Greywater Reuse: A Sustainable Solution for Water Crisis in Bengaluru city, Karnataka, India

Parameshwara Murthy P. M., Sadashiva Murthy B. M. and Kavya S.

***Abstract*—**India is facing a critical problem of water scarcity due to declining water sources. Hence water treatment has become an area of significant concern especially in metropolitan cities like Bengaluru which is facing acute water shortages due to rapid population growth and unplanned urbanization. Currently there is a deficit of 155 MLD of water for domestic purposes in the city and it is projected to reach a value of 514 MLD by the year 2025. This situation necessitates the need for water conservation and substitution of fresh water with a suitable alternative. Greywater recycling is a viable option to minimize the deficit demand and supply in the city. It is estimated that recycling treated greywater for non-potable purposes in multi-storey buildings alone can significantly reduce the overall demand. Hence, the study focuses on reviewing and proposing certain efficient, sustainable and economically feasible greywater system for multi-storey buildings**.**

***Index Terms*—**Economically feasible systems, Greywater recycling, Multi-storey buildings, Non-potable purposes, Water conservation**.**

I. Introduction

With a diverse population that is three times the size of the United States but one-third the physical size, India has the second largest population in the world.

Although India has made improvements over the past decades to both the availability and quality of municipal drinking water systems, its large population has stressed planned water resources. One among the major metropolitan cities of India facing water crisis is Bengaluru in the state of Karnataka, the third most populous city of the country with a population of 10.2 Million and density of 47% as of 2015. The average annual rainfall in Bengaluru is 859 mm and it is very obvious that such low level rainfall has resulted in the decline of ground water levels. Some bore wells that are not too deep have gone dry.

Half of the population of Bengaluru will have to be evacuated in another 10 years if the problem of water crisis is not solved immediately. Currently, the water deficit in the city is 155 MLD and is expected to reach 514 MLD by 2025. The trend of water supply & demand in the city from past 15 years is as shown in Fig. 1.

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Parameshwara Murthy P. M., Research Scholar, Department of Environmental Engineering, SJCE, Mysuru, Karnataka, India

Sadashiva Murthy B. M., Professor, Department of Environmental Engineering, SJCE, Mysuru, Karnataka, India

Kavya S., Research Scholar, Department of Environmental Engineering, SJCE, Mysuru, Karnataka, India

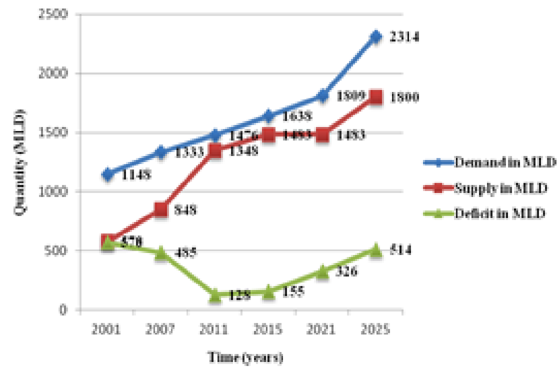

Fig.1.Trend Of Water Supply And Demand In Bengaluru City.

Therefore it is highly essential to reduce surface and ground water use in all sectors of uses and to substitute freshwater with alternative resources. Rainwater and greywater are good alternative resources. Rain water harvesting is one of the most useful options of water conservation but it has some limitations such as it is only useful for areas receiving good amount of rainfall throughout the year. Greywater reuse is a viable option that can be very useful in water arid and semi-arid areas [8]. Greywater is available in abundance in highly populated areas since its generation escalates multifold in these areas [4].

Greywater constitutes about 70% of household water consumption with lower concentration of organic matter and fewer pathogens as compared to domestic wastewater. Therefore, greywater may be treated and reused much easily than composite domestic wastewater for the point of treatment technologies applied and relevant costs [6].

A number of technologies have been applied for greywater treatment worldwide, varying in both complexity and performance. However the most advanced technologies that are being adopted widely in recent years are Membrane Bio Reactors (MBRs) and Sequential Batch Reactors (SBRs) [5]. Combined implementation of greywater recycling and water conserving devices is very feasible for multi-storey buildings with a payback period of 4.1 years only for a 20 storey building on adopting Membrane Bioreactor technology [3].

A study on treatment of greywater from domestic source using Membrane Filtration shows the percentage of TOC removal to be 83.4% and turbidity of the effluent to be less than 1 NTU. Also, according to the results the effluent was free of suspended solids and E. coli and had an excellent physical appearance [7].

In case of application of Sequential Batch Reactor for treatment of domestic greywater, the removal efficiency of organic matter increases with increase in cycle time. A study carried out in Iraq using SBR states that the maximum removal of nitrate was 57% for a cycle time of 12 hours. However, there was a convergence in values when in comparison with Iraqi specifications [1].

Membrane Bioreactor system provides a high degree of treatment of greywater in terms of suspended solids and organic matter removal [1]. Removal efficiencies as high as 85%, 94% and 63% can be achieved for COD, BOD and TKN respectively by treating greywater with Membrane Bioreactor technology [2].

On reviewing various previous studies, it was noticed that treating greywater with Membrane Bioreactor goes one step ahead with high treatment efficiency and less area requirement. The most critical aspect that has to be taken into consideration while selecting a treatment technology for Bengaluru city is the area required for installation of the technology, since there is severe pressure on requirement of area for new constructions due to hyper-urbanization in the city. Hence, this paper mainly discusses the feasibility of greywater recycling using Membrane Bioreactor technology in multi-storey buildings in Bengaluru city.

II. Materials & Methods

2.1 Background

Currently there are 1, 01,426 numbers of multi-storey residential apartments in Bengaluru city according to the data collected from Bengaluru Urban Water Supply and Sewerage Board (BUWSSB).

Total volume of water supplied to these buildings is approximately 143 MLD. By treating and reusing the greywater generated from these buildings for various purposes like flushing, landscape irrigation etc., 5.8% of the total water demand of the city can be reduced.

2.2 On-Site Greywater Treatment System

The on-site greywater treatment system includes the greywater treatment unit as well as the conveyance system for collection of raw greywater from each flat, conveyance of treated greywater to the storage tank and distribution of the treated greywater from storage tank to WC cisterns. The schematic layout of greywater conveyance system is shown in Fig. 2.

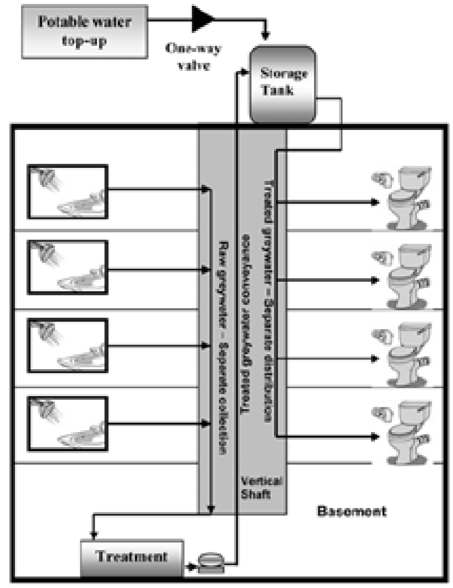

Fig. 2. Schematic Layout Of Greywater Conveyance System.

In order to reuse the greywater, a separate pipe should be installed in the vertical shaft in order to convey the raw greywater to the basement where the treatment unit is situated. The treated greywater is then pumped to the top of the building to the storage tank from where it will be conveyed gravitationally through a separate pipe to the WC cisterns. In case of shortage of greywater in the storage tank, freshwater will be topped up through a one-way valve and in case of excess, it will be discharged through the sewer line of the building.

2.3 Membrane Bioreactor

The treatment technology considered for economic feasibility study is the Membrane Bioreactor system, which is one of the most advanced compact intensive treatment technologies available to treat wastewater.

Following are some of the advantages of Membrane Bioreactor system:

- Consistent and superior treated water quality
- Product water is independent of feed variability
- Turbidity of 0.1 NTU can be expected even with higher feed water turbidity
- Modular design for easy expansion
- High MLSS (8000-1200 mg/l) and long SRT
- No residual chemicals in the treated water
- Easy sludge handling (Less sludge wasting due to higher Sludge age)
- Removal of micro nutrients
- Automated operations that require less operator attention
- Makes plant capacity augmentation easy where space is a constraint

The Membrane Bioreactor unit generally consists of a Coarse screen (10mm), Grit chamber, Oil and grease trap, Fine screen (6mm), Equalization unit, Aeration tank, Membrane Bioreactor and a disinfection unit. Schematic flow diagram of Membrane Bioreactor-based Greywater treatment unit is shown in Fig. 3.

Fig. 3. Schematic Flow Diagram Of Membrane Bioreactor-Based Greywater Treatment Unit.

2.3.1 *Costs*

Capital Cost

The capital costs of all system components including installation costs were collected from leading manufacturers and distributors (who requested anonymity).

Following is the break-up of capital costs:

- Design & Engineering : 3-4%
- Equipments : 40-46%
- Civil works : 30%
- Miscellaneous : 20% of total cost (Including installation, execution, commissioning etc.)

Operation and Maintenance (O&M) Costs

The O&M costs include:

- Cost of chemicals (mainly hypochlorite and citric acid for tentative maintenance cleaning and recovery cleaning)
- Labor cost
- Cost of instrument calibration (which is required to be done once in a year) &
- Cost of energy required for treatment and conveyance (at current rate of Rs. 6/hp in Bengaluru city)

Based on the above data, assumptions and considerations, an economic analysis for Membrane Bioreactor system was performed and the results are presented in the following section.

III. Results And Discussion

The capital cost of Membrane Bioreactor system is very sensitive to the size of the system. The specific investment cost (costs per flat) of the Membrane Bioreactor system becomes lower than Rs. 12,000 (US $ 176) for each flat when the number of flats exceeds 100.

The specific cost and O&M costs per flat is reduced with increasing number of flats, whereas the specific income does not change with size, as it stems out from reduced water demand of each flat.

The economic feasibility of treating greywater using Membrane Bioreactor technology was analyzed for varying number of flats. Greywater Reuse system payback periods for buildings with varying number of flats are as shown in Fig. 4.

The analysis was done considering the current water and energy costs in Bengaluru city. The cost of chemicals required for tentative maintenance and recovery cleaning was obtained from leading chemical dealers and the cost required for instrument calibration was collected from Membrane Bioreactor manufacturers.

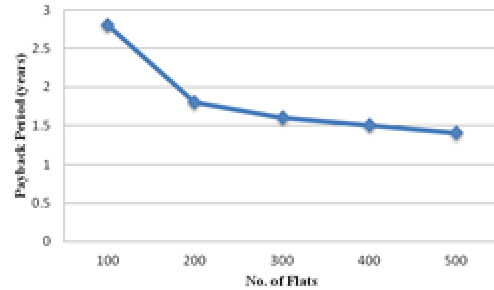

Fig. 4. Greywater Reuse System Payback Periods For Buildings With Varying Number Of Flats.

The Membrane Bioreactor-based reuse system becomes economically feasible when the number of flats exceed 55. The payback period decreases from 2.8 years for 100 flats to 1.4 years for 500 flats which seems to be very economical.

A case study was done by considering an integrated residential complex having 1,828 numbers of flats, a hospital (with 200 beds), a school (with 1,000 students) and a shopping mall (with 25 employees and 175 visitors per day on an average), for which the payback period is $\leq$1 year.

Recycling of greywater does not eliminate the need of a separate treatment plant for treating black water. For this reason, estimations were done on combined area required for installation of a greywater treatment system as well as a separate black water treatment system. The total area required for a Membrane Bioreactor-based greywater treatment system in addition with a conventional black water treatment system (assumed as extended aeration) is 14% less than the total area required for the black water treatment system treating combined wastewater (greywater + black water). The outcome of this analysis shows that the Membrane Bioreactor system has least footprint (since it eliminates the need of a clarifier) and therefore is most suitable for cities like Bengaluru with lack of area for new constructions.

Energy is another important aspect to be considered before implementing any technology. Hence energy requirement for the Membrane Bioreactor-based greywater system was estimated with the help of information collected from leading Membrane Bioreactor manufacturers. According to the estimation, the combination of Membrane Bioreactor-based greywater system and the conventional treatment plant (with extended aeration) required to treat the black water from a building consumes approximately 20% less power when compared to the conventional treatment plant (with extended aeration) treating the combined wastewater from a building.

3.1 Subsidies, Incentives And On-Site Renewable Energy Generation

On-site greywater reuse offers a regional/national scale benefits in regions like Bengaluru which are suffering from water scarcity. Thus, in countries like India where cost is a constraint for the development and implementation of any advanced technologies, the national and or the local authorities may encourage greywater reuse systems by providing subsidies per litre of greywater reused; reduced interests on loan borrowed for investment of these systems, reduced energy costs for treatment and conveyance of greywater and reduced property taxes for greywater reusing buildings, etc.

Also, the governments can implement on-site renewable energy generation by installing wind turbines, solar panels, and other renewable energy generating technologies so that water and wastewater treatment facilities with adequate land and roof area could install on-site renewable energy generators, complementing their efforts to reduce green house gas (GHG) emissions through energy efficiency.

IV. Conclusions

The economic feasibility of on-site greywater reuse systems in multi-storey buildings of Bengaluru city was analyzed in this synopsis. Considering a water price of Rs. 60/KL (US $0.9), the Membrane Bioreactor-based greywater system becomes economically feasible when number of flats exceeds 55 units. The payback period decreases from 2.8 years for 100 flats to 1.4 years for 500 flats. The system will be much more feasible when incorporated for integrated residential complexes. The system is very efficient in terms of area and energy consumption, since it occupies 14% less area and consumes 20% less energy than the conventional combined greywater and black water treatment system.

Hence, the on-site Membrane Bioreactor-based greywater treatment system is the most suitable compact and energy efficient system for Bengaluru city. Incorporation of this system in multi-storey buildings can reduce the overall water demand of the city and hence resolves the problem of water shortage as well as area shortage to a great extent

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Parameshwara Murthy P. M. was born in Bengaluru, India in 1970. He received the B. E. degree in Civil-Environmental Engineering from Sri Jayachamarajendra College of Engineering, Mysuru, Karnataka, India, under University of Mysore, Mysuru and M. E. degree in Environmental Engineering from University Visvesvaraya College of Engineering, Bengaluru, Karnataka, India in 2009-10 respectively.

Currently he is associated with the Department of Environmental Engineering, Sri Jayachamarajendra College of Engineering, Mysuru, Karnataka, India as a Ph. D. scholar. His main area of research interest is treatment and reuse of greywater in urban areas.

He has more than 15 years of experience in the field of design and erection of wastewater treatment plants and systems.

Mr. Parameshwara Murthy has served as a Secretary in the Karnataka Environmental Engineering Research Institute in the past.

Dr. B. M. Sadashiva Murthy was born in Mysuru district, India, in 1967. He received the B. E. degree in Civil Engineering, from University of Mysore, Mysuru, Karnataka, India in 1989, M. Tech degree in Environmental Engineering from University of Mysore, Mysuru, Karnataka, India in 1993, Post Graduate Diploma in Environmental Planning from University of Mysore, Mysuru, Karnataka, India in 1993 and Ph. D. degree in Civil Engineering Sciences from Visvesvaraya Technological University, Belgaum, Karnataka, India in 2010.

He has 23 years of teaching experience including 15 years of Research experience while working at Sri Jayachamarajendra College of Engineering, Mysuru as a Professor. He has also taught Science students of University of Mysore, Mysuru, Karnataka, India and Karnataka State Open University, Karnataka, India and he also serves as an investigator for several research projects.

Dr. Sadashiva Murthy has published 15 international journals, 4 national journals and 17 conference proceedings and has presented research papers in several conferences such as International Workshop on Geoenvironment and Geotechnics - GEOENV 2008, held during, September 7-9, 2008, at Milos Conference center George Eliopoulos, Milos Island, Greece and International Conference on Environmental Science and Technology held during August 6-9, 2007 at Houston, Texas, USA. Also, he is a reviewer to several journal publishing bodies such as International Journal of Engineering Research, International Research Journal of Agricultural Science and Journal of Environmental Science and Water Resources.

He is a member of International Water Association (IWA), Water Environment Federation (WEF) and Rivers of the World Foundation (RWF) and life member of Indian Society for Technical Education, Indian Association for Environmental Management, Indian Society of Environmental Science and Technology and Institute of Public Health Engineering. Also, he is a fellow of Institute of Engineers, India (F-119023-3).

Kavya S. was born in Mysuru, India in 1990. She received B. E. degree in Environmental Engineering from Vidya Vardhaka College of Engineering, Mysuru, under Visvesvaraya Technological University, Belgaum, Karnataka, India in 2012 and M. Tech degree in Health Science & Water Engineering from Sri Jayachamarajendra College of Engineering, Mysuru, Karnataka, India in 2014.

She has been working as an Environmental Engineer from past one year. Her main areas of research interest are water and wastewater management and water and air quality modeling.

Ms. Kavya has published two international journals titled “Multivariate analysis for distribution of phytoplankton communities in two lakes of Mysuru” in the Global Journal for Research Analysis and “Bacillariophyceae as ecological indicators of water quality in two lakes of Mysuru” in the Universal Journal of Environmental Research & Analysis in 2014.