and the colloidal suspension is termed stable [18]. Coagulation is considered to be a chemical treatment process that destabilizes colloidal particles as opposite to the physical treatment operations of flocculation and filtration that follow [19]. The correct dose of coagulant depends on he water being treated, and may vary from day to day [20].

Summary of coagulation unit design:

- Detention time (Q_{max}) = 40 s
- Detention time (Q_{min}) = 3 min
- Nos. of tanks = 2
- Dimensions of each tank 2.6m (length), 2m (width), and 2m (depth).

Other design criteria for flash mixer according to [16] and [21]:

- Velocity of flow = 0.9 $m.s^{-1}$
- Rotation of blade = 100 RPM
- Head loss = 1 m
- Power required = 0.041 kw/1000 m^3/day
- Velocity gradient (G) = 100 to 1000 s^{-1}

Details of flash mixer are shown in references [16] and [21]:

3- Flocculation

Flocculation refers to the process of accretion or agglomeration of the particles of floc into masses of sufficient weight and bulk so that they may settle rapidly in the sedimentation basin [22]. It implies a chemical bridging mechanism that enmeshes the particles in a three-dimensional network [23].

Summary of design flocculation unit:

- Detention time = 25 min
- Height = 3.8 m
- Diameter = 12 m

Other design criteria according to [16] and [24]:

- Velocity of flow = 0.2 to 0.8 $m.s^{-1}$
- Total area of paddles = 10 to 25 % of cross-section area of the tank.
- Distance between the paddle tips = 1 m
- Velocity gradient (G) = 10 to 75 s^{-1}
- Dimensionless factor (G t) = 10^4 to 10^5
- Power consumption = 0.06 to 0.08 kW/m^3/min

References [16], [21], and [24] depict details of flocculation units.

4- Rapid Filtration

Filtration is defined as the passage of a fluid though porous medium to remove matter held in suspension. In water purification, the matter to be removed includes suspended silt, clay, colloids, and microorganisms including algae, bacteria, and viruses [23]. Typically, rapid sand filters consist of 0.4–1.2 m of sand, usually of an effective size of 0.5–1 mm, supported by gravel and under drains [25]. According to [22], the effective sand ordinarily used in between 0.4 to 0.55 mm with a uniformity coefficient of less than 1.8; the filtering material consists of 30 to 45 cm layer of gravel underlying 67.5 to 75 cm of sand. Cross- section of the media in a coal – sand dual media filter and supporting gravel layer shown by [15]. Steel and McGhee stated that the sand depth ranges from 60 to 70 Cm; the effective size and uniformity coefficient of 0.45 to 0.55 mm and 1.2 to 1.7, respectively.

Summary of design filter unit is shown below:

A- Filter tank

- Nos. of filters = 14
- Filtration rate = 6.25 m/h
- Effective size = 0.55 mm
- Uniformity coefficient = 1.6
- Depth of filter media = 60 cm
- Depth of base material = 50 cm
- Height of water above filter = 1.5 m
- Free board = 30 cm
- Total height of filter tank = 2.9 m
- Dimensions of filters = 5 m (length), 4.3 m (width), and 2.9 m (height)
- Surface area of filter = 21.5 m^2
- Back washing time = 10 min

B- Under drain system:

i- Lateral pipes

- Distance between laterals = 20 cm
- Nos. of laterals per side = 25 No.
- Total Nos. of laterals = 50 laterals
- Ratio of total area of perforations to area of filter = 0.004
- Total area of perforations = 860 cm^2
- Diameter of perforations = 12.5 mm
- Area of perforation = 1.23 cm^2
- Nos. of perforations = 664 per tank
- Nos. of perforations per lateral = 14 Nos.
- Nos. of perforations per side = 7 Nos.
- Total cross-sectional area of laterals = 1720 cm^2
- Area per lateral = 34.4 cm^2
- Diameter of laterals = 6.62 cm

ii - Mani fold

- Ratio of manifold area to total area of laterals = 1.6
- Area of manifold = 2752 cm^2
- Diameter of manifold = 60 cm

iii – Back washing

- Discharge of backwashing = 6 % of Q_{max}
- Washing time = 10 min
- Discharge = 19.3 m^3/min
- Rate of backwashing = 54 m/h
- fluidized bed = 10% of filter depth

iv – Backwashing troughs

- Nos. of troughs = 2 No.
- Discharge per trough = 9.65 m^3/min
- Shape = circular cross-section
- Diameter = 98 cm
- Free board = 5 cm

Details of filtration unit are shown in references [15], [17], and [22].

5- Disinfection

Terminal disinfection of piped drinking-water supplies is of paramount importance and is almost universal, since it is the final barrier to the transmission of waterborne bacterial and viral disease [25]. The median turbidity of filtered water before disinfection should not exceed 1 NTU; it should not exceed 5 NTU in any individual sample [25]. Free Cl_2 may be used as disinfectant. The amount of disinfectant ranges between 0.05 to 2 $mg.l^{-1}$ as a maximum free residual chlorine. The time required for completion disinfection performed in storage tank is 0.5 hour.

6- Storage and Pumping

After complete purification of water in the treatment-plants, water has to be stored in big underground reservoirs. From these reservoirs water may be directly pumped to the main distribution lines or it may be pumped to the elevated reservoirs from where it flows to the distribution system automatically under gravity [16]. The location of pumping stations has unimportant bearing on the pressure maintained in the distribution system. Uniformity of pressure would require a central location for the station [17]. The hydraulics of the system is important in determining the most desirable location of main and auxiliary pumping stations.

Summary of design ground storage tank is here under written:

- Detention of water in storage tank = 1.5 hour
- Volume = 2812.5 m^3 (depend on Q_{max})
- Dimensions = 28 m (length), 20 m (width), and 5 m (height)
- Free board = 50 cm

COST ANALYSIS

The main advantage of direct filtration is the potential for capital cost savings up to 30%; because of elimination sedimentation tank, sludge collection, and maintenance. There may be savings of 10 to 30 % in chemical costs; less amount of coagulant is required to produce a filterable floc than to produce a settleable floc. Operation and maintenance costs are reduced, produce less and dense sludge when compared with conventional treatment-plants. Also the collection of solid waste is easier in troughs during backwashing [5].

CONCLUSIONS AND RECOMMENDATIONS

1- Greater-Zab raw water requires treatment and can not be used for drinking directly, because turbidity values are greater than the acceptable limit (5 NTU) for drinking water [23], [25], [26], [27], and [28]. The raw water must be treatable to yield a potable water meeting the drinking standards [15].
2- Since turbidity values are less than 100 NTU and according to recommendation reported by [5], it is prefer to use direct filtration process instead of rapid filtration.
3- For water treatment-plants constructed previously on Greater-Zab River water, the water can be treated by direct filtration method(eliminating sedimentation tank) during months May to October; also turbidity values recorded by [10] during mentioned period confirm this suggestion.
4- Increasing filtration rate to 6.25 m/h instead of traditional filtration rate 5 m/h; this causes increasing treated water quantity. Results reported by [7] agree with the present study.
5- Decreasing construction, operation, and maintenance costs by up to 30%; due to eliminating sedimentation unit.

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