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Water Conservation and Environmental Sustainability Approach

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Abstract. Water availability is finite over the world, which requires a controlled usage due to increased population, urbanization, and uneven population distribution. Domestic water usage is one of the major consumptive uses of water, which not only uses the precious water resource but also imparts considerable environmental effects through its carbon emissions in the installation and operational phases. Controlling domestic water usage can help reduce both water consumption and protect the environment. For this purpose, a case study was carried out, where an existing housing society (with fixed billing system) was compared to the metered water supply scheme of similar parameters. Water usage for the two societies was compared to assess the potential water saving, using a conservative assessment. The analysis included both installation and recurring works variables along with their carbon emissions. Suggested policy parameters, by introducing bylaws and other regulatory procedures, to be applied at all residential societies across Pakistan, have also been defined for enforcement of the water metering system. The results show that anticipated water conservation and enforcement of bylaws can not only preserve the precious water resource but can also reduce the carbon credits to help develop a sustainable approach.

Keywords: Water Metering, Water Conservation, Environmental Sustainability, Carbon Credits, CO_2 Emissions.

1 Introduction

Uneven distribution of finite water resource and increasing population makes it difficult to conserve water while meeting the agricultural, domestic, commercial, industrial and ecological needs of water. Additional contributing factors include urbanization, population increase and uneven distribution of water converse to global population distribution. Industrialization and technological advancement have contributed to form a further complex matrix generating global impacts, with the USA and China producing the highest carbon emissions in the world. Because of high population density, population growth rate, proximity of the region adjacent to China, and with stressed water availability in the region, South Asia is one of the most affected regions for water scarcity index. Pakistan is no exception to this situation. Environmental impacts and global warming demands a sustainable approach for water conservation and usage. Domestic water usage contributes considerably to global water needs. Water conservation through water metering and volume based payment in area of domestic usage can help preserve precious water resource and save upon carbon credits to conserve both water and environment to form a sustainable approach.

2 Literature Review

Pakistan is a water scarce country with having already crossed the water stressed index in year 1990 and water scarcity index in year 2017 as per standards defined by World Health Organization (WHO). The projected increase in the population is about 2.5 times by 2025 in comparison to 1990 population level, resulting in the same increase for water demands, which enforces reduction in per capita annual availability of water. A comparison of the water availability is given in Table 1 with other countries of the world. The availability of water per capita per year accounts for the projected increase of the population and the anticipated depletion of the water both in water reservoirs as well as in the ground water due to over extraction. The number of pumping units in Pakistan for ground water extraction has increased by more than 100% since 1990 with no statistical records of over extraction quantities [1].

Water conservation measures like water metering are actively being taken by many developed countries like USA, France, Germany, UK etc. However, Pakistan is not making use of the available methods with already depleting surface and ground water resources and increasing population. Water metering ensures effective use of water with charges comparable to the used volume of water in comparison to flat rate payment irrespective of the used quantity [2].

Table 1: Comparison of Water Availability for Different Countries

Country	**Year (in Cu M/ Capita-Year)**		
	1955	**1990**	**2025**
China	4597	2427	1818
Philippines	13507	5173	3072
Mexico	11396	4226	2597
USA	14934	9913	4695
Iraq	18441	6029	2356
Pakistan	5250	1672	837

In 2010, the Universal Metering Program (UMP) was initiated by Southern Water in South East England being a water stressed area. This program resulted in an installation of 500,000 meters covering 90% of the houses in the area with volume based payment, resulting in a considerable reduction in water consumption [3]. Various studies have shown a remarkable reduction in water consumption after installation of metering system with volume based payments. One of the very earlier studies was conducted by Hanke in Boulder, Colorado which showed a 35% decrease in domestic water use [4]. Various other studies showed decrease of domestic water consumption with metering and volume based payments [5,6,7,8]. A summary of water reduction is shown in Table 2.

Table 2: Summary of Domestic Water Reduction Based on Metering System

Country / Area	Reduction Achieved
East England	16.5%
Boulder , Colorado, USA	35%
California, USA	54 Gal/Day
Bakersfield	37 Gal/Day
Chico	13 Gal/Day
Fresno	17%
Multiple Areas	15%

Charles conducted a study to formulate a parameter based formula for the water consumption in a residential society [9]. Variables included market value of dwelling (V), age of the dwelling unit (a) which accounts for the leakages and wastage, number of persons per dwelling (d_p), billing periods (p_w) and average water pressure (k) for annual quantity of domestic use per dwelling unit per day (q_{ad}) as shown in Equation 1.

$$q_{ad} = f\,(V,a,d_p,k,p_w) \qquad (1)$$

The linear regression resulted in two different relationships with public sewers and with septic tanks, as given by Equation 2 and Equation 3, respectively.

$$q_{ad} = 206 + 3.47V - 1.30\,p_w \qquad (2)$$

$$q_{ad} = 30.2 + 39.5\,d_p \qquad (3)$$

Water supply and usage enforces both capital and recurring costs. The capital cost includes a huge infrastructure to include underground and overhead water tanks both in the society and in the household units, pipe lines, pumping units, and civil works for water purification and filtration. The recurring cost includes operational and maintenance cost. This not only imparts high economic value but also accounts for a high production of carbon emissions over the life time. A unified carbon emission expression can be applied to the life cycle, which calculates the carbon emissions (E) based on the engineering quantities (Q) and the emission factor (EF) as given by Equation 4 [10]. The detailed material emission calculation accounts for the material preparation, transportation and on-site construction. Carbon emissions for some building material relevant to water supply schemes and related to pumping/ recurring activities are listed in Table 3 and Table 4 respectively.

$$E = Q \times EF \qquad (4)$$

Table 3: Carbon Emissions for Building Materials (Related to Water Supply)

Construction Material	CO_2 Emission Factor
Steel Bar	3.15 tCO_2/t
Cement	0.86 tCO_2/t
Concrete	0.48 tCO_2/m^3
Composite Mortar	0.34 tCO_2/m^3
Cement Mortar	0.40 tCO_2/m^3
Clay brick	0.20 tCO_2/t
Concrete Block	0.12 tCO_2/m^3

Table 4: Carbon Emissions for Water Pumping (Related to Water Supply)

Construction Material	CO_2 Emission Factor
Raw Coal	2060 gCO_2/Kg

Diesel	970 gCO_2/kWh
Electricity	3180 gCO_2/Kg
Natural Gas	2700 gCO_2/Kg
Solar Photovoltaic System	50-250 gCO_2/kWh
Nuclear Power	10-130 gCO_2/kWh
Wind Turbines	15-25 gCO_2/kWh
Bio-Diesel	1900 gCO_2/Kg
Wood Residues	1750 gCO_2/Kg

3 Research Methodology

This study comprised of the collection of data from a housing society with flat billing system which provides us sufficient data for the housing units types, water pumping system information comprising of its yield and recurring cost, housing society bylaws for the water storage and domestic use policy, and financial details for billing cost and pumping/maintenance cost information. A housing society (Askari XIV) was selected for the purpose, which provided us with sufficient data of above mentioned parameters. The methodology adopted is presented in the schematic diagram in Figure1.

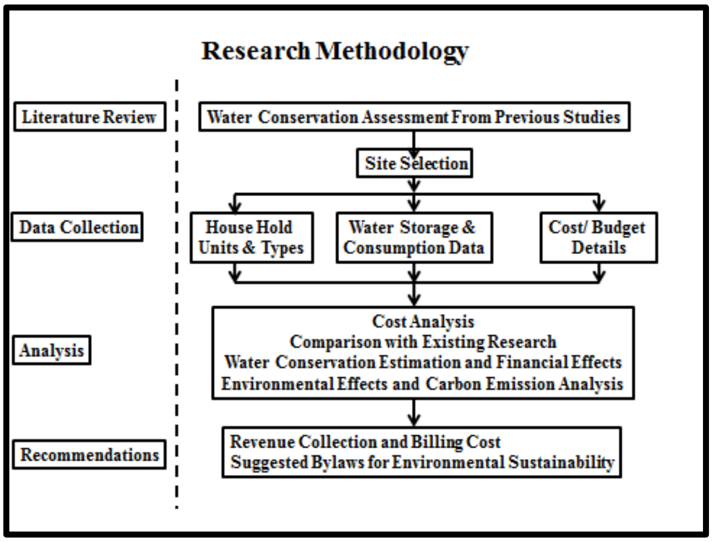

Figure 1: Schematic Diagram for Research Methodology

4 4 Analysis

The society consisted of a total of 1699 units which formed three categories of housing units in three sectors of the society, including separate units (SU), semidetached units (SD), and flats. A total of 8 pumps (five 15 HP pumps and three 25 HP pumps) with underground and overhead water tanks ensured water supply at the stipulated times. Although the pumping capacity had reduced over time due to numerous factors including water table depletion, the capacity was still sufficient to meet the consumer needs. Water statistics showed that 88% of the water supply in the housing society was consumed in the housing units, whereas, commercial and horticulture sector consumed 5% and 7% of the water supply, respectively. Although the data for water consumption for each housing unit were not available but the sector wise type of houses and average inhabitants were available for each housing unit, which helped normalize the data for water consumption of each unit compared to water supply/ pumping for each sector (sector wise water consumption/ water pumped in the system data were available).

The analysis showed that water supply was being made at a subsidized rate on a flat billing system, which covered only 10-15% of the recurring cost depending on the type of units and the number of inhabitants. The available water, as per pumping statistics, was about 190 liter/capita/day, which is about 95% of international health standards (Indian Code of basic requirements for water supply, drainage and sanitation i.e., IS1172:1993, Revised 2002). International health standards encompass a high safety factor, thus there were no water shortage complaints in the society.

As the society bylaws allowed storage of water both in overhead and underground water tanks, with flat billing system, without meters, costing only 10-15% of actual recurring cost, which resulted in a high rate of excess water usage. These factors envisaged a high rate of water usage reduction. However, the society was compared to the water reductions achieved in previous studies as mentioned in Table 2 above. A safe conservative estimate of 17% was assessed basing on the comparison of different parameters of the under study society, with the societies of previous researches, which included climatic conditions, water availability, public awareness, water consumption patterns, and effects of metered billing. Thus the water requirement was anticipated to be reduces to about 153 liter/capita/day. This reduced the total water requirement from international standards of 388862 gallons/day and available water of 370788 gallons/day to 330532 gallons/day for the existing number of inhabitants and housing units as shown in Figure 2.

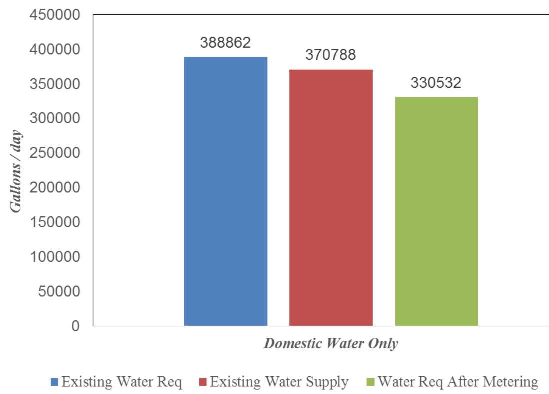

Figure 2: Water Demand for Different Options

Most critical parameter contributing to water reduction is attributed as the cost effect which accounts for volume based payments with no subsidies. With the suggested billing criterion having existing use of water, the billing cost will increase to about 4-6 times depending of type of house and number of inhabitants, which will have serious implications for users. This will help reduce the water consumption considerably. An anticipated reduction of 17% to about 153 liter/capita/day will increase the billing cost to about 2 -2.5 times, which will help achieve the desired water reduction. Thus a serious penalty in the water billing exceeding 153 liter/capita/day for each housing units can help prevent the excess water usage with less effects on the billing cost. Although the increase in water billing is very high but the total effects on the monthly household budget with existing water consumption and anticipated water consumption is 2.5% and 1% respectively. The detailed cost analysis is shown in Figure 3.

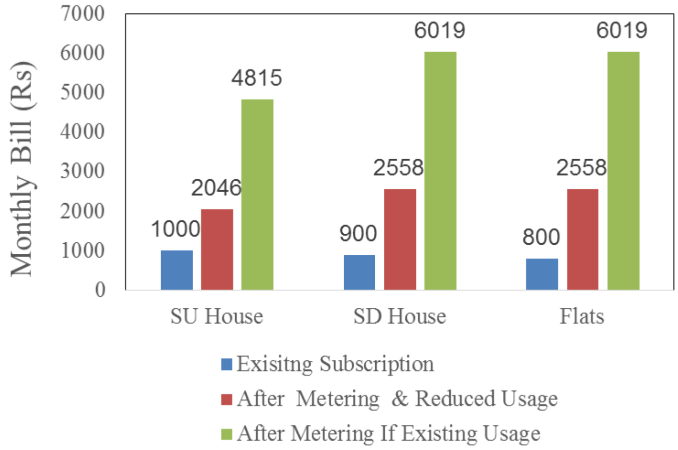

Figure 3: Water Billing for Different options

Current water supply and demand balance along with the available storage capacity both in underground and overhead water tanks of the society can easily accommodate the daily water requirement including the peak hours demand. Also the overhead water tank can fulfil the requirement of gravitational flows to the housing units' overhead water tanks. Thus the underground water tanks impart and additional cost and environmental impact, both for the construction of the underground water tank and the additional pumping of each housing unit to shift water into the overhead water tank. Thus elimination of underground water tanks can save upon the CO_2 emissions for construction of these tanks and for the recurring pumping. The pumping carbon emission for small pumping units is negligible, which is neglected. However, the construction CO_2 emissions for all the housing units of the society impart a heavy carbon emission load to the environment, which amounts to 4125 tons of CO_2 as one time measure. The details are shown in Table 5.

Table 5: CO_2 Emissions for Underground Water Tank Construction

S. No	Material	CO_2 Emission	CO_2 Emission Ton

		Ton/House	(For all Units)
1	Concrete and Bricks	1.6264	2267.2
2	Steel	1.33	1857.2
3	**Total**	2.96	4125

The reduced water consumption also results in reduced water pumping requirement for the society water supply system, resulting in saving the carbon credits (for reduced pumping of 2.5 hours per day for 8 pumps, including three 25 HP and five 15 HP pumps), which amounts to about 75 tons of CO_2 per year, calculated according the carbon emissions given in Table 4 above. The comparison is shown in Figure 4.

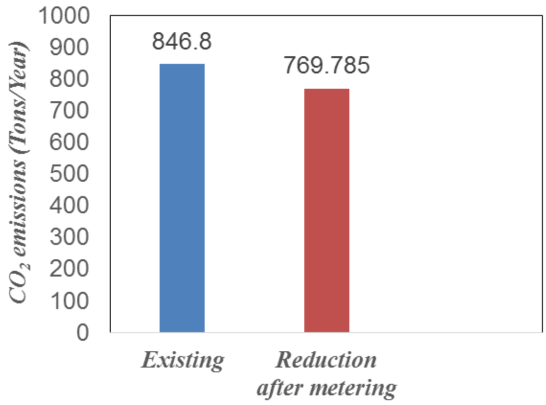

Figure 4: Carbon Emission Comparison for Pumping of Existing and Reduced Water Supply

5 Recommendations

Based on the effects generated by the water conservation technique, following is recommended to be implemented as pilot project, for further implementation on gross root level:

- Water meters be installed in all the housing units
- Volume based billing system be implemented without any subsidy
- Heavy penalty be imposed in the billing for higher units consumption then the anticipated reduced rate of 153 litter/capita/day to enforce water saving
- Billing cycle be continued on monthly basis
- Changes be incorporated in the housing society bylaws where the underground water tanks are not allowed to be constructed
- Public awareness campaigns be also run for a better and faster outcome

6 Conclusion

Water is a precious resource which needs conservation for its sustainable use to meet the population thrust and diversified uses of water for human needs. The environmental impacts for the anthropogenic activities related to water supply also need to be reduced for sustainability. Therefore, this case study has been carried out to investigate these two parameters of water conservation and CO_2 emissions' reduction. Practical application of the same can help identify further room of improvement and application of gross root level.

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