DESIGN OF DRINKING WATER TREATMENT PLANT FOR RURAL COMMUNITIES

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Abstract:

In most parts of India, water is directly supplied to the public without proper treatment. Poor drinking water quality has become a common issue in rural and semi-urban areas in the country, which need to addressed in a sustained way. Thenur, one of the drought prone village in perambalur district, suffers severely from poor quality of drinking water and other health related issues. There are currently 22 active water sources(open wells and bore wells) in the village out of which only two sources has been accepted for drinking purpose and others are utilized for domestic (except drinking and cooking) and irrigating purposes since it does not meet the drinking water standards. The drinking water is supplied only for 2 or 3 days(approx.1hr/day) per week. If other water sources in the village is properly treated and supplied, the improved quality and quantity of drinking water can be provided. This project addresses the design and feasibility aspects of water treatment plant which particularly suits rural communities. The objective of this project is to provide a simplified model of the treatment unit ,which treats saline ground water. The treatment processes includes 1.flocculation,coagulation and sedimentation, 2.rapid sand filter, 3. Electro-dialysis, 4.solar evaporation(for recirculation).

Keywords: contaminants, sedimentation, electro-dialysis, visking tubing semi-permeable membrane, total dissolved solids(TDS).

1. INTRODUCTION:

Availability of fresh portable water is a fundamental need for all sectors of the society. In a country like India, brackishness of groundwater is considered to be a major thread to the living society. Approximately 97 million people rely on surface water and unprotected dug wells and springs (WHO/UNESCO, 2012). According to 2011 census, only 71% of urban households and 35% of rural households are supplied with piped water. Furthermore, very less percentage of which is supplied with treated water. Hence there is a high reliance on ground water resources to meet the population needs. According to central ground water board report (2010), 60% of ground water sources are contaminated with high salt content with TDS ranging 500ppm to 3000ppm. Approximately 73% of Indian villages use ground water as their primary source of drinking water[3]. Due to the prevalence of chemical contamination in Indian ground water sources, non-governmental organizations are looking forward to install a most efficient water treatment plants. Many have already installed RO plants, most of which have failed due to improper maintenanceIn this paper, a water quality analysis is made for Thenur village in Perambalur dist, Tamilnadu and the design aspects of primary treatment plant is also included. And the feasibility analysis of electro-dialysis plant( replacing ion exchange membranes by
visking tube semi-permeable membrane) for rural areas is also done.

2. STUDY AREA:

2.1. Population:

Thenur is a drought prone village located in Kunnam taluk of Perambalur district, Tamil Nadu with total 757 families residing. The Thenur village has population of 2747 of which 1371 are males while 1376 are females as per Population Census 2011.

2.2. Water supply scenario:

There are 20 active water source (bore wells and tube wells) in the village. Out of which only two sources has been accepted for drinking purpose and others are utilized for domestic (except drinking and cooking) and irrigating purposes. Current drinking water supply seems to be insufficient for the people. The drinking water supply for the village varies from 2 to 4 days (approx. 1hr per day) per week. If other water sources in the village is properly treated and supplied, the fate on poor quality drinking water can be relieved.

The main source of water supply is from open wells in thottapadi lake (2kms away from the village). The water from the wells is pumped to the overhead tank in the village centre and supplied to the community for 2 to 4 days per week.

2.3. Water quality analysis:

The ground water quality in the village is analyzed for the worst cases. Four non-portable water samples has been taken from different sources (bore wells and dug wells) and tested in the laboratory inorder to identify various contaminants which exceeds permissible limit. The following table shows the results of water samples and compares it with BIS and WHO standards.

2.3.1. Physical parameters:

<table>
<thead>
<tr>
<th>S.NO</th>
<th>PARAMETERS</th>
<th>WHO STANDARDS</th>
<th>BIS STANDARDS</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>APPEARANCE</td>
<td>Clear and colourless</td>
<td>Clear and colourless</td>
<td>Clear and colourless</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.</td>
<td>TASTE</td>
<td>Non objectional</td>
<td>Non objectional</td>
<td>Agreeable</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.</td>
<td>ODOUR</td>
<td>odourless</td>
<td>odourless</td>
<td>Odourless</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.</td>
<td>TURBIDITY (NTU)</td>
<td>5</td>
<td>10</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>5.</td>
<td>ELECTRICAL CONDUCTIVITY (MICROSIEMENS/ cm)</td>
<td>1000-2000</td>
<td>750-2250</td>
<td>1978</td>
<td>1810</td>
<td>1215</td>
<td>1599</td>
</tr>
<tr>
<td>6.</td>
<td>TDS, mg/L</td>
<td>500</td>
<td>500</td>
<td>3774</td>
<td>1147</td>
<td>1265</td>
<td>865</td>
</tr>
</tbody>
</table>
2.3.2. Chemical parameters:

<table>
<thead>
<tr>
<th>S. NO</th>
<th>PARAMETERS</th>
<th>WHO STANDARDS</th>
<th>BIS STANDARDS</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>pH</td>
<td>7-8.5</td>
<td>6.5-8.5</td>
<td>7.91</td>
<td>7.3</td>
<td>7.8</td>
<td>7.22</td>
</tr>
<tr>
<td>2.</td>
<td>Alkalinity (mg/L)</td>
<td>100</td>
<td>200</td>
<td>275</td>
<td>553</td>
<td>254</td>
<td>319</td>
</tr>
<tr>
<td>3.</td>
<td>Total Hardness (mg/L)</td>
<td>300</td>
<td>300</td>
<td>489</td>
<td>467</td>
<td>273</td>
<td>618</td>
</tr>
<tr>
<td>4.</td>
<td>Calcium (mg/L)</td>
<td>75</td>
<td>75</td>
<td>109</td>
<td>93</td>
<td>86</td>
<td>123</td>
</tr>
<tr>
<td>5.</td>
<td>Magnesium (mg/L)</td>
<td>50</td>
<td>50</td>
<td>63</td>
<td>66</td>
<td>81</td>
<td>61</td>
</tr>
<tr>
<td>6.</td>
<td>Sodium (mg/L)</td>
<td>200</td>
<td>200</td>
<td>647</td>
<td>98</td>
<td>206</td>
<td>193</td>
</tr>
<tr>
<td>7.</td>
<td>Potassium (mg/L)</td>
<td>12</td>
<td>12</td>
<td>140</td>
<td>59</td>
<td>43</td>
<td>22</td>
</tr>
<tr>
<td>8.</td>
<td>NITRATE (mg/L)</td>
<td>100</td>
<td>100</td>
<td>16</td>
<td>77</td>
<td>54</td>
<td>69</td>
</tr>
<tr>
<td>9.</td>
<td>CHLORIDE (mg/L)</td>
<td>200</td>
<td>250</td>
<td>672</td>
<td>428</td>
<td>125</td>
<td>233</td>
</tr>
<tr>
<td>10.</td>
<td>FLUORIDE (mg/L)</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>11.</td>
<td>SULPHATE (mg/L)</td>
<td>200</td>
<td>200</td>
<td>335</td>
<td>927</td>
<td>139</td>
<td>132</td>
</tr>
<tr>
<td>12.</td>
<td>PHOSPHATE (mg/L)</td>
<td>1</td>
<td>1</td>
<td>0.04</td>
<td>0.09</td>
<td>0.1</td>
<td>0.02</td>
</tr>
</tbody>
</table>
3. DESIGN ASPECTS:

In order to make the treatment plant efficient, it was planned to treat the water in three stages: Sedimentation with coagulation, followed by rapid sand filter and Electro-dialysis process.

3.1. DESIGN OF SEDIMENTATION TANK:

The population of Thenur village by 2030 is forecasted as 3500 people. The per capita water required for drinking and cooking is assumed to be 7 litres/day and 5 litres/day respectively. Hence, the total demand for the village per day is 46,000 litres (46 m$^3$).

3.1.1. QUANTITY OF ALUM REQUIRED PER DAY:

From jar test report, the required alum dosage for various samples varies from 17 mg/l to 25 mg/l. Hence, adopt a dosage of 25 mg/l of Alum. Therefore, total quantity of alum required per day is approximately 0.8 kgs for coagulation process.

3.1.2. DESIGN OF SETTLING TANK:

Average quantity of water to be treated per hour is 2.87 m$^3$ (i.e. Assuming maximum hourly demand to be 1.5 times the average demand of water). The detention period of settling tank is taken as 2 hours and the required capacity of settling tank is 6 m$^3$. Therefore, assuming effective depth of the tank to be 1.5 m, the breadth and length of the tank is calculated as 2 m and 3 m respectively.

3.1.3. DESIGN OF FLOC CHAMBER:

Assuming effective depth of floc chamber equal to half of the depth of sedimentation tank and detention period for floc chamber as 10 minutes, the total capacity is calculated as 0.5 m$^3$. Considering, width of floc chamber is equal to width of sedimentation tank, the length of floc chamber works out to be 0.78 m.

3.2. Design of rapid sand filter:

3.2.1. Design of filter units:

Assuming that 3% of filtered water is required for washing of filter every day, the total filtered water required per day is found out to be 47380 litre. Further it is assumed that 30 mins are lost every day in washing the filter and hence, quantity of filtered water required per hour is 2016.17 litres. Assuming the rate of filtration as 3000 lit/hr/m$^2$, the area of filter required is 0.7 m$^2$.

Let the length of filter be 1.3 times it’s width. Therefore, length and breadth of filter is calculated as 0.75 m and 1 m respectively.

3.2.2. ESTIMATION OF SAND BED:

The thickness of the sand bed can be checked against break through of floc through sand bed by calculating the minimum thickness required by Hudson formula (Qd$^3$/l = Bi x 29323). Minimum thickness of sand bed required to avoid break through of floc through sand bed is 14 cm. Hence assume thickness of sand bed of 60 cm is adequate to avoid break through of flocs.

3.2.3. ESTIMATION OF GRAVEL SIZE GRADATION:

Assuming size gradation of gravel from 2 mm at top to 50 mm at bottom, the required depth for 2 mm, 5 mm, 10 mm, 20 mm and 50 mm gravel is found out to be 9.17 cm, 12.1 cm, 9.2 cm and 12.1 cm respectively. The total gravel bed of thickness is 52 cm.

3.3. Electro-dialysis system:

3.3.1. Comparison with RO:

Table 2. maintenance and functionality comparison for RO and ED [3].

3.3.2. stack components:

An ED stack consists of two electrodes, a cathode and an anode, along with a series of anion (AEM) and cation exchange membranes (CEM) separated by spacers that provide two isolated flow paths. Each set of anion and cation exchange membranes constitutes a cell pair. All of these components are packaged in a housing that has inlets and outlets for the feed water, desalinated (dilute) water, reject (concentrate) water, and rinse solution for the electrodes. Current ED stacks contain titanium electrodes that are coated with platinum. The use of these electrodes in a small-scale in-home system requires additional consideration. When a voltage potential is applied across the electrodes, water molecules dissociate at the cathode to produce hydroxide (OH-) ion and hydrogen gas (H2). At the anode, hydrogen ions (H+), oxygen (O2), and chlorine gas (Cl2) are produced.

3.3.3. Model:

A simplified model has been made as shown in the fig (a). the electrodes(copper electrodes) are placed at a spacing of 7cm. In order to reduce the capital cost on ion exchange membranes, it is replaced by visking tubing semi-permeable membrane(cos ts around 900 Rs./metre). The diameter of the visking tube used is 14mm.

4. RESULTS AND DISCUSSIONS:

Four samples having TDS ranging 900ppm to 1650 ppm, is fed into our ED model. The TDS at outlet varies from 400 to 500ppm which is safe to drink. The results are as shown in the table.During the process, the salts from concentrated water passes through the membrane and gets dissolved in the low concentrated water. This water in the chamber can be treated by solar evaporation technique and again recirculated to the stack. In case of small scale dissolved solids removal process, this ED with semi-permeable tubing system can be effectively implemente

5. CONCLUSION:

The performance of ED with semi-permeable visking tubing system was evaluated for water desalination of lower dissolved solid content. It was observed that ED unit is efficient for desalination of ground water (TDS: 900ppm to 1700 ppm) with desired TDS (less than 500ppm) and high water recovery. To avoid damage of tubing membrane, the water was pretreated by sedimentation process followed by rapid sand filter. The reported ED system provided with proper pretreatment is thus demonstrated to be promising way of ground water treatment in rural areas.
References:


