Understanding the Water Footprint of the Urban Dweller

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"*Future wars will be fought over water, So Save Every Drop*". A sticker carrying this slogan was hanging out loose from a dripping faucet near the society club house of Roseland Residency, a cooperative housing society in India's IT hub, Pune. Mr. Raju Kulkarni has just taken over as society treasurer and one of the first bills to come up for sign off was the water tanker invoice. Being an environmental engineer by profession, the quantum of bill comes as a shock to Mr. Kulkarni. The society was compliant with the requirements for rain water harvesting and the city experienced normal rainfall in the year. Yet water was being purchased in huge quantities even in rainy season through tankers. Mr. Kulkarni knows that the solution to this conundrum lies in the understanding of water footprint and effective recycling. He needs to set about gathering data and presenting an effective solution to the society's management committee.

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Introduction:

Roseland Residency is spread over 12 acres, comprising of 1000 flats in 5 towers and containing over 2500 residents. It is a 25 year old society but well maintained with almost all residents co-operative in paying up maintenance dues. According to the Hindu Business Line, the average water consumption is about 135 liters per person per day, with 90 litres for toilet and bathing, 40 liters for washing and cleaning, and another 5 liters each for cooking and drinking and the demand keeps increasing rapidly due to several factors such as mechanization of household activities through the usage of washing machines, dish washers and Jacuzzi bath showers. (Veldkamp, T. I. E., et al.,2017) An assessment of how water is consumed for human purposes can be done by calculating the water footprint (direct + indirect) of a consumer. This includes not only the consumption but also the pollution of water by the user. The direct water footprint includes calculation of the direct use of water at home for activities such as drinking, bathing, washing, cleaning, toilet, cooking and gardening, to name just the major ones. The indirect water foot print includes the usage of water by a consumer through the goods and services consumed such as food, clothes, paper, energy and other industrial goods. (Ojha et al., 2020). Mr. Kulkarni plans to only consider the direct water footprint for formulation of the proposal.

Rainwater harvesting is mandatory for housing societies in Pune and the Pune Municipal Corporation (PMC) has been enforcing this law since 2016. Even before the law was enforced, Roseland Residency had proactively commissioned a pilot rainwater harvesting project covering one tower by spending Rs.2.5 to Rs.3 lakh in 2009. (TOI, 2012). Since then, they have extended the project to all towers. Yet, after a decade the society is unable to manage daily needs without the support of water tankers. The total demand of the water in the society is around 1000 - 1200 lakh liters per annum, while the water received for the PMC is around 70 - 80 lakh litres per annum, the rest of the water comes from the bore wells and water tankers. (Hindustan Times, 2019). Mr. Kulkarni briefs the key members of the management committee of some ground work that needs to be done before any brain storming session for save water costs is conducted. In addition, there are also some terms one needs to be familiar with, in order to make a fruitful discussion on water conservation at the society level.

A. Water Mapping:

A four-phased approach can be adopted for effective water mapping.

1. Prepare for the assessment: This stage includes gathering historic water usage data of sample flats and conducting an initial meeting with key personnel to develop a plan of action.

2. Conduct water audits and build a water balance chart: Once a baseline is developed, the society can quantify the use of water at process level. It can be identified if any specific activity is causing wastage of water or excessive use.

3. Evaluate efficiency opportunities: Options such as low flow fixtures, revamping the storm water drains, grey water recycling and their cost benefit analysis can be looked into in the third phase.

4. Compile results and prioritize: Once a pilot study is carried out, the results can be compiled regarding the costs and resultant benefits of options analysed in the third phase and only acceptable solutions can be prioritized for application.

B. Water Balance:

A water balance chart compares the total water supplied to the site to the actual water consumed at the equipment and process level. The chart also identifies the largest consumers and the potential problem areas with high leak rates. While it is an ideal situation to achieve a perfectly balanced chart, it may not be practically possible to balance more than 80% of the water sources to its uses. Any difference in the water balance equation is attributed to wastages and leakages.

Water balance equation: Total water input = Total water output.

C. Water costs for the year:

The water tanker costs vary depending on the season of the year. During the peak summer, the movement of water tanks between different parts of urban settlements, and their cost can vary from Rs.500 to Rs.1,500 each depending on the month of the year. The volume of a single water tank is around 8000 litres and an indicative chart of the water costs for six months of the year in which the society depends more on water tankers is provided in Exhibit 1. The society on an average procures 20 water tankers a day from the months of January to June. The total price to be paid by the society to procure water tanks to satisfy their needs during the summer season comes out to be between Rs.5 – Rs.10 lakhs per month. Exhibit 2 provides the break-up of water sources for the society on any average day in summer. If the new scheme can show a reduction in this cost, it will lend a lot of support to Mr. Kulkarni's proposition.

The Proposition

After initial assessment of water usage, the following means could be proposed as action plans with a cost benefit analysis worked out:

A. Revisit Ground Water Recharge
B. Grey Water Recycling
C. Low Flow Fixtures
D. Water Audit and Meter system

A. Ground Water Recharge

The current supply for daily usage from ground water is around 150000 litres per day and during summer season this number is highly reduced. The collection through rain water harvesting is estimated to be not more than even 50000 litres during the peak rainy season because of silt deposit and blockage of drains.

An estimate of cost to be incurred for ground water recharge pits and depth of material for recharge pits is given in exhibit 3. Mr. Kulkarni feels that in order to calculate the increased rain water collection, one must carefully consider the annual rainfall, the size of the terrace area (30000 sq.m) and open area (9000 sq.m) for rain water collection and the relevant runoff coefficient (reference IS Code: 15797 : 2008).

B. Grey Water Recycling

Grey water recycling is the removal of unwanted suspended materials from the ground water collected and disinfecting the same to make it useful or discharging to sewer lines

according to the laws applicable. (Al-Zou'.,et al.,2017) Each individual's water requirement is 135-150 lit/day. This results in generation of around 72 litres of grey water a day, which can be recycled to the extent of 80%. The cost of recycling would amount to around Rs.20 per individual per day. (Sushmitha, M et al., 2019).Such recycled water can be used within the residential building for toilets, irrigation, car washing, cleaning etc. In order to use grey water in the toilets, the society needs to be additionally equipped with a two pipe system in such a way that the toilet flush water is provided from such recycled water (Widiastuti, N et al 2008; Godfrey et al., 2009; Parjane & Sane, 2011; Sudarsan J S et al., 2021). A grey water recycling plant can be set up at as low as Rs. 65,000 or as high as Rs. 5 lakhs. The society may decide on whether they want to go in for a high-end plant or a basic model. If the society adopts proper operation and maintenance systems, there is no need for any additional treatment to reuse the water for domestic purpose. In case the same water is used for a longer period, disinfection in the form of chlorination is sufficient.

C. Low Flow Fixtures

Over the years there has been a change in the use of low-flow pipes instead of conventional ones. These are sold at a higher price of 20% compared to regular ones. Low flow adjustments reduce water consumption and also have a positive return on investment made over the years in terms of water use and energy use. Various options for residential home applications include:

1. Low-flow toilets

Toilets account for about 30% of household water use. These toilets use approximately 4.8 liters of water per flush in comparison with 6 liters of water per flush used by conventional toilets. This saves about 10 liters of water / day (in a family of 4).

2. Low flow shower heads

A reduction in consumption by around 2 litres per minute can be achieved by low flow shower heads. This can save around 80 liters of water per day (in a family of 4 people, depending on the bathing time of 10 minutes)

3. Low flow taps

Taps account for more than 15% of domestic water. A water-based bathroom sink faucet can reduce that consumption by more than 30%. That equates to about 2,000 gallons [2,000 L] of water a year.

4. Water-saving tap aerators

By attaching an aerator at the end of a tap or by inserting it into an existing pump, one can hope to reduce the flow of water by 6 litres per minute. This way about 50% save in usage of tap water can be achieved. Usually the aerators are installed in kitchen faucets and bathroom sinks. Aerators such as bubble flow, customer flow, airing flow can be used for this purpose.

Roseland residency estimates that in case all the water outlets in each flat need to be replaced with low flow fixtures, it would cost around Rs. 2 crores, so as to achieve a 15% overall reduction in water consumption. However, as this involves too many changes in the

existing drainage system and structural changes in each resident's housing unit, this idea is not going to be carried forward.

D. Water Audit or Water Meter System

Many residential buildings do not limit the use of water by individual residents. Instead, citizens are charged a fixed amount of housing. Each purchase has never been equitable which results in many citizens paying for the use of others as well. This makes people less concerned about the waste of water in their homes.

Automatic meter reading (AMR): A standard water billing system involves a person visiting each residence and reading the data meter manually. The information collected is used for payment. Manual reading can lead to errors and can lead to corruption. The billing system is therefore likely to be error-free and ineffective. There are potential for leaks and theft that have not yet been identified. The traditional meter provides complete water and does not provide details of when water is used in each meter area. Traditional water meters require a back up charge which may not cost the right amount.Meter Data Management offers several benefits to both services and customers. (Puust, R., et al., 2010) (Kainz et al., 2021) Includes long-term meter data management with a lot of information obtained from smart meters. The information is then verified using a valid engine and stored in a database for payment purposes. (MoHUA, 2020).

Meters play a double role - and meters also detect leaks. Being connected devices, they raise an alarm when they see unusual usage. (Ramos et al., 2020)

Water Meter Data Management (WMDM) includes intelligent data collection, planning and management.)Download and record periodic water readings to identify the amount of water used by the consumer. It makes consumers aware of water use. Water meter readings are automatically collected without human intervention. (Hsia, S. C et al.,2012)

After production, the meters will have a unique ground ID (UUID) that will be printed on the meter and will serve as part of the serial number of the meter. Under normal operating conditions the Data Concentrator Unit will periodically check the meter to read its meter details. It is the Data Concentrator Unit that constantly initiates communication between meters.

The WMDM system enables direct data storage and fast data management for most of the data delivered by smart metering systems. The WMDM system will mainly import data, and verify, debug and measure and make it available for analysis and payment purposes and also it helps in leak detection too indirectly.(Mounce, S. R et al., 2015).

Each meter is connected to a SIM, and WMDM uses existing Global System for Mobile Communications (GSM) networks to transmit data and receive data. It promises fast and accurate billing. The system provides warnings about suspected leaks and theft. (Sudarsan J S et al., 2021; Nazif, S.,et al., 2010). The ultrasonic meters cost around Rs. 11,000 a piece and look worth installing. The society may need 6 meters.

Conclusion:

Each of the above propositions have a lot of potential for saving water and making Roseland residency self-sufficient. However there is also a cost involved in implementing

each of them. In the summer, water is scarce in apartment buildings and the issue of water management is often the subject of strife among neighbors. As people continue to pursue water misuse in apartments, followed by a major water crisis, it becomes a very big challenge for apartments to meet the needs of its residents. While it is common fact that clearance of storm water drains regularly, recycling grey water and installation of low flow devices are the best way forward for water conservation, in a residential society it is a challenge to obtain acceptance from its members with regards to the cost involved in each of these initiatives. Raju Kulkarni is now faced with one such task. He needs to present each of the propositions with an appropriate cost-benefit analysis and then put them up to vote for adoption either wholly or in part. The impact of the proposal will determine whether the society opts to go forward on a progressive note.

Case Questions:

1. Help Mr. Kulkarni create a water balance chart for a sample residential tower based on data in the case and exhibits. You may make suitable assumptions
2. Perform a cost benefit analysis for each of the propositions listed in the case and estimate the potential water saving for each of them. In your opinion which propositions are most likely to be approved by and adopted by the society? Give reasons.
3. Calculate and estimate in how many days/ months of time, the society may be able to recover the cost spent on the three water saving alternatives under consideration, by way of opportunity save in reduction of purchase of water tankers (use pay-back method).

References:

1. Al-Zou'by, J. Y., Al-Zboon, K. K., & Al-Tabbal, J. A. (2017). Low-cost treatment of grey water and reuse for irrigation of home garden plants. Environmental Engineering and Management Journal. https://doi.org/10.30638/eemj.2017.035.
2. Godfrey, S., Labhasetwar, P., & Wate, S. (2009). Greywater reuse in residential schools in Madhya Pradesh, India—A case study of cost–benefit analysis. *Resources, Conservation and Recycling*, *53*(5), 287-293.
3. Hindustan Times. "PCMC plans 'electromagnetic' water meters to ensure 24x7 water supply." https://www.hindustantimes.com/cities/pcmc-plans-electromagnetic-water-meters-to-ensure-24x7-water-supply/story-wJJlczE4LwgSxox1gCtZHP.html (2019) (accessed on March 16, 2021)
4. Hsia, S. C., Hsu, S. W., & Chang, Y. J. (2012). Remote monitoring and smart sensing for water meter system and leakage detection. *Wireless Sensor Systems, IET*, *2*(4), 402-408.
5. IS 15797: 2008 (Indian Standard). (2008). "Roof top rainwater harvesting – guidelines." Bureau of Indian standards, New Delhi. 1–1
6. Kainz, O., et al. "Non-standard situation detection in smart water metering." *Open Computer Science* 11.1 (2021): 12-21.
7. MoHUA. "Advisory on Water meters, Instrumentation and SCADA". CPHEEO (2020)
8. Mounce, S. R., Pedraza, C., Jackson, T., Linford, P., &Boxall, J. B. (2015). Cloud Based Machine Learning Approaches for Leakage Assessment and Management in Smart Water Networks. *Procedia Engineering*, *119*, 43-52.

9. Nazif, S., Karamouz, M., Tabesh, M., &Moridi, A. (2010).Pressure management model for urban water distribution networks. *Water resources management*, *24*(3), 437-458.
10. Ojha, Hemant, et al. "Scarcity amidst plenty: Lower Himalayan cities struggling for water security." *Water* 12.2 (2020): 567.
11. Parjane, S. B., & Sane, M. G. (2011). Performance of grey water treatment plant by economical way for Indian rural development. *International Journal of ChemTech Research*, *3*(4), 1808-1815.
12. Puust, R., Kapelan, Z., Savic, D. A., and Koppel, T. (2010).“A review of methods for leakage management in pipe networks.” Urban Water J.,7(1), 25–45.
13. Ramos, Helena M., et al. "Smart water management towards future water sustainable networks." *Water* 12.1 (2020): 58.
14. Sudarsan J S, Kakuru Jyothi Priyanka Reddy, Haseeb.A.H. Biyabani Purnima Kumari and Swati Sinha, (2021), “Impact of Fragile Water Management Strategies and Mitigation-A Case Study of Pune City, India” IOP Conf. Series: Materials Science and Engineering 1026(1),1-6.
15. Sudarsan.J.S , Vaishampayan.S, Srihari.V ., (2021). Grey water recycling as a tangible solution to water crisis: A case study in Thiruvananthapuram, India International Journal of Energy and Water Resources, https://doi.org/10.1007/s42108-021-00116-6.
16. Sushmitha, M. B., Chanakya, H. N., & Khuntia, H. K. (2019). Efficient Grey Water Treatment and Reuse Options for India — A Review. Springer Nature Singapore Pte Ltd, 3(July), 143–149. https://doi.org/10.1007/978-981-13-2619-6.
17. TOI. “Pimpri-Chinchwad Municipal Corporation sets up water monitoring system”.http://timesofindia.indiatimes.com/articleshow/12829191.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst (2012) (accessed on March 16, 2021)
18. Veldkamp, T. I. E., et al. "Water scarcity hotspots travel downstream due to human interventions in the 20th and 21st century." Nature communications 8.1 (2017): 1-12.
19. Widiastuti, N., Wu, H., Ang, M., & Zhang, D. ke. (2008). The potential application of natural zeolite for greywater treatment. Desalination, 218, 271–280. https://doi.org/10.1016/j.desal.2007.02.022.
20. Worm, J. (2006). *AD43E Rainwater harvesting for domestic use* (No. 43). Agromisa Foundation.