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Treatment of Gray Water for Reusing in Non-potable Purpose to Conserve Water in India

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Abstract

The scarcity of fresh water is one of the major issues at different places in India which necessitates human's attention for conservation of sustainable water. The natural resources of potable water are becoming insufficient to satisfy consumer's day to day demand. Peoples are searching solutions in different ways to combat the terrible situation. The treatment and reuse of gray water is one of the promising steps for conservation of water. Gray water is waste water generated from showers, bath, sink, kitchen, washing machine, laundry except toilet water. It can be treated by physical, chemical, biological and natural methods or a combination of these methods. Gray water can be reused for toilet flushing, garden and plant irrigation, agricultural irrigation, floor washing, car washing, ground recharging etc after a suitable treatment. A statistical analysis of total domestic water consumption, gray water production and treated water generation is shown in this paper. The analysis shows that treated water obtained from light gray water in residential buildings is sufficient to satisfy the non-potable domestic demand such as toilet flushing, house cleaning and garden irrigation by upto 35% of total domestic demand. In case of mixed gray water, excess 20 – 25% of treated water can be used for ground recharging, landscape irrigation or some other non-potable purposes. The study reveals that it is possible to save a lot of fresh water every day by recycling and reusing treated gray water.

Key Words: Water conservation, Waste water, Gray water, Treatment of gray water, Constructed wetland, Reuse of gray water.

INTRODUCTION

Water, the essential need of all living beings is becoming an important matter of concern in this era as the source of water is getting depleted throughout the world. The rapid growth of population demands more and more water in all sectors: domestic, agricultural and industrial. Increased demand in water supply with improved living standard, unplanned urbanization, ground water extraction, surface water pollution, water intensive agriculture, industrialization are contributing depletion of future fresh water supply globally. In India also, the crisis of water is a big issue as millions of people do not have access to sufficient, safe fresh water for drinking and sanitation purposes. So, conservation of water is an important matter of concern. One of the promising steps for conservation of water is treatment and reuse of gray water (1, 2, 3). By reusing gray water for non-potable purposes such as toilet flushing, floor washing, car washing, garden irrigation etc. (1,4), it is possible to reduce the demand of fresh water to some significant extent; otherwise a lot of water is getting lost after a single use.

The present study aims to review the necessity of gray water treatment and research work done on gray water treatment in India, gray water characteristics, the treatment technologies and reuse of treated gray water.

GRAY WATER TREATMENT AND REUSE IN INDIA – WHY?

A study by International Water Management Institute (IWMI) predicted that there will be severe water scarcity in India by 2025 (1, 5, 6). In India the per capita surface water availability goes on decreasing with time and it is projected to reduce drastically by the year 2050 as shown in figure 1 (1,7).

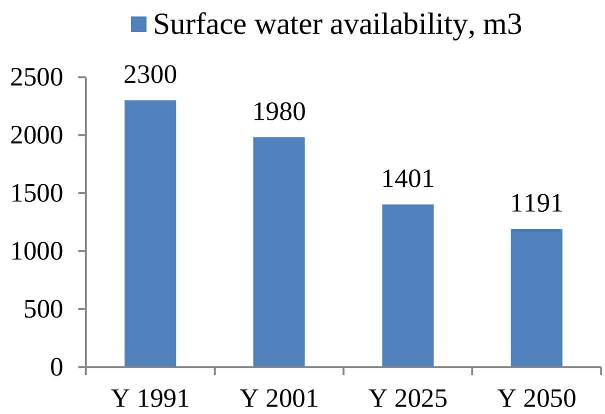

Figure 1: Per capita surface water availability in decreasing trend

Different states of India including Uttar Pradesh, Madhya Pradesh, Bihar, Jharkhand, Haryana, Karnataka, Gujarat, Maharashtra, Rajasthan, Andhra Pradesh, Telengana, Odisha are facing serious problem in managing water to the consumers. Over 300 districts in 13 states of India are facing shortage of drinking water as reported on 10th May, 2016 in Livemint. In Uttar Pradesh and Madhya Pradesh the most number of districts, 50 and 46 respectively are affected due to crisis of water (8). As per news in January, 2017 in Times of India, 30 towns from Andhra Pradesh and Telengana face water crisis as the demand of drinking water rises (9). By 2030, minimum 21 cities in India will move towards zero ground water level as reported by World Bank on 9th June, 2018 in Business World (10). Many big cities like Chennai, Hyderabad, Coimbatore, Vijayawada, Simla and Kochi are moving towards severe water shortage. There are acute water crisis in cities like Delhi and Bengaluru. As per British Broadcasting Corporation (BBC) news on 11th February, 2018, Bengaluru is likely to run out of drinking water (11). Alarm bells are ringing in front of us to wake up for the rise in fresh water demand. We are now in the middle of cross road where further unsustainable and impractical uses of fresh water are not acceptable. In the present context of water scarcity, it's a crucial time to think about it and the steps to combat the situation for us as well as for our future generation. So, treatment and reuse of gray water for various non-potable purposes is gaining a significant momentum of discussion for conservation and management of sustainable water.

RESEARCH WORKDONE ON GRAY WATER TREATMENT IN INDIA

A lot of research work has been carried out on treatment and reuse of gray water at different institutes and R & D sectors in India to get suitable methods for conservation of water.

Shegokar et al studied and designed a laboratory scale gray water system. They concluded that only physical operation such as gray water collection, sedimentation and filtration using nylon rope and storage system could be taken as a viable alternative method to conventional treatment system in rural areas (12). In Nashik, Maharashtra the design of lab scale gray water treatment plant was suggested by the researchers. They developed the system for small college campus in rural areas (1). A training course was carried out under Innovative Ecological Sanitation Network India (IESNI) on Small-Scale Constructed Wetlands for Graywater and Total Domestic Wastewater Treatment in Pune, Maharashtra (13). David Prashant Asirvadam et al worked on treatment of gray water using constructed wetland system with Canna Indica plant. They compare the characteristics of gray water before and after treatment and concluded that constructed wetland system would be a better solution for treatment of low organic gray water due to its simple, low operational and maintenance cost (14). Gorky S. S. from Tamilnadu, India worked on treatment of gray water using constructed wet lands. They used this natural system to treat the water on laboratory scale. Researcher concluded that sub-surface vertical flow constructed wet land could be used effectively for treatment of gray water (15). Edwin et al reported that natural treatment systems are the better alternative for treatment of waste water, especially in developing countries (5).

CHARACTERISTICS OF GRAY WATER

Gray water is defined as all waste water streams come out from buildings except toilet water. Gray water is mainly comprised of effluent from showers, bath, sink, kitchen, washing machine and laundry. Typically, gray water comprises 55 – 75% of total consumption of domestic water depending on total water consumption, habit of the people, climate etc (1, 4, 16, 17). In India, as per IS: 1172- 1957, the total domestic water consumption is about 135 liters/capita/day under normal conditions (18) of which 70 – 90 liter is generated as gray water (4). The gray water mostly contain food residues, oil and fats, soap, shampoo, hair, bleach, various body care products, tooth paste shaving waste, detergents etc. It may contain traces of urine and feces (5, 19). The waste water from kitchen sink, dish washers, laundry is more contaminated and termed as dark gray water. Whereas, less contaminated bathroom waste water is known as light gray water (17) which accounts for about 50 – 60 percent of total gray water (5, 20). The relative distribution of total domestic water consumption and gray water production as given by Edwin et al are shown in Table 1 and Figure 2 (5).

Table 1: Distribution of total domestic water consumption

Domestic Water Consumption for							
Drinking and Cooking	Toilet Flushing	Gardening/ Others	House cleaning	Bath and Shower	Hand Basin	Kitchen/ Dishwashing	Laundry
3%	26%	2%	6%	31%	4%	17%	10%
				Gray water = 62%			

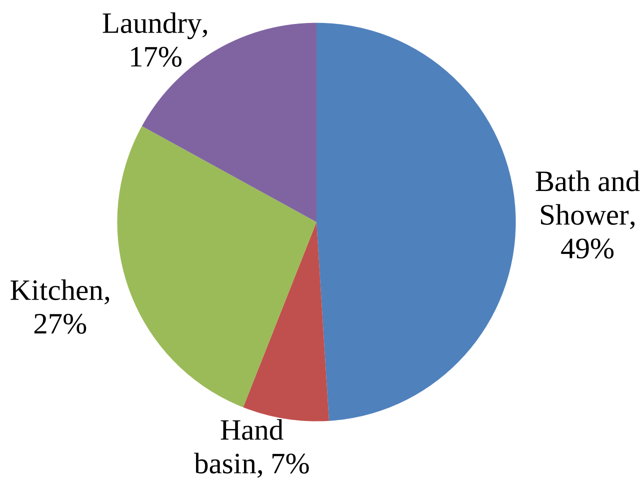

Figure 2: Gray water production from various sources

The characteristics of gray water are highly variable and depend upon availability and consumption of water, food habits, life style etc. (4, 17, 21, 22). In published literature, the characteristics of gray water were found to vary highly from one household to other household, complexes to community centers, and also from one geographical location to another location (4). Gray water contains suspended solids, different organic substances (23), metals, inorganic ions (17, 24, 25), xenobiotic compounds (4), and traces of microorganisms especially E. coli (17, 26). The characteristics of dark gray water are given in Table 2 (27). The pH is found to vary from 7.3 – 8.1. Laundry gray water is more alkaline in nature compared to kitchen and bath water. Suspended solid contributed by food and dust particles, hair etc. The biochemical oxygen demand (BOD_5) and chemical oxygen demand (COD) are found to lie in the range 56 – 100 mg/L and 244 – 284 mg/L. In general high BOD content is observed in kitchen gray water whereas high COD content is observed in laundry and bathroom gray water. Laundry waste water also contribute higher amount of sodium, phosphate and various xenobiotic compounds (4, 28). Microbial load in gray water is generally less, especially, bathroom and laundry waste water are less contaminated with microorganisms compared to kitchen waste water (17). But rarely enteric pathogenic bacteria like *Salmonella* and *Campylobacter* may present in kitchen waste water (29). Faecal contamination in gray water may come from washing faecally contaminated clothes, child care and washing raw meats (30). As per WHO-guidelines (2006) faecal contamination is the main hazard in gray water, which contributes infections and illness to human in contact with gray water (31).

Table 2: Characteristics of dark gray water in India

Parameters	Unites	Values	Parameters	Unites	Values
pH	-	7.3 – 8.1	BOD_5	mg L^{-1}	56 - 100
EC	µS cm^{-1}	489 – 550	COD	mg L^{-1}	244 - 284
Turbidity	NTU	20.6 – 38.7	Total coliform (TC)	CFU/100 mL	3.74×10^4 to 3.8×10^4
Total suspended solids (TSS)	mg L^{-1}	12 – 17.6	Na	mg L^{-1}	43.8 – 48.1
Nitrate (NO_3^-)	mg L^{-1}	0.5 – 0.63	K	mg L^{-1}	8.3 – 15.2
Total nitrogen (TN)	mg L^{-1}	42.8 – 57.7	B	mg L^{-1}	1.3 – 1.5
Phosphate (PO_4^{3-})	mg L^{-1}	1.52 – 3.36	Cl^-	mg L^{-1}	7.4 – 12.9

GRAY WATER TREATMENT TECHNOLOGIES

The gray water treatment methods mainly depend upon the volume of gray water, its physico-chemical and biological characteristics, energy requirement and the purposes for which treated water to be used. There is no specific universally accepted technology for treatment of gray water (5). The technologies used for treatment of gray water consist of physical, chemical and biological or a combination of these processes (17, 28, 32, 33). To achieve the quality standard of non-potable water, gray water needs removal of suspended particles, oil and grease, turbidity, microorganisms etc. It also needs proper level of pH, BOD, COD in treated water. Different components of gray water treatment are screening, sedimentation, filtration, biological treatment, chemical coagulation, disinfection etc. (4, 7). The overall process usually consists of pretreatment, main treatment and post-treatment steps (17, 33).

Pretreatment: Pretreatment is used for separation of coarse particle, oil and grease to avoid clogging in the subsequent treatments. Solid particles can be removed by using fine screen, size < 6 mm (1). Oil and grease must be removed by using grease trapping system or making some other arrangements. Pretreatment step must be followed before any physico-chemical or biological treatment steps.

Main treatment: Physico-chemical and biological treatment steps are the main treatment steps in treating gray water to achieve the quality standard of treated water to be used for different non-potable purpose.

Post-treatment: After main treatment, disinfection viz. chlorination or UV treatment is also required to achieve the total coliform (TC) and residual chlorine (RC) standard in treated water.

Physico-chemical treatment: It is observed that only physical processes i.e. plain sedimentation and filtration are not sufficient to meet the water quality standard (17, 28, 33, 34), especially for medium to high strength gray water. Rather more conventional method is sedimentation with chemical coagulation and then filtration. The combined steps remove very fine suspended matter and microorganisms in large extent.

Biological treatment: Several biological treatment steps viz. Rotating Biological Contactor (RBC), Fluidized Bed Reactor (FBR), Sequencing Batch Reactor (SBR), Membrane Bioreactor (MBR), Upflow Anaerobic Sludge Blanket (UASB) etc. have been reported in literature for treatment of gray water (4, 5, 17). After aerobic biological treatment, bio-solids are removed, consequently re-growth of microorganisms and odor formation are avoided which makes gray water more stable to store for a longer periods. Hence, medium to dark gray water could be treated using biological treatments (17, 32). However, MBR is the most efficient biological treatment method which combines biodegradation with membrane filtration for separation of solid-liquid (4, 35). This method generally does not require post-filtration and chlorination, showing 100% removal of total coliforms (4). The physico-chemical and biological parameters of treated gray water through MBR meet various reuse standards (28, 36). But, the investment and operational cost of MBR are very high compared to other biological methods and thus less convenient for developing countries (37).

A general flow scheme of treatment of gray water by conventional methods is given in figure 3. The conventional chemical processes viz. sedimentation with coagulation, followed by a filtration and/or disinfection, can reduce the suspended solids, organic matters and surfactants in light gray water to an acceptable level to be used for non potable purpose (17).

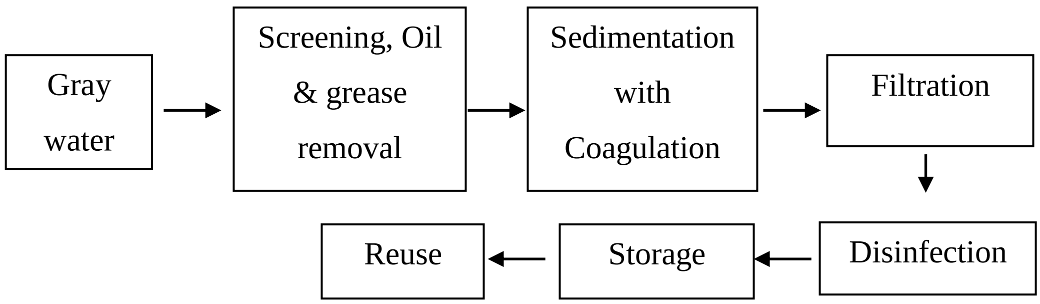

Figure 3: Flow scheme for treatment of gray water by conventional methods

Natural treatment: Recently, the natural treatment systems are gaining popularity in treating waste water as the best alternative to the conventional treatment methods (5). Few examples of natural gray water treatment systems are horizontal-flow constructed wet land (HFCW), vertical- flow constructed wet land (VFCW), constructed soil filters (CSF), vertical flow filter (VFF) etc. These system include physical, chemical and biological processes altogether such as filtration through filter media (sand, gravel, rock etc.), chemical precipitation and adsorption, photosynthesis, and aerobic or anaerobic microbial degradation (17). These methods are recommended for treatment of light to medium gray water to produce good quality effluent with relatively low capital, operational and maintenance cost compared to mechanical systems (5). They can be used for treatment of dark gray water with a disinfection step if low pathogen level is required in treated water (28). Researchers stated that in terms of treatment performance, operating and maintenance cost, the constructed wet land (CW) system can be taken as the most economical and environment-friendly technology for treatment and reuse of gray water (17). A schematic diagram of light gray water treatment and recycling by natural method is given in figure 4.

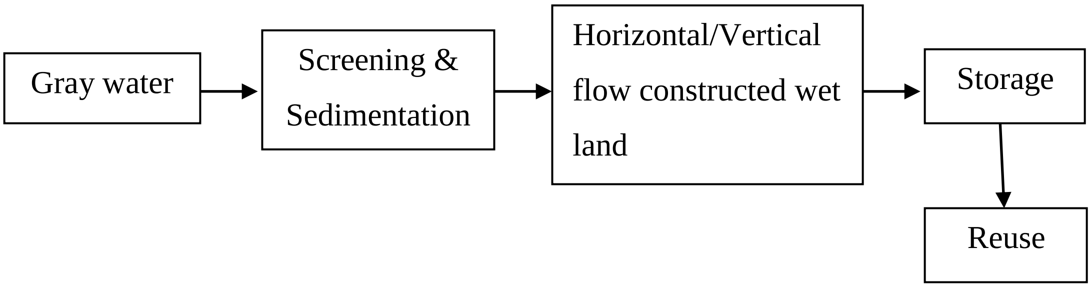

Figure 4: Treatment of light gray water by constructed wet land

REUSE OF TREATED GRAY WATER

The treated gray water can be reused for toilet flushing, garden and landscape plant irrigation, agricultural irrigation, floor and car washing (1, 4). It can be used for ground recharging (4). In industry, treated gray water is mostly used in cooling tower (5, 38). The quality of water used for these purposes are not essentially be of portable quality. So, treated gray water could be utilized easily for non potable use with necessary treatments. The reuse of gray water for toilet flushing alone could reduce the fresh water demand by 10 – 20% (39). And the reuse of gray water for toilet flushing and garden irrigation could reduce the total domestic water consumption by up to 50% (40). Agricultural irrigation is mostly favored in tropical countries (5). However, the cumulative accumulation of sodium and other micro-pollutants in soil may affect the growth of plants after several years of usage (40). It needs more research to know the exact fact as only a few studies have done on this area which reported that micro-pollutants in soil are degraded over time (41, 42). For its maximum uses gray water treatment schemes must be simple and economical. At the same time gray water reuse must be environment friendly without causing any public health hazard. But there are no laws and regulations on the treatment and reuse of gray water in many developing countries including India (43). Central Pollution Control Board (CPCB), India suggested the standard for quality of treated waste water (44) which is Indian Standard (IS) for maximum permissible limit of industrial effluent disposal into environment. The World Health Organization (WHO) published gray water reuse guidelines in 2006. Microbial requirements are mainly taken into consideration in this guideline (31). However, some difficulties were observed to follow this guideline as full understanding was required by all users (17). In 2015, the WHO published sanitation safety planning methods covering the safe use and disposal of waste water, gray water and excreta (45). In developed countries like UK, USA, Canada, Japan, Germany, Israel, Sweden and Australia promote research on processing and reuse of gray water. Country wise, different gray water reuse guidelines and standards are there. The quality standards of treated waste water by CPCB and US EPA are given in Table 3.

Table 3: Quality standards of treated waste water

Standards		pH	BOD mg/L	Turbidity (NTU)	TSS mg/L	FC cfu/ 100 ml	RC mg/L	Reference
CPCB India	On land for irrigation[a]	5.5-9	100	-	200	-	-	CPCB (2008) (ref: 44)
	Into inland surface water[b]	5.5-9	30	-	100	-	1	
	Into Public sewers[c]	5.5-9	350	-	600	-	-	
USEPA	Unrestricted use[d]	6-9	10	2	-	0	1	USEPA (2012) (ref: 46)
	Restricted use[e]	6-9	30	-	30	200	1	

[a] *Indian Standard: 3307 (1974)* [b] *Indian Standard: 2490 (1974)*

[c] *Indian Standard: 3306 (1974)* [d] *Toilet flushing, landscape irrigation, crop eaten raw*

[e] *Agricultural irrigation for processed food and non-food crops, construction uses, industrial cooling*

Table 4: Analysis of total water consumption, gray water production and treated water generation

No. of persons	Average domestic water consumption[1] (lit/day)	Mixed GW production[2] (lit/day)	Light GW production[3] (lit/day)	Treated water[4] production (lit/day)		Percent of treated water production w.r.t water consumption (%)	
				From mixed GW	From light GW	From mixed GW	From light GW
6	810	486	267	460	250	55.56	30.86
50	6,750	4,050	2,227	3800	2,100	56.30	31.11
100	13,500	8,100	4,455	7,800	4,200	57.78	31.11
150	20,250	12,150	6,682	11700	6350	57.78	31.35
200	27,000	16,200	8,910	15,500	8,500	57.41	31.48

[1] *In India average domestic water consumption is 135 lpcd in normal condition (Ref: 18)*

[2] *Mixed gray water production is taken as 60% of total water consumption (Ref: 1, 4, 16, 17)*

[3] *Light gray water (excluding kitchen and laundry) production is taken as 55% of total gray water production (Ref: 5, 20)*

[4] *Assuming 4-6% reduction in volume of treated water in treatment process*

However waste water treatment and reuse is not common in India except industrial waste water, which is reused in cooling tower. The gray water treatment and its reuse are still in primitive stage in India. Recently the Brihanmumbai Municipal Corporation (BMC) in Mumbai has passed the by-laws to make it mandatory for all new residential and commercial buildings to have rain water harvesting system and gray water reuse system (5).

A statistical analysis is shown in table 4 for single house hold having 6 members and for complexes of 50, 100, 150 and 200 peoples. Table 4 shows a trend of total domestic water consumption, total mixed gray water generation, light gray water generation, and approximate amount of treated water production from mixed and light gray water. Light gray water from bathroom source is produced in lesser quantity, but it needs more simple method for treatment compared to mixed gray water. If the gray water is treated in suitable method, only a little less volume will be generated after treatment depending on treatment methods. Assuming 4-6% reduction in volume of treated water, Table 5 shows that approximately 7,800 liters and 15,500 liters treated water is produced from mixed gray water whereas, 4,200 liters and 8,500 liters treated water is produced from light gray water for complexes of 100 and 200 members. Even for six member single house hold approximately 460 liters and 250 liters treated water is produced from mixed gray water and light gray water respectively. Table 4 also shows that the production of treated water from mixed GW and light GW is around 55-60% and 30-35% of domestic water consumption respectively. This treated water can be reused in houses by upto 35% for non- potable purpose such as toilet flushing, house cleaning and garden irrigation (Table 1**).** So, treated water from light gray water is sufficient for domestic reuse. In case of treatment of mixed gray water, excess 20 – 25% of treated water can be used for ground recharging, landscape irrigation or some other non-potable purposes. So, everyday, we can save a large volume of fresh water by reusing treated gray water which could reduce the fresh water consumption significantly.

CONCLUSION

The above discussion concludes that gray water treatment and reuse must be taken as a promising step for conservation of sustainable water in present context of water scarcity in India in near future. The technology should be adopted based on gray water characteristics and the purpose for which treated water is to be used. The reuse of treated water can reduce our fresh water requirement for non-potable purpose such as toilet flushing, garden irrigation, floor and lawn washing etc. considerably in everyday life as shown in Table 4. Treated gray water is a substitute of fresh water to be used for non-potable purpose. The action may be taken by the Government to motivate the public for implementation of gray water treatment plant in large buildings, complexes, public centers, and also for single house hold especially in water shortage areas.

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