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# Smart Water Solution for Monitoring of Water Usage Based on Weather Condition

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## ABSTRACT

Conservation of water in urban areas is an ongoing challenge in which technology like IoT and WSN is playing a very crucial role. Studies show that 54% of India is facing absolute water scarcity or high economic water stress. To address this challenge the forecasting and monitoring of water consumption along with effective management and distribution are important. This paper implements the seasonal threshold constraint on water distribution which conserves a significant amount of water loss over uniform supply around the year by considering end-user behavior changes according to the season. The results have been confirmed through simulation of the proposed algorithm Weather-based Smart Water Monitoring (WSWM). This extensive study only suggests a possible alternative approach to design the water distribution system to conserve water. However, more work is required for achieving an optimized approach for sustainable urban water management.

**Key words:** Smart Water, Wireless Sensor Network, Water Sustainability, Water Grid.

## 1. INTRODUCTION

Water is a resource that is essential for the survival of mankind. Though 70 per-cent of Earth surface is covered with water, availability for human use is very less [1-2]. Drastic climatic change and explosive population growth has led us to critical problems like water scarcity and water pollution. Approximately 2.7 billion people are living in water shortage already [2-4]. The increasing water demand and depleting water resources gives rise to challenges such as sustainable smart water management systems [5-6].

### 1.1. Water Consumption Scenario in India

India which is home to 16 percent of the world population has only 2.5 percent of landmass and only 4 percent of water resources. Though an approximate of 4,000 trillion liters of precipitation is received every year only 1,869 trillion liters are retained by the inland water bodies and man-made reservoir [7-8]. Out of the total amount of water available 1,122 trillion liters can be exploited due to topological constraint and inefficient distribution networks. In 2010 consumption of the country was 581 trillion liters out of which the domestic demand is around 41 trillion liters [9-10]. With the growth of population and an increase in demand the per capita availability of water has come down and is likely to decrease further in the future [11-12]. By 2025 it is expected to lower by 36 percent and by 2050 the forecast is a decrease of 60 percent in per capita water availability. While water scarcity is ever increasing, a huge amount of water is lost in the process of distribution in India [13-14]. These scenarios further justify the need for an effective water management system that monitors consumption and achieves proper distribution which can be attained through IoT and ICT [15-16].

### 1.2. IoT and ICT

IoT is the concept where everything that is network-enabled be connected to form a network. The information collected from a network are needed to be converted, stored, protected, processed, transmitted and retrieved [17-18]. The technology involved in this information processing is ICT. The application of these technologies is extensive and plays an important role in the planning of smart cities [19-20]. The various applications of IoT and ICT in designing smart cities are shown in Figure 1.This paper focuses on the improvement of an energy-efficient clustering algorithm by extending the existing algorithms LEACH and SEP. For our work, we have considered homogeneous energy level among sensor nodes and the nature of sensor nodes are static [21-22]. Our proposed algorithm is a mimic of the chameleon attack which executes in two phases. The first phase implemented the calculation of residual energy of SNs and sorting them in descending order. From the sorted value, the top 10% of High residual energy-based nodes clubbed in a set called CH-set. And the second part of execution is responsible for cluster formation by measuring the INN gap which is based on nature-inspired phenomena [23-25] . Our proposed procedure advocates against the adopted sub-operations by our existing traditional algorithms LEACH and SEP. The simulation and evaluation of REACH are compared against the above said traditional algorithms individually. In our clustering process, we also paid the same level of attention to the energy-saving scheme [26-27].

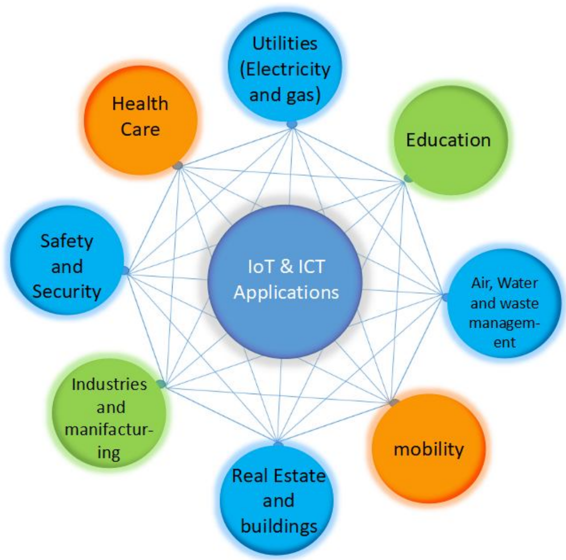


**Figure 1:** Application of IoT and ICT in Smart Cities

### 1.3. Household Water Consumption

Water consumption of a household is always affected by various factors like the size of the family, topology, income, etc. Season is also one of the factors affecting household water consumption [28-29]. An average Indian uses about 150 liters of water a day but water requirement may vary from 48 to 74 liters per person per day in winter to 66 to 104 liters per person per day in summer. Figure 2 represents the domestic water consumption per household and capita per day of major cities in India [30-31].

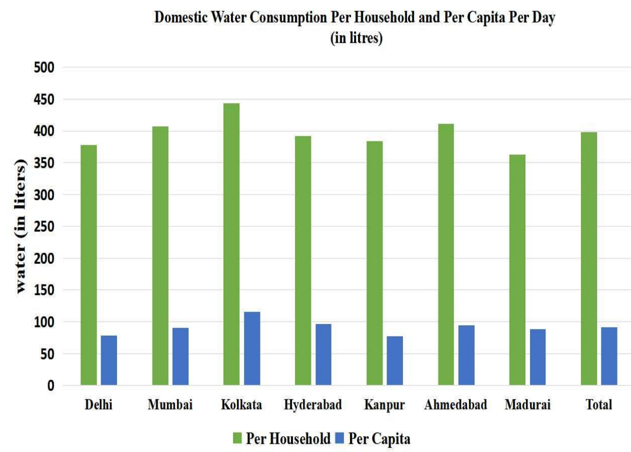


**Figure 2:** Water Consumption Rate Per Capita

Smart water management is one of the many challenges of a Smart City plan that can be solved through ICT based technology. Figure 3 shows various problems that are needed to be addressed to achieve an effective smart water management system. However, water consumption monitoring is the prime focus of this study as consumption monitoring can help the inefficient use of water and conservation [32-33]. Information collected about water consumption of a household from the smart water meter can be used for consumption monitoring [34-35].


**Figure 3:** Components of a Smart Water Management System

The rest of the paper is organized as follows; Section 2, discusses the recent developments in the field of smart water management using IoT or ICT briefly. Section 3, shows the proposed model for water consumption monitoring and supply distribution to conserve water. Section 4, discusses the algorithm for threshold detection and the results of the simulation. Section 5 concludes the paper and highlights some of the future issues that are to be addressed.

## 2. LITERATURE REVIEW

Optimization at the water distribution stage is considered as an important step for saving water and capital in the urban water cycle. Some studies show early leak detection [36] and determination of peak demand for pumping schedules [37] can achieve this goal. The methodology followed in this study starts with the installation of a high-resolution Smart water meter. The end-use consumption patterns are developed by analyzing data collected from the Smart water meter and normalization of these patterns is done for each end-use. Estimation of indoor and out-door consumption of water splits is carried out leading to the development of final AD patterns and peak demand curves. Some studies also show that understanding customer demand can achieve better water efficiency [38] and making the customer aware of their consumption can help in water-saving [39]. Most of these studies are paper-based interventions like leak notification letters, feedback postcards, In-home displays, and online portals [40] and suggest customer's awareness as a key factor in sustainable management of water [41]. However, the domestic water consumption is influenced by various weather conditions, economic and socio-demographic factors [42]. Water consumption varies significantly with variation in temperature. Higher temperature results to increase in water consumption [43]. Precipitation also affect the water consumption. Water demand forecast with various explanatory variables of consumption [44]. Re-engineering of some traditional urban water management processes by application of smart water meter[45] and advanced data analytic tools was also suggested and use of a software tool that automatically dis-aggregates and synthesizes higher consumption rate water end-use data of costumer into reports using a hybrid combination of data mining techniques and pattern recognition algorithms for better water use monitoring has also been proposed [46]. Optimization of pipe network modeling, Improvisation in water demand forecast, and development of more targeted conservation programs during the time of water scarcity can be achieved by the use the pro-posed software [47]. Along with the Smart metering technology, this software can lead to better detection of leaks, reduction of peak demand, pumping schedule optimization, and improvisation in the management of wastewater. for water management has been attempted by researchers [47]. Some researchers have used weather conditions in the construction of water demand models using a non-linear climatic effect based on monthly time series and annual time-series.

## 2. PROPOSED METHOD

After an extensive study, it was found that it is necessary to supply water to consumers based on the seasonal threshold. A model is proposed to implement it effectively. This model suggests the collection of consumption data from the user and calculates the threshold for each season. Water is supplied based on the threshold.

### 3.1 Protocol Architecture

The first step towards designing an efficient monitoring algorithm is protocol de-sign which chalks out the overall study flow and highlights the requirements for the algorithm. Data about water consumption behavior collected from various sources used to set an approximate threshold for every season. The algorithm WSWM is designed based on the architecture model shown in Figure 4. The purpose of the algorithm is to monitor water consumption and to keep a check on excess water supplies. The realization of the architecture and WSWM is achieved by simulation along with the data evaluation after seasonal channelization to show that water can be conserved by following this model. Figure.4 shows the protocol architecture of the proposed model.

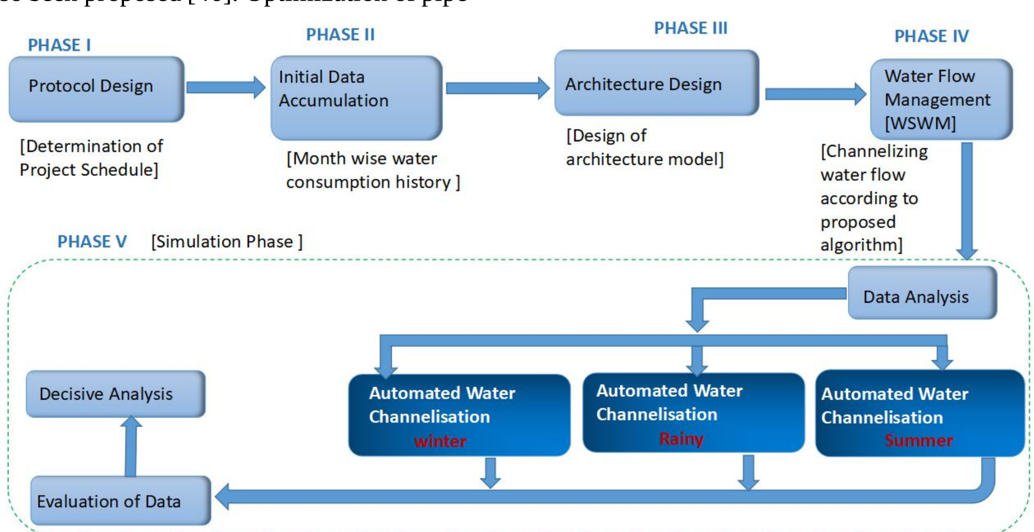


**Figure 4:** Protocol Architecture

### 3.2 System Model

Each node in the network is a smart water meter along with a data logger or sensor which sends data to the cluster head [34-36]. The cluster head sends accumulated in-formation to the base station. The base station maintains a log table that is accessed by the WUC (Water Utility Centre). The log table contains an identifier for each node and water consumed at that node per month is updated. The WUC fixes the threshold for water uses and has the authority to change it based on weather and availability. The node where the reading of the meter exceeds the predetermined threshold is charged with an extra amount or the supply is stopped. Figure 4 shows the proposed system model. It is a combaination of 4 phases such as; protocol design, intital data accumulation, architecture design and water flow management. The water flow management unit is assisted by data analysis section. This section monitors water usages during the different times of a year. These collected data from several monitoring sections, forwarded for further evaluation. The analysis on same collected data, helps to bring a clear picture for efficient decision making process. The decisions like tariff plans, water consumption monitoring, water supply monitoring, generation of water wastage and water usage reort.

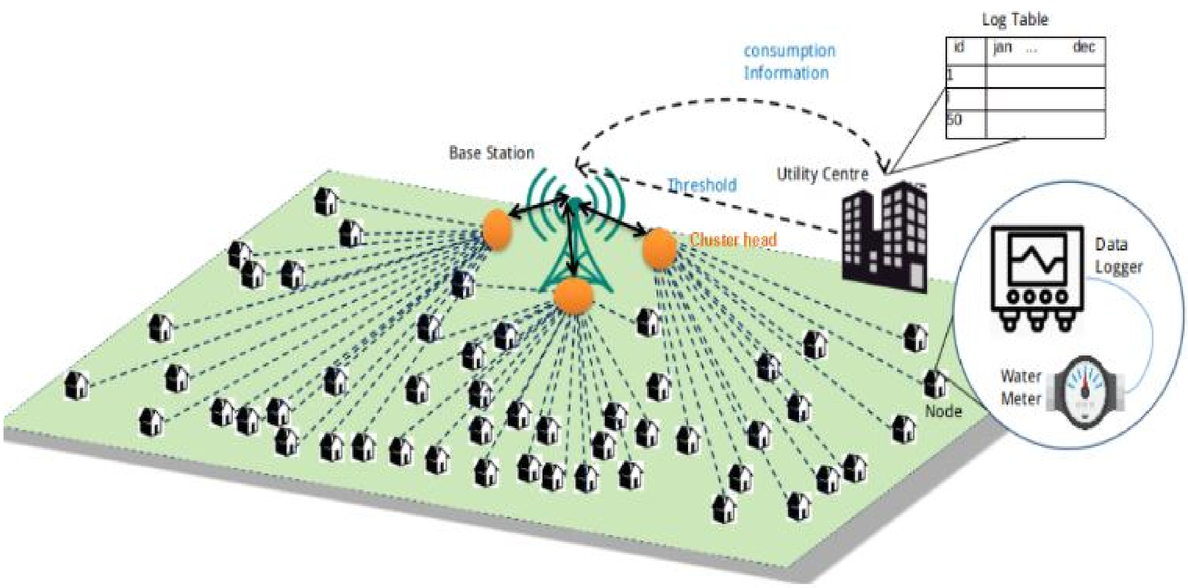


**Figure 5:** System Model

## 4. PROPOSED ALGORITHM

### Weather based Smart Water Monitoring (WSWM) Algorithm

The algorithm which is used here to determine the threshold for each season and the action that is to be taken with variation in weather is named Weather-based Smart Water Monitoring (WSWM) algorithm.

**Algorithm: WSWM**
**Input:**
Per head Water consumption ($\mathbf{w_p}$)
Member in a family ($\mathbf{n}$)
Per family Water consumption ($\mathbf{w_f}$) = $\mathbf{w_p \times n}$
Threshold Water consumption ($\mathbf{Th_w}$)
**Process:**
1. Initialize Water supply from Utility Centre (U.C.)
2. Initialize $\mathbf{Th_w}$ based on weather
3. Initialize Calendar
4. Check(month) & fix ($\mathbf{Th_w}$)
5. Compute(wp) & Compute($\mathbf{w_f}$)
6. If ($\mathbf{w_f \geq Th_w \times n}$)
   **Stop** (Water supply from U.C.)
   **Go to** (Extra water demand phase)
   **Apply** (Extra Charges)
   **Else**
   **Abort** (Water Supply)
7. Repeat Steps (1- 6) for each day at each node (where each node represents a house).
8. Return (water consumption statistics)
9. Stop

**Output:**
1. Monitoring water consumption
2. Reduce excess water consumption
3. Generating revenue

**Sub-Algorithm: Extra Water Demand Phase**
**Input:** Data (Water monitoring sensor data from each node)
**Initialize:** Excess water demand from costumer end.
**Process**:

1. SN (data)=> BS
2. BS(Information)=> UC
3. UC (Decisive Operation)

**Output**: Decisive Action

Where, the per head water consumption is ($\mathbf{w_p}$), number of members in a family is (**n**) and threshold ($\mathbf{Th_w}$) are taken as inputs Weather based Smart Water Monitoring (WSWM). Every day threshold for a household is calculated by multiplying the number of members with the predetermined threshold. The total consumption of a household is denoted as $\mathbf{w_f}$. The value of the $\mathbf{Th_w}$ varies according to the season as $\mathbf{Th_{ws}}$ for summer, $\mathbf{Th_{wr}}$ for rainy and $\mathbf{Th_w}$ for winter. The per family water consumption ($\mathbf{w_f}$) is compared to threshold. If $\mathbf{w_f}$ exceeds the household threshold decisive action is taken by the utility center either in the form of extra charge or abortion of water supply depending upon the availability.

### 4.1. Results and Discussion

The simulation is done using CupCarbon U-one 3.8.2. A cluster of 40 sensor nodes along with a base station is deployed and a homogeneous family structure of 4 members along with uniform water usage patterns are considered here. The threshold for each season is set at each node. When the supply from the base station exceeds the seasonal threshold, the node sends a signal to the base station to stop the supply. Figure 6 shows the deployment of sensor nodes and base stations for a single cluster. Here 40 sensor nodes along with a sink node are deployed over an area of Sambalpur *(Ref: Fig.6)*.


**Figure 6:** Deployment of SN

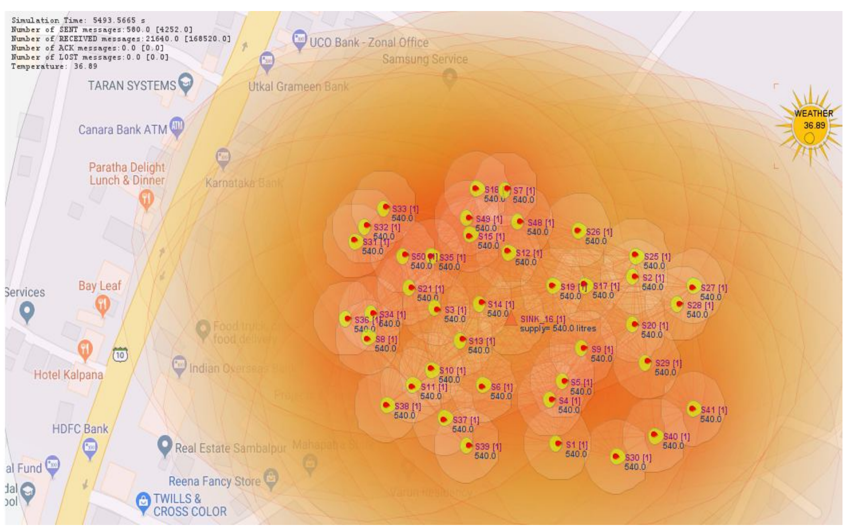


**Figure 7:**(a) Simulation for Summer

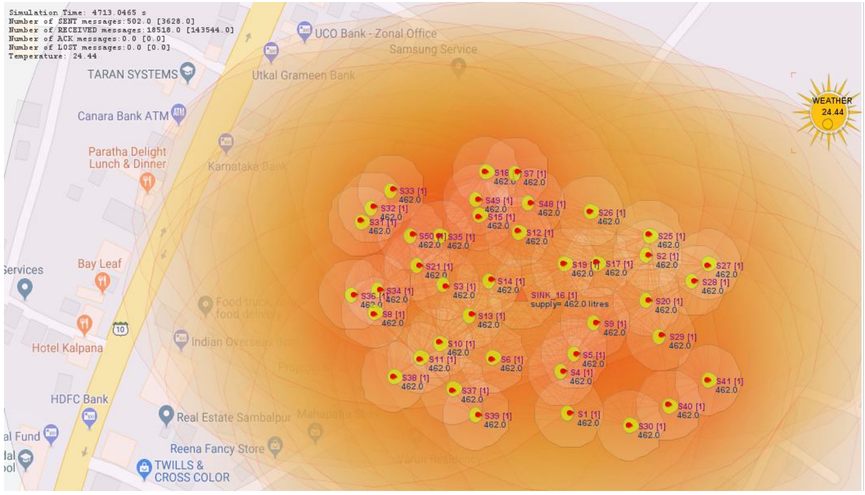


**Figure 7:** (b) Simulation for Rainy Season

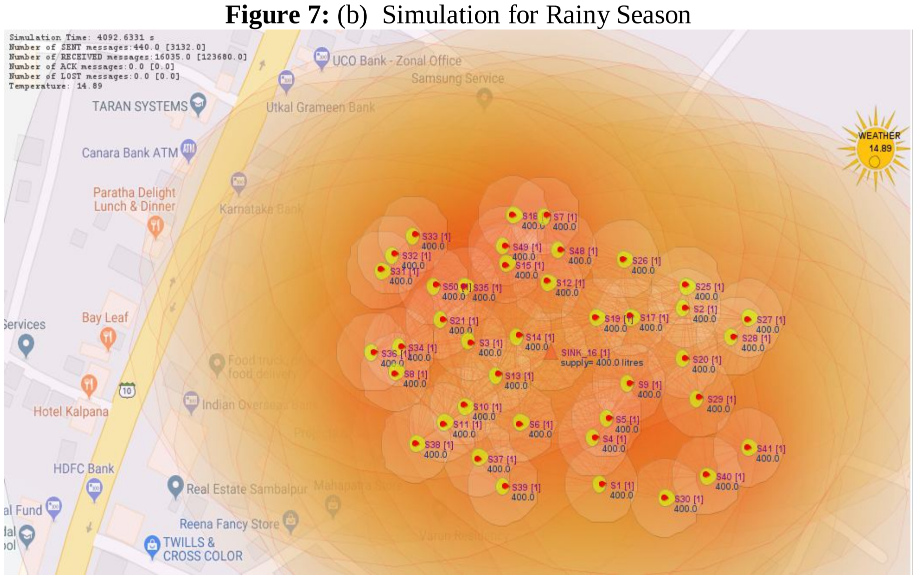


**Figure 7:**(c) Simulation for Winter

Figure 7(a) shows the simulation for the summer season where the temperature is 36.89-degree Celsius and the threshold is set to 540 liters per day per node. Figure 7(b) shows the simulation for the rainy season where the temperature is 24.44 degrees Celsius and the threshold is set to 462 liters per day per node. Figure 7(c) shows the simulation for the summer season where the temperature is 14.89-degree Celsius and the threshold is set to 400 liters per day per node.

Figure 9 represents the comparison between uniform supply throughout the year and supply based on the seasonal threshold. The blue curve and the red curve represent the uniform water supply around the year and supply based on seasonal threshold respectively, whereas the green curve represents the amount of water that can be saved per month in liters. The water supply can lower to 6828.24 kl from 8760 kl in a year. An approximate of 1931.76 kl of water can be conserved in this cluster in a year.

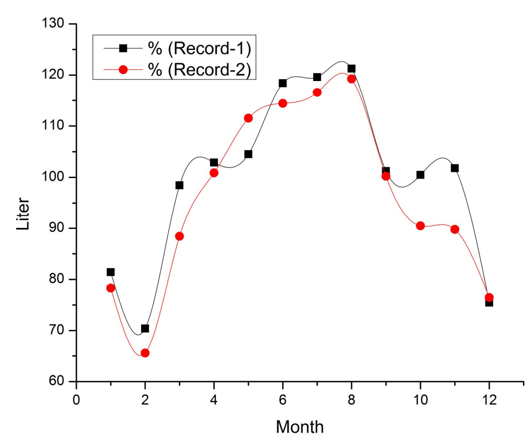


**Figure 8:** (a). Average daily water requirement per person based on the 12-months

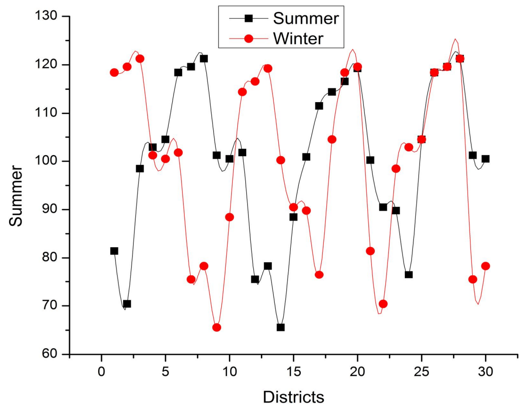


**Figure 8 :**(b). District Wise Water Monitoring Statistics

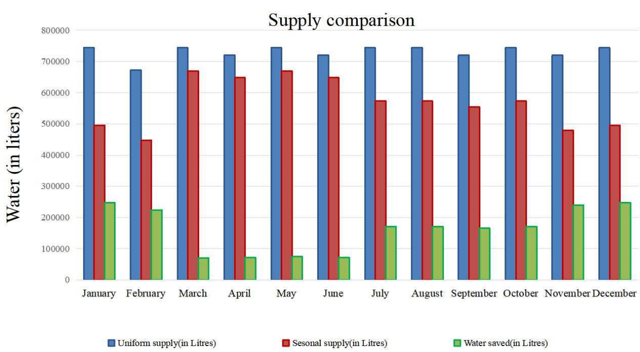


**Figure 9:** Uniform and seasonal supply comparison

Figure.10 illustrates the water consumption statistics based on summer and winter season. During this study data of 30 districts of Odisha state has been used. From the graph it can be clearly understandable that the water consumption during summer is comparatively hiogher then winter.

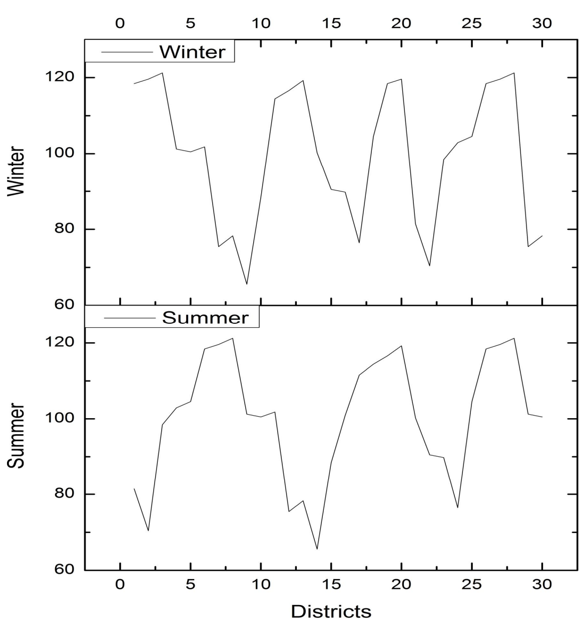


**Figure 10:** Season wise water consumption within 30 districts

## 5. CONCLUSION

Water is the driving force for the survival of life on Earth. The gap between supply and demand is gradually increasing which, is an alarming issue for survival. The uncontrolled supply and uses are the main cause of water loss. The existing system fails to monitor and control the wastage of water. The proposed WSWM model regulates the water supply based on weather conditions which save a substantial amount of water from wastage. The deployment of smart water is a long term and gradually evolved process. The adoption of the threshold factor gives two major advantages such as regulated water consumption and revenue generation. In our result, we illustrated the clear difference in water consumption by weather conditions. The possible future direction of investigation is a consideration of floating water demands from the end-user.

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## APPENDICES

**Table 1:** District Code used for Figure 8(b)

| | | |
|---|---|---|
| 1. Angul | 11. Ganjam | 21. Koraput |
| 2. Balangir | 12. Jagatsinghapur | 22. Malkangiri |
| 3. Balasore | 13. Jajpur | 23. Mayurbhanj |
| 4. Bargarh | 14. Jharsuguda | 24. Nabarangpur |
| 5. Bhadrak | 15. Kalahandi | 25. Nayagarh |
| 6. Boudh | 16. Kandhamal | 26. Nuapada |
| 7. Cuttack | 17. Kendrapara | 27. Puri |
| 8. Deogarh | 18. Kendujhar | 28. Sambalpur |
| 9. Dhenkanal | 19. Khordha | 29. Sonepur |
| 10. Gajapati | 20. Koraput | 30. Sundargarh |