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DESIGN OF WATER TREATMENT PLANT FOR DBATU CAMPUS

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Abstract— ***Water is precious commodity that contributes human to live. Various surface and sub-surface sources of pure water is provided by mother earth to all the living beings. Most of the natural water sources are polluted due to various anthropogenic and innate activities. Due to the pollution of water it is incompetent for the use, so to make the competent it is necessary to be treated in water treatment plant (WTP). The objective of this project is to design water treatment plant for population of 5500 near the DBATU college campus with latitude** 18°10'6.32" N **and longitude** 73°20'8.19" E **which is located at taluka-Mangaon, Dist-Raigad (MH). Though Konkan region have plenty of water but due to soil characteristics and sloppy nature of ground, water does not get percolated. In rainy season plenty of rain fall in this region, but in summer DBATU campus face the problem of water scarcity. The present WTP in DBATU campus is unable to complete the water demand. The components of WTP are not in working condition. The pipelines and the pressure filter is almost rusted, working period of present WTP is finished. So there is need of new WTP. We designed WTP particularly deals with hydraulic design for a 2MLD to be constructed according to life span of 20 years for the component of WTP. The project compromises design of WTP unit combined as Clariflocculator.***

Keywords— Water treatment plant, Pressure filter, Clariflocculator, MLD, Chlorination, Rapid sand filter, Pre-settling tank

I. INTRODUCTION

Human body contain 60% of water. Water is the most important part of life to the human and it is provided by mother earth to us. Out of 100% of water on earth 97% of water is in the form of ocean and it is salty water which is not accessible for drinking purpose. The remaining 3% is fresh water and out of 3%, 2% is in the form of ice or frozen water. 1% of fresh water is available as surface water and sub-surface water. Surface water is available in the form of river, lake, pond, etc.

Dr. Babasaheb Ambedkar Technological University is one of its kinds in Maharashtra state. It is the only technological university in the state. The university has very large campus area of about 500 acres and surely there is more scope for development as this university stands for the demand of granting it the charge as the state university. The university not only consists of engineering streams but also diploma engineering streams and post-graduation engineering streams having about 5500 population.

Image: Map of DBATU campus

The university campus has educational (university main building, IOPE building) as well as residential buildings (staff quarters and hostels) which have different water demands. To meet these demands we need sufficient and safe water. For this we need to install a water treatment plant of sufficient capacity to obtain treated water. There exists old water treatment plant of capacity 0.75 MLD; presently which is insufficient since its design period is nearly over. Considering all the aspects of expansion and development of university campus for design period of 20 years, we need to design a water treatment plant of capacity 2 MLD.

II. OBJECTIVES

1. To supply water that is aesthetically desirable for university campus.
2. Identifying problems in the current system and proposing solutions.
3. The present water treatment plant is not capable to provide total demand of university campus. So we designed new treatment plant.

III. METHODOLOGY

1. Population forecasting:

We used Arithmetical increase method for population forecasting. In this method the population increases with respect to time. According to forecasting, the final population of DBATU campus is 5500 for present year. According to population and design period we concluded that the capacity of WTP is 2 MLD.

2. Water sample tests:

We collected four water samples from nearby water sources i.e. Savitri river, Goregaon dam, Panhalagar dam, Gagangiri weir. We conducted four hourly test, daily test and Weekly test on samples. From the results, Goregaon dam is more reliable source than other water sources.

TABLE I

Sample test results

Sr.No	Parameters	Unit	Desirable Limits	Goregaon dam result	Present WTP result
1.	Chloride	Mg/lit	Max 200	64.98 Mg/lit	36.98 Mg/lit
2.	Sulphate	Mg/lit	Max 200	14.8 Mg/lit	9.5 Mg/lit
3.	Alkalinity	Mg/lit	Max 200	228 Mg/lit	174 Mg/lit
4.	TDS	Mg/lit	Max 200	78 PPM	79 PPM
5.	RFC	Mg/lit	0.2 Mg/lit	0.1 PPM	0.2 PPM
6.	PH	-	6.5 to 8.2	7.0	7.2
7.	Turbidity	NTU	Max 2	2.0	1.5
8.	Calcium	Mg/lit	Max 75	79.22 Mg/lit	49.29 Mg/lit
9.	Magnesium	Mg/lit	Max 30	1.5 Mg/lit	0.386 Mg/lit

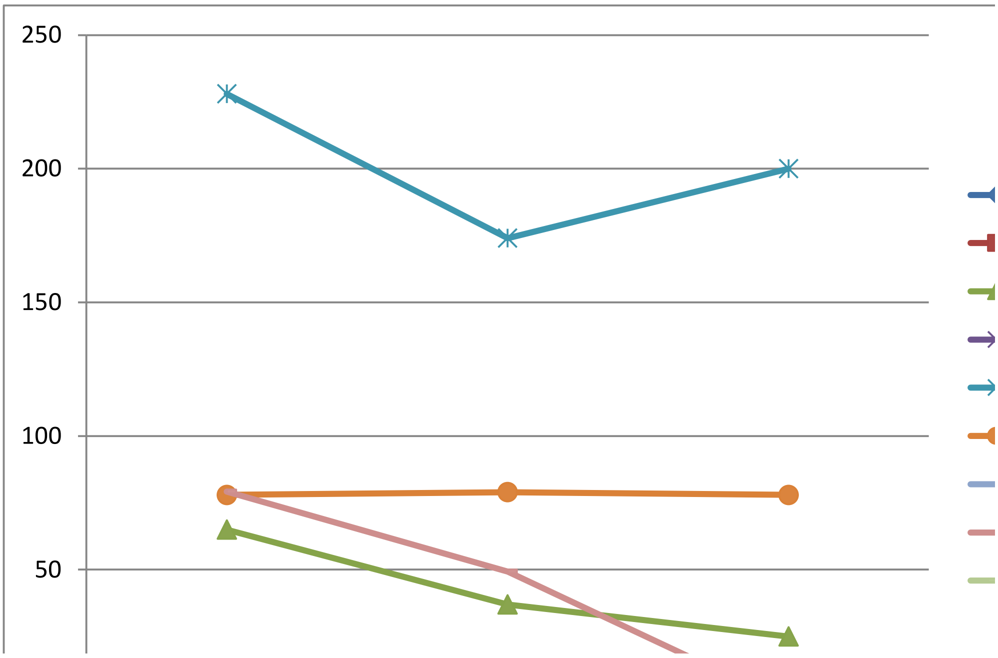

Fig-1 Sample test result vs Standard test result

3. Proposed layout for the plant:

The raw water comes from Goregaon dam through pipeline and it is directly provided to cascade aerator through inlet pipe. Cascade aerator of circular type provided with seven steps. After aeration pre-settling small channel unit is provided for settling of heavier particles. Alongside the approach channel of water, mixing tank is provided. Chemical house is also provided for storage adjoining to mix tank. The other WTP units are Clariflocculator, Rapid sand filter (RSF), Chlorination tank and treated water tank. In RSF two filter beds are provided. The chlorination is done by supplying chlorine gas through water. Treated water is collected in treated water tank and provided to elevated water tank. Wash water tank also kept over the RSF.

COMPONENT PARTS OF HYDRAULIC DESIGN:
1. INLET PIPE
2. CASCADE AERATOR
3. PRE-SETTLING TANK
4. APPROCH CHANNEL
5. CHEMICAL HOUSE
6. MIXING TANK
7. CLARIFLOCCULATOR
8. RAPID SAND FILTER.
9. CHLORINE GAS SUPPLY
10. TREATED WATER TANK
11. ELEVATED WATER TANK

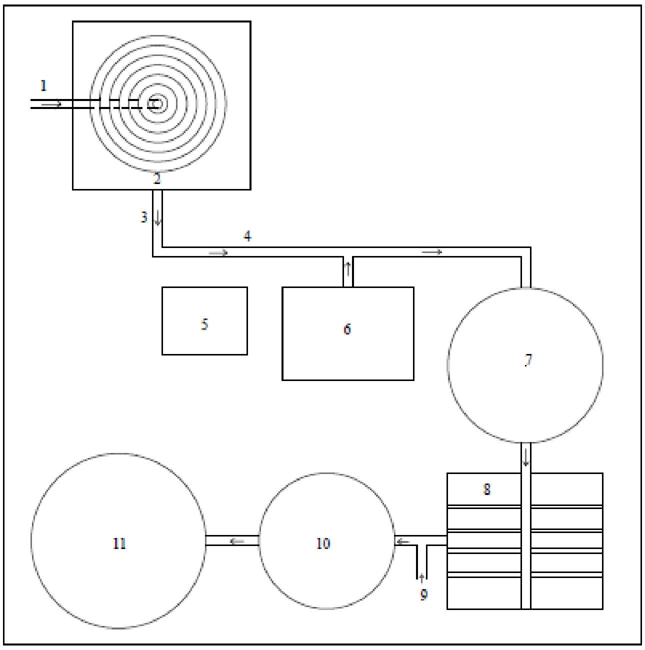

Fig.2 Schematic Representation of Proposed Layout for WTP

IV. HYDRAULIC DESIGN:

Capacity – 2 MLD

1. Cascade aerator:
It consists of seven steps in which riser 300 mm and treads 120 mm.
Assume surface overflow rate = 0.0453 $m^2/m^3/hr$
Surface area of aerator = 83.33 m^3 /hr × 0.0453 $m^2/m^3/hr$ =3.77 m^2
Assume discharge velocity of water = 1.2 m/sec
Area of discharge pipe = Q/V = 0.023 m^3/sec /1.2 m/sec = 0.0191 m^2
Diameter of discharge pipe = 200 mm
Diameter of central pipe = 200 mm, Central shaft wall thickness = 200 mm
Outer diameter of central shaft = 200+200+200= 600 mm
Area of central shaft = π/4 .d^2 =0.28 m^2
Total area of cascade aerator = Total area of central shaft + Surface area of cascade aerator
= 3.77 + 0.28
1111 =4.05 m^2
Therefore, **D= 2.25 m**
Width of steps, first step width = 600 + 2 × 120 = 840 cm , likewise 1080 cm , 1320 cm, 1560 cm, 1800 cm, 2040 cm, 2280 cm widths of second, third, fourth, fifth, sixth, seventh respectively.
Channel around width of aerator:
Flow = 83.33 m^3/hr, assume channel W/D = 1, Velocity = 0.6 m/sec
Width = √83.33/ (0.6 × 3600) = 0.2 m.

2. Pre-settling tank:
Assume velocity =0.2 m/min
Discharge = 83.33 m^3/hr
A=Q/V = 83.33/0.2×60 =7.0 m^2
Assume width = 2.5 m
Assume depth = 2.8 + 0.5 (free board)
Length = v × t = 0.2 × 30 = 6 m

3. Approach Channel:
Q = 83.33 m^3/hr = 0.023 m^3/sec
Q = A × V
0.023 = A × 0.6
A = 0.038 m^2, Assume **B = 0.3 m & D = 0.013 m**
Provide **0.3 m × 0.13 m** channel.

4. Mixing Tank:
Mechanical flash mixer will be used for mixing the coagulant solution with water.
Capacity of flash mixer = 0.023 × 60 =1.38 m^3
Providing depth 1.5 m + 0.3 (free board)
Sides of tank = √1.38/1.5 = 0.95~ 1.0 m
Provide **1.0 m × 1.0 m × 1.8 m** size tank

5. Design of outlet Pipe:
Velocity range = 0.6-2.0 m/sec, Assume 1 m/sec velocity
Q = A/V = 0.023/1.0 = 0.023 m^2
A = π÷4×d^2
Therefore **D = 0.17 m**
Provide diameter of pipe as 0.2 m

6. Clariflocculator:
Assume depth of tank = 4.5 m, Detention period = 1.5 hr
Water outlet = 83.33 m^3 /hr, then Outlet = Inlet
Total Outlet = Water + solid = 83.33 + 3 % (80) = 83.33 + 1.5 = 84.53 m^3 /hr
For design of center pipe inlet velocity = 1.2 m/sec

A) Design of Clarifier zone:
For design of clarifier zone, surface overflow rate =1.2 – 4.5 m^2/m^3/hr
For volume, D = 3-4.5 m
a. Central Pipe, V = 1.2 m/sec & Q = 84.53 m^2/m^3/hr, Therefore A = 0.0196 m^2
D = √0.0196/ π = 0.158 mm ~ 200 mm

B) Design of flocculator zone:
Detention time = 30 min
V = Flow × Detention time = 30 × 84.53 = 42.415 m^3
Assume depth of tank = 4.5 m Therefore **A = 9.43 m^2 & D =3.5 m**

C) Clariflocculator zone:
Q = 84.53 m^3 /hr, Surface overflow rate = 1.2-4.5 m^2/m^3/hr. Assume surface overflow rate = 3 m^2/m^3/hr
Area of clarifier = 84.83/3 = 28.17 m^2, Therefore D = 6 m
Diameter of Clariflocculator = Diameter of centre pipe + Diameter of flocculator + Diameter of clarifier zone
= 0.2 + 6.0 + 3.5
= 9.7 m
Diameter of Clariflocculator = 9.7 + 0.4 (additional diameter)
= 10.1 m
Actual area of Clariflocculator = π/4 × $(10.1)^2$
= 80.11 m^2
Volume of Clariflocculator = Area × Side water depth
= 80.11 × 4.5
= 360.49 m^3

7. Rapid sand filter:
Assume rate of filtration = 4.5 × 10^3 lit/hr/ m^2
Total filter area = 2 × 10^6 /23.5 × 4.5 × 10^3
= **18.91 m^2**

Number of filter beds required = $1.22 \times \sqrt{Q}$
$= 1.22 \times \sqrt{2}$
$= 1.75 \sim 2$
Area of each bed = 18.91/2 = 9.45 m^2
L/W ratio of filter bed is between 1.12 – 1.6
Assume L/W = 1.3
L= 1.3 × W, A = L × W
= 1.3W × W
= 9.45/ 1.3
W = 2.69 m
L = 3.5 m
Provide filter beds of **3.5 m × 2.69 m** in two numbers.

TABLE II
Detail of filter media

Sr. No.	Material	Effective size	Thickness
1.	Fine sand	3-6 mm	15 cm
2.	Medium sand	6-12 mm	15 cm
3.	Coarse sand	12-20 mm	15 cm
4.	Gravel grade 1	20-40 mm	15 cm
5.	Gravel grade 2	40-45 mm	15 cm
6.	Very fine sand	0.1-0.45 mm	75 cm

A) Under drain system:
1) Area of orifice = 0.3% × Filter bed
= 0.003 × 3.5 × 2.69
= 0.028 m^2
2) Area of laterals = 2 × 0.028 = 0.056 m^2
3) Area of manifold = 1.5 × Area of laterals
= 1.5 × 0.056
= 0.084 m^2
Diameter of manifold = $\pi/4 .d^2$
= 0.084
d = 0.327 m
D = 327 mm ~ 350 mm
4) Design of laterals
Adopt cross section of laterals to be 7.5 cm diameter.
Cross section area of one lateral = $(0.75)^2 \times \pi/4 = 0.00442$ m^2
Number of laterals = 0.056/0.0044 = 14
Spacing of lateral = Inner length of filter bed /Number of lateral on one side
= 3.5/5
=0.5 m ~ 500 mm/cc
Length of lateral on each side of Manifold = Width of filter bed – (Diameter of manifold/2)
= 2.7 – (0.35/2)
=2.525 m
This is less than 60 times the diameter of laterals i.e. = 60 × 0.075 = **4.5 m**
Hence it is safe.
5) Design of orifice
Total area of orifice = 0.028 m^2
Now adopt a nozzle spacing of 30 cm c/c
Total area of orifice per lateral = 0.028/14 = 0.002 m^2
Number of orifice per lateral = 2.525/0.3 = 9
Cross section area of each orifice = 20/9 = 2.22 m^2
D = $\sqrt{4/\pi \times 2.22}$ = **1.68 cm ~ 2 cm**

8. Chlorination tank:
The residual chloride proposed for water is 0.2 ppm, to achieve it, it is proposed to provide 1.55 ppm.
One number of chlorination unit proposed which is working on chlorine gas will treat 2 MLD water.
Quantity of chlorine gas required per day = $2000 \times 1 \times 1000 \times 1.55 \times 10^6$
= 3.1 kg/day
Quantity of gas = 3.1/24 = 0.129 kg/hr
One automatic device capable of delivery **0.129kg/hr** are fixed in filter house.

9. Treated water tank:
Quantity of water to be stored = 2000/3 = 666.67 m^3
Underground treated water tank having capacity about 8 hours will be provided.
Assume depth of water is 4 m.
Therefore, **D = 15 m.**

10. Wash water tank:
Quantity of wash water as 2.5% total water filtered.
Quantity of wash water = (2.5/100) × 3.5 × 2.5 × 4500 × 23.5
= 24890 lit/unit
The wash water tank should have storage capacity to store wash water for two units at least.
Therefore, 24890 × 2 = 49780 = 49.78 m^3
Assume depth of water tank 3 m.
Therefore, A = 49.78/3 = 16.59 m^2.
Provide square tank as **4.1 m × 4.1 m.**

11. Back washing of filter:
Air water wash for 5 min and rate of air is 1.25 m^2 /m^3/hr
Volume of air required = 1.25 × 5 × 2.69 × 3.5 = 59 m^3/bed
Rate of wash water = 36 m^2/m^3/hr
Duration of wash water is 15 min
Quantity of water = (36/60) × 15 × 3.5 × 2.7 = **85 m^3**
Quantity of water required per bed per sec = (36/3600) × 9.45 = 0.095 m^3/sec
Spacing will be 1.8 m, which will run parallel to length, therefore, 2.7/1.8 = 1.54 ~ 2
Therefore no of trough = 2
Let the width of each trough is 20 cm
Each trough will take half of 0.095 m^2/sec = 0.04725 m^2/sec
Discharge trough each trough = 1.375 b × $h^{2/3}$
0.04725 = 1.375 × 0.2 × $h^{2/3}$
Therefore, **h= 0.31 m**
Add 3 cm free board, Provide 2 trough with dimensions **0.2 m × 0.41 m**

12. Elevated water tank:
Provide depth of tank 6 m.
Area of tank required = 2000/6 = 333.33 m^2
Therefore diameter of water tank, **D = 20.6 m**
Depth = 6+0.5 (free board) = 6.5 m

13. Chemical dosage:
Alum:
Average alum dose required for various season - 50 mg/lit for mansoon season
- 25 mg/lit for winter season
- 10 mg/lit for summer season

Let's consider alum dose 50 mg/lit
Quantity of alum = water to be treated × 50 mg/lit
= (2 ×10^3 × 50)/1000 = 100 kg
5 % of strength solution prepared
Quantity of water required for 100 kg of alum to make 5 % strength solution = 100 × (1000/5) = 2000 lit

TABLE III
Size description of different designed units of WTP

Sr. No	Unit description	Size in 'm'
1.	Cascade aerator	D = 2.25 m, rise = 350 mm, tread = 120 mm, 7 steps
2.	Pre-settling tank	2.5m × 3.3m × 6m
3.	Approach channel	0.3m × 0.13m
4.	Mixing tank	1.0m × 1.0m × 1.8m
5.	Clariflocculator	D = 10.1m, A = 80.11 m^2, volume = 280.41 m^3
6.	Rapid sand filter	2.69m × 3.5 × 1.3m.
7.	Treated water tank	Depth = 4m, D = 15m
8.	Wash water tank	4.1m × 4.1m × 3m
9.	Elevated water tank	Depth = 6.5m, D = 21m

V. Conclusion

The last few decades' development of water treatment plant and provisions of water treatment have been found to be an essential requirement for the campus. The above study demonstrates the hydraulic design for 2 MLD water treatment plant considering the key factors such as source, area, demand and water requirement. This treatment plant will provide adequate quantity of water according to the demand and which fulfil future demand also. This paper will provide a detailed idea to the researchers for hydraulic design.

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