Possibilities of Reuse of Domestic Wastewater in MES

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Most of water bodies of India including rivers, ground waters and lakes are heavily polluted. Cost of water treatment is increasing day by day. Reuse of wastewater, is not only an economic solution to mitigate the problem but, is also a social requirement. It not only reduces the requirement of fresh water but also brings down the cost of treatment. The treated domestic wastewater has many applications including watering golf fields, fire fighting, cooling towers, flushing and construction activities etc. MES has already started using recycled wastewater. In this paper qualitative and quantitative requirements of various reuses have been discussed. Cost effective suggestions have been given which can be adopted in MES. A paradigm shift in handling wastewater as a profitable asset rather than a liability has been suggested.

1. INTRODUCTION

1.1 India is a water stressed Nation. Access to safe drinking water is important as a health and development issue at a national, regional and local level. With the rapid pace of development and population growth availability of potable water has fallen in terms of quantity and quality. Fig 1 about availability of water, per capita per year, shows that today we are water stressed Nation. (Ref 1)

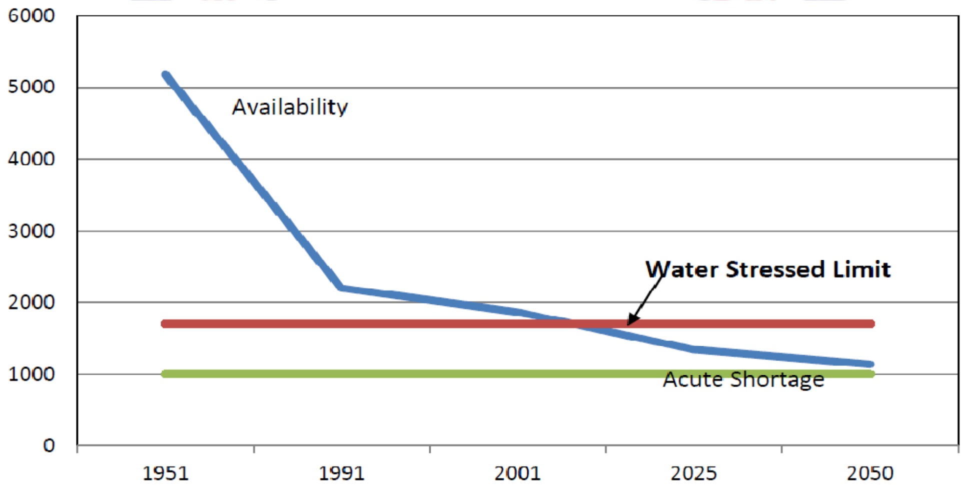


Fig. 1. AVAILABILITY OF WATER (PER CAPITA/YEAR)

1.2 With 80 countries and 40% of the world's population facing chronic water problems and with the demand for water doubling every two decades, conservation of fresh water and reuse of wastewater is the need of hour. The largest source of reuse resides in agriculture and the equally largest misplaced resource is sewage in the habitations.

1.3 In India treated sewage is being used for a variety of applications such as (a) Farm Forestry, (b) Horticulture, (c) Toilet flushing, (d) Industrial use as in non-human contact cooling towers, (e) Fish culture and (f) Indirect and incidental uses. In MES, recycling of treated sewage is in practice since last 8-10 years. It is mostly restricted to (a) Watering Golf fields, (b) horticulture and (c) for Eco-lakes. However, there is a need to increase the reuse not only quantitatively in these fields but also possibilities for new applications are to be explored.

1.4 Attempt has been made in this paper to understand possibilities of recycling of domestic wastewater in MES in totality so that demand for fresh water is minimized.

2. UNDERSTANDING REUSE OF WASTEWATER

2.1 **Types of Reuse of Wastewater**. Wastewater reuse can be categorized as Indirect Reuse and Direct Reuse. When the wastewater is mixed in a natural water body for reuse, it is termed as 'Indirect Reuse'. Similarly if no mixing with natural water body is done and treated wastewater is directly reused, it is termed as 'Direct Reuse'. Another classification is based on intended use, in this we have 'Non-Potable' uses and 'Potable' uses. Fig 2 below summarizes all types of reuses.

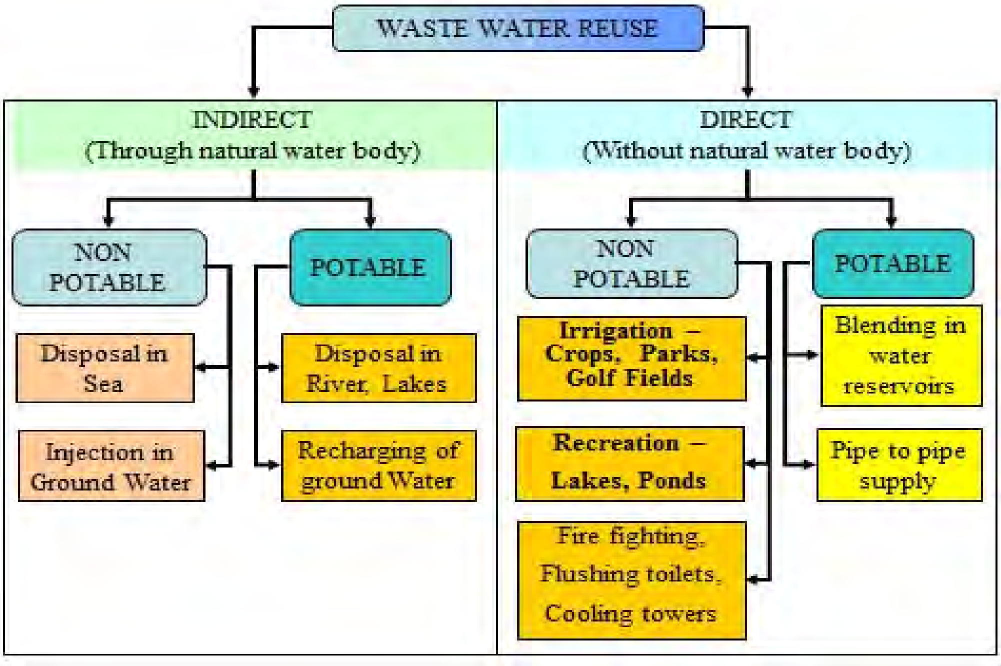


Fig. 2. Types of Reuses of Domestic Wastewater

2.2 Direct Non Potable Reuse. Wastewater can be reused directly in many ways viz; for irrigation in agriculture, parks and golf fields. It can be stored in lakes or ponds for recreation for growing aquatic life. Uses in urban areas can be construction activities, flushing toilets, cooling towers and fire fighting etc. It is this area of reuse which can result in immediate reduction of demand for fresh water in MES. In many stations of MES, reuse for watering golf fields has been there since last many years and few stations (Jodhpur, CME Pune etc) have created artificial lakes using treated sewage. At DRDO HQs treated wastewater is being used for cooling towers. There are no known examples of reuse for flushing and fire fighting in MES.

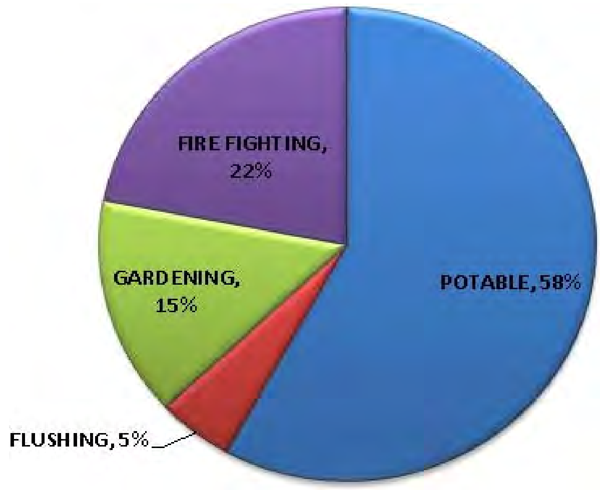


Fig. 3. Non-Potable Requirement of Water

2.3 Saving of fresh water by reuse in MES Demand of fresh water in any station is governed by Scales of Accommodation. It has given detailed water authorisation for various types of users and usages. On analysis of the various scales it is revealed that roughly 42% of total water requirement in non-hilly areas is for non-potable application as shown in Fig 2 below. It can be seen that 58% potable water demand will generate sufficient wastewater which if treated properly can meet non-potable demands of gardening, flushing and fire fighting. This can bring down requirement of fresh water to about 60% only.

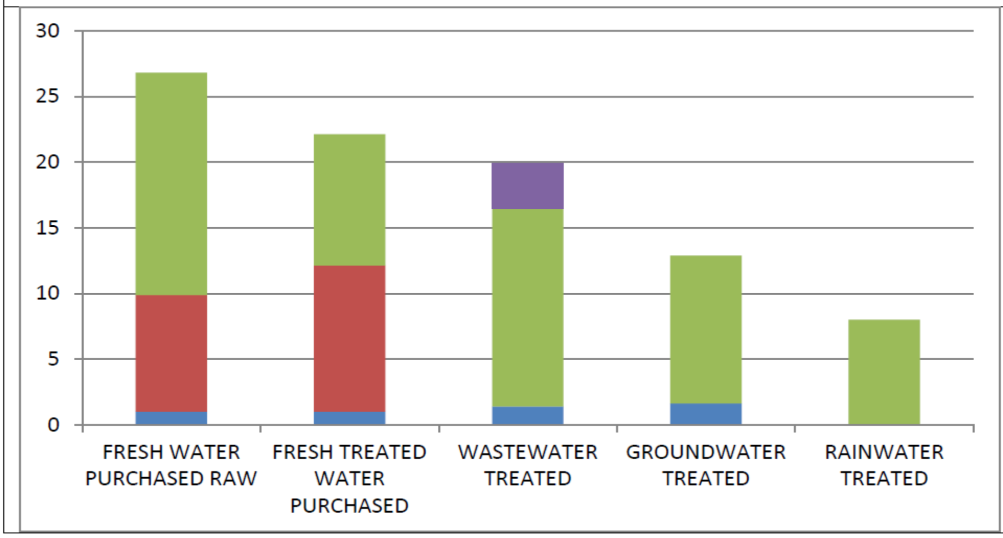
2.4 Economics of Reuse of Wastewater Cost comparison analysis was carried out at a seminar 3 held at Jodhpur Military Station during 2008 to ascertain financial benefits of reuse of wastewater. Following five types of waters available there, were used in analysis:
(i) Raw Fresh Water from Rajasthan Jal Board (RJB).
(ii) Treated Fresh Water from RJB.
(iii) Ground Water extracted through bore-wells.
(iv) Rainwater harvested from roof top harvesting.
(v) Treated Domestic Wastewater (sewage).

2.4.1 At Jodhpur, at that time, water was available raw as well as treated from State authorities on payment. It was available at a price of Rs 8.89/KL from RJB and further treatment including disinfection was done by MES at a cost of Rs 16.95/KL. At the same time for certain pockets treated water was purchased at a rate of Rs 11.13/KL and was supplied to users after disinfection in MES pump Houses at a cost of Rs 10/KL. There were also few bore-wells for remotely located small demands. Ground water was pumped bore-wells and disinfected before supply at a cost of Rs 11.24 /KL. Rates for treating sewage up-to tertiary treatment were calculated from prevailing ED rates which was Rs 15.1 /KL. to bring it to disposal standards and additional Rs 3.4 /KL for tertiary treatment to make it reusable. Cost of rainwater treatment, Rs 8/KL was adopted from proposed RWH works. Analysis of rates is summarized at table 1 below and the graph is reproduced at Fig 3.

TABLE 1: ANALYSIS OF RATES OF VARIOUS WATERS AT ARMY JODHPUR

Cost (Rs/KL)	Fresh Water from RJB		Sewage Generated at Station and Treated	Borewewll Water Chlorinated by MES	Rainwater Harvested, Filtered and Chlorinated
	Raw Water Treated by MES	Treated Water From RJB Chlorinated by MES			
BASIC COST	1	1	1.39	1.63	0
TARIFF	8.89	11.13	0	0	0
M & O COST	16.95	10	15.1	11.25	8
POLISHING TREATMENT			3.4		
TOTAL	26.84	22.13	19.89	12.88	8
AVAILABILITY	**Dependance On rjb**	**Dependance on Rjb**	**Available In house.**	**Unreliable**	**Scanty**

FIG 3 : COMPARISON OF COST OF VARIOUS WATERS FOR NON POTABLE USES



2.4.2 It can be seen from above analysis that, wastewater reuse is most economic for used non potable application (In this case it was for eco-lake). In fact, out of the total cost of 19.89 /KL, 15.1 /KL is mandatory expenditure to bring wastewater at standards of disposal and only Rs 3.4 /KL is spent extra to make it reusable. Thus, about 25%-30% extra expenditure over mandatory expenditure, will make sewage reusable for most non-potable applications while it will result in saving of fresh water which costs 1.25 times more than the cost of treated wastewater. To summarize, we **can say that each litre of fresh water, if used twice will bring down its cost to 40%.**

3. GUIDING PRINCIPLES FOR REUSE IN MES

In Defence establishments, where MES cover is available, various types of reuses as listed below discussed. Quality of treated sewage required for each use is summarized at table 2. Each case is discussed in following paragraphs.

(a) Watering Golf fields and horticulture

(b) Eco-lakes

(c) Construction work

(d) Cooling Towers

(e) Fire fighting

(f) Flushing Toilets

S. N.	Parameter (2)	Unit (3)	Golf course, (4)	Non edible Crops (5)	Toilet Flushing (6)	Fire Fighting (7)	Eco lakes (8)
1	**Turbidity**	NTU	<2	AA	<2	<2	<2
2	**SS**	mg/l	nil	30	nil	Nil	nil
3	**TDS**	mg/l	2100	2100	2100	2100	2100
4	**pH**		6.5 -8.3	6.5 -8.3	6.5 -8.3	6.5 -8.3	6.5 -8.3
5	**Temperature**	^{0}C	Ambient	Ambient	Ambient	Ambient	Ambient
6	**Oil & Grease**	mg/l	10	10	10	Nil	nil
7	**Res. Chlorine**	mg/l	> 1	Nil	> 1	> 1	> 0.5
8	**Total Kjeldhal Notrogen**	mg/l	10	10	10	10	10
9	**BOD**	mg/l	10	20	10	10	10
10	**COD**	mg/l	As Arising	30	As Arising	As Arising	As Arising
11	**Dissolved Phosphorous**	mg/l	2	5	1	1	1
12	**Nitrate Nitrogen as N**	mg/l	10	10	10	10	5
13	**Faecal Coliform**	MPN/ 100 ml	nil	230	nil	Nil	nil
14	**Helminthic Eggs**	count/l	As Arising	<1	As Arising	As Arising	As Arising
15	**Colour**		Colourless	As Arising	Colourless	Colourless	Colourless
16	**Odour**		No foul odour	No foul odour	No foul odour	No foul odour	No foul odour

3.1 Watering Golf fields and horticulture: This is one of the most common uses of treated wastewater in MES. Optimum utilization of sewage in irrigation means the complete and judicious use of its three main components, viz., water, plant nutrients and organic matter in such a way that (a) the pathogenic infection is neither spread among the workers, nor among the users or consumer (b) the groundwater is not contaminated, (c) there is maximum output per unit volume of sewage, (d) there is no deterioration of the soil properties and (e) none of the three components are wasted. The quality of treated wastewater is listed at column 4 of table 2. It can be seen that recommended value of BOD is 10 mg/l which is more than the discharge standards being proposed in country including MES. Thus, it will always be economical to reuse wastewater for irrigation. However, one must also take care of other important parameters like TDS (<2100mg/l), Faecal Coliform (Nil), Total Nitrogen (10mg/l) and suspended solids (Nil).

3.1.1 Water Requirement and Drainage: The principle to be borne in mind in irrigation management is to irrigate only when it is required and only to the extent it is required by the crop/grass. The water requirement depends on the soil type, the crop/grass and the climate. The water requirement (cm) of main soil types to be wetted to a depth of 30 cm required by most of the crops is given in Table 3 below. The infiltration rate of the soil determines how much water will reach the crop root zone and eventually percolate to the subsoil. It is dependent upon soil texture and structure and the structural stability of the soil.

TABLE 3: Water Requirements (CM) to wet Different Soils

S. No.	Type of Soil	Water Requirement (CM)	SN	Type of Soil	Water Requirement (CM)
1	Sandy	1.25	4	Silty-Clay	6.25
2	Silty-Sand	2.50	5	Clay	7.50
3	Silty	5.00			

3.1.2 **Water Salinity and Drainage**. The infiltration rate is also dependent upon both the salinity of the water and the sodium adsorption ratio (SAR) of the soil which is a measure of the ratio of sodium ions to calcium and magnesium ions in the soil. SAR, if kept below 18mg/l does not pose any problem to soil. In order to maintain a favourable salt balance, excess water must be able to drain from the surface and from the root zone. Good drainage is important in arid and semi-arid areas (most of India). For the soils where impermeable strata is met which restricts percolation of water, a drainage system about 40-50 cm below the ground will be an excellent solution to get rid of excess water. Table 4 shows effect of TDS on crops, however, for most application TDS below 2100 mg/l is recommended for reuse. Further, it is desired that TDS of irrigation water should not be more than TDS of ground water. Similarly, care must be taken when higher water table (within 2 m bgl) is encountered during dry periods. Water can rise to the surface by capillary action, evaporate and leave behind dissolved salts. Salt accumulation reduces crop yields and ultimately makes soil unfit for agriculture.

TABLE 4 : Crop Response to Salinity of Irrigation Water

	TDS (mg/l)	Electrical Conductivity (mhos/cm)	Crop Response
1	< 500	< 0.75	No Detrimental Effects usually noticed
2	500 – 1,000	0.75 – 1.50	Can have Detrimental Effects on Sensitive Crops
3	1,000 – 2,000	1.50 – 3.00	May have adverse Effects on many Crops
4	2,000 – 5,000	3.00 – 7.50	Can be used for salt tolerant plants on permeable soils with careful management practices

TABLE 5 : Wastewater Application Techniques Based on Health Protection

	Factors Affecting Choice	Special measures for wastewater
Flooding	Lowest cost, Exact levelling not required.	Through protection for fieldworkers, crop handlers and consumers.
Furrow	Low cost, Levelling may be needed	Protection for fieldworkers.
Spray and sprinkler	Medium water use efficiency, Levelling not required, Advanced sprinklers reduce potential contamination by 1 log unit.	Minimum distance from houses and roads 50 – 100 m, Anaerobic wastewater should not be used.
Subsurface (Drip Irrigation)	High cost, High water use efficiency, Higher yields, Potential for significant reduction of crop contamination Can substantially reduce exposure to pathogens by 2 – 6 log units.	Localized irrigation, selection of non-clogging emitters; filtration to prevent clogging of emitters.

3.1.3 Irrigation Technique. The choice of application method of wastewater for irrigation can also affect the health of farm workers, consumers and the nearby communities. Various irrigation techniques are Flooding, Furrow, Spray and sprinkler and drip method as explained in table 12 below. It can be seen that drip irrigation is the techniques which have least risk and is also most efficient.

3.1.4 Alternative Arrangement during Non-irrigating Periods During rainy and non-irrigating seasons, golf fields / farms may not need any water for irrigation. Even during irrigating

season, the water requirement fluctuates significantly. Hence, satisfactory alternative arrangements have to be made for the disposal of sewage on such occasions either by storing the excess sewage or discharging it elsewhere without creating environmental hazards. The following alternatives are generally considered:

a) Provision of holding lagoons for off-season storage. They enable irrigation of a fixed area of land to varying rates of crop demand. They may also serve as treatment units such as aerated or stabilization lagoons, provided the minimum volume required for treatment is provided beyond the flow-balancing requirement. Need for having eco-lake (or holding lagoons or impoundments) is therefore justified in order to use the treated sewage during off-season storage.

b) Discharge of surplus treated sewage to river or into sea with or without additional treatment depending on ground condition. Combining surface discharge facilities with irrigation system is quite common and often quite compatible.

c) Resorting to artificial recharge in combination with an irrigation system where feasible. Additional treatment, if required has to done as per norms and in consultation with CGWB.

3.1.5 Protection against Health Hazards[4] Use of treated wastewater for irrigation/ watering should not normally be done if fresh water sources are located within 1 km of sources, or on areas with groundwater levels less than 2 m below the surface. Measures should be taken to prevent pollution of artesian water. Sewage farms must be separated from residential areas by at least 300 m horizontal distance. The public health aspects of sewage farming should be considered from the viewpoints of exposure of farm workers to sewage and that of the consumers to the farm products. The workers must be well educated in the sanitary rules on the utilization of sewage for irrigation as well as with personal hygiene. All persons working in such areas must undergo preventive vaccination against enteric infections and annual medical examination for heliminthoses and be provided treatment if necessary. Direct grazing on sewage farms should be prohibited.

3.2 Reuse for flushing toilets. Considering that the Indian water closets when flushed can sprout and splash the flush water above the rim and onto the foot rest areas, it is necessary that such reuse shall be only after activated carbon and ultra-filtration membranes. For this double network of pipes and OH tanks are essentially required. This reuse can-not be made mandatory unless adequate quality control checks are enforced. The quality of treated sewage required is listed in column 8 of table 2 at appendix ‘B’. It can be seen that these are similar to those of irrigation discussed above except for quantity of dissolved Phosphorus which is 1 mg/l against 2 mg/l for irrigation.

3.3 Reuse for Cooling Waters. Reuse as cooling water is one of the most common industrial applications of reclaimed treated sewage. Typical guidelines for cooling water quality are given in Table 6 and may be used where specific requirements are not given. Treated sewage can be reused in cooling towers in two ways i.e. to be used only once through cooling tower or to be recirculated in evaporative cooling tower.

3.3.1 *Once through Cooling Water*. In addition to recommended values of table 6, SN 1 to 8; residual chlorine > 1 mg/l can serve the purpose.

3.3.2 *Recirculating Cooling Water.* In addition to the once through cooling standards, additional treatment is usually provided to prevent scaling, corrosion, biological growths, fouling and foaming. Additional criteria are listed at SN 9-13 of table 6. To determine the quality and quantity of water required for reuse in a cooling system, where an open re-circulating system is adopted for air conditioning cooling water, the amount of water to be kept for re-circulating in the system is approximately 11 litres/min for every ton of refrigeration capacity when the temperature drop is 5°C in the cooling tower. For such a situation, the water loss in evaporation and other losses is about 1% -2% of the re-circulating water.

The recirculating water shows the tendency for deposition of scale, reduction in hardness and in alkalinity is the usual means of control. For this reason, partial zeolite softening (by blending the softened water with by-passed hard water), plus acid feeding if required for reduction of alkalinity provide a relatively simple and flexible means of preventing excessive scaling.

Where nitrates and phosphates in the make-up water are necessary to be reduced, the biological treatment given to sewage at the secondary stage can itself be modified to include nitrification-denitrification and the addition of alum or ferric done in the final settling tank.

3.4 Reuse for Eco-Lakes (Impoundments) Storage of treated wastewater in open ponds is technical requirement and is in harmony with most of other reuses. For irrigation, during non-irrigating periods as discussed above, treated effluent can be stored in open unlined ponds. Similarly for fire fighting the stored treated effluent can be used provided approach road to pond is there. The size of such ponds is governed by water balance between losses by (evaporation + percolation + any use) and intake per day. These ponds can be any aesthetically pleasant shape; however, depth should be kept about 1 – 1.50 m. In order to avoid septic conditions aeration by way of fountains or cascades is considered essential. The quality criteria of treatment are listed in column 11 of table 2. The requirement of free chlorine of 0.5 mg/l after disinfection can be dispensed with if no human contact is envisaged and there is aquatic life in the pond. It can be seen that the parameters are stricter than those for irrigation; therefore, it can be good idea to water for irrigation from these ponds without any further treatment except chlorination.

TABLE 6 : QUALITY OF TREATED SEWAGE FOR COOLING WATERS2

FOR MAKE UP WATER				
SN	**Parameter**	**Unit**	**Range**	**Remarks**
1	pH		6.8-7.0	variation < 0.6units in 8 h
2	Av TDS with 2.0 cycles in recirculating water	mg/l	3,000	extra 25% permissible on 8 h average
	Av TDS with3.5 cycles in recirculating water	mg/l	1,000	extra 25% permissible on 8 h average
	Av TDS with 6.0 cycles in recirculating water	mg/l	500	extra 25% permissible on 8 h average
3	Oil & Grease	mg/l	0	Absent
4	BOD5	mg/l	< 5	
5	Chlorides	mg/l	< 175	
6	Ammonia	mg/l		No appreciable amount
7	Alkalinity (cuastic)		Absent	
8	Alkalinity (CaCO3))	mg/l	< 200	
	ADDITIONAL CRITERIA FOR RECIRCULATING WATER			
9	Silica (As SiO2)	mg/l	< 150	
10	Phospates, Sulphates	mg/l		Below solubility limit
11	Alkyl Benzene Sulponate (ABS)			Foam not to persist more than 1 min after 10 min of vigorous shaking of recirculating water
12	Langelier Index		0.4 to 0.6	At skin temp of heat exchange surface
13	Ryzner Stability Index		6.0 to 7.0	

3.5 Reuse for Construction work. Following uses in the construction industry are envisaged

(a) Soil compaction

(b) Dust control

(c) Washing aggregates

(d) Mixing and curing

As per IS 456 para 5.4 water used for mixing and curing shall be clean and free from injurious amounts of oil, acids, alkalis, salts, sugar, organic material or other substances that may be deleterious to concrete or steel. Potable water is generally considered satisfactory for mixing concrete. Permissible limits for solids shall be as given in table 7 below. These limits are normally available in treated sewage in modern STPs followed by tertiary treatment. In the stations where builders purchase water from MES, they can be asked to collect the same from eco-lakes, if quality parameters are within limits else minor corrections for quality by online softening or filtration can be done.

TABLE 7: Permissible Limits for Solids in Water for Concreting[5]

SN	Parameter	Unit	Limit
1	Acidity	mg/l	< 50
2	SO4	mg/l	< 400
3	TDS	mg/l	< 3000
4	Chloride	mg/l	< 500
5	pH		6.5 – 8.5

3.6 Reuse for fire fighting. UG fire fighting tanks are provided in MES at all key locations. These tanks are filled with fresh water through piped supply. In emergency, there can be shortage of water for any reason. Treated sewage stored in open ponds as suggested above can prove to be very useful in such cases. The quality criteria for fire fighting are listed in column 9 of table 2. This is nearly similar to that of Eco-lakes (impoundments), therefore, such waters can be directly used for fire fighting. Approach road to eco-lake for fire-tenders circumventing the ponds is considered essential for speedy actions.

4. TECHNOLOGY FOR TREATMENT

In order to achieve the desired water quality, in addition to biological treatment of sewage through MBBR or any other approved technology, multi media filtration, adsorption through granular activated carbon followed by excess chlorination are recommended. For use in evaporative cooling and construction works, softening may also be required. Regular and serious monitoring of quality is considered essential for the success of reuse. The concept of Command Test Labs in MES where bio-chemical tests can also be conducted, the quality monitoring of treated effluent should not be a problem.

1. **Piping and Cross-connection Control** Residual chlorine > 0.5 mg/l, in the distribution system meant to carry treated sewage for reuse is recommended to reduce odours, slime and bacterial growth[6]. It is crucial to be able to differentiate between piping, valves and outlets that are used to distribute treated effluent or reclaimed water and those that are used to distribute potable water. Cross connections with fresh water supply system must be avoided. For this colour-coding (preferably violet) for the components including pipes and fixtures used to distribute reclaimed water not intended for drinking water is done. The spindles used should be detachable so that these can be kept in safe custody and operations are done by authorized persons only. In addition it is advisable to post areas such as parks and yards with warning signs stating that the piped water there is not for human consumption. The signage should be in all the major languages of the region.

2. **Awareness Programmes.** Education is the key to overcoming users fears about a reuse system, particularly fears that relate to public health and water quality. In-depth discussions, training and workshops are required to be held. Success stories must be shared with all. Water audit for all stations must be done and possibilities of reuse be explored.

3. **Conclusion.** Non-potable reuse of treated sewage is not only need of the hour but also financially viable. Saving of about 40-50% of fresh water is possible if treated sewage is used for watering arboriculture, kitchen gardens, golf fields, fire fighting, cooling tower and construction activities etc. Necessary executive directions from appropriate authorities and change in mind set at lower formations are essentially required.

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