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Hydraulic Design of Water Treatment Plant - A Case study for Srinagar town

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Abstract—*Water is an essential requirement for the body of the any living organisms. The human body contains more than 70% of water and many essential minerals required for human body are present in the purer water. Mother Nature has provided us the several sources of the pure water located in surface and subsurface of the earth. But we humans for satisfying our needs have generated pollution in these natural sources making the source of water unfit for the use. Hence, water has to be treated by the local water supplying authority of a town before supplying water to the society from the source to facilitate public with clean, fresh and palatable water. Therefore, Water Treatment Plant (WTP) is an essential requirement for the society of any town. So, the focus of this research paper is on the hydraulically designing a WTP. This paper particularly deals with the proposed hydraulic design for a 3 MLD WTP to be constructed at DhikwalGaon of Srinagar municipal board at PauriGarhwal district situated in state of Uttarakhand, India. The WTP project has been launched by UttarakhandPey Jal Nigam. In this study, all the necessary units of a WTP have been proposed and hydraulically designed considering the key factors such as source, society demand and degree of water treatment required.*

Keywords—*Water Treatment Plant, Palatable Water, Primary settling chamber, secondary settling chamber, coagulation unit, flocculation tank, rapid sand filter.*

I. INTRODUCTION

Water is one of the most important resources in our life and it is the major Earth's natural resources. However, the freshwater supply in our earth is a control resource, which means the total amount of freshwater, is limited. Most of the world's water supply is saltwater stored in the oceans. About 97% of the water stored in the ocean is salt water. Only 3% of the world's water supply is a freshwater where two-third out of the 3%, of that water is frozen, forming the polar ice caps, and icebergs. The remaining one-third of freshwater is available as either surface water or ground water and ground water accounts for two thirds of this amount. Surface water is the water that is visible above the ground surface, such as rivers, ponds etc [7]. The concern area of the study here is DhikwalGaon (village) which has its municipal board Srinagar at PauriGarhwal district situated in state of Uttarakhand, India. To serve the demand of the water supply for the DhikwalGaon (village), pumping water supply scheme of WTP was launched by UttarakhandPey Jal Nigam. The aim of scheme is to deliver the palatable water for the people of DhikwalGaon(village).The proposedWTP has the treatment capacity as 3 MLD, in which extra 5% loss during the treatment process is considered and therefore the design flow works has been worked out for 3.15 MLD. The source of raw water is obtained by pumping from the Alaknandariver dam upstream.

Figure 1:Political map of Garhwal District in state of Uttarakhand, India

II. PROPOSED LAYOUT FOR THE PLANT

Initially,raw water inlet chamber has been provided for measurement of flow and uniform distribution of the flow to further plant units. Pre-settling unit is proposed afterwards for effective settling of heavier particles from the flow. The other units of treatment included are coagulation, flocculation, secondary settling, and rapid sand filtration. For the flocculation as gentle mixing is required, it was obtained by diffusing low pressure compressed air through the water held in tank. Back wash of RSF is done using compressed air and back wash water. Back wash water storage tank was kept over the operating platforms of the filters.
For storage of chemicals and housing chemical solution tanks, a separate building was made adjoining to filter house. The solution tank is housed in a hall made of the roof of the filter units. The chemical storage tanks have acid proof

lining. Alternately,HDPE tanks of suitable size were used for chemical solutions. Dosing of chemical solution with raw water was done at the dosing chamber.

To distribute and regulate the flow for the ensuring units, common (intermediate) chambers were provided between different stages of treatment. Drain is required to be provided between different stages of treatment plant to carry underflow and overflow from various units. Dual units have been provided to facilitate operational shutdown and maintenance process.

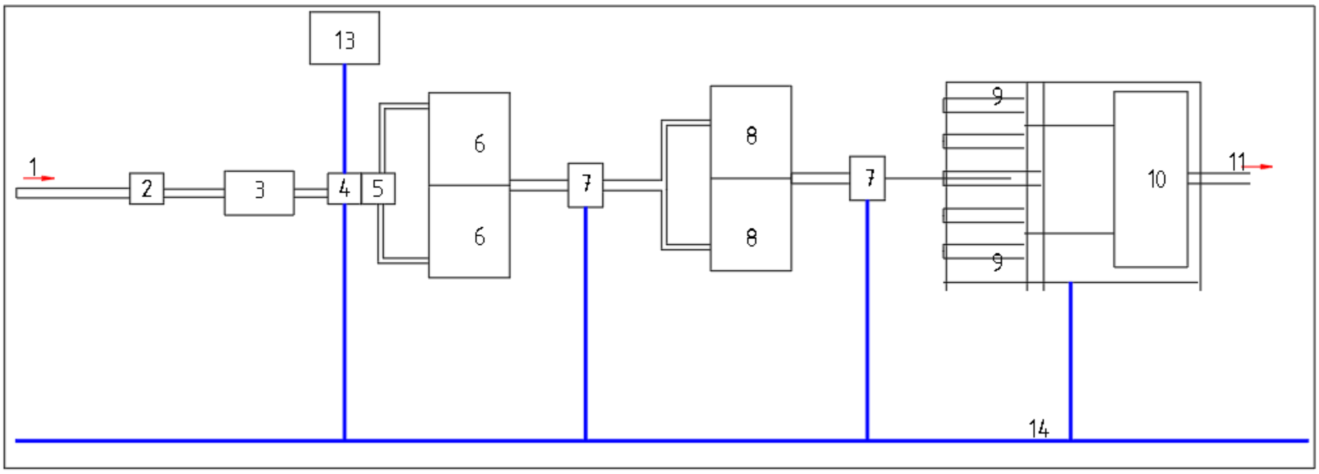

Figure 2:Schematic Representation of Proposed Layout for WTP

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III. HYDRAULIC DESIGN

Capacity – 3.15 MLD or 3150 m3/d (considering 5% losses)

Two parallel units (from flocculation unit) have been designed for treatment of 3.15 MLD water.

It means each unit(from flocculation unit) will treat 1.575 MLDwater.

3.1Raw water inlet chamber

It consist of single chamber with 90 degree v-notch in between having free fall. This will provide measurement of flow and uniform distribution of the flow to further units [6].

Chamber provided 1mx1m x 2.25m SWD. The V-notch may be cut out of a plate. The edges and scale of the V-notch may be of aluminium or brass or SS.

3.2 Pre-settling Tank

This single unit is designed for 3.15 MLDcapacity

Assume horizontal flow velocity of 0.2 m/min and detention period of 0.5 hr [6]

Length of the tank required = 6 m

Cross-sectional area of the tank required =11 m^2

Assume water depth in the tank = 3 m

Width of the tank = 3.7 m
And 0.5 m depth provided for sludge zone
Total depth of the tank = 3 +0.5 = 3.5 m
So, Pre-Settling tank of dimension **6.0 m X 3.7 m X 3.5 m** is required (with sloping bottom for effective collection of settled sludge)

3.3Overflow, underflow and wastewater drain
An overflow pipe of 200mmdia will be provided on the first inlet chamber. A scour outlet pipe and valve of 125mm dia will be provided at bottom of the first chamber.
A 500 mm dia drain of RCC Hume pipe with intermediate chambers is laid parallel to the treatment units at a minimum slope of 1 in 250 to drain out the overflow, waste water and sludge. Alternately a RCC/brick masonry drain be put with the removable slabs on the top [6].

3.4 Dosing and Mixing chamber
It consists of twin chamber with 90 degree v-notch in between having free fall. The dosing of the alum coagulant to the raw water will occur in dosing chamber whereas mixing of the same with raw water will occur in mixing chamber.
Both the chambers provided are of sizes 1mx1m x 2.25m SWD.

3.5 Coagulation Units

Total flow to be treated for 3.15 MLD

Approximate alum dose = 60mg/l [6]

Concentration of stock solution of the chemicals is 8% [6].
Capacity of the solution storage tank = to be adequate to serve for 8 hours flow [6].
No. of solution storage tanks: 2 no's for alum (1 for dissolving chemical and 1 for storage of the solution)
Solution dosing tanks: 2

<u>**Size of the Units**</u>
Total flow to be treated = 3.15 MLD.
Quantity of alum required at a dose of 60 mg/l = 95 kg in 8 hours [6].
Volume of the solution at 8% strength for 8 hours working = 1.1875 m^3
Min size of solution tanks to be put= 1m X1m X 1.5 m (considering capacity of 1.5 $m^{3)}$
Size of solution dosing tank of HDPE/PVC (2no's.) = **1m X 1m X 0.7 m**
Type of dosing: Float controlled submerged orifice tube. Alternately pumps may be used for dosing of solutions.
System of dissolving: By pumped recirculation of the solution to and from the solution tanks.
Capacity of the chemical solution mixing pumps: **1.0HP*10m head with 25 mm dia** pipes.
No of pumps for mixing of chemical solutions: 2 no's for each chemical plus standbys.
Each solution tank has to be provided with a sludge hopper, pit and sludge valve of brass or SS at the bottom

Size of one unit of flocculation:-
Each flocculation tank will have the following sizes [6]:
Assuming the detention time of 10 min, capacity required, capacity for each tank will be 11m^3
1. Provided tank of size : 2 X 2 X 3 = 12m^3
2. Available Detention Time =10.9 min
3. Quantity of air required @150 lpm/m^2 = 600 lpm
4. Pressure of the air required at the point of discharge at tank bottom: 3.5 m
5. HP of the twin lobe blower to be used for the air agitation: 1.5HP.

Size of flocculation unit- **2.0 m x2.0 m x3.25m** (two units)

3.6 Secondary Settling Unit/tank
It will be an upward flow inclined type of rectangular shaped tank having sludge hopper at the bottom. The settling will take place on the multiple corrugated AC sheets held at 45^0slope with 20cm horizontal spacing in the tank. Standing size of corrugated AC sheet is taken as 1m wide and 2.5 m long.

Size of one unit:
a. Size of Settling Zone
Design flow= 1575 m^3/d
Assumed Surface loading rate (SLR) = 30 m^3/m^2/d
Area of settling tank = Q/SLR= 53 m^2

Area of the sloping plates required = 76 m^2
Provide 2no's. of 1 m wide X 2.5m long AC sheets in a row,
So, No. of rows = 16 rows
Provide width of the tank with 2 nos. of sheets in a row = **2.4 m**
At a horizontal gap of 12.5 cm between two rows of the tier of the plates length of the tank for 16 rows = 2.00 m
Adding 0.6m width of inlet channel& baffle wall,
So, total length of the tank = 2.00 + 0.6 = **2.6m**

b. Size of Bottom Hopper
Two hopper bottoms will be provided at the bottom. With the above dimensions of the settling tank, the top size of the individual bottom hopper will be 2.6 m X 2.4 m
With 1.6 m x 1.2 m length flat apron at floor levels a horizontal offset (H) of 0.5 m is left on each side of the hopper.
Provide a vertical depth of 0.5 m in the hopper, side slope = 1:1

c. Weir loading
Provide one numbers of 0.3 m X 0.5 m overflow collection troughs on full width of the tank at water surface.
Total weir length = 8.0 m (edges)
Weir loading = 196.87m^3/m/d (o.k. as it is less than 300 m^3/m/d) [6].

3.7 Rapid Sand Filter Design(RSF)

Capacity of RSF = 3.15 MLD

3.7.1 Sand Filtering media

Filtered water required per hour = 0.131ML/hr

Assume the rate of filtration be 6000 l / h / m^2 of bed [6].

Area of filter = 21.875 m^2

Provide two units and each bed area is = 10.937 m^2

Assume L = 3.8 m

So, B =2.88m;

Therefore, adopt 2 filter units each of dimensions (effective size) ~ **3.8 mx 2.9 m (for factor of safety)**

Provide 0.5 m for wide washwater gutter along 3.0 m length

Therefore total size of the bed will be **3.8 X 3.4 m**.

1). Assume depth of sand = 75 cm. (*finer at the top and coarser at the bottom and can be laid in layers*).

Effective size (D_{10}) of sand particles = 0.35 – 0.55 mm.

Uniformity Coefficient - 1.3-1.7

Below sand layer provide 60 cm gravel support layer (*finer at the top and coarser at the bottom and can be laid in 5 layers).*

Layer No. (From top towards bottom)	1	2	3	4	5
Gravel Size (mm)	*3-6*	*6-12*	*12-20*	*20-40*	*40-80*
Thickness (mm)	*100*	*120*	*120*	*120*	*140*

3.7.2 Depth of the Tank

1. Media Depth - 1.35 m
2. Depth required for column of Standing water - 2.15
3. Free Board - 0.5 m

Total height – 4.00 m

3.7.3 Under-drainage system

Total area of holes = 0.2 to 0.5% of bed area.

Assume 0.2 % of bed area = 0.022 m^2

Area of lateral = 2 (Area of holes of lateral) (for 8 mm dia holes)

Area of manifold = (Area of laterals)

So, area of manifold = 2 x area of holes = 0.044 m^2

Assume width of manifold = 25 cm.

Depth of manifold =25cm

So, **size of manifold is 25x 30 cm**.

Assume c/c of lateral = 30cm.

Total numbers of lateral=12 Nos. on either side

Total lateral on both side = 24 Nos.

Length of each lateral =1.75 m

C.S. area of lateral = 2 x area of perforations per lateral.

Assumed dia of holes = 8 mm

Number of holes = 440 No's.

Providing two rows(staggered) in each lateral in 60 degree angle

Number of holes per lateral = 20Nos. in two rows (10 No's holes in one row)

Spacing of holes = **17.5 cm c/c**

Area of perforations per lateral =10.05 cm^2

C.S. area of each lateral = 2 x area of perforations per lateral = 20.1 cm^2.

Diameter of each lateral = 65mm dia.

Check: Length of lateral should be < 60 d = 60 x 6.5 = 3.90 m, l =1.75m (Hence acceptable).

Rising washwater velocity in bed = 50 cm/min. (= 500 lpm/m^2)

Washwater discharge per bed = 0.0918 m^3/s.

Velocity of flow through lateral = 6.52 m/s (ok)

Total lateral area = 241.2m^2

Manifold velocity = 2.1 m/s which is less than maximum permissible velocity of 2.4 m/s, hence ok [6].

3.7.4 Wash water Trough

Discharge of wash water per bed = 0.0918 m^3/s. Size of bed = 3.8 m x 2.9 m

Assume 2 troughs running lengthwise at 3.8m.

Discharge of each trough = Q/2 = 0.0459 m^3/s.

$$Q = 1.376 \times b \times h^{3/2}$$

Assume b = 30 cm

Therefore, h = 25 cm

Hence, 2 wash water troughs of size 30 cm x 25 cm laid in slope [6]

3.7.5 Air compressor unit

For air compressor unit 600-800 l of air/ min/ m^2 bed area [6].

Take 600 l/min/m^2:

Air flow rate required = 0.6 x 3.8 x 2.9 = 6.61 m^3/min

Pressure of air : 0.35 kg/cm^2

Provide Twin lobe blower of 2.5 HP, Air pipe 8 cm dia vertically connected on manifold.

3.7.6 Wash Water StorageTank:

At 500 lpm/m^2 and for washing time of 5 min [6]

water required = 500 x 3.8 x2.9 x 5 = 27.55$m^{3.}$

Provide a washwater storage tank of capacity = 3.8 m x 3.4 m x 2.13m

Apart from that provide a free board of 0.3 m.

So, **size of Wash water storage tank is 3.8 x 3.4 x 2.5 m.**

3.7.7Clean Washwater Gravity main

Design flow: 0.0918m^3/s

Dia. of downflowwashwater pipe (velocity =3 m/s) = 25 cm.

3.7.8 Wash water Drainage Pipe
Rate of wash water =500 lpm/m^2=0.092 m^3/sec
Assume velocity of flow = 2 m/sec
Dia of outlet pipe for dirty water required = 24.18 cm
Provide 25 cm pipe
3.8Inlet and Outlet pipes to the filter unit

For carrying a discharge of 1.575 MLD = 0.0182 m^3/s to each of the two filter units a MS pipe of 150 mm dia may be provided.

Same for the outlet pipe from the filters.

3.9 Chamber b/w the units (Intermediate Chambers)
Wherever required 1m x1m x 1m chambers will be provided between different stages of treatment to feed the flow to the next units. These chambers will have the outlets at the top for overflow and scour connection at the bottom. The flow to and from the units will be carried under gravity by pipes of suitable sizes with valves [6].

3.10 Clear Water Chamber (CWR)
A set of 3 chambers each of size 1.0x1.0x2.0 m SWD, will be put to receive effluent of the two filter units.

Table-1 Size description of different designed units of WTP

Si. No	Unit description	Size in 'm'
1.	Raw water inlet chamber	1mx1mx2.25m
2.	Pre-settling chamber	6mx3.7mx3.5m
3.	Dosing chamber and Mixing chamber	1mx1mx2.25m
4.	Flocculation tank	2mx2mx3.25m
5.	Secondary settling tank	2.6mx2.4mx3.5m
6.	Rapid sand filter	3.8mx3.4mx4m
7.	Back wash tank	3.8mx3.4mx2.5m
8.	Intermediate chambers	1mx1mx1m
9.	Clear water chamber	1mx1mx2m.

IV. CONCLUSION

Provision of water treatment and development of water treatment plant has been found to be an essential requirement for the society from last few decades. The above work/study demonstrates the hydraulic design for the 3MLD water treatment plant considering the key factors such as source, area demand and degree of water treatment required. The hydraulic design for the above plant has been proposed and the construction of the same will be commissioned as earliest at DhikwalGaon, Uttarakhand. This paper will provide a detailed idea/overview to the researchers for hydraulically designing a water treatment system according to given conditions.

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