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Design Of Raw Water & Waste Water Treatment Plant

Preeti Singh*

[1*]Assistant Professor, Dept. Of Civil Engineering, Guru Ghasidas Vishwavidyalaya (A Central University), Bilaspur (C.G.), India -495509

***Corresponding Author:** Preeti Singh
*Assistant Professor, Dept. Of Civil Engineering, Guru Ghasidas Vishwavidyalaya (A Central University), Bilaspur (C.G.), India -495509

Abstract

This research work which emphasizes the wise approach to systematically put the wastewater to pretreatment to treat the water to the desired degree as per the standards, prior to its disposal, so that the water may also be made eligible for its reuse/ recycle for irrigation etc. purpose and thus the waste be transformed successfully to a resource. The objectives of this work are complete design of raw water & Waste water treatment plant with limiting input data and Excel spreadsheet for the above waste water treatment plant design have been prepared for quick design of desired units with varied input data within the specified range. The proposed treatment plant is efficient for bringing down the wastewater characteristics to the desired standard of disposal as applicable for Mahoba Town in U.P. For the design purpose, the average discharge for fresh water treatment and design discharge for waste water treatment has been adopted 16500 m^3/day and 26400 m^3/day respectively, various treatment units have been successfully designed as per standards and have been proposed for a population of 1 lakh people (Mahoba town). The treatment plant has been designed with the design period of 25 years.

Keywords: *Skimming Tank, Grit chamber, Aeration tank,*

Introduction

Absolute pure water is never found in nature but contains suspended, colloidal & dissolved impurities. Hence treatment of water to absolute removal of these impurities. The world is facing today, the water scarcity. Due to the mismanagement of water, the fresh water is been harnessed with great pace and generation of waste water and hence its safe disposal has become a concern. To cope up with the present problem of water scarcity, the wastewater treatment and it's recycling are given the prime importance everywhere. The wastewater if treated to the desired degree will be helpful to reuse/ recycle it for activities like irrigation, air conditioning, washing and other industrial usage etc. As a result, the fresh underground/surface water may be spared and the water scarcity problem may be properly addressed. In context to the above, the wastewaters generated in the municipal vicinity are required to be properly disposed by adopting proper sanitation techniques and giving the pre-treatment to it. The salient design units of raw water treatment include intake, pumping, pre-sedimentation (in some cases), coagulation, flocculation, clarification, adsorption, filtration, disinfection, storage, and pumping to treat water for consumption. And salient design units of waste water treatment include receiving chamber, Screens (Coarse/ Fine), pumping units, Grit chamber, Skimming Tank, PST, ASP, Aeration tank, SST, Sludge drying beds and disinfecting tank.
Methodology

The population to be served during such period will have to be estimated with due regard to all the factors governing the future growth and development of the city in the industrial, commercial, educational, social and administrative spheres. There are various methods to estimate the population. Three methods are considered for Estimation of papulation for 25 years are given below.

S.No.	Forecasting Methods	Papulation (P_{2046})
1.	Arithmetical increase method	56708.5 (person)
2.	Geometrical increase method	93574.59 (person)
3.	Incremental increase method	72190(person)

Expected Papulation after 25 years = 1,00,000 Persons
Quantity= Per capita demand x Population
Calculation of Water Demand: (AS PER IS: 1172:1993)
Expected population after 25 years: -1,00,000 (person)
Domestic demand, public use etc.: - 135 lpcd
For forecasted population = (135 x 100000) lpcd =13.5 MLD

Industrial demand: - 30 lpcd
For forecasted population = (30 x100000) lpcd =3 MLD
So, Average daily demand = (13.5+3) MLD =16.5 MLD
Max. daily demand = 1.8 x average daily demand= (1.8 x 16.5) MLD =29.76 MLD
Max. daily demand = 30 MLD
By assuming 5 % losses in WTP,
Max. daily demand = 31.5 MLD=32 MLD
Fire Requirement:
It can be assumed that city is a residential town (low rise building) Water for fire demand (As per government of India recommendation formula)
$Q = 100\sqrt{P}$
Where, Q = Fire demand in kilo litre /day,
P = Population in thousands.
So, $Q = 100\sqrt{100} = 1000$ (kilo liter) =1 MLD
Coincident draft = MDD + Fire demand = (32 +1) MLD = 33 MLD
Assuming 10% losses in distribution system =36.3 MLD
The quantity of water required for municipal uses for which the water supply scheme has to be designed requires following data: (i) Water consumption rate (Per Capita Demand in litres per day per head), (ii) Population to be served. Water quality is determined by physical, chemical and microbiological properties of water. These water quality characteristics throughout the world are characterized with wide variability. Actual data is compared with standard data in given table 1.

Table 1 - Comparison of Actual Data⋆ and Standard Data

S. No.	Characteristics	Acceptable	Cause for Rejection	Actual Value
1.	Turbidity	5	10	25
2.	pH	6.5 to 8.5	<6.5 & >8.5	7.5
3.	Total hardness (as Ca CO3)	300	600	550
4.	Total Dissolved Solids (TDS)	500	2000	1500
5.	MPN (no. 100)	0	50	3.5
6.	Alkalinity (Total)	200	600	500
7.	Chloride	250	1000	200
8.	Fluoride	1	1.5	1
9.	iron	0.1	1	1.5
10.	Nitrate (as NO3)	45	100	0
11.	Manganese	0.05	3.0	3.5
12.	Carbonate	60	120	110

⋆ - Water testing Laboratory, Uttar Pradesh Jal Nigam, Mahoba (U.P.)

Due to analysis following units are required to be designed for water treatment plant
Intake Structure:
Intake well
Jack well
Rising main
Pumping unit
Treatment unit
Raw water Reservoir
Aeration unit
Coagulant dose
Lime soda dose
Chemical dissolving tank
Chemical house
Flash mixer
Clariflocculator
Rapid sand filter
Chlorination unit
Storage unit
Underground storage tank

Elevated service Reservoir

Design of units

Intake structure- Intake structures are used for collecting water from the surface sources such as river, lake, and reservoir and conveying it further to the water treatment plant. There is a reservoir intake in this intake unit. It is Situated in 'URMIL DAM'.
Specification of Intake structure
Height- 18.34m,
Length- 4700m,
Gross storage capacity-116.35m^3
Reservoir area- 2770m^2

Intake well- Intake consists of opening. Strainer or grating through which the water enters, end the conduct conveying the water, usually by gravity to a well or sump from the well, the water is pumped in to the main or treatment plant. Intakes should also be so located and designed that possibility of interference with the supply is minimized and where uncertainty of continuous serviceability exists, intakes should be duplicated.
Specification of intake well
Detention time-10 to 15 min
Diameter- 5 to 10 m (max 15 m)
Depth - 4 to 10 m
Velocity of flow -1.0 to 1.5 m/sec
Number of units- 1 to 3 (max 4)
Free board- 5 m
Design Assumptions
Detention time = 10 min
Design Calculation
Flow of water required = [32 MLD / (3600 x 24 x 10^3)] =0.370 m^3/sec
Volume of well = (flow of water req. x detention time) = (0.370 x 10 x 60) cum.m= 222 m^3
Cross-sectional area of intake well = 222 / 4 =55.5 m^2
Dia of intake well = $\sqrt{}$ (4 x 55.5)/ π = 8.40 m (10 m < ok)
So, we will provide a intake well of diameter = 8.40 m

Summary

Table 2– Design of intake well

S.No.	Particular	Description
1.	Number of intake wells	1 unit
2.	Diameter of intake wells	8.4 m

Pen stock -These are the pipes provided in intake well to allow water from water body to intake well. These pen stocks are provided at different levels, (as H.F.L., W.L., L.W.L.). Trash racks of screens are provided to protect the entry sizeable things which can create trouble in the penstock. At each level more than one penstock is provided to take account of any obstruction during its operation. This penstock is regulated by valves provided at the top of intake wells.
Specification Pen stock
Velocity through penstock - 0.6 to 1.0 m/s
Diameter of each penstock - less than 1 m
Number of penstocks for each intake well - 02
Design Assumptions
Number of penstocks for each intake well = 2
Assuming velocity =1 m/s
Design calculation
Cross sectional area of pen stock =[0.370/ (1 x 2)] = 0.185 m^2
Dia of pen stock = 0.485 m=0.5 m

Summary

Table 3 - Design of Pen Stock

S.No.	Particular	Description

1.	No of pen stock	2 unit
2.	Dia. Of pen stocks	0.5 m

Specification of **Coarse Screens**
Q (m^3/s) - 0.370 m^3/s
Velocity - 0.9 to 1.5 m/sec
Space between the bars - 30 mm
Dia. Of bars - 1cm
Design Calculation
Area of screen = (Q/V) = (0.370/0.9) m^2 = 0.42 m^2
Width of screen = (Area/ depth) = (0. 42/0.5) m= 0.84 m
No. of opening = (Net width / clear spacing between two bars) = (0.84/0.050) = 16.8=17 (assume)
No of bars = (No. of opening – 1) = (17 – 1) =16
No of plate = 2
Total no. of bar = 16 +2= 18
Total width = [(No. of opening x clear spacing) + (no of bars x dia. of bars)]
= [(17 x 0.05) + (18 x 0.01)] =1.03 m
At 60 ^{0}, Length of screen = (2/$\sqrt{3}$ x depth) = 0.577 m

Summary

Table 4 - Design of Coarse Screens

S.No.	Particular	Description
1.	Width of screen	0.84 m
2.	No. of opening	17
3.	Total no. of bar	18
4.	Total width	1.03 m
5.	Length of screen	0.577 m

Jack well
This structure serves as a collection of the sump well for incoming water from the intake well from where the water is pumped through the rising main to the various treatment units
Design criteria
Detention time = 0.5 x detention time of intake well= (0.5 x 10) min= 5 min
Design calculations
Capacity of Jack well = (0.370 x 5 x 60) = 111 m^3
Cross sectional area of jack well = (111/4) m^2 = 27.75 m^2
Dia. of jack well = 5.94m

Summary

Table 5 – Design of jack well

S.No.	Particular	Description
1.	Dia. Of jack well	5.94 m
2.	Capacity of Jack well	111 m^3
3.	Detention time	5 min

Rising main: - These are the pressure pipes used to convey the water from the jack well to the treatment units.
Specification Rising main
Velocity- 0.9 to 1.5 m/sec
Diameter- < 0.9 m
Design Calculation
Economical diameter D = 0.97 $\sqrt{Q}$ To 1.22 $\sqrt{Q}$= 0.590 TO 0.742= 0.7 m
Cross sectional area of pipe = 0.384 m^2
Velocity = (Q/A) = (0.370/0.384) m/s= 0.97 m/s

Summary:

Table 6 – design of Rising main

S.No.	Particular	Description
1.	Economical diameter	0.7 m
2.	Velocity	0.97 m/s

Pumps- In the water treatment plant, pumps are used boost the water from the jack well to the aeration units.
Design of pump: -
Friction loss in rising main = (F.P. $V^2/2gd$) = [{0.06 x160 x $(0.97)^2$}/ (2 x 9.81 x0.7)] =0.65
Total head of pumping =hs+ hd + hf+ minor losses= (4.20 + 4.80+ 0.65+ 1) m =10.65 m
Pump Capacity = (9.81 x 1.73 x 10.65) / 0.735 x 0.75= 328 HP

Summary

Table 7– Specification for pump

S.No.	Particular	Description
1.	Velocity	0.97 m/s
2.	Frictional head	0.06
3	Capacity	328 HP

The aim of water treatment is to produce and maintain water that is hygienically safe, aesthetically attractive and palatable; in an economical manner. Conventional treatment including perchlorinating, aeration, flocculation and sedimentation, rapid gravity filtration and post chlorination are adopted for highly polluted surface waters laden with algae or microscopic organisms.
1. Raw water reservoir - Raw water reservoir is designed for the storage of raw water taken from the intake structure. The main purpose for this construction is to create a working process under the action of gravity so that treatment process may not get affected by the failure of pumping units.
Design Calculation -:
Capacity of reservoir = 50 000 m^3
Detention time = 24 hr
Discharge required for pumping = (50 x 10^6)/ (10^3 x 24 x 3600) = 0.578 m^3/second
Depth = 15 m
Area of reservoir = 50000/15 = 3333.34 m^2

Summary:

Table 8 – design of Raw water reservoir

S.No.	Particular	Description
1.	Capacity of reservoir	50 x10^3 m^3
2.	Depth	15 m
3.	Area of Reservoir	3333.34 m^2

Design of Aeration Unit- Aeration is necessary to promote the exchange of gases between the water and the atmosphere.
Design criteria for Cascade aerator
Height of structure = 2 m
Surface loading rate = 0.015 – 0.045 m^2/m^3/hr
Design calculation
Discharge Q = 0.370 m^3/s
Assuming surface loading rate = 0.04 m^2/m^3/hr
Surface loading rate = Area / flow rate
Area = (surface loading rate *flow rate) = {(0.04 m^2/m^3/hr)*(0.370*3600)m^3/hr}= 53.28 m^2
Area of cascade aerator =53.28 $m^2 \simeq 54$ m^2
Diameter of cascade = 8.2 m
Assuming tread length = 0.5 m
Total number of treads = (diameter of cascade – diameter of central shaft) / tread length
= (8.2 – 1) / 0.5 = 14.4 $\simeq$ 16

Number of treads on one side = 16/2 = 8
Number of rise = 8
Assuming height of rise = 0.2 m
Total height of cascade aerator = 8 x 0.2 = 1.6 m
Summary :

Table 9 – design of Cascade Aerator

S.No.	Particular	Description
1.	Diameter	8.2 m
2.	Area	54 m^2
3	Number of rise	8
4	Number of tread	8
5	Total height	1.6 m

The coagulant dose in the field should be judiciously controlled in the light of the jar test values. Alum is used as coagulant

Design Criteria for Alum Dose
Alum required in particular season is given below
Monsoon = 30 mg/L
Winter = 15 mg/L
Summer = 5 mg/L
Alum required: Per day alum required = 30x 10^{-6} x 32 x 10^6 = 960 kg/day
For one months (30 days) = 960 x 30 = 28800 kg
Number of bags when 1 bag is containing 50 kg= 576,
If 15 bags in each heap = 39 heaps
If area of one heap be 0.2 m^2, then total area required=7.8 m^2.

Design Criteria for Lime-Soda Process:
Lime And Soda Required
Molecular weight of $CaCO_3$ =40+12+48 = 100
CaO = 40+16 = 56.
100 mg/L of $CaCO_3$ alkalinity requires = 56 mg/L of Cao
110 mg/L of $CaCO_3$ requires = (56/100) x 110 = 61 .6 mg/L of Cao
Lime Required for Magnesium:
24 mg/L of magnesium requires = 56 mg/L of CaO.
1 mg/L of magnesium requires = 56/24 mg/L of Cao
3.5 mg/L of magnesium requires = (56/24) x 3.5 = 8.2 mg/L of CaO.
Hence, the total pure lime required = 61.6 + 8.2 = 69. 8 mg/L
56 kg of pure lime (Cao) is equivalent to 74 kg of hydrated lime
Hence hydrated lime required = (69.8 x 74) / 56 = 92.23 mg /L
Total quantity of lime required for WTP = 92.23 x 10^{-6} x 32 x 10^6= 2951.36 Kg/day
For 1 months = 2951.36 x 30 = 88540 kg
One bag contains 50 kg. Number of bags required = 1770 bags
If 15 bags in each heap, number of heaps = 118 heaps
If area of one heap is 0.2 m^2 = 23.6 m
Soda (Na_2CO_3)
Soda is required for non – carbonate hardness as follows
100 mg/L of NCH requires = 106 mg/L of Na_2CO_3 = 63.6 mg /L
Total quantity of soda required = 63.6 x 10^{-6} x 32 x 10^6 = 2035.2 Kg / day
For one month = 61056 Kg
Number of Bags (if each bag contains 50 Kg) = 1222 bags
If 15 bags in each heap = 82 heaps
Area covered = 16.4 m^2
Total area for all the chemicals = 7.8 + 23.8 + 16.4 = 48 m^2
And 30 % additional storage for chlorine
Total area required foe chemicals = 63 m^2
Provide a chemical house room = 8m x 8m
Chemical dissolving tank:

Total quantity of chemicals = 960 + 2952 + 2035 = 5947 Kg / day
Total area required = 1.6 m^2
Dimension of tank = 2.0 m x 2.0 m

Summary:

Table 10 - Design Of Chemical House

S.No.	Particular	Description
1.	Alum required	960 kg / day
2.	hydrated lime required	2952 Kg/day
3.	soda required	2035 Kg / day
4.	Chemical house	8m x 8m
5.	Chemical dissolving tank	2.0 x 2.0 m

Flash Mixer - Rapid mixing is and operation by which the coagulant is rapidly and uniformly dispersed throughout the volume of water to create a more or less homogeneous single or multiphase system. Flash mixture is one of the most popular methods in which the chemicals are dispersed. They are mixed by the impeller rotating at high speeds.
Design Criteria for Mechanical Rapid Mix Unit
Detention time = 30 to 60 seconds
Velocity of flow = 4 to 9 m/sec
Depth = 1 to 3 m
Impeller Speed = 100 to 250 RPM
Ratio of tank height to diameter 1 to 3:1
Design Calculation
Design flow = 0.370 m^3/ sec
Detention time = 30 sec
Ratio of tank height to diameter = 2:1
Rotational speed of impeller = 120 RPM
Volume of flash mixer = detention time x inlet flow = 30 x 0.370 = 11.1 m^3
Volume of tank = Height x area
11.1 = 2 D x 0.785 D^2
Diameter = 1.91 (provide 2 m) And free board = 0.5 m
Power required for agitation or mixing units
Power = μ x G^2 x volume of tank= 1.0087 x 10^{-3} x 600 x 600 x 11.1= 4030 Watt = 4.03 KW
Design of impeller in flash mixer
Diameter of impeller = 0.4 x dia of tank = 0.4 x 2 = 0.8 m
Velocity of tip of impeller $V_r = 2\pi$ r n / 60 = 2 x 3.14 x 0.4 x 120 / 60 = 5.0 m/s
Area of Blade of impeller As P = ½ x C_d x 1000 x A_p x $(5.0)^3$
A_p = 0.035 m^2
Then, provide 4 blades of size of 0.1 m x 0.085 m

Summary:

Table 11 - Design Of Flash Mixer

S.No.	Particular	Description
1	Rotational speed of impeller	120 RPM
2	Volume of flash mixer	11.1 m^3
3.	Power required for agitation or mixing units	4.03 KW
4.	Diameter of impeller	0.8 m
5.	Number of blades	4

Clariflocculator- Clariflocculator is a combination of flocculation and clarification in a single tank. It has two concentric tanks where inner tank serves as a flocculation basin and the outer tank serves as a clarifier.
Design calculation:
(a) Flocculation unit:
Discharge = 32 MLD = 22.22 m^3 / minutes
Assuming detention time = 30 min
Volume = t_d x Q = 30 x 22.22 = 666.67 m^3
Let depth = 4 m,

Aera = Volume / Depth = 666.67 / 4 = 167.7 m^2
Diameter = 15 m
Power Required P = μ x G^2 x volume of tank= 0.89 x 10^{-3} x 40 x 40 x 666.67 = 949.33 Watt
P= 950 Watt
(b) Design of Clarifier:
Detention time = 3 hrs = 180min
Discharge = 0.370 m^3 /sec = 1332 m^3/ hr
Volume of tank = 3 x 1332 = 3996 m^3
Assuming surface overflow rate = 40 m^3/m^2/day
Surface area of Clariflocculator = 1332 x 24 / 40 = 800 m^2
Diameter of clarifier unit = 35 .27 m
Depth = 3996 / 800 = 5 m
Sludge depth = 0.5 m
Free board = 0.5 m

Summary:

Table 12 – Design of Clariflocculator

S.No.	Particular	Description
1.	Volume of flocculator	666.67 m^3
2	Depth	4 m
3	Diameter	15 m
4	Power required to impeller	950 Watt
5.	Volume of clarifier unit	4000 m^3
6.	Diameter	35 m
7.	Total depth (including free bord & sludge depth)	5 m

Design Rapid sand filter- Rapid sand filtration is a purely physical drinking water purification method. Rapid sand filters (RSF) provide rapid and efficient removal of relatively large suspended particles.

Design calculations:
Required flow of water = 1332 m^3/hr
Quantity of water used in backwashing = 4 %
So, design flow for filter = 1.04 x 32 x 10^3 /23.5 = 1416 m^3/ hr
Assuming rate of filtration = 5 m^3/m^2/ hr
Aera = design flow / rate of filtration = 1416 / 5 = 283.2 m^2
Number of units = 1.22 $\sqrt{Q}$ = 1.22$\sqrt{32}$ = 6.9
for safe side we will provide 10 filter units
area of each unit = 28.32 m^2
provide filtration unit of 7m x 5 m
Design calculation for back washing:
Back washing time = 30 minutes
Wash water rate = 40 m^3/m^2/ hr
Wash wate discharge = 40 x 28.32 = 1132.8 m^3/ hr = 0.314 m^3/sec
No. of trough = 4
Discharge per unit trough = 0.0785 m^3/sec
Free board = 0.1 m

Summary:

Table 13– Design of filters

S.No.	Particular	Description
1	Design flow	1416 m^3/ hr
2	Number of units	10
3	Size	7 m x 5 m
4	Back washing time	30 minutes
5	Wash wate discharge	1132.8 m^3/ hr

Disinfection unit- Water disinfection means the removal, deactivation or killing of pathogenic microorganisms.
Design calculation -:
Chlorine dose (in form of free chlorine) = 0.5 mg/L
Residual chlorine = 0.2 mg /L
So, chlorine required per day = $32 \times 10^6 \times 0.5 \times 10^{-6}$ = 16 Kg/ day
For one month = 16x 30 = 480 kg

Summary:

Table 14 – Design of Disinfection unit

S.No.	Particular	Description
1.	Chlorine residual	0.2 mg/L
2.	Chlorine dose	16 kg / day

Distribution system- A water distribution systems is one in which the drinking water is transported from the centralised treatment plant. These systems aim to preserve the quality and quantity of water, as well as maintain sufficient pressures in the distribution of water.
Underground storage reservoir (U.S.R.)
This reservoir is used for storing the filtered water. from this water is pumped to E.S.R.
Assuming pumping hours = 8 hr per day
Detention time of reservoir =4 hours
Free board = 0.5 m
Capacity of Reservoir = Q x detention time = $(32 \times 10^6 \times 4 \times 10^{-3}) / 24 = 5333.34\ m^3$
Say 5400 m^3
Depth = 4 m, Aera = 1350 m^2

Summary:

Table 15 – Design of Underground storage reservoir

S.No.	Particular	Description
1.	Capacity	5400 m^3
2	Detention time	4 hr

Elevated Service Reservoir- The treated water from the underground reservoir is pumped to the E.S.R. and then supplied to the consumers
Water demand for distribution = 37 MLD
Assuming 25 % of storage for reserve stock = 37 + 9.25 = 46.25 MLD
Design flow = $46.25 \times 10^6 / 10^3 \times 8 \times 3600 = 1.60\ m^3/ sec$
Power of pumping unit = (9.81 x 1.60 x 10.65) /0.735 x 0.75 = 303 HP
Capacity of Reservoir = Q x detention time = $46.25 \times 10^6 \times 4 \times 10^{-3} / 24 = 7708\ m^3$
Provide 2 E.S.R. at different sites
Each of capacity = 3850 m^3

Summary:

Table 12 – Design of Elevated service reservoir

S.No.	Particular	Description
1.	Design flow	1.6 m^3/sec
2	Power of pumping unit	303 HP
3	No. of units	2
4	Capacity of Reservoir	3850 m^3

The treatment of Wastewater consists of many complex functions. The degree of treatment depends upon the characteristics of the raw inlet Wastewater as well as the required effluent characteristics. Treatment processes are often classified as:
Preliminary treatment
Primary treatment
Secondary treatment
Tertiary treatment

Preliminary Treatment- It consist solely in separating the floating materials like tree branches, papers, pieces of rags, wood, etc, and heavy settable inorganic solids. The processes under this are: Screening, Grit chamber And Skimming tank.
Primary Treatment- Primary treatment removes the materials that can be easily collected from the raw wastewater and disposed of. The main purpose of the primary clarification stage is to produce both a generally homogeneous liquid capable of being treated biologically and a sludge that can be separately treated or processed.
Secondary Treatment- It is designed to substantially degrade the biological content of the wastewater such as are derived from human waste, food waste, soaps, and detergent. The majority of municipal and industrial plants treat the settled Wastewater liquor using aerobic biological processes.
Tertiary Treatment- The purpose of tertiary treatment is to provide a final treatment stage to raise the effluent quality before it is discharged to the receiving environment (sea, river, lake, ground, etc.).

Table 13- Characteristics Of Wastewater

S. No.	Parameter	Tested value
1	BOD	240 mg/l
2	COD	550 mg/l
3	pH	6.5
4	Oil and grease	65 mg/l
5	Total suspended solids	600 mg/l
6	Nitrogen	75 mg/l
7	Total coliform	100000 MPN/ml
8	Total dissolved solids	760 mg/l

⋆ - Water Testing Laboratory, Uttar Pradesh Jal Nigam, Mahoba (U.P.)

Calculation Of Population and Discharge
Total Wastewater Discharge (in lpcd) = 80% of water consumption
Total water consumption = 16.5 MLD
Total wastewater = 80% of 16.5 MLD = 13.2 MLD
Assuming peak factor = 2
Discharge = 26.4 MLD = 26400 m^3/ day
Receiving Chamber- it is the structure to receive the raw Wastewater collected through Underground Wastewater System. It is a rectangular shape tank constructed at the entrance of the Wastewater treatment plant. The main sewer pipe is directly connected to this tank.
Design of Receiving Chamber
Wastewater collecting tank is designed for peak Wastewater flow i.e. 26.4 MLD
Capacity of tank = 27 MLD
Volume =27000 m^3
Note -: From the convenience point of view, we will provide 2 receiving chambers.
Volume of each chamber = 27000 m^3/2 = 13500 m^3
Detention period =24 hr
Depth =15 m
Area of tank = (13500 /15) m^2 = 900 m^2
Design Of Coarse Screen:
Peak discharge of Wastewater = 0.306 m^3/sec
The velocity at average flow is not allowed to exceed 0.7 m/sec
Net area of screen openings required, A = Q/V = 0.437 m^3/s
Net width of screen = Area /depth = (0.437 /1) = 0.437 m
We are using rectangular steel bars in the screen, having 1 cm width, and placed at 5 cm clear spacings, and width of water = 1m
Gross area = [(0.437 *6) /5] = 0.437 m
NO. of opening =net width/clear spacing = (0.437/0.05) = 8.74
Hence, we are assuming 10 opening No. of bars = (No. of opening – 1) = (10 – 1) = 9
With including end bars Total no. of bars = (9+2) =11
Total gross width = [(no. of opening * clear spacing between bars) + (no. of bars * dia. Of bars)] = [(10*0.05) +(11*0.01)] = 0.61m
Length of screen = [(2/√3 *depth)] = [(2/√3 *1)] = 1.15 m
Gross area = [(2/√3 *0.524)] = 0.60 m^2

Table 14 – Specification of Coarse Screens

S.No.	Particular	Description
1.	Q (m^3/s)	0.306 m^3/s
2.	Velocity	0.7 m/sec
3.	Space between the bars	50 mm
4.	Gross area of screen needed (m^2)	0.60 m^2

Design of Pumping unit -:
Wastewater flow for pumping = [(27 *10^6)/ (10^3 *10* 3600)] = 0.750 m^3/sec
Total head of pumping = 10.65 m
Assuming efficiency of pump = 75 %
Pump capacity = [(9.81*0.750*10.65)/(0.735 *0.75)] = 142.14 HP
Note -: Provide a pump of capacity 150 HP.
Economical Diameter (D) = $0.97\sqrt{Q}$ To $1.22\sqrt{Q}$ = 0.536 m to 0.674 m (Q = 0.306 m^3/sec)
Avg. diameter =0.605 m
Area of pipe = 0.287 m^2
Velocity = Q/A= 0.306/ 0.287 = 1.06 m / sec

Table 15 – Specification of pumping unit & rising main

S.No.	Particular	Description
1	Wastewater flow for pumping	0.750 m^3/sec
2	Pump capacity	150 HP
3	Diameter of Rising main	0.605 m

Design Of Grit Chamber
Peak flow rate = 0.306 m^3/sec
Let horizontal velocity of flow (V_h) = 0.2 m/sec
Now, Q = $V_h \times A$
Where A =Q/ V_h = 0.306/0.2 = 1.53 m^2
Assuming average detention period = 180 sec
Volume = Q * detention period = 0.306 * 180 = 55.08 m^3
For periodically routine cleaning there will two champers are used
The volume of one chamber = (55.08/2) =27.54 m^3
Assuming depth of 1.5m and width to depth ratio 2:1
Width of channel =1.5*2 = 3 m
Length of channel = 28/ (1.5*3) = 6.22 m
Increasing the length by about 20% to account for inlet & outlet
Provide length = (6.22 +1.2444) = 7.5 m
Note -: The grit chamber should be designed for the size of 7.5 m *3m *1.5m

Table 16 – Specification of Grit Chamber

S.No.	Particular	Description
1.	Flow rate	0.306 m^3
2.	The volume of one chamber	27.54 m^3
3.	Length of Grit chamber	7.5 m
4	Width of Grit chamber	3 m

Design of fine screens -:
Design flow = 0.306 m^3 /sec
At avg. flow design velocity =0.8 m/s
Area required = 0.306/0.8 = 0.382 m^2
Side water depth provided of = 0.5m
At peak flow design velocity = 1.6 m/s
We are providing bars at 40^0 to the horizontal

Clear area = [(0.306)/ (1.6 sin 40^0) = 0.297 m^2 = 0.3 m^2
Clear opening of fine screens = 10 mm = 0.010 m
So, size of bars = 50 mm * 10 mm
Net clear width of channel = 0.3/1 = 0.3 m
No of openings = net width/clear opening = 0.3/0.01 = 30 openings
No of bars = 30 -1 = 29
Including End bars = 29 +2 = 31 bars
Width of channel = [(31*10) + (30 +10)] = 610 mm = 0.61 m
Note -: The fine screen is designed for the size of 0.6m* 0.5m (SWD) *0.5m (FB).

Table 17 – Specification of Fine Screens

S.No.	Particular	Description
1.	Q (m^3/s)	0.306 m^3/s
2.	Velocity	0.8 m/sec
3.	Space between the bars	10 mm
4.	Number of bars	31
5.	Width of Channel	0.61 m

Design Of Skimming Tanks
Surface area required for the tank =[(6.22*10-3*Q) / (V_r)]
Where Q = Rate of flow of Wastewater in m3/ day
V_r =minimum rising velocity of the oily material to be removed in mm/ day
Q = 0.306 m^3 /s = (0.306 *60*60*24) m3 /day = 26400 m^3/day
V_r =0.25 m/min = (0.25 *60*60*24) m/day = 360 m /day
So; Area = [(6.22*10-3 *26400)/360]= 0.46 m^2 = 0.5 m^2
Depth of skimming tank = 3m
Length to breadth ratio = 1.5 :1
Therefore L =1.5B
L*B =1.5B2
B = 0.577m
L = 0.866 m
Note -: Skimming Tank is designed for the size of 0.866 m *0.577m *3m

Table 18 – Specification of Skimming tank

S.No.	Particular	Description
1	Peak flow rate	0.306 m^3/s
2	Area of tank	0.5 m^2
3.	Length of tank	0.9 m
4.	Width of tank	0.6 m

Design Of Primary Sedimentation Tank:
Total Amount of wastewater to be treated = 26.4 MLd
Peak Wastewater flow = 0.306 m^3/sec
Assuming surface loading = 40 m^3/m^2/day
Assume detention time = 2 hrs
Volume of Wastewater = [(26400*2) /24] = 2200 m^3
Provide effective depth = 2.5 m
Surface area = (2200 / 2.5) = 880 m^2
The surface area of the tank = 26400/40 = 660 m^2
By using a greater area of above two (i.e. – 880 m^2)
Thus, Diameter of tank = $\sqrt{\frac{880*4}{\pi}}$ = 33.48 m = 33.50 m
Note -: Primary sedimentation tank is designed for [33.5 m (dia.) + 2.5 (depth) + 0.5 (FB)]

Table 19 – Specification of Primary sedimentation tank

S.No.	Particular	Description
1	Peak Wastewater flow	0.306 m^3/sec
2	The surface area of the tank	880 m^2

3	Diameter of tank	33.50 m
4	Detention period	hours

Design Of Aeration Tank
No. of Aeration tank = 2
Peak Flow of Wastewater (Q) = 0.306 m^3/s = 26400 m^3/day
Peak flow at each tank = 13,200 m^3/ day
Initial Bod (Y_o) = 240 mg/liter
Final Bod (Y_e) = 20 mg /liter
Efficiency(ή) =[{(initial Bod – final Bod) *100}/Initial Bod]=[{(240-20)*100}/240]=91.7 %
F/M ratio = 0.4 & MLSS(X_t) =3000 mg /l
Volume of tank required(V) = [(Q*Y_o)/{(F/M) * X_t}]= [(13200*240)/(0.4*3000)] = 2640 m^3
Assume The depth of tank = 4.5 m
The width to depth ratio (B/D) = 2.5 m
B = 11.25 m (D =4.5 m) = 12 m
Now D = 4.5 m B = 12 m
Then L= [Volume / (b*d)]= [(2640)/ (4.5*12)] = 48.8 m say 50 m
Note -: The Aeration tank is designed for 50m* 12m * 4.5m
Volume provided = (50 * 12 *4.5) m^3 = 2700 m^3
<u>Salient Checks For Design:</u>
(i) Check for Aeration period / HRT
Hydraulic retention time (t) = [(V*24) / Q]= [(2640*24) / 13200] = 4.8 hrs
Since, hydraulic retention time (t) lies between 3-6 hrs Hence, It is ok
(ii) Check for volumetric loading
Volumetric loading =[(Q*Y_o) /V] = [(13200* 240)/2640] = 1200 g/m^3 = 1.2 kg /m^3
Since, Volumetric loading lies between 1.0 to 1.5 Hence It is ok
(iii) Check for return sludge ratio
Return Activated sludge = (Q_r)/Q = [(X_t)/ {(10^6/S.V. I) -X_t}]
S.V.I = Sludge volume index
Q = Peak flow at each tank
Q_r = sludge recirculation rate
X_t= MLSS
So; Return Activated sludge = [(3000)/ {(10^6/115) – 3000}] = 53 %
(iv) Check for S.R.T (θ_c)
V *X_t = [{(α_y*Q) * (Y_o-Y_e) * θ_c} / {1+ (k_e* θ_c)}]
Here, Constant for municipal Wastewater w.r.t MLSS (α_y) = 0.5
Constant for municipal Wastewater (k_e) = 0.06 d^{-1}
Initial Bod (Y_o) = 240 mg/liter   Final Bod (Y_e) = 20 mg /liter
Volume (V) = 2640 m^3 MLSS (X_t) =3000 mg/liter
Peak flow at each tank (Q) = 13200 m^3/day
So, 2640 *3000 = [{(0.5*13200) * (240 – 20)}/ {1+(0.06 * θ_c)}]
θ_c = 8.13 = 8 days
Aerator & Air diffusors -:
BOD_5 applied to each tank = 240 mg /liter
Avg. flow in each tank = 13200 m^3/day
BOD_5 removed in each tank = (13200 * 0.240) kg / day =3168 kg / day = 132 kg / hr
Oxygen requirement = 1kg / kg of BOD applied
Peak oxygen demand = 125 %
Oxygen transfer capacity of the aerator for standard condition =1.41 kg /HP/hr
Oxygen transfer capacity at field condition = (0.9 * 1.41) kg/hp/hr = 1.269 kg/HP/hr
Oxygen to be applied to each tank = (1.0 *132 *1.25) kg/hr = 165 kg /hr
H.P. Of aerator in each tank = (165 /1.269) HP = 130 HP
Hence, provide 4 aerators of 40 HP each.

Table 20 – Specification of Aeration tank

S.No.	Particular	Description
1	Peak flow in aeration tank (m^3/day)	0.306 m^3/sec
2	BOD in inlet (mg/litre)	240 mg/l
3	BOD at the outlet (mg/liter)	20 mg/l

4	BOD removed in the activated plant (mg/liter)	220
5	F/M ratio	0.4
6	The required volume of the tank (m^3)	2640 m^3
7	Depth of aeration tank (m)	4.5 m
8	Length of aeration tank (m)	50 m
9	Width of aeration tank (m)	12 m

Design Of Secondary Sedimentation Tank
No. of secondary clarifier =1
Wastewater flow (Q)= 26400 m^3/day
Re-circulated flow is 53% of Q
Re-circulated flow =13992 m^3/day
Total in-flow = (26400 +13992) m^3 /day= 40392 m^3/day
Hydraulic detention period = 2 hours
The volume of the Tank= [40392/ (2/24)] m^3= 3366 m^3
Assuming liquid depth = 3.5 m
Area =(volume/depth) = (3366/3.5) =961.74 m^2
Surface loading rate of avg. flow = 25 m^3/m^2/ day
Hence, The surface area provided = [Wastewater flow / Surface loading rate of avg. flow]
= [26400/25] m^2 = 1056 m^2
Using a greater of two value Surface area (A) = 1056 m^2
Diameter = $\sqrt{\frac{1056*4}{\pi}}$ = 36.7 m = 37 m

Table 21 – Specification of Secondary sedimentation tank

S.No.	Particular	Description
1	Quantity of Wastewater (m^3/day)	26400
2	The volume of the tank (m^3)	3366
3	Detention period (hours)	2
4	The surface area of the tank (m^2)	1056
5	Depth of tank (m)	3.5
6	Diameter of the tank (m)	37

Designing of sludge drying bed
Sludge applied = 0.09 Kg/day
Peak flow rate = 26400 m^3/day
Sludge applied = 26400 x 0.09= 2376 kg/day
Assume specific gravity = 1.015
Solid content = 2%
the volume of sludge $= \frac{\text{Sludge generated}}{\text{1000 x specific gravity x solid content}} = \frac{2376}{1000 \text{ x } 1.015 \text{ x } 0.02}$ = 117.04 m^3/day
According to the weather condition of the location, the beds get dried out about 10 days
Number of the cycles in one year = 365/ 10 = 37 cycles
Period of each cycle = 10 days
Volume of sludge per cycle = 117.04 x 10 = 1170 m^3
Assume spreading layer of 0.3 m/ cycle
Area of bed required = 1170 /0.3 = 3900 m^2 ≈ 4000 m^2
Provide 10 numbers of beds.
Area of each bed = 400 m^2
Note -: Bed dimensions = 25m x 16m.

Table 22– Specification of Sludge drying beds

S. No.	Particular	Description
1	Flow (m^3/day)	26400
2	The volume of sludge (m^3/day)	117.04
3	Width of bed (m)	16
4	Length of bed (m)	25

Designing Of Disinfection Tank -:
Peak rate flow = 26400 m^3/day
Assume depth of tank = 4.5 m
Detention period = 30 min = 1800 seconds
Volume of tank = flow x detention period = (26400 x 1800)/(60 X 60 X 24) = 550 m^3
Surface area = 550 / 4.5 = 123 m^2
Assuming dosage of Cl_2 = 5 mg/ l
Cl_2 required = 26400 x 5 x 1000 =132000 g/day = 132 Kg/day

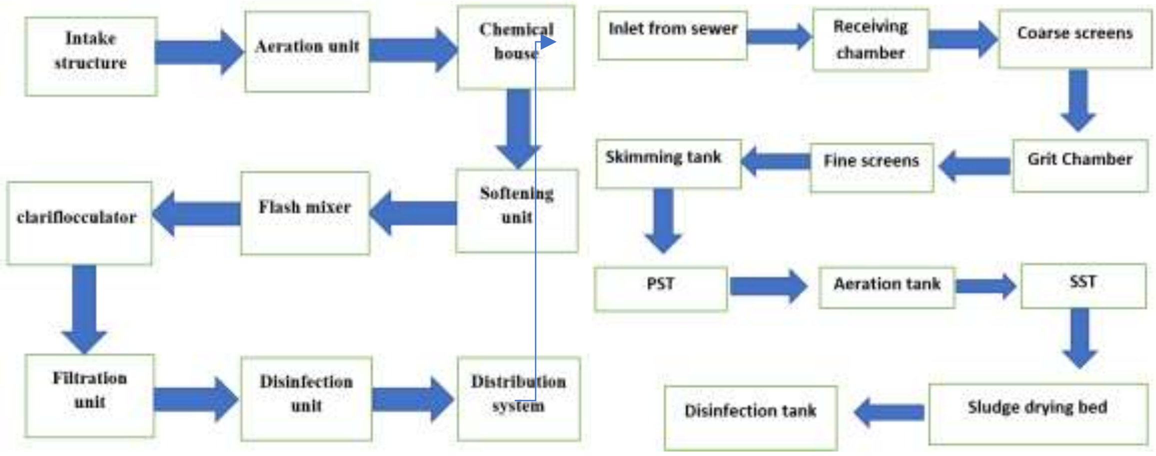

Fig1- Schematic Diagram for Complete Raw water and Wastewater Treatment

Conclusion

The present work emphasizes the wise approach to systematically put the complete Row water and wastewater to pretreatment to treat the water to the desired degree as per the standards, prior to its disposal, so that the water may also be made eligible for its reuse/ recycle for irrigation etc. purpose and thus the waste be transformed successfully to a resource. The design of the water supply treatment plant (starting from the source to the supply reservoir) and the treatment of the waste water for the small Mahoba town at U.P., carried. Excel spreadsheet for the design of various treatment units of both Raw water and the waste water treatment plant have been prepared for quick design of the desired units with varied input data within the specified range. This design has been carried out with reference to the 1 lakh population with the design discharge of 26400 m^3/ day and the design period adopted is 25 years period. Various treatment units have been designed as per Indian standards. The excel spreadsheet prepared for the raw water supply treatment plant and also for the waste water treatment plant are ready reference for the design of desired units using the varied input data within the set limitations.

DESIGN DETAILS OF RAW WATER TREATMENT PLANT

WATER DEMAND	FORECASTED POPULATION OF TOWN =	100000	Person
	MAXIMUM DAILY DEMAND =	32	Mld
INTAKE STRUCTURE	INTAKE SOURCE GROSS CAPACITY =	116.35	cum
	DIAMETER OF INTAKE WELL =	8.4	m
	CAPACITY OF RAW WATER RESERVOIR =	50000	cum
	PUMP CAPACITY =	330	hp
AERATION UNIT	DIAMETER OF CASCADE AERATOR =	8.2	m
	TOTAL HEIGHT OF CASCADE AERATOR =	1.4	m
CHEMICAL HOUSE	ALUM REQUIRED =	960	kg/day
	TOTAL LIME REQUIRED FOR WTP =	2950	kg/day
	TOTAL SODA REQUIRED FOR WTP =	2035.2	kg/day
	TOTAL AREA OF CHEMICAL HOUSE =	61.724	m^2
FLASH MIXING UNIT	VOLUME OF FLASH MIXING TANK =	11.1	m^3
	POWER REQUIRED FOR FLASH MIXING =	4030	watt
CLARIFLOCCULATOR	VOLUME OF FLOCCULATION TANK =	666	m^3
	DIAMETER OF FLOCCULATION TANK =	15	m
	VOLUME OF CLARIFIER UNIT =	3996	m^3

	DIAMETER OF CLARIFIER UNIT =	32	m
FILTRATION UNIT	DESIGN FLOW FOR FILTERS =	1416.17	cum/hr
	NUMBER OF FILTRATION UNIT =	10	
	AREA OF FILTRATION UNIT =	28.32	m^2
DISINFECTION UNIT	CHLORINE REQUIRED PER DAY =	16	kg/day
DISTRIBUTION UNIT	CAPACITY OF UNDERGROUND STORAGE RESERVOIR (U.S.R.) =	5333	m^3
	DESIGN FLOW FOR DISTRIBUTION =	1.736	cum/sec
	POWER OF PUMPING UNIT =	330	hp
	CAPACITY OF ELEVATED SERVICE RESERVOIR (E.S.R.) =	25000	m^3
	AREA OF E.S.R. =	2500	m^2

DESIGN DETAILS OF WASTEWATER TREATMENT PLANT UNITS

INPUT DATA	FORECASTED POPULATION AFTER DESIGN PERIOD =	100000	persons
	PEAK SEWAGE FLOW =	26400	m^3/day
SCREEN CHAMBER	GROSS AREA OF SCREEN NEEDED =	0.61	m^2
	AREA REQUIRED FOR SCREEN =	0.3825	m^2
	NUMBER OF BAR IN FINE SCREEN =	31	bars
GRIT CHAMBER	VOLUME OF TANK =	55.08	m^3
	NUMBER OF CHAMBER =	2	
	WIDTH OF CHAMBER =	3	m
	DEPTH OF TANK =	1.5	m
	LENGTH OF CHAMBER =	7.344	m
SKIMMING TANK	PEAK SEWAGE FLOW TO TANK =	26400	m^3/day
	AREA OF TANK =	0.46	m^2
	DEPTH OF TANK =	3.00	m
	WIDTH OF TANK =	0.55	m
	LENGTH OF TANK =	0.827	m
PRIMARY SEDIMENTATION TANK	DETENTION PERIOD =	2	hours
	AREA OF PST =	881	m^2
	DIAMETER OF TANK =	33.51	m
	DEPTH OF TANK =	2.50	m
	FREE BOARD =	0.50	m
AERATION TANK	NUMBER OF TANKS =	2	
	INITIAL BOD =	240	mg/l
	FINAL BOD =	20	mg/l
	EFFICIENCY =	91.67	%
	VOLUME OF TANK =	2640	m^3
	HYDRAULIC RETENTION TIME =	4.8	hours
	VOLUMETRIC LOADING RATE =	1.2	kg/day/m^3
	RETURN SLUDGE RATIO =	43	%
	SOLID RETENTION TIME =	8	days
	DEPTH OF TANK =	4.5	m
	TOTAL WIDTH OF TANK =	11.25	m
	TOTAL LENGTH OF AERATION TANK =	52	m
	OXYGEN REQUIRED FOR EACH TANK =	165	kg/hr
	POWER REQUIRED FOR AERATION =	130	HP
SECONDARY SEDIMENTATION TANK	RECIRCULATED FLOW =	14012.35	m^3/day
	TOTAL INFLOW =	40450.752	m^3/day
	VOLUME OF TANK =	3370.896	m^3
	AREA OF TANK =	1058	m^2
	DIAMETER OF TANK =	37	m
SLUDGE DRYING BED	SLUDGE APPLIED =	2376	kg/day
	VOLUME OF SLUDGE =	117.04	m^3/day
	PERIOD OF CYCLE =	10	

	SURFACE AREA=	3901.48	m^2
	NO. OF BED PROVIDED=	10	
	VOLUME OF BED =	499.2	m^3
	BREADTH OF BED =	16	m
	LENGTH OF BED =	24	m
DISINFECTION TANK	DETENTION TIME=	30	min
	VOLUME OF TANK=	550	m^3
	LENGTH OF TANK =	13.5	m
	BREADTH OF TANK =	9	m
	DEPTH OF TANK =	4.5	m
	QUANTITY OF CHLORINE REQUIRED=	132	kg/day

References

1. Lin et al (2001) "A Critical Review on Performance of Wastewater Reuse Systems" International Journal of Environmental Research and Development. ISSN 2249-3131 Volume 4, Number 3 (2014).
2. Tansel B. (2008) "Competitive Adsorption of Metal Ions on Peanut Testa (Arachis hypogaea L.) Extract Using Cation Exchange Resins" New Technologies for Water and Wastewater Treatment: A Survey of Recent Patents. Recent Patents on Chemical Engineering, Vol.8 No.12, 2021
3. Le Chevallier et al (2013) "Water Treatment and Pathogen Control: Process Efficiency in Achieving Safe Drinking-water" Water Intelligence Online Vol.12
4. Pant et al "Disinfection of wastewater: Comparative evaluation of chlorination and DHS-biotower" Journal of Environmental Biology October 2007, 28(4) 717-722 (2007)
5. Baroniya et al "Operation and Maintenance of Water Treatment Plant at BNP Campus Dewas, India: A Case Study" ISCA Journal of Biological Sciences Vol. 1(1), 83-86, May (2012)
6. Brandt M.J., Johnson K.M., Elphanston A.J., & Ratnayaka D.D. (2017). Twort's Water Supply. 7th Edition, Published by Elsevier Ltd.
7. Sarker Rahman and Tarek Zayed, (2008),"Performance of Water Treatment Plant Elements" World Environmental and Water Resources Congress
8. Sayyed Hussaina, Vinod Maneb, Surendra Takdea, Arif Pathan, Mazahar Farooquic,(2010), "Comparison between Treated and Untreated water so as to study water treatment plant of Ahmadpur dist. Latur," International Journal of Modern Engineering Research (IJMER) . Vol.1, Issue2, pp-564-569
9. M. A. ElDib and Mahmoud A. Azeem Elbayoumy,(2009), "Evaluation of A Water Treatment Plant Performance-Case Study", Seventh International Water Technology Conference IWTC7 Egypt 1-3
10. Baroniya Mamta, Baroniya Sanjay Singh and Jain Monica, (2012), "Operation and Maintenance of Water Treatment Plant at BNP Campus Dewas, India: A Case Study", ISCA Journal of Biological Sciences, Vol. 1(1), 83-86,
11. T.A Khan,D.kumar,Abul Hansat,& R.C.trivedi,(2005),"Physico-chemical studies of drinking water and performance evaluation of WTPs in Delhi",Enviromedia,Poll Res.24(1):13-18
12. Hammer, M. J. & Hammer, Jr. M. J. (1996). Water and Wastewater Technology. 3rd edition. Prentice–Hall, Inc. [8] Bureau of Indian standards: IS 10500:2012
13. Sarika M. Mankar, Dr. P. B.Nagarnaik,"Performance Evaluation of A Water Treatment plant (case study), International journal of advanced engineering sciences and technologies vol No. 7, Issue No.2, Page 286–289.
14. Guidelines for drinking-water quality, 1st addendum to third edition, vol. 1, ISBN: 92 4 154696 4, World Health Organization, Geneva, Switzereland.
15. Maiti S. K. (2001) Handbook of methods in Environmental studies, V1: Water and wastewater analysis, ISBN 81-8577- 34-0, ABD pub. Jaipur (RJ), India, pp-18-19.
16. Pathak M. (2012) Assessment of Physico-chemical quality of municipal water samples of Makronia sub-urban area of Bundel khand region, India, Annals of the University of Oradea, EU, June 2012, E-ISSN 2065-1619, pp-122-127.
17. Patil Y. Y. and Raut P. D. (2010) Studies on the status of open wells in Kolhapur city Journal of Advances in Science and Technology 13(1)" ISSN :0971-9563, pp-165-170.
18. Rahman and Zayed (2009) Condition Assessment of Water Treatment Plant Components, J. Performance of Constructed facilities, Vol. 23, No. 4, ISSN-0887-3828, pp-276–287.
19. Bureau of Indian standards: IS 7090 : 1985
20. Bureau of Indian standards: IS 7208 : 1992
21. Bureau of Indian standards: IS 8419 (part 1) : 1977
22. Bureau of Indian standards: IS 9222 (Part 1) : 1990
23. Bureau of Indian standards: IS 11570 : 1985
24. Water testing Laboratory, Uttar Pradesh Jal Nigam, Mahoba (U.P.)

25. Official website of Jal Nigam - http://jn.upsdc.gov.in/
26. Manual on Sewerage and Wastewater Treatment Systems – 2013 Central Public Health & Environmental Engineering Organisation (CPHEEO), Ministry of Housing and urban Affairs, Government of India.
27. IS:10500 Draft Indian Standard Drinking Water – Specification (Second Revision of Is 10500).
28. IS 1172: 1993 Code of Basic Requirements for Water Supply, Drainage and Sanitation.
29. Davis, M. L., & Cornwell, D. A. (2008). *Introduction to environmental engineering*. McGraw-Hill Companies.
30. Arcadio P. Sincero and Gregoria A Sincero, Environmental Engineering, A Design Approach, PHI Learning Pvt. Ltd., New Delhi, 110001
31. Azad, A.S., "Design of primary Wastewater treatment plant". Madras Agricultural Journal,81:5, pp 272–273, 1995
32. Besnarek, W., and Tkaczyk, P. folia – "Wastewater treatment and disposal" agricultural journal, pp 50 – 72; 1999
33. IS: 6908-1975 Indian Standard Code: Wastewater and Drainage
34. IS:7022 (PT 11)-i979Indian Standard Code: Glossary of Terms Relating to Water Wastewater and Industrial Effluents PT II
35. IS:1538-(PT-XXIV)-1 982Indian Standard Code: Press Pipes for Water. Gas and wastewater
36. IS 5600: 2002 Indian Standard Code: Pumps-Wastewater and Drainage-Specification
37. IS: 5600-1970Indian Standard Code: Specification for Wastewater and Drainage Building Elements IS: 6279:1971Indian Standard Code: Equipment for grit removal devices IS 6280:1971 Wastewater screens
38. IS 8413 (PT 2):1982Indian Standard Code: Requirements for biological treatment equipment Part 2 Activated Sludge process Wastewater Engineering Treatment and Reuse" by Metcalf & Eddy.
39. Chemistry for Environmental Engineering and Science" by Sawyer, McCarty, and Parkin.
40. Environmental Engineering: Wastewater Disposal And Air Pollution Engineering (Volume - 2)" by Santhosh Kumar Garg.
41. Industrial Water Pollution Control" by W.W. Eckenfelder Jr.