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DESIGN OF WATER SUPPLY SCHEME FOR EWS HOUSES IN AGRA, UTTAR PRADESH, INDIA

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Abstract: The research paper highlights the recent work carried out on the water quality status and water supply near Kalindi Vihar Colony, Tedi Bagiya, Agra, India. The Current research has been carried out on Ground water quality in the area in order to design a water supply scheme for an under developing residential colony i.e. EWS houses there. It also includes the provision of design of water treatment scheme for the area in order to supply the treated water to the houses.
Keywords: Water, Surface Water, Ground Water, Water Quality, Water Supply, Water Treatment Scheme.

1. Introduction

The research site is located in the district of Agra in the state of Uttar Pradesh, India. The site is located near Kalindi Vihar, Tedi Bagiya on the outskirts of the city of Agra.

1.1 Agra formerly known as Akbarabad is a city on the banks of the river Yamuna in the northern state of Uttar Pradesh, India, 363 kilometer west of state capital, Lucknow and 200 kilometers south from national capital New Delhi. The modern city of Agra was founded way back in the 16th century by Sikandar Lodhi, who was a king of the Lodhi dynasty. In geographical terms, the city of Agra lies between 26°44' N to 27°25'N and 77°26'E to 78°32'E. The city is located at an average altitude of 171 meters or 561 feet above the sea level. Agra features a semiarid climate that borders on a humid subtropical climate. The city features mild winters, hot and dry summers and a monsoon season. It is one of the most populous cities in Uttar Pradesh and the 19th most populous in India. Agra district population grew by 21% in the decade 2001-2011 and 31% in the decade 1991–2001. On the basis of landmass, Agra is the third largest city in the state of Uttar Pradesh. Because 80 % of the city's sewage flows into Yamuna River, it is 20th most polluted city in India. Agra Airport (Kheria Airport) is about 12.5 km from city center. Agra is on the central train line between Delhi and Mumbai (Bombay) and between Delhi and Chennai. Agra is famous for its Historical monuments like Taj Mahal, Agra Fort, Sikandra, Fatehpur sikri, etc.

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1.2 Research Site: As mentioned above the site is located on the outskirts of the city. The geographical location of the work site is about 27°22'N, 78°08'E. The Site is located near NH 2 (towards Tundla) which connects Agra to Kanpur. From Aligarh it is about 80 km and it takes about 2 hrs to reach the site travelling on NH 93 which connects Agra to Aligarh. At proposed work site, EWS (Economically Weaker Section) Houses are to be constructed for economically backward section of society. This Project comes under the proposed Welfare Scheme of "Manyawar Shri Kanshiram Ji Shahri Garib Awas Yojna" undertaken by the erstwhile Government of Uttar Pradesh led By Shrimati Mayawati Ji. The work is being handled by U.P. Housing & Development Board under the supervision of Agra Development Authority. The site is an extension of Kalindi Vihar Yojana of Agra Development Authority, under Sector – H. Under the proposed work, 337 houses are to be built.

1.3 Objective of Study: The main objective of the study was to propose a water supply scheme for the above mentioned project of 337 houses. Other works included finding out possible location of sources of water in the area, testing of the water quality, comparison of those values with standards specified by the government. Proposal of water treatment technologies depending upon the results of water quality tests carried out in the whole area. Water quantity estimation, population estimation, design of intake structures, and pumping apparatus, mode of conveyance of water, Water Storage structures and finally water supply network (water distribution network).

2. Water Quality Parameters:

Public, in general, judges the quality of water supplied based on its appearance, taste and odor at the point of its use. Although appearance, taste, odor etc., are useful indicators of the quality of drinking water, their presence may not necessarily make water unsafe to drink. In the same way, the absence of any unpleasant qualities does not guarantee water to be safe for consumption. True that drinking water should be aesthetically pleasing, ideally looking clear, colorless and well aerated with no unpalatable taste and odor. However, suitability in terms of public health is determined by microbiological, physical, chemical and radiological characteristics. Of these, the most important is microbiological quality. Also a number of chemical contaminants (both organic and inorganic) are found in water. These cause health problems in the long run and, therefore, detailed analyses are warranted. The drinking water, thus, should be:

- Free from pathogenic (disease causing) organisms.
- Clear (with low turbidity and little color).

- Not saline (salty in taste).
- Free from offensive taste or smell.
- Free from compounds that may have adverse effects on health or harmful in long term.
- Free from chemicals that cause corrosion of water supply system or stain clothes washed using it.

To ensure safe drinking water, detailed quality standards for physical, chemical, microbiological and radiological characteristics of water have been proposed by different countries and international organizations.

3. Laboratory Analysis of Water Quality:

Materials & Methods:

After initial survey of the site, following notable features were found out:

a) Source of water: Ground water b) Mode of water: Bore - well

3.1 Sampling: The water samples were brought from the Agra and analyzed for different parameters in the Environmental engineering laboratory of Civil engineering department, Z.H.C.E.T, Aligarh Muslim University, Aligarh, Uttar Pradesh, India. Dark plastic bottles of 2 liters capacity each with a stopper were used for collecting samples. Each bottle was washed with 2% Nitric acid and then rinsed three times with distilled water. The bottles were then preserved in a clean place. The bottles were filled leaving no air space, and then the bottle was sealed to prevent any leakage and stored in a cool place. Each container was clearly marked with the name, location and date of sampling.

3.2 Sampling Points: After initial survey of the site, the study area was divided suitably into four parts depending upon the location of source of water. Thus a total of four samples were taken from the whole area from the location of source of water randomly. In the first week of sampling, samples from two points were taken in two bottles of 2 liters each. Similarly in next week, samples from the other two points were taken in two bottles of 2 liters each. The exact points of location of samples are mentioned and shown in figure below.

1. Near the under construction area of EWS houses
2. Near the Electric Sub station
3. From akhara situated near the main road connecting NH 93 to NH 2
4. At the midpoint of service road and Nallah.

At all the sampling point’s source was ground water and mode of water was bore – well.

Figure 3.1 Aerial Photograph showing the Location of Sampling Points

3.3 Water Quality Parameters tested in the laboratory: Following parameters were tested in the laboratory:

3.3.1 pH

3.3.2 Turbidity: Nephelometer Method

3.3.3 Temperature

3.3.4 Sulphate: Nephelometer Method

3.3.5 Alkalinity

3.3.6 Total Hardness: EDTA Titration Method

3.3.7 Dissolved Oxygen, DO: Winkler Azide modified Titrimetric Method

3.3.8 Biochemical Oxygen Demand BOD: Winkler Azide modified Titrimetric Method

3.3.9 Chloride: Argentometric Titration Method

3.3.10 Total Solids

3.3.11 Chemical Oxygen Demand COD: Closed Reflux Titrimetric Method

3.3.12 Fluoride: SPANDS Spectrophotometric method using HACH instrument DR 5000 Method no. 8029

3.3.13 Nitrate: Spectrophotometer Method using HACH DR 5000 series, Method 8039, Cadmium Reduction Method, Powder pillows.

3.3.14 Iron: Spectrophotometer Method using HACH DR 5000 series, Method 8146, 1, 10 Phenanthroline Method, Powder pillows.

4. Results and Observations:

Table 4.1 Water Quality Result Sample 1

S.No.	Parameter	Value
1	pH	7.10
2	Temperature	28°C
3	Turbidity	3 NTU
4	Dissolved Oxygen D.O.	3 mg/l
5	Total Alkalinity	**400 mg/l**
6	Biochemical Oxygen Demand BOD	**5 mg/l**
7	Chemical Oxygen Demand COD	**19.2 mg/l**
8	Total Dissolved Solids	**2400 mg/l**
9	Total Hardness	**440 mg/l**
10	Calcium Ions Ca^{++}	108 mg/l
11	Magnesium Ions Mg^{++}	41.3 mg/l
12	Chloride Cl^-	**769.8 mg/l**
13	Sulphate SO_4^{2-}	**432 mg/l**
14	Fluoride F^-	0.83 mg/l
15	Nitrate NO_3^{2-}	4.3 mg/l
16	Iron Fe	0.1 mg/l

Table 4.2 Water Quality Result Sample 2

S.No.	Parameter	Value
1	pH	7.18
2	Temperature	28.5°C
3	Turbidity	3 NTU
4	Dissolved Oxygen D.O.	2.5 mg/l
5	Total Alkalinity	**420 mg/l**
6	Biochemical Oxygen Demand BOD	**5 mg/l**
7	Chemical Oxygen Demand COD	**6.4 mg/l**
8	Total Solids	**2500 mg/l**
9	Total Hardness	**390 mg/l**
10	Calcium Ions Ca^{++}	96 mg/l
11	Magnesium Ions Mg^{++}	36.5 mg/l
12	Chloride Cl^-	**757.2 mg/l**
13	Sulphate SO_4^{2-}	**424 mg/l**
14	Fluoride F^-	0.84 mg/l
15	Nitrate NO_3^{2-}	4.4 mg/l
16	Iron Fe	0.23 mg/l

Table 4.3 Water Quality Result Sample 3

S.No.	Parameter	Value
1	pH	7.12
2	Temperature	28.3°C
3	Turbidity	4 NTU
4	Dissolved Oxygen D.O.	4.5 mg/l
5	Total Alkalinity	**380 mg/l**
6	Biochemical Oxygen Demand BOD	**10 mg/l**
7	Chemical Oxygen Demand COD	**32 mg/l**
8	Total Dissolved Solids	**2600 mg/l**
9	Total Hardness	**410 mg/l**
10	Calcium Ions Ca^{++}	112 mg/l
11	Magnesium Ions Mg^{++}	31.6 mg/l
12	Chloride Cl^-	**914.8 mg/l**
13	Sulphate SO_4^{2-}	**360 mg/l**
14	Fluoride F^-	1.02 mg/l
15	Nitrate NO_3^{2-}	6.5 mg/l
16	Iron Fe	0.3 mg/l

Table 4.4 Water Quality Result Sample 4

S.No.	Parameter	Value
1	pH	7.20
2	Temperature	29°C
3	Turbidity	5 NTU
4	Dissolved Oxygen D.O.	3.5 mg/l
5	Total Alkalinity	**420 mg/l**
6	Biochemical Oxygen Demand BOD	**12 mg/l**
7	Chemical Oxygen Demand COD	**45 mg/l**
8	Total Dissolved Solids	**3000 mg/l**
9	Total Hardness	**520 mg/l**
10	Calcium Ions Ca^{++}	140 mg/l
11	Magnesium Ions Mg^{++}	41.3 mg/l
12	Chloride Cl^-	**1039.8 mg/l**
13	Sulphate SO_4^{2-}	**592 mg/l**
14	Fluoride F^-	1.13 mg/l
15	Nitrate NO_3^{2-}	2.1 mg/l
16	Iron Fe	0.4 mg/l

Most of the values for various water quality parameters found are below desirable limit to render water as acceptable. But at few places, the values are more than the desirable limit. However at few places, the values are found below maximum permissible limit to render water acceptable after slight modification or treatment. There is no major variation in the values of pH, Temperature, Turbidity, DO, BOD, Total Alkalinity, Magnesium, Iron for the whole area. But as far as values of other parameters are concerned like Total hardness, Total Dissolved Solids, Fluoride, Calcium, Chloride, Sulphate, COD, Nitrate there is considerable variation in the values obtained for the whole area. pH, Temperature, Turbidity of all the samples were within desirable limits. As far as Values of BOD are concerned, sample's 1, 2, 3 are within maximum permissible limits. The value of DO for the area is also less. In the present study area, Phenolphthalein Alkalinity was absent from all the samples which indicates absence of Hydroxyl and carbonate ions and presence of bicarbonate ions. Value of Chloride is high, more than desirable limit and for the sample 4 it is more than maximum permissible limit. Value of Sulphate is very high almost unacceptable for all the samples collected from the area, barring sample 3 where it is just below the maximum permissible limit. Water is very hard and needs to be treated. Value of TDS is also very high and is unacceptable for all the samples and needs to be properly treated. Value of Fluoride, Iron is within desirable limit for most of the samples. Arsenic is absent from water, which indicates in general the absence of most of the heavy metals and highly poisonous ions from water. In general, water in the area is acceptable to a certain limit only and needs to be further treated before being supplied to houses especially for drinking purposes. The treatment of water should involve such a scheme that would effectively, efficiently remove / reduce TDS, hardness, alkalinity, sulphate, and chlorides to render water suitable for public use. The treatment scheme will be discussed in detail in the next chapter. The high values obtained for TDS, Alkalinity, Hardness, Chloride and Sulphate can be attributed to the location of Municipal Solid Waste Landfill (Sharda Landfill) in the vicinity of the site.

5. Population Forecast:

Known: Number of EWS houses: 337

Assumption: People expected to be living in each house (average): 3

Total Expected Population of the EWS houses area (2012): 337 X 3 = 1011

Estimation of future population in the area by geometrical increase method:

From the census records, % increase in population is as: 20.5, 21.2, 20, 31 and 20.1

Geometric mean $r_g = (0.205 \times 0.212 \times 0.20 \times 0.31 \times 0.201)$ ^ (1/5) = 0.2222

Population of the area in 2020 = Population in 2012 X $(1 + r_g)^{0.8}$

$= 1011 \text{ X } (1 + 0.2222)^{0.8} = 1187$

Population of the area in 2042 = Population in 2012 X $(1 + r_g)^{3}$

$= 1011 \text{ X } (1 + 0.2222)^{3} = 1845$

6. Water Demand:

Expected Population for 2012: 1011

Expected Population for 2042: 1845

Average rate of water supply as per Indian standards = 135 lpcd

(Including domestic, commercial, public, and wastes)

Water required for whole area for population expected as of 2012 = 1011 x 135 = 136485 l/day = 0.14 MLD

Water required for whole area for population expected as of 2042 = 1845 x 135 = 249075 l/day = 0.25 MLD

Assume, Peak Factor = 1.2

Peak daily demand for 2012 population = 0.14 x 1.2 = 0.17 MLD

Peak daily demand for 2042 population = 0.25 x 1.2 = 0.3 MLD

The whole system is to be designed for the future population of 2042 that is design period of 30 years assumed at the beginning only.

6.1 Design Capacity for Various Components

(i) Intake structure daily demand = 0.3 MLD

(ii) Pipe main = 0.3 MLD

(iii) For units at the treatment plant = 0.3 MLD

(iv) Lift Pump = 1.5 x 0.3 = 0.45 MLD

7. Intake Structures:

1. **Intake Well**

   1 a. Design Flow Rate – 0.3 MLD

   1 b. Design

   i) Number – 1

   ii) Velocity of flow – 0.75 m/second

   iii) Detention time – 10 minute

   iv) Depth – 4 m

   v) Diameter – 0.82 m

2. **Pen Stock**

   i) Number of pen stock for each intake well - 2

   ii) Velocity through pen stock - 0.6 m/sec

   iii) Depth – 3 m

   iv) Diameter – 0.06 m

3. **Bell Mouth Strainer**

   i) Velocity of flow - 0.25 m/sec

   ii) Diameter – 0.13 m

4. Gravity Main

i) Velocity – 0.7 m/sec

ii) Diameter – 0.08 m

5. Jack Well

i) Detention Time – 5 min

ii) Diameter – 0.67 m

iii) Suction Depth – 7 m

iv) Overall Depth – 9 m

6. Rising Main

(i) Velocity – 1 m/sec

(ii) 0.07 m

7. Pump

i) Design Flow Rate – 0.45 MLD

ii) Pump Efficiency – 75 %

iii) Number – 2 in parallel of which 1 is as standby

iv) Power – 1 HP (0.75 kW)

8. Water Treatment Technologies:

As per the results obtained from water quality analysis, it can be seen that the water in the area is having high amount of TDS, Hardness, Alkalinity, Chloride, Sulphate which renders the water unsuitable for drinking and various other purposes. So it needs to be treated.

TDS, Hardness, Chloride, Sulphate can be removed by Reverse Osmosis. Hardness and Alkalinity can also be reduced by Chemical Precipitation: Water softening (Lime Soda Softening). Both the above mentioned process is dealt in detail below.

8.1 Chemical Precipitation: Lime- Soda Ash Water Softening

8.1.1 Calculation of Lime – Soda Ash Dosage

For calculation of quantity of lime and soda required for treating the water in the area, values of water quality test result of sample 4 is taken as they are the maximum for the whole area. The idea behind this is to treat the maximum value and subsequently the lesser values will be treated automatically.

Sample 4

The water parameters used to calculate the dosages are:

Water flow rate = 0.30 MLD = 300 m^3/day

pH = 7.2

Total Alkalinity = 420 mg/l

Total Hardness = 520 mg/l

Calcium, Ca^{2+} = 140 mg/l

Magnesium, Mg^{2+} = 41.3 mg/l

Chloride, Cl^{-} = 1039.7 mg/l

Sulphate, SO_4^{2-} = 592 mg/l

As Total Alkalinity < Total hardness, Carbonate Hardness = Total Alkalinity = 420 mg/l

Non Carbonate Hardness = Total Hardness – Carbonate hardness = 520 – 420 = 100 mg/l

As pH = 7.2, So Total Alkalinity will be due to HCO_3^- only.

Hence, HCO_3^- = 420 mg/l = 420 / 61 = 6.88 meq/l

Ca^{2+} = 140 mg/l = 140 / 20 = 7 meq/l

Mg^{2+} = 41.3 mg/l = 41.3 / 12 = 3.45 meq/l

SO_4^{2-} = 592 mg/l = 592 / 48 = 12.33 meq/l

Cl^- = 1039.7 mg/l = 1039.7 / 35.5 = 29.29 meq/l

Hardness causing species:

$Ca(HCO_3)_2$ = 6.88 meq/l, $CaSO_4$ = 0.12 meq/l, $MgSO_4$ = 3.45 meq/l

Chemical Reactions Involved:

i) $Ca(HCO_3)_2 + Ca(OH)_2 = 2\ CaCO_3 (\downarrow) + 2\ H_2O$.

ii) $CaSO_4 + Na_2CO_3 = CaCO_3 (\downarrow) + Na_2SO_4$

iii) a. $MgSO_4 + Ca(OH)_2 = Mg(OH)_2 (\downarrow) + CaSO_4$

b. $CaSO_4 + Na_2CO_3 = CaCO_3 (\downarrow) + Na_2SO_4$

Lime Required:

Lime required in form of Quick lime CaO (M.W. = 56, Equivalent Weight = 56 / 2 = 28)

Lime required = 6.88 + 3.45 + 1.25 (excess lime to raise pH) = 11.58 meq/l

= 11.58 (meq/l) X 28 X 300 (m^3/day)

= 97272 g/day = 97.27 kg/day

Purity of lime provided in the market = 90 %

Total lime required = 97.27/0.9 = 108.10 (kg/day) X 365 (day/year) = 39456 kg/year = 39.46 metric tons/year.

Cost of lime @ present market rate of 90 $ per metric ton

= 39.46 X 90 X 54 = Rs. 1, 91,776 /- per year (INR)

Soda Ash Required:

Soda ash required in form of Na_2CO_3 (M.W. = 106, Equivalent Weight = 106 / 2 = 53)

Soda ash required = 3.45 + 0.12 = 3.57 meq/l

= 3.57 (meq/l) X 53 X 300 (m^3/day) = 56763 g/day = 56.76 kg/day

Purity of Soda ash in the market = 90%

Total Soda ash required = 56.76/0.9 = 63.07 (kg/day) X 365 (day/year) = 23020 kg/year = 23.02 metric tons/year

Cost of Soda ash @ present market rate of 225 $ per metric ton

= 23.02 X 225 X 54 = Rs. 2, 79,693 /- per year (INR)

This method reduces the calcium hardness to 40 mg/l as $CaCO_3$ and magnesium hardness to 10 mg/l as $CaCO_3$. Hence finished water will have 50 mg/l of carbonate hardness only.

Recarbonation required: addition of CO_2 to maintain pH. Recarbonation is done in single stage only in settling tank. Amount of CO_2 required = 1.25 meq/l (to remove excess lime).

8.1.2 Design of Various Treatment Units

8.1.2.1 Chemical Storage Room: Provide a room of dimension = 10 m X 8.5 m

8.1.2.2 Rapid Mixing Tank:

i) Detention Time – 50 seconds
ii) Velocity Gradient – 600 /seconds
iii) Diameter – 0.57 m
iv) Depth – 1 m
v) Rotational Speed of Impeller – 120 rpm
vi) Diameter of Impeller – 0.24 m
vii) Velocity of tip of Impeller – 1.5 m/sec
viii) Power Required – 63.18 Watts
ix) Blades Number – 5
x) Blades Size – 0.1 m X 0.11 m

8.1.2.3 Sedimentation Tank:

i) Removal efficiency – 80 %
ii) Surface Overflow Rate – 33.5 m/day
iii) Detention Time – 2.5 Hours
iv) Diameter of Tank – 3.38 m
v) Depth of Tank – 3.48 m
vi) 90° V – Notch Number – 53
vii) Spacing Between two Notches – 20 cm
viii) Depth of Notch – 5 cm

ix) Effluent Box Size - 1 m X 1m

x) Diameter of Outlet Pipe – 1 m

xi) Effluent Launder Size – 0.4 m Width X 0.33 m Depth

8.1.2.4 Rapid Sand Gravity Filter:

i) Rate of Filtration – 4 m^3/m^2/hour
ii) Number of Filters – 2 , 1 as a standby
iii) Diameter of Filter – 1.83 m
iv) Depth of Filter – 1.5 m
v) Effective Size of Sand for Filter – 0.5 mm

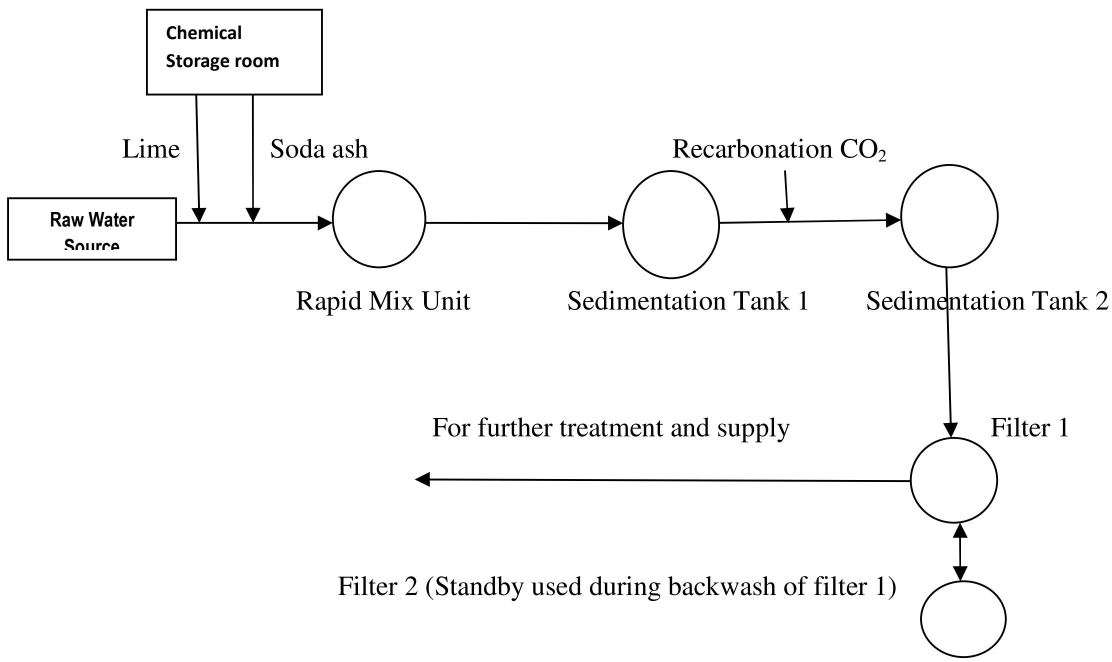

Figure 8.1 Flow sheet of Lime – Soda ash softening process used for water treatment

RO unit can be installed in two ways, one in which small indoor unit is installed in each individual house of either same capacity or different capacity depending upon the use and affordability of individual household owner. There are various companies in India which are manufacturing these units like Kent, Excel water treatment systems, Bionics advance filtration systems ltd, watts premier etc. These units cost approximately Rs. 5,000/- inclusive of all taxes for smallest capacity 15 LPH, and so on for higher capacities. These costs have to be borne by individuals who want to install them in their house.

The other way is to install a large composite unit of sufficient capacity at the beginning of supply as a part of treatment scheme. This method is suitable or becomes necessary at places where the raw water is of poor quality. This method is also costly, it is more effective and beneficial as it removes most of contaminants from water and provides clean and clear water to everyone which can be used for all purposes. There are various companies in India who are manufacturing these units like Excel water treatment systems limited, aqua puro systems limited, H_2O systems limited etc. The housing scheme is under construction, and is being constructed for economically weaker sections of society it is better to provide a large composite unit at the beginning of supply line as a part of treatment scheme which already includes lime soda softening. There are two reasons behind it one is the water quality of the area is poor and secondly the individual who are going to reside in these houses will not be able to afford the cost of individual units. After taking into mind all considerations, in depth market survey was done for finding out the manufacturers of these large units. A few of them are listed below:

a) Excel Water Treatment systems limited
b) Aqua puro systems limited
c) H_2O water solutions limited

RO plants available in market are of various capacities like 100 LPH (Litres per hour), 200 LPH, 500 LPH, 1000 LPH, 2000 LPH, 5000 LPH, 10000 LPH and so on. As per water quality available in the area and water demand, 12000 LPH capacity is suitable for the site. All the specifications and design for this capacity RO unit are given below.

8.2.1 Design of RO plant of 12000 LPH:

RO Plant Capacity, q = 12000 LPH (288 m^3/day)

Inflow, Q
Outflow required for daily purpose, Q' = 300 m^3/day
TDS raw water = 3000 mg/l
Assumptions, Recovery factor = 90 % = 0.90

Salt Rejection rate, S = 95 % = 0.95

Design Pressure = 4140 kN/m^2

Water flux rate = 0.82 m^3/m^2 day

Packing density = 820 m^2/m^3

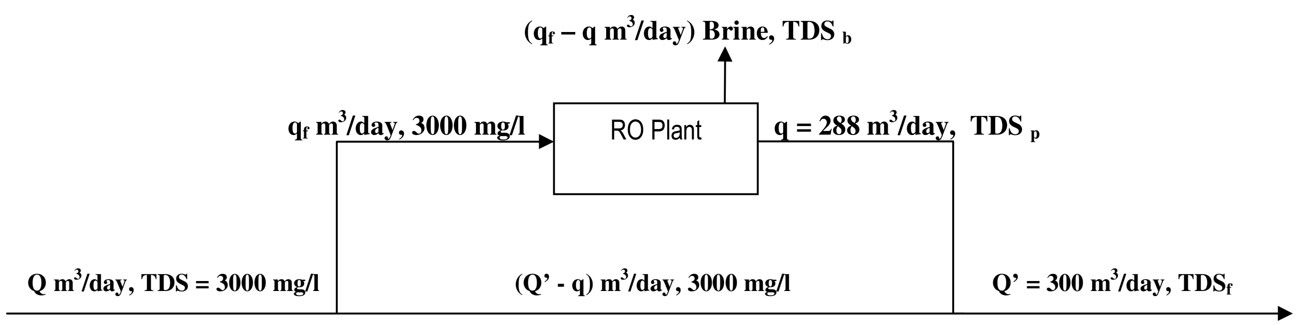

Figure 10.4 Schematic Mass balance of RO unit provided

TDS after RO unit, TDS_p = [3000 mg/l / 0.90] x (1 – 0.95) = 167 mg/l

(Q' – q) = 300 – 288 = 12 m^3/day

Apply mass balance for determining TDS in finished water TDS_f,

12 m^3/day X 3000 mg/l + 288 m^3/day X 167 mg/l = 300 m^3/day X TDS_f mg/l

TDS in Finished water TDS_f = 280.5 mg/l < 500 mg/l, O.K.

Feed water flow to RO system, q_f = 288 / 0.90 = 320 m^3/day.

Brine flow to be disposed off (q_f - q) = (320 – 288) = 32 m^3/day

Raw water flow, Q = 320 m^3/day + 12 m^3/day = 332 m^3/day = 13850 LPH

TDS in brine TDS_b = (0.95 x 3000) / (1 – 0.90) = 28500 mg/l

For a flux rate of 0.82 m^3/m^2 day, the area of RO membrane = 288 / 0.82 = 351.22 m^2

Assuming packing density to be 820 m^2/m^3,

Total module volume = 351.22 / 820 = 0.42 m^3

Assuming a module of volume 0.03 m^3

Total number of module = 0.42 / 0.03 = 14

Water power consumption = 4140 kN/m^2 x (332 / 60 x 60 x 24) = 16 kW

Brake power assuming 95 % pump efficiency = 16 / 0.95 = 16.8 kW

Motor power assuming 88 % motor efficiency = 16 / 0.88 = 18.2 kW

Treatment Scheme includes following units:

a) Raw Water Pump
b) Pressure Sand Filter
c) Activated Carbon Filter
d) Micron Cartridge Filter
e) Anti - Scalant dosing system
f) High Pressure Pump
g) RO module

8.2.2 Cost Analysis:

Basic Cost of 12000 LPH RO system: Rs. 30, 00,000 /-

VAT @ 12.5 % = Rs. 3, 75,000 /-

Transportation cost = Rs. 50,000 /- (from Delhi to Agra)

Installation Cost = Rs. 20,000 /-

Miscellaneous Cost = Rs. 10,000 /-

Total Cost = Rs. 34, 50,000 /-

If, a small RO unit of capacity 50 LPH is to be installed in each house

Overall Cost of 50 LPH RO unit: Rs. 12,000 /- per unit

Total units to be installed in area: 337 units (= 337 houses)

Total cost of all units = 337 x 12,000 = Rs. 40, 50,000 /-

After comparing the cost of both the type of RO unit, it can be concluded that single unit of 12000 LPH is more economical and beneficial too.

9. Water Distribution & Supply Scheme:

9.1 Water Storage Tank:

Distribution reservoirs also called service reservoirs are the storage reservoirs which store the treated water for supplying the same during emergencies and also help in absorbing the hourly fluctuations in water demand. Depending upon their elevation with respect to the ground they are classified as underground reservoir and elevated reservoir. Underground reservoir is used for storing the filtered water which is now fit for drinking. From this, the water is pumped to elevated service reservoir. Normally the capacity of this type of reservoir depends upon the capacity of the pumps and hours of pumping during a day. If the pumps work for 24 minutes then the capacity of this reservoir may be between 30 minutes to 1 hour. But underground storage reservoir is prone to contamination sometimes. Hence mostly at all places elevated service reservoirs are constructed. The elevation of the service reservoir should be such as to maintain the minimum residual pressure in the distribution system consistent with its cost effectiveness. The staging height of service reservoirs is normally kept as 15 – 20 m. Here in our case also elevated reservoir is provided and hence designed.

9.1.1 Design

Assumed Capacity of elevated service reservoir = $(^2/_3)$ x daily peak supply

Assumed Detention time = 15 hours.

Capacity of elevated service reservoir = $(^2/_3)$ x (0.3 MLD x 1000 / 24) x 15 = 125 m^3

Assume free board = 0.3 m

Provided depth = 5 m

Overall depth = 5.3 m

Area of tank = 125 / 5 = 25 m^2

Diameter of tank = $\sqrt{25 \text{ x } (4 /\pi})$ = 5.7 m

Hence we provide 1 Elevated service reservoir of capacity 125 m^3, having a detention time of 15 hours, overall height 5.3 m and diameter 5.7 m.

9.2 Pumping System

9.2.1 Rising Main:

(i) Velocity – 1 m/sec

(ii) 0.07 m

9.2.2 Pump:

(i) Design Flow Rate – 0.45 MLD

(ii) Pump Efficiency – 75 %

(iii) Number – 2 in parallel of which 1 is as standby

(iv) Power – 1 HP (0.75 kW)

9.3 Design of Supply Pipes

Till date no direct method are available for the design of distribution pipes. While doing the design first of all diameters of the pipes are assumed, the terminal pressure heads which could be made available at the end of each pipe section after allowing for the loss of pressure head in the pipe section when full peak flow discharge is flowing are then determined. The determination of the friction losses in each pipe section is done. The total discharge flowing through main pipes is to be determined in advance. Hazen William formula is widely used for determine the velocity through pipes. It states:

$$V = 0.355\ C\ R^{0.63}\ S^{0.54}$$

Head loss due to friction is determined by Hazen Williams formula:

$$H_f = 6.81\ (V/C)^{1.85}\ (L/D^{1.167})$$

Flow through pipes can be calculated by Hazen Williams formula:

$$Q = 0.278\ C\ R^{2.63}\ S^{0.54}$$

Where, H_f = head loss due to friction in pipes, m

V = velocity in pipes, m/sec

Q = flow rate, m^3/sec

C = coefficient of roughness

D = diameter of pipe, m, R – Mean Hydraulic Radius

L = length of pipe, m

S = slope of energy grade line (h_f/L).

Value of C, for cast iron pipe new – 140, 5 years old – 130, 10 years old – 120, Cement concrete lined – 120, Welded steel – 120, Plastic – 140

In the distribution system for any closed network of the pipes the following conditions must be fulfilled:

(a) The quantity of water entering a junction must be equal to the quantity of water leaving the same junction. In other words entering flow must be equal to the leaving flow i.e. law of continuity is satisfied.

(b) The algebraic sum of the pressure drops around closed loop must be zero i.e. there shall be continuity in the pressure.

Following are the various methods for the analysis of flow in pipe network

(1) Circle Method

(2) Equivalent Pipe Method

(3) Electrical Analogy Method

(4) Hardy Cross Method

Hardy cross method is most widely used here.

In this method the corrections are applied to the assumed flow in each successive trail. The head loss in each pipe is determined by pipe flow formula. The successive corrections are made in the flow in each pipe. The heads are balanced and principle of continuity is satisfied at each junction.

As per the site plan provided by the Agra development authority, the houses are scattered in three regions. First region has 255 houses, some single storey, some double storey. Second region has 65 houses, mostly single storey. Third region has remaining 17 houses, all single storey. Hence the supply scheme is also designed accordingly. The total flow rate is also divided into three portions depending upon the ratio of number of houses (water demand is calculated in these portions depending upon population forecasted similarly as in chapter 2) in each regions. This also helps in efficient and effective design of pipes using hardy cross method as loops gets minimized and simplified.

9.3.1 Assumed Flow Rate: **a)** Region 1 – 227 m^3/day

b) Region 2 – 58 m^3/day

c) Region 3 – 15 m^3/day

Manual design of Supply Pipe by Hardy Cross Method:

a. Material – Cast Iron

b. Main Pipe – Line

i) First Region - Dia. – 150 mm, Length – 200 m, Velocity – 0.15 m/sec

ii) Second Region – Dia. – 150 mm, Length – 500 m, Velocity – 0.04 m/sec

iii) Third Region – Dia. – 100 mm, Length – 1000 m, Velocity – 0.022 m/sec

c. Sub – Main Pipe – Line

i) Diameter – 100 mm

ii) Region 1 – Pipe Length – 7000 m, Average Velocity – 0.08 m/sec

iii) Region 2 – Pipe Length – 1450 m, Average Velocity – 0.04 m/sec

10. Conclusion

Water supply scheme for EWS houses in Agra has been designed for a period of 30 years. As the housing scheme is under construction, the exact population residing in the area and other data is not known, only data available is that 337 houses are being constructed and their plot size. So population has been estimated at the rate of 3 persons per house, if the housing scheme is completed this year itself estimated population in the area will be around 1011 persons. For a design period of 30 years population has been estimated up to the year 2042 by geometric mean method taking into account population of Agra for the past 5 decades and it comes out to be 1845. Water demand in the area is calculated as per standard of 135 lpcd which comes out to be 0.25 MLD and 0.3 MLD after taking into account a peak factor for the design period. Water available in the area is mostly ground water. Presently, most common mode of water supply in the area is through bore – well. Water samples were collected from four different locations around the whole area for laboratory analysis. After conducting laboratory analysis for various parameters, it was found that water in the area is unsuitable for drinking purpose and also for various other uses. The results of the analysis were found unsatisfactory as discussed above. The high range of sulphate, chloride, TDS, alkalinity, hardness can be attributed to the presence of Sharda Landfill in the vicinity of site. For piped water supply scheme, this water needs to be treated first before being supplied to houses. Method of treatment adopted includes softening of water by lime soda softening process and removal of TDS, sulphate, chloride by reverse osmosis process.

Lime soda softening treatment units includes a chemical storage room of size 10 m by 8.5 m for storing lime and soda ash, a rapid mixing tank of diameter 0.57 m and depth 1 m for mixing the chemicals with the help of blades mechanically, circular sedimentation tank of diameter 3.38 m and depth 3.48 m for settling of flocs formed and a rapid sand gravity filter of diameter 1.83 m, depth 1.5 m constructed from sand of effective size 0.5 mm for filtering the water. The total amount of lime and soda ash required for complete treatment of water is 39,456 kg/year lime and 23,020 kg/year soda ash which will cost approximately around Rs. 1, 91,776/- lime/year and Rs. 2, 79,693 soda ash/year. The sludge generated from sedimentation tank and rapid sand filter is collected in drain pipes and collectively removed by treatment through sludge drying bed. Treated water is further pumped up to the Reverse Osmosis plant for further treatment. Reverse Osmosis plant has a designed capacity of 12000 LPH (240 m^3/day) and contains 14 modules each of individual volume 0.03 m^3. Final treated water has minimum hardness of 40 mg/l, TDS of 285 mg/l.

Treated water is pumped up to an elevated service reservoir (storage tank) for further storage before final supply. Storage tank of capacity 125 m^3, height 5.3 m, diameter 5.7 m is used for this purpose. A pump of 1 HP is used for pumping treated water to elevated storage reservoir. Required amount of water is supplied from storage tank with the help of control valves to the supply pipes. As the houses are scattered in three different regions, so the supply scheme is also designed accordingly. First region has 255 houses which are supplied with a total 227 m^3/day of treated water from storage reservoir through a PVC pipe of diameter 150 mm. This flow is further supplied accordingly to the houses in this region through the PVC sub main pipes of diameter 100 mm. Second region has 65 houses which are supplied with 58 m^3/day of treated water from storage reservoir through a PVC pipe of 150 mm. This flow is further supplied accordingly to the houses in this region through the PVC sub main pipes of diameter 100 mm. Third region has 17 houses which are supplied with 15 m^3/day of treated water from storage reservoir through a PVC pipe of diameter 100 mm. Here there is no requirement of sub – main pipe.

As these houses are being constructed for economically weaker sections of society, the water can directly be supplied through with the help of bore – well pumps as is done by many people in their houses in general and also those who are living in the vicinity there. This mode will be less costly as compared to the one which has been discussed here. The initial plan was same as just mentioned above, but after the results of analysis of water it became necessary to treat the water before supply and hence a full water supply scheme was designed for benefit of the people who are going to reside there. People will get safe, clean & clear water. Coming to the added cost factor for constructing these houses due to the water treatment & supply scheme, of course people who are going to reside in these houses cannot afford the cost of it and they don't need to do it too as they are being provided these houses as a part of government residential scheme for weaker sections of society and thus the whole cost should be borne by the government.

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