MUNICIPAL WASTEWATER REUSE IN ARID REGIONS - SCOPE FOR IRRIGATION IN MADURAI CITY

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ABSTRACT

As water can neither be created nor destroyed, more than 80% of quantity of water used for domestic purposes appear as wastewater. Increasing water demand due to growing population coupled with human related activities against the constant water resources solicits attention of the water managers to think of wastewater as a source of water across the world. Wastewater deserves recognition as a source of irrigation water in different countries around the world. India becomes water stress with the per capita available water dropping down below 2000 cubic metre per head per year. Uneven distribution of water resources from north to south makes water crisis severe in the states like Tamil Nadu. Available water is shared by different sectors and stiff competition between sector viz: drinking and irrigation prevails. In India, the total wastewater generation from the urban towns has been assessed as 38474 MLD. It indicates its potential for reuse in water management. Wastewater reuse has been in practice at selected locations around the world including India. Guidelines, clearly explaining the health associated factors, have been developed and prescribed by the EPA, US and WHO. Sewage treatment plants are installed to treat the sewage by the government and effluent may be used for indirect and direct reuse purposes. The forecast of the wastewater generation from Madurai City Corporation indicates the quantity of 162.8 MLD at 2014 and is likely to be 338.7 MLD in the year 2044. The irrigation potential of wastewater reuse is assessed as 3000 ha with crops like groundnut, maize, millet etc during 2014 and about 6000 ha during 2044. Scope for utilizing the existing minor irrigation tanks/ponds may be used for storage. Such tanks may also be useful in polishing the water quality as a result of natural purification. Scope for groundwater recharge through soil-aquifer treatment is also more.

Keywords: Wastewater Generation, Reuse, Irrigation, SBR Technology.
1.0 INTRODUCTION AND BACKGROUND

Environment of the earth is unique in nature. Presence of water (hydrosphere) on the crust of earth planet keeps the earth as the only live planet in the solar system. Scriptures reveal that all the living organisms have originated from the water. The total quantity of water available has been estimated at 1.40 billion cubic kilometre. As per the law of conservation of mass "mass can neither be created and destroyed", the earth's total water remains constant for millions of years and is going to be unchanged in the years to come. Appearance of water in the hydrological cycle is in different forms. Evaporation and condensation process render the water to appear as rainwater, surface water and groundwater. Out of available water, major portion, 97%, is seen as salty water in the ocean. The balance 3% is not directly useable. Only about 0.6% of the total water is found as fresh water for the entire demand. Uneven distribution of water within the countries and the regions within a country is another detrimental factor. Water is essentially required for the sectors: Irrigation, Drinking, Industry, Energy and other purposes. Rain water, surface water (river, lake, pond and dam), groundwater and sea water are generally considered as the sources of water for the various demands. Though the water available stands at fixed level, the demand is steadily increasing in lieu of increasing population coupled with industrialization and growing agricultural food production.

Entire development of a country rests with its water resources. Countries located in the arid and semi arid regions mostly experience water shortages. Water becomes scarce commodity and even play a role of deciding the ruling power. Conflicts between countries, states and even at village level are seen worldwide due to shortages of water. Competition between the sectors is also pronounced. Forecast indicates the next world war at the cost of water. As the quantity of water supplied for drinking need becomes wastewater (used water) after use. It is now considered as a source across the globe for the water management as shown in figure 1. As both industry and populations continue to increase and freshwater availability decreases, wastewater becomes an important regional planning variable.

Figure 1: Water resource, use and treatment cycle
With this in mind, an attempt has been made to analyse the wastewater generation potential from Madurai City corporation, Tamil Nadu, India and its scope of reuse for the water management especially for irrigation.

2.0 WATER DEMAND IN INDIA AND TAMIL NADU

India with varied climatic conditions and uneven distribution of water sources enters into the list of water stress countries in the world. In India, the total quantity of water available is assessed as 4200 Billion cubic metre. The water demand for irrigation, drinking, industry, energy and other purposes for the year 2010, 2025 and 2050 assessed by the Ministry of Water Resources (MoWR) and by National Council for Integrated Water Resources and Development (NCIWRD) is shown in figure 2 and figure 3 respectively. It is observed from the figures that the demand for all the sectors is showing increasing trend. The water supply demand for the 498 class I cities is put at 44769 Million Litre per Day (MLD) while the 410 class II towns demand 3324 MLD of water. So, the total drinking water demand for the urban area is 48093 MLD. It indicates the wastewater generation potential and suggests the scope for reuse after required treatment for varied applications. Now-a-days, various technologies have been developed for the treatment and reclamation of wastewater across the world. The matter of concern is only the cost.

![Figure 2: India's water requirement for various sectors](image)

Source: Ministry of Water Resources, Government of India
Figure 3: India's water requirement for various sectors


Tamil Nadu is the water starving state next to Rajasthan in India. With the 80% of the geographic area of hard rock, groundwater potential is declining day by day warranting an alternate choice of source for water. In respect of Tamil Nadu, the total population, as per census 2011, is 721.38 lakh (Rural- 371.89 lakh and Urban - 349.49 lakh). There are 42 class I cities with the same number of class II towns. The drinking water demand for the class I cities and class II towns is shown in figure 4. Tamil Nadu accommodates 94614 rural habitations. Out of which 84003 habitations have been supplied with 40 litres per head per day (LPCD) of water. The balance 10611 villages receive at about 20 LPCD. The water demand in the year 2020 has been assessed as 2170 Million Cubic Metre.
3.0 WASTEWATER REUSE

Wastewater reuse is classified into Indirect reuse and direct reuse. In indirect reuse, reclaimed water from the used water (wastewater) is discharged into the natural streams, rivers and recharge of groundwater through aquifer (figure 5). Groundwater augmentation by artificial recharge is also done. It is sometimes called as Soil aquifer treatment (SAT). Most of the natural purifications taking place in the river beds are of SAT form. It is reported that the micro-organisms have the tendency to stick to the solid surfaces when they come across during travel. Based on which the distance between the water source and any disposal point is mostly suggested to prevent pollution.
Direct reuse application includes the use of reclaimed water for agricultural, industrial and residential irrigation. Reclaimed water from the sewage is used for drinking (direct potable use) purposes (NEWater) in Singapore. Further, the reclaimed water can be used for many other purposes. Non-irrigation uses for reclaimed water are:

- **Urban reuse:**
  - Ornamental landscape water features and golf course water features such as ponds and fountains
  - Fire protection
  - Dust control and concrete mixing on construction sites
  - Vehicle and window washing
  - Toilet flushing in public, commercial, and industrial buildings

- **Industrial reuse:**
  - Cooling water
  - Boiler make-up water
  - Industrial process water

- **Intentional indirect potable reuse.**

Indirect potable reuse refers to the discharge of wastewater into a water body where it is then knowingly or unknowingly drawn for water supply in the river courses. For example, many water sources have been located for the cities lie along the river course of Cauvery in Tamil Nadu. The effluent from the sewage treatment plants after natural purification (passing through a stream, channel etc) reaches the river bed. This occurs unintentionally in most of the rivers, as the downstream water treatment plants use treated water discharged by upstream wastewater treatment plants.

Wastewater reuse is not of recent origin, but has been in practice across the world since 1912. Reuse of wastewater for water lawns and supplying to ornamental lakes in golden gate park, San Francisco, California, USA is an example of early twentieth century. NEWater project, reclamation of potable water from sewage project, in Singapore has been in operation since 2003. South Africa, USA, Israel, Australia, India, Singapore, Japan, etc are the countries started extensively practice the wastewater reuse.

In India, wastewater irrigation is increasingly used for crops such as vegetables, fruits, cereals, flowers and fodder. Kolkata (formerly known as Calcutta) has a long history of using wastewater stabilization tanks for aquaculture. An estimated 2.4 t/ha of fish is produced annually in Kolkata from about 3200 ha of ponds with inflow of about 3 m³/sec. Throughout India, many industries recycle wastewater to reduce the requirements for freshwater. Thanks to the enforcement of zero discharge concept. This trend is led by industries in Saurashtra, Gujarat and Chennai. Vadodara is the third largest city in Gujarat and growing rapidly. At present, water there is used by three major sectors. Industrial use began in the 1950s and 1960s with oil, chemical and pharmaceutical plants. It is concentrated in such peri-urban areas as Nandesari, Bajuva, Ranoli and Makarpura, where a separate effluent channel handles much of the industrial effluent. Domestic water supply serves a population estimated at about 1.5 million in 2001. A large agricultural area extends well beyond the peri-urban limits into the rural areas to the southwest of the city. Municipal sewage is used to grow vegetables, wheat, paddy rice, and flowers along an 80-km stretch of the rivers Jambuva, Vishwamitri and Dhadar. It is termed as the municipal sewage use area (MSU area). Effluent is also used for irrigation along a 56.3-km stretch of the Effluent Channel Project (termed as the ECP area). Area irrigated with treated wastewater in various cities in India is given table 1.
Table 1: Area irrigated with wastewater in various cities in India

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Name of the City</th>
<th>Direct use, ha</th>
<th>Indirect use, ha</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Ahmedabad</td>
<td>890</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Amirstar</td>
<td>1124</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Bhilai</td>
<td>607</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Bikner</td>
<td>40</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Calcutta (Kolkata)</td>
<td></td>
<td>12900</td>
</tr>
<tr>
<td>6</td>
<td>Delhi</td>
<td>1214</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Gwalior</td>
<td>202</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Hyderabad</td>
<td>110</td>
<td>40500</td>
</tr>
<tr>
<td>9</td>
<td>Jamshedpur</td>
<td>113</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Kanpur</td>
<td>1300</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Lucknow</td>
<td>150</td>
<td></td>
</tr>
</tbody>
</table>

In Noida, around 69 MLD of treated sewage water is generated each day at the two sewage treatment plants. It is reported fit for use in construction and irrigation activities. Sequential Batch Reactor (SBR) technology in two sewage treatment plants has been installed in the city. The levels of organic pollutants in treated water have gone down and the average level of BOD in water has become reduced to just about 10 mg per litre. It is planned to use the treated effluent for construction and irrigation purposes. The Authority currently uses treated wastewater to irrigate some green belts in the city. Excess water is released in Yamuna river. The move will reduce the burden on groundwater considerably. Further, it has been proposed to construct an additional STP of 87 MLD capacity with SBR technology. In Karnataka, Hubli-Dharwad, reuse project is an one of the examples of wastewater reuse projects. Chennai Metro Water Supply and Sewerage Board sells treated wastewater to the public sector undertakings for industrial purposes.

Zero discharge wastewater treatment with reuse system is in operation since July 2009 in a dwelling house at Dindigul, TN. The house accommodates two families having 3 people in each family. Daily 600 litres of water is being pumped from a borewell by means of 5.0 HP motor coupled with air compressor and stored in 2 numbers of 300 litres sintex tanks placed on roof. As mixing of black water and grey water makes the treatment a little complex, Grey water and black water are collected separately with separate plumbing arrangement. The photographic image of the planter bed shown below (Photo 1).
4.0 WASTEWATER GENERATION AND SEWAGE TREATMENT FACILITY AT MADURAI CITY

4.1 About Madurai
Madurai city corporation is one among the ten metropolitan cities in Tamil Nadu. Having located at almost in the southern part of the state, it is the city for education and business. City covers an area of 148.99 square kilo metre. Climate prevailing is arid to semi arid. Rainfall is occasional. Annual rainfall varies from 547.0 mm to 1264.0 mm against the normal rainfall of 891.50 mm. Groundwater table level fluctuation during 1991 to 2012 is found to vary between 4.0 metre and 11.10 metre below ground level. The 2011 census population is 15.64 lakh. The population from 1961 to 2011 is tabulated (Table 2) and the projected population for the future by different methods (arithmetic increase, incremental increase, geometric increase and line of best fit) is shown in figure 6. It is observed that the population has increased to almost three fold over a period of 5 decades. In addition to urbanization, more and more adjacent areas are merged with the city corporation limit.
Table 2: Population of madurai City Corporation

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Year</th>
<th>Population, lakh</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1961</td>
<td>4.24</td>
</tr>
<tr>
<td>2</td>
<td>1971</td>
<td>5.49</td>
</tr>
<tr>
<td>3</td>
<td>1981</td>
<td>8.20</td>
</tr>
<tr>
<td>4</td>
<td>1991</td>
<td>9.41</td>
</tr>
<tr>
<td>5</td>
<td>2001</td>
<td>10.67</td>
</tr>
<tr>
<td>6</td>
<td>2011</td>
<td>15.64</td>
</tr>
</tbody>
</table>

The forecast indicates that the population during the year 2044 is more than 30 lakh. It is almost double the 2011 census population. The present water supply level is more than 100 LPCD and it is planned to increase to 135 LPCD. Vaigai river is the major source for the city's drinking water demand. Surrounding area of the city is an agricultural area.
4.2 Wastewater generation

Wastewater quantity generation is generally assumed as 80% of quantity of water supplied for drinking purpose. Assuming the per capita rate as 100 litres per head per day, the quantity of wastewater generation is shown in figure 7.

Forecast indicates a wastewater quantity of around 160 MLD and 300 MLD at present and in 2014 and 2044 respectively. Almost a constant quantity of wastewater can be expected from the city as the drinking water supply has to be consistent.

4.3 Sewage Treatment (Wastewater) Plant

Madurai city has 2 numbers of sewage treatment plants located one at Avaniyapuran and another at Sakkimangalam. The former has 125 MLD capacity and the latter's capacity is 47.50 MLD totaling to 172.50 MLD. Among various sewage treatment technologies available (Oxidation ditch, Activated sludge process, extended aeration(ASP), Up flow anaerobic sludge blanket (UASB), fluidized aerobic bio reactor(FAB), moving bed bio reactor (MBBR), sequential batch reactor (SBR), membrane bio reactor (MBR), waste stabilisation ponds, etc, the sewage treatment plant of Madurai
employs SBR technology (otherwise called as C-Tech basins) with necessary primary treatment unit (screen, grit removal) and disinfection and sludge handling arrangement due to the following advantages.

- Less area to install the plant
- Good efficiency in treatment, like reducing BOD, COD, TSS, etc.
- Biological nutrient control for total nitrogen
- No need of secondary treatment.
- Reducing the treatment time.
- Total working in Automation so less manpower.
- Total process take in aerobic method no need of anaerobic no danger.
- Reduced energy consumption
- Biological phosphorus control.

Photo 2: Aerial view of Sewage treatment plant with irrigation tank at Madurai
Figure 8: Flow diagram sewage treatment process at Madurai
Table 3: Characteristics of raw Sewage and treated with EPA standard

<table>
<thead>
<tr>
<th>Sl.No</th>
<th>Parameter</th>
<th>Raw sewage (Range)</th>
<th>Treated effluent</th>
<th>EPA standard for reuse</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Biological oxygen demand (BOD), mg/L</td>
<td>200-300</td>
<td>Less than 10</td>
<td>30</td>
</tr>
<tr>
<td>2</td>
<td>Chemical oxygen demand (COD), Mg/L</td>
<td>400-500</td>
<td>Less than 100</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Total suspended solids, mg/L</td>
<td>200-400</td>
<td>Less than 10</td>
<td>30</td>
</tr>
<tr>
<td>4</td>
<td>Total Kjedahl Nitrogen, as N, mg/L</td>
<td>12-15</td>
<td>Less than 10</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Ammonia Nitrogen as N, mg/L</td>
<td>5-10</td>
<td>Less than 2</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Total phosphate as (PO₄), mg/L</td>
<td>3.5</td>
<td>Less than 2</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Faecal coliform, Numbers/100 mL</td>
<td>1 Million</td>
<td>Less than 200</td>
<td>200</td>
</tr>
<tr>
<td>8</td>
<td>pH</td>
<td>7.0-9.0</td>
<td>7.9</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Oil and Grease, mg/L</td>
<td>15-20</td>
<td>Less than 5</td>
<td></td>
</tr>
</tbody>
</table>

The city's sewage is collected through a net work of sewer lines to the main pumping station (MPS) and then pumped to the inlet chamber at STP. The flow diagram of the treatment system is depicted in figure 8. Effluent from the STP is collected through pipes to Chlorination tank. After chlorination, final effluent is conveyed through pipes to the different ponds. The sludge which is pumped to Centrifuge after adding poly electrolyte wherein sludge is thickened as cakes.

The characteristics of raw sewage and treated effluent with the Environmental Protection Agency (EPA) of USA Standard for reuse in agriculture with restricted access irrigation is tabulated (Table 8). It is observed that the strength of the sewage indicates that it is almost domestic sewage as the BOD is less than 300 mg/L. No industrial effluent mixing is observed. It may the fact that city limit does not accommodate any major industries. The treated effluent quality meets the standard set by EPA and Tamil Nadu Pollution Control Board (TNPCB) for restricted access irrigation. The highly improved characteristics of the treated effluent shows the efficiency of the sewage treatment technology, ie SBR technology.

Many numbers of small and minor irrigation tanks, ponds and other structures are available adjacent to the city and the sewage treatment plant. Natural channels prevail to facilitate the conveyance of effluent to the ponds. Tamil Nadu is known for the ponds (kulam, Kuttai and Oorani) and irrigation tanks. 3511 tanks are available in Madurai district against the 86746 numbers in Tamil Nadu. These tanks may be used for storing the effluent from the STP and used for irrigation. Storing the effluent open to atmosphere may improve the quality of water by way of aeration and natural settling. Every chance is there to increase the dissolved oxygen level.

4.4 sewage farm

Wastewater reuse is not new for the Madurai city corporation. It has two sewage farms. One is located at Avaniyapuram with an area extend of 385 acres, which is utilized for both solid waste dumping yard and sewage farm. Guinea grass is grown in 145 acres and the rest is used for solid waste management. Sakkimangalam sewage farm incorporates 180 acres of land. Photo 3 shows the guinea grass grown in the farm. Annual revenue earned from the sewage farm on selling fodder is about Rs.40.00 lakh.
After wetting the farm, reclaimed water flows into the nearby irrigation tank and stored. These tanks are dry in most of the months in a year. They receive flow only during north-east monsoon i.e during October and November.

4.5 Irrigation Potential

Mostly groundnut, maize, sorghum, sunflower, etc are cultivated in and around Madurai due to the climatic conditions and water resources availability. The area may be brought under wastewater irrigation has been workout considering the daily wastewater generation expected during 2014 and 2044 based on the average crop water need with crop period. The average area which may be irrigated works out to 3000 ha (Table 4). It doubles in the year 2044. The number of crops can be grown comes as 4 for beans, 3 for maize and one crop for cotton.

Table 4: Irrigation potential of wastewater generation from Madurai

<table>
<thead>
<tr>
<th>Crop</th>
<th>Crop water need, mm</th>
<th>Average Crop water need, m</th>
<th>Crop period, Days</th>
<th>Crop water per day, m</th>
<th>Area can be irrigated, ha</th>
<th>Number of Crops</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Beans</td>
<td>300-500</td>
<td>0.40</td>
<td>83</td>
<td>0.00482</td>
<td>3378</td>
<td>7028</td>
</tr>
<tr>
<td>Citrus</td>
<td>900-1200</td>
<td>1.05</td>
<td>240</td>
<td>0.00438</td>
<td>3721</td>
<td>7742</td>
</tr>
<tr>
<td>Cotton</td>
<td>700-1300</td>
<td>1.00</td>
<td>187</td>
<td>0.00535</td>
<td>3044</td>
<td>6334</td>
</tr>
<tr>
<td>Groundnut</td>
<td>600-700</td>
<td>0.65</td>
<td>120</td>
<td>0.00542</td>
<td>3006</td>
<td>6253</td>
</tr>
<tr>
<td>Maize</td>
<td>500-800</td>
<td>0.65</td>
<td>95</td>
<td>0.00684</td>
<td>2379</td>
<td>4950</td>
</tr>
<tr>
<td>Sorghum/Millet</td>
<td>450-650</td>
<td>0.55</td>
<td>125</td>
<td>0.00440</td>
<td>3700</td>
<td>7698</td>
</tr>
<tr>
<td>Soya beans</td>
<td>400-700</td>
<td>0.55</td>
<td>143</td>
<td>0.00385</td>
<td>4233</td>
<td>8806</td>
</tr>
<tr>
<td>Sunflower</td>
<td>600-1000</td>
<td>0.80</td>
<td>142</td>
<td>0.00563</td>
<td>2890</td>
<td>6012</td>
</tr>
</tbody>
</table>

Wastewater generation - 162.8 MLD during 2014
- 338.7 MLD during 2044
5.0 CONCLUSION

Water drawn from a water resource for domestic purpose appear as wastewater after use. The three stage treatment viz: primary, secondary and tertiary/advanced treatment render the treated effluent as a water resource. As the prime concern is given to supply drinking water at even critical circumstance, the wastewater generation enjoys its consistency/dependability than other natural water resources like river, etc. Wastewater deserves recognition as a source of irrigation water in different countries around the world. In India, the total wastewater generation from the urban towns has been assessed as 38474 MLD. It indicates its potential for reuse in water management. Wastewater reuse has been in practice at selected locations around the world including India. Guidelines, clearly explaining the health associated factors, have been developed and prescribed by the EPA, US and WHO. The forecast of the wastewater generation from Madurai City Corporation indicates the quantity of 162.8 MLD at 2014 and is likely to be 338.7 MLD in the year 2044. Madurai city has two wastewater treatment plants with the total capacity of 172.50 MLD. The irrigation potential of wastewater reuse is assessed as 3000 ha with crops like groundnut, maize, millet etc during 2014 and about 6000 ha during 2044. 3511 tanks are available in Madurai district against the 86746 numbers in Tamil Nadu. The existing minor irrigation tanks/ponds may be used for storage. Storage of effluent in such tanks may also help in improving the water quality as a result of natural purification. Scope for groundwater recharge through soil-aquifer treatment is also highly encouraging. Existing sewage farm earn an annual return of Rs.40.00 lakh from selling of fodder grown.

REFERENCES