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REVIEW ARTICLE

A review on water consumption reducing technology, IoT and AI for household applications

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ABSTRACT

Industrialization and increased population have increased water demand enormously but climate change and depleting water resources have created water stress in many countries all over the world. At the same time development of internet of things (IOT) based technologies is happening very fast. This paper reviews research works in the area of water consumption, water quality analysis and water demand forecasting using mathematical models, water reduction technologies. Since IOT is relatively new, web articles and blogs are seen to be discussing an application of IOT for water consumption reduction, however full fledged research articles are missing. Hence a scope of IOT in water consumption pattern analysis and thereby reduction in water consumption is discussed in this paper. This study thoroughly analyzes the water consumption pattern that varies as per income groups, industries, gender, age, socio-economic status. Study reveals that water quality also affects water consumption and spread of diseases. Mathematical models were studied so as to understand the effectiveness of these models in water consumption forecasting that helps in better management. Study has identified the shortcomings like incorrect approach, inadequate data, and incorrect method of data collection, less or no use of scientific methodologies for water consumption determination and less technological use. Study suggests the use of advanced technologies like internet of things, sensors can help in real time data collection and monitoring of water equipment with standardization of methods. It concludes with comments on the possibility of IOT/AI integration for reduction of water in domestic settings.

Keywords: water consumption; water stress; smart technology; sanitation; water quality; AI in water conservation

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1. Introduction

Water is the most essential element for humans; only 2.5% of the total storage is available for human use, while the rest is stored in rivers, lakes, groundwater, and glaciers. Rain received by earth is the main source of water. With increased population, rapid urbanization and industrialization have created great pressure over the available water resources, making world water stress. Climate change, global warming leading to change in rain patterns, melting of glaciers, depleting available water resources making the whole scenario worse.

As per the NITI Aayog Report of India, water consumption is generally classified as industrial, agricultural and domestic. Industrial water consumption amounts to 80% of all available water while agriculture and domestic consumption amounts to 10% each. There is spatial and temporal variation in water use throughout the region, assuming the per capita water consumption per day for rural and urban areas will be 50 liters and 150 liters respectively in 2021[1].

One of the sustainable goals is SDG6 i.e. universal access to water and sanitation, as per world health organization there is correlation between water consumption and health, education. Minimum 50 liters per capita water consumption is required for low health concerns to fulfill requirements of laundry, hygiene, consumption, bathing etc. due to adequate supply of water, time wasted in search will be reduced which can help in improving educational and health status of people. The World health organization (WHO) used data from various organizations working in the field of sanitation and government sources. Such data was used to correlate the water consumption with health level. As per WHO domestic water is the one which is used for hygiene and cleanliness[2].

The Bureau of Indian standards suggests the water consumption of minimum 130 liters per capita per day[3]. Population growth, urbanization, economic development and Climate change are depleting the available water resources. Situation will be more devastating if corrective actions are not taken. During the last few decades the percentage of increase in water consumption is almost double the population increase which indeed increased water stress[4].

2. Water availability and consumption patterns

The study conducted by Aqueduct has ranked countries as per their water stress from low to extremely high. India with water stress score 3.62 ranked 28 in 2010, while its water stress score would be 3.61 in 2040 and will be ranked at 40 in high water stress criteria[5].

The increase in pollution due to heavy industries, transportation has a large scale effect on the environment. Due to climate change, events like tropical cyclones, frequent droughts, floods, extreme heat, sea level rise have increased[6]. The climate change has also affected agriculture as groundwater levels are dropping continuously so arable lands become water scarce. The salinization of land takes place due to coastal flooding, sea level rise, its risks low lying human habitat and also their sources of livelihood like fishery gets affected. Such effects can be observed due to ocean acidification also[7].

The growth of industries needs more water so in many areas limited groundwater is extracted. The waste coming from such industries gets dumped in rivers, lakes which pollutes the water and also gets percolated to groundwater. In some cases the water ecosystem gets damaged due to pollutants like arsenic, fluorine. Such pollutants are found in the drinking water of people nearby such sources. This polluted water affects the health severely[8].

As water resources are becoming scarce the judicious use of available water resources is an important task. So proper forecasting of water demand and its consumption needs to be done. Multiple regression analysis, bootstrap analysis will be useful in forecasting models. Water consumption has variations as seen from the study conducted in west Bengal, India which considers both direct and indirect uses[9]. The consumption pattern also shows some variation as per the rural and urban areas[8] the water demand in cities like jaipur has increased many fold due to rapid industrialization, the study shows that, there exists a socio-economic difference in water consumption pattern. The low income group consumes less water (60 liters per capita per day) while the higher income group consumes more water. (130 liters per capita per day) the high water consumption might be due to the use of home appliances[10]. ANOVA test used to find relation between household income and water consumption patterns[11].

The management of water resources is vital so needs proper forecasting models, using multiple linear regression models, bootstrap analysis.

Study conducted in 7 major cities like Delhi, Kolkata, Madurai, ahmedabad, Hyderabad, Mumbai, Kanpur shows the socio economic effect on water consumption. Domestic water consumption was found to be around 90 liters per capita per day. Factors like culture, climate, culture, food habits and working conditions, level of development, and physiology affects the requirement of water[11].

Fogarassy et al. tried to determine the human water consumption in monetary terms. Using the consumer price of water, the total asset value was calculated. Natural rain, polluted water, irrigation water used for monetary value is adjusted water value[12].

With globalization the tourism industries have flourished over the world. This industry uses municipal water for their consumption also the groundwater. Sussane Beckan has investigated the water use pattern by the tourism industry in 21 countries. Special attention was paid to municipal water supply as more people are dependent on this water supply. Results of this study show that there was wide disparity in water consumption spatially and temporally. The water consumption observed was more in developed countries than developing countries. Per capita consumption, guest per night gives a detailed idea about the water consumption. So the tourism industry needs more water saving technology and water harvesting techniques to be developed[13]. This can be supported by the idea of toilet economy which is projected to reach $ 62 billion by 2021 in india,which needs understanding of water consumption use sectors and their pattern[14].

Hamdar and Hamdan conducted a study in Lebanon to determine how much water is needed for per crop ton increase. To estimate the relation between independent and dependent variables regression analysis is used. Model found to be effective and accurate. The result shows that models used are accurate and water demand per ton has increased. The model helps in predicting the optimum water requirement and helps reduce water consumption[15].

Rise in population over the last few decade's leads to 7 billion population. Such a huge population needs more food grains; this demand has created increased pressure over agriculture. To increase the food production use of pesticide, fertilizers have also increased which needs more water. The new techniques of drilling used to exploit groundwater for agriculture from deeper depths. Such activities have resulted in reduction in groundwater and groundwater pollution. To determine the status of groundwater study conducted by Gorantla et al. in the state of Andhra Pradesh, India. Water table fluctuation approach was used which looks at groundwater level fluctuations over the period of time. Specific yield of soil used to determine the percolation capacity of soil. Such an approach was applied to only areas with confined aquifers. By determining the levels of groundwater regions were classified as safe, semi critical, critical and over exploited. Such categorization helps in corrective actions to be taken[16].

The study conducted in the Lima region of Peru, considered the internal and external factors for water consumption determination. Study suggests that older people consume more water, gender wise consumption difference is small while households having more appliances consume more water[17]. Economic conditions, physical properties, climatic conditions, and technological use are the main drivers in residential water consumption[18].

3. Water consumption and sanitation

UNESCO along with the UN applied the WASH strategy i.e. water, sanitation and hygiene but such strategies have failed in the backdrop of poor participation of stakeholders and professionals. The study was conducted to find out motivating the factors using Abraham Maslow's hierarchy of needs theory. Using. The theory focuses on physical needs, social needs, security needs, self esteem needs and self actualization needs. The study focuses on identifying the needs of the people which are satisfied and which are not satisfied because of which the WASH strategies fail[19]. Lack of sanitation infrastructure, poor water quality and less awareness about health and sanitation leads poor people to schistosomiasis, which are water-borne diseases. This disease is more prevalent in sub-Saharan countries. It was observed that the disease was prevalent in the areas where open defecation and unhygienic disposal of human excreta was done. Such unhygienic practice pollutes the drinking water. The attempt was made by Mulopo and Chimabari to determine the baseline for prevalence intensity and risk factor for schistosomiasis and soil transmitted helminths (STH) in the Madeya Village of

Kwazulu Natal. Use of WASH strategy can be helped to reduce prevalence of schistosomiasis[20].

WASH strategy can be made effective by the use of toilet tripods, O'Reillyn and Louis worked on factors such as sanitation infrastructure development and its use. Study also shows that besides the availability of good infrastructure, people fail to use it. The reason behind this is the lack of awareness or dirty infrastructures. as shown in **Figure 1** the toilet tripod is based on Social pressures, political will, political ecology affects the speed of sanitation programmes. The use of 3 elements helps in better implementation.

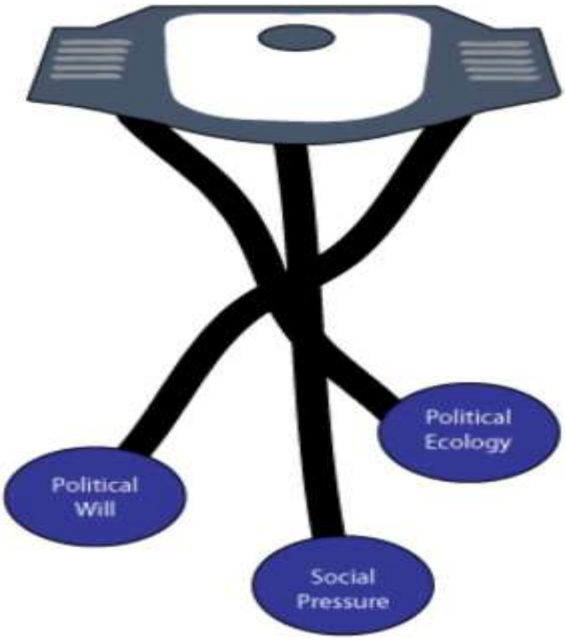

Figure 1. Toilet tripod.

The will to govern is the political will. If funding is made available for infrastructure it signifies the political will. Performance based awards; implementation strategy also results from political will so it is the first leg of toilet tripod. Shame, human behavior, and attitude creates the social pressure, which is the second leg. Moral obligation is exerted by social pressure. Due to social pressure they can build their toilet and use it. Political ecology is the third leg which has an economic aspect. Due to growth in development administration, governments seem concerned about the change in land use, change in basic infrastructure, and change in water use pattern. Such change brings the people under the development processes and makes people use toilets. Village surveys were conducted to study the effect of such strategies on the programmes of toilet adoption. During the surveys personal interviews were conducted so estimate the actual data of toilet use[21].

SHEWA-B program which was implemented by UNICEF along with Bangladesh Department of Public Health Engineering (DPHE) in 2007 till 2013. Main focus of the program was on underserved areas which were inhabited by more than 20 million people. The aim of the program was to reduce disease caused by WASH and diarrhea. So promotion of hygiene was the main aim. The mid assessment of the program showed that hygiene infrastructures were poorly developed which resulted in no improvement in behavior of the people e.g. washing hands after toilets. Program needed a targeted implementation as respiratory diseases and diarrhea were prevalent in the children below the age of 5 years. The program was implemented in the rural, urban areas and also in the schools. The assessment was done by conducting individual meetings and community meetings. Community meetings were held to promote the awareness among the people about WASH programs. The promoters were appointed, trained and later supervised to assess the working. Promoters were made to deliver 6 key ideas to the people as shown in **Table 1** to participants in the SHWE-B program[22].

Table 1. Key messages by promoters.

Sr No.	Key Message
1	wash both hands with water and soap before eating or handling food
2	wash both hands with water and soap or ash after defecation
3	wash both hands with water and soap or ash after cleaning a baby's bottom,
4	Safely collect and store drinking water,
5	dispose of children's feces in hygienic latrines,
6	Use hygienic latrine (all family members, including children).

The assessment of the program is the important task of any program. Sinha et al. studied the approaches for the assessment of toilets or use of latrine. Passive latrine use monitor (PLUM) compared with self reporting. Questionnaire based interviews and the data from PLUM were compared to arrive at some conclusion[23].

During the COVID-19, the refugees face the acute problem of sanitation, Rafa et al. have reviewed the conditions of refugees and the problems they face. The challenges are mentioned in **Figure 2**.

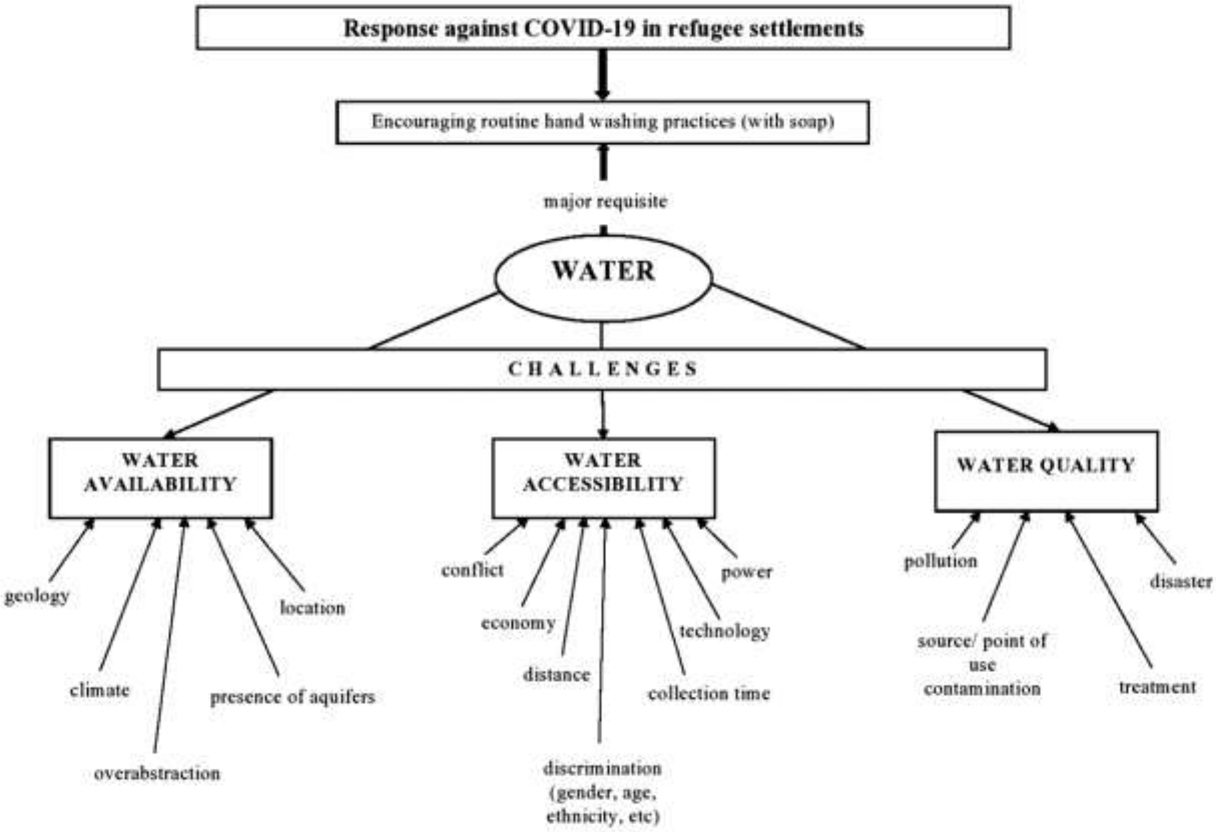

Figure 2. Challenges in safe water availability and accessibility in preventing COVID-19 in refugee settlements.

Water access, water quality and its availability affects the sanitation when hand washing is not practiced during the spread of COVID-19, such a pandemic makes the population vulnerable to infection and communicable[24].

4. Focus on water use for toilets

As seen earlier many studies were conducted to determine the water consumption pattern, many studies also done to reduce the water consumption using traditional and advanced methodologies. Domestic water consumption amounts to 10% of total water use. Major portion of domestic water is consumed by toilets and hygiene. A traditional toilet uses around 13–15 liters per flush. Such a large amount of water can be reduced.

Sarode proposed the idea of an automatic flush system. In this system flush was fitted with a sensor, microcontroller, and actuator. Results of the study shows that a small amount of water was used for flushing[25], similar study conducted by Atta which also uses sensors, actuator and microcontroller. Water use was reduced and cleanliness also maintained[26]. To solve the problem of combined sewer overflow (CSO) in China which causes water pollution Lei et al. have worked on optimization of CSO tank.The simulation method (infoworks) is used to predict future overflow patterns. It is based on the long-term simulation of the historical rainfall records to accomplish the statistical analysis of the overflow under the continuous actual rainfall conditions[27].

Hashemi et al. in their study have discussed some innovative toilet technologies for smart and green cities. The bi-sloped conveyor belt can separate the solid and liquid waste and nutrients of liquid be used for some purposes. Also 4.5 liter water saving toilets have modified the design so that less water is required per flush[28]. So there is an immediate need of intervention to harvest and to reduce the wastage of water. Use of advanced methods and technologies can help in such objectives.

Use of water efficient toilets can save more water and also will achieve hygiene. Such objectives can be achieved through use of waterless urinals for homes and buildings, even for agriculture and industrial purposes. Waterless urinals as shown in **Figure 3** saves water and energy due to less volume of water use. As less water is used the spread of communicable diseases can be prevented. As urine contains 95% of water which requires less water. When hard water is used it forms scum over the pan which causes blockages. The bad odor comes from the bacterial metabolism which emits ammonia giving a foul smell, so using waterless urinals as shown in **Figure 3** odor from urinals can also be eliminated along with water reduction[29].

Figure 3. Membrane type odor trap manufactured by bio ceramics.

Human urine has some important nutrients which get wasted when it mixes with human excreta. This mix also causes communicable diseases. Trimmer et al. assessed the working and effectiveness of urine diverting toilets (UDT) as shown in **Figure 4**. A school based demonstration was done in Kalisizo, Uganda. The study was performed to see the changes in the attitude of the people towards the UDT. So in the earlier stages people were made to participate in the preparation and construction. Then demonstration facilities were provided in primary schools. Focus was provided on awareness about use. The use and knowledge about demonstration facilities were assessed qualitatively. The conditions like pH, temperature, moisture content were also monitored[30].

Koelmans et al. have reviewed the various studies being conducted to determine the presence of microplastics like PVC, PET etc. microplastics are the fragments of plastic with size less than 5 mm which is present in the form of films, fibers, fragments, foams which deteriorates the quality of flowing water or drinking water, food and air being inhaled which affects human health. It emphasized the need for a scientific method for assessment. Only few studies provide the quantifiable data and its reasonable methodologies[31].

Figure 4. Urine diverting dry toilet (UDDT).

The large ships exerts a larger amount of pressure on surrounding ecology causing waves or pressure over the mud or coastal profile causing turbidity, erosion, sediment suspension etc. so study was conducted by Mao to characterize the ship induced hydrodynamics. The study was conducted in the Changzhou segment of the Grand Canal, in Jiangsu Province, China. The data was recorded like wave height, pressure, wave velocity and Froude number[32]. Similarly, Casila et al. made an attempt to quantify the water quality and flow. In this study the flux of salt, suspended sediments (SS) and dissolved oxygen(DO) were recorded in two rivers Sumida and Shakujii of Japan. The mass balance method was used to estimate the discharge, salinity, SS concentration, and DO concentration at a station with missing data[33–36]. Deteriorating water quality which affects the water consumption and can spread the water borne diseases. Logistic regression analysis reveals the significant association between water borne and enteric disease occurrences[37].

Water quality indicators like biological oxygen demand (BOD), chemical oxygen demand (COD), total nitrogen (TN), total phosphorus (TP), pH of water, ammonia ions, and temperature used to determine the status of drinking water[38–41]. Domestic wastewater treatment system together with septic tank and up flow anaerobic filter with constructed wetland could be useful for improving water quality first order kinetic model, mass balance method, multiple regression model will be helpful in determining efficiency of the system for various water pollutants[41].

As mentioned earlier many studies have been conducted at global level to find out the accurate water consumption pattern, its variability and socio economic status. Studies being conducted have no specific data for calculation of water consumption as methodologies used are incorrect or lack objective. Some studies use questionnaires to collect the data which may give incorrect values[5,9–11] or some use government data on water supply of municipalities which may have problems like leakages[5,10,11]. The activity wise domestic water consumption also lacks accuracy as no scientific methods were used for data collection[8,10,11].

Studies on water consumption by the tourism sector have used only data from Aquastat and earth check databases which lack spatial and temporal variation in water consumption[13]. Hamda et al. worked on economic modeling of water need determination which only considers actual rainfall data, whereas surface runoff and groundwater recharge data is not available[15]. Forgussay et al. attempt to determine water value based on water used per hectare which is adjusted water value (AWV) has not considered land correction factor and population density[12]. Similarly in the study conducted by Shanmukh et al. used specific yields of regions which may vary locally and can have different values. So ground water level measurement must be corrected in this scenario[16]. Some methods developed to reduce the water consumption like automatic flush systems which have not provided validation of results[25]. Purity based flush system is used only for urinals and its effectiveness may vary with solid waste[26]. The study of Marshall and Kaminsky used Moslows theory of motivation for the need of stakeholders for successful strategy but the needs in social context are dynamic. Research should examine how to design strategies as per the needs or motivations with the changing times[19]. Findings shows that insufficient training, poor survey methods of audit and feedback Factors are causes of Poor Implementation of SHEWA B, enough motivations are required for successful implementation of strategy.

It also suggests that instead of only motivation, direct infrastructure could help more. Poorly defined performance index, method of survey which based on recall was faulty[22]. In the study conducted by Sinha et al. PLUMs used may not give reliable data, while data size should be larger so as to reach a conclusion[23]. The study on micro plastic presence in water asks for more reliable studies on water quality also more criteria for reliability check of study need to be provided[31]. The result of the study by Maro shows that High discharge, salt, SS, and DO fluxes were found at the stations on the Sumida River. This is because the channel cross-section at the Sh-D Station was smaller, and the Sumida River has many upstream tributaries such as the Arakawa, Shingashi, and Shakujii rivers[33]. The study of water forecasting models suggests careful analysis of the effect of block pricing policies and distribution of users per block for estimation of distributive effects of these policies[42]. For long term forecasting larger data set required. Monthly, quarterly, seasonal, yearly forecasting helps[43,44].

5. Water consumption measurement strategies

This section reviews the different methodologies used by various experts for determination of water consumption pattern and water reduction technology. In order to set the target for water reduction one must understand the behavioral approach of the people towards the water consumption. One of such approaches is cluster approach where any area is divided into different groups. The classification might be upon income, type of appliances used, and type of household. This is the easiest method so no technical skills are required as such. The data for water consumption were determined using interviews. The questions were asked so that qualitative and quantitative data will be obtained[8,9,17]. When cluster approaches based on income were used like high income group (HIG), Middle income group (MIG), Low income group (LIG). This kind of study shows the socio-economic effect on water consumption[10,18]. In case of urban areas with big population and income diversity along with income groups of HIG, MIG, LIG slum and mixed income groups can be studied which gives a clear idea of spatial water consumption variety. User data can be verified with the help of municipal supply, water leakages and water demand[10,11,17]. Some studies used the data of the particular water consumption like cattle feeding, cooking, toilet etc.[8].

Shaban and Sharma had identified these clusters; electoral rolls were used to do the random sampling of households. Minimum eight interviews were conducted from every cluster. Wives were target respondents as they were the caretaker of almost every activity that happens at home. Schedules were decided for interviews. The activity wise use of vessels were identified and its volume measured. If tap water is used for any activity the time for which tap was open was noted with volume flow rate through tap was also recorded. So the total volume of water used can be determined by multiplying time for which tap was open and its volume flow rate. Bucket volume was used as a tool for measurement of the amount of water used for the toilet and capacity of the flush tank[11].

Water footprint method was used to determine the amount of water used or consumed in agriculture. The method uses the types of crops sowed and amount of water that crop needs for its growth[12,15]. The monetary value of water was determined using the consumer price of water and water footprint. Natural rain water was used for determination but some of the water gets wasted as surface runoff so to compensate, water allowance coefficient was used. The final value was the adjusted water value. This water value shows the water burden over the people[12].

The Energy and resources institute of India (TERI) made an attempt to understand the water stress over the different regions in India. So TERI divided India into 6 different regions with various states. Water consumption was classified for agriculture, industry and domestic use. Water availability, consumption and its demand was forecasted using the PODIUM Sim model. This model analyzed the sectoral demand for water in future, annual rainfall patterns and determined the water consumption patterns[1].

Hamdar and Hamdan studied the economic modeling of water needs determination for agriculture in Lebanon. Study determined how much water is needed for per crop ton increase. Data like number of years, volume of water needed and agriculture produced in tones were used. Variables like dependent and independent were correlated using regression analysis. Reliability test, variance and tolerance test were performed to find the reliable and accurate model[15].

Beckan tried to understand the significance of the tourism industry in water consumption. In this study the data of EC3 global's earthcheck benchmarking system aquastat database was used. Some indicators lie water risk vulnerability index, per guest water use, and per capita water consumption data for 21 countries studied. The aim of the study was to understand the spatial and temporal water consumption variation[13].

Groundwater becomes the important source of water for irrigation but overexploitation leads to drop in its levels. Gorantla et al. attempted to understand and apply the methods used to estimate groundwater recharge. Water table fluctuation (WTF) method uses the fluctuations in the water level over the time, this method can be applicable to unconfined aquifers.

Data collection was done from piezometric observation wells. Groundwater recharge was determined for shallow water levels in a short span of time. Depth of fluctuation, specific yield, overall yield and its variation used to estimate the recharge of ground water. Using data variation percentage for areas determined and areas were classified as over exploited, critical, semi critical, safe[16].

6. Water saving technologies for toilets

An automatic flush system as shown in **Figure 5** was designed and developed by Sarode for sanitation to be used in public toilets. The system consisted of an IR receiver module, IR transmitter module and microcontroller. IR LEDs act as signal emitters. When the user approaches the system IR receiver module receives signals reflected from the user and the system gets activated, indicated by 'ON' LEDs. When LEDs are ON for more than 5 seconds then the system becomes ready for flush. As and when a person moves from the spot flush activates after 10 seconds and for 10 seconds. Whole system was controlled using an AT89C2051 microcontroller[25].

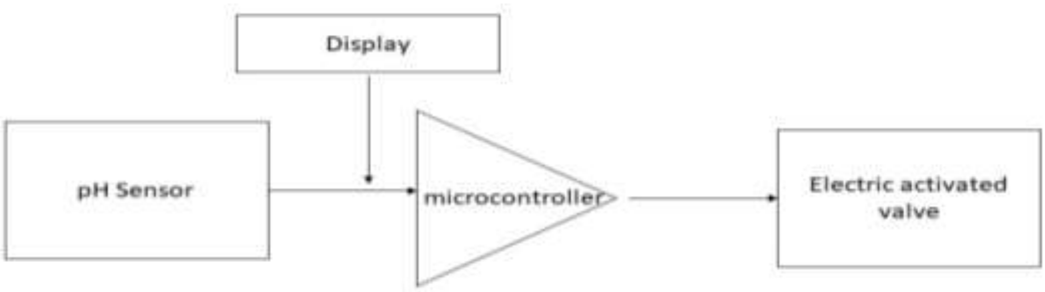

Figure 5. Smart flushing system.

A smart flushing system was developed by Atta. A purity sensor was used here to check the water quality when someone is using the system. The purity sensor attached to the base of the water bowl. When the purity sensor detects a change in water quality the system gets activated using a PIC16F88 microcontroller, when quality comes to normal the system stops. The purity sensor checks the pH, conductivity. The optical sensors can be used with purity sensors[26]. The water quality can be improved when the impurities get absorbed. A nano mesocellular foam (MCF) silica synthesized from a hydrothermal method developed by Li et al. solution adsorbs the impurity using nickel. During the experiment the effect of pH, Temperature, adsorbent amount, initial concentration of nickel and capacity of adsorption on rate of adsorption was determined. Kinetic model (pseudo 1st and 2nd order), used to prepare the MCF using Hydrothermal method and BJH method used for pore size distribution[36].

When water flows over the surface to exert force over the surface which gets eroded with time. Abbaspour et al. tried to understand the phenomena of this erosion. Experiments were conducted with plates placed at particular places. The location and angels of the plates were also varied with horizontal and reverse beds. Froude number varied from 4–9 and hydraulic jumps in open channels were studied. Hydraulic jumps were recorded using ultrasonic sensors. Data processed using VisiDAQ software. Angles of buried plates, Froude number, time of experiment, depth and length of profiles used for simulation models and effect determination on scour profiles[34]. Water depth change patterns were studied by Gholammi. A sharp bend of 120 degree was provided in numerical study. The flow behavior changes with sharp bend in flow channels. A numerical model with 90 degree was prepared, the results of the model applied to change in pattern for 120 degrees. Water depth change, flow velocity and discharge rate were used as variables to simulate change in water depth VOF multiphase model was used. The RNG turbulence model was used for Reynolds stresses. Simulation done by using fluent[35].

The problem of sewer overflow during the rainy season was frequently observed in China, so Lei et al. studied the nature of combined sewer flow in detention tanks using common design methods. Here, rainfall simulation models and control effects were studied. The historical data of rainfall was collected over the year and simulations were performed to analyze the continuous actual rainfall pattern statistically. Overflow amount, Overflow frequency, control rate of CSO pollution load, CSO amount control were used for simulation[27].

Hashemi, et al suggested an innovative toilet system. In the new water-saving toilet shown in **Figure 6**, the siphon system was redesigned and substituted with a spring. The height of the water column was raised such that the center of gravity shifts to the left while flushing. The increased weight pushes the spring downwards and the waste gets discharged into flush using water of only 4.5 liters. When discharge is done spring comes back to its normal position and water will be retained so no bad smell is noticed[28]. Again bi-sloped conveyor belt toilets (**Figure 7**) also recommended which were waterless. Here no water was used as the solid and liquid wastes were collected separately using bi-sloped conveyor belt. Solid wastes collected in the feces tank while liquid was collected in the urine tank. Using microorganisms and additives the urine and feces were converted into biodegradable form like fertilizers[28].

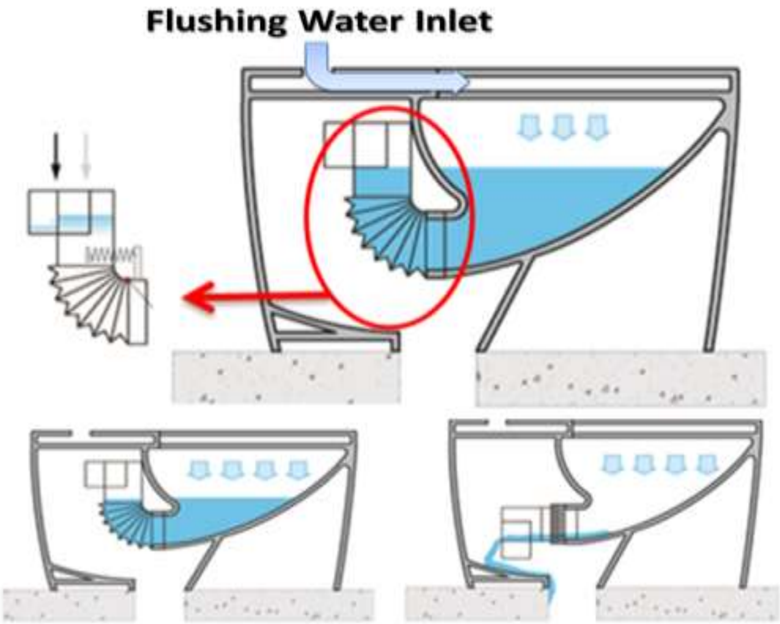

Figure 6. Urine Source separator basket for the 4.5- liter water-saving toilet.

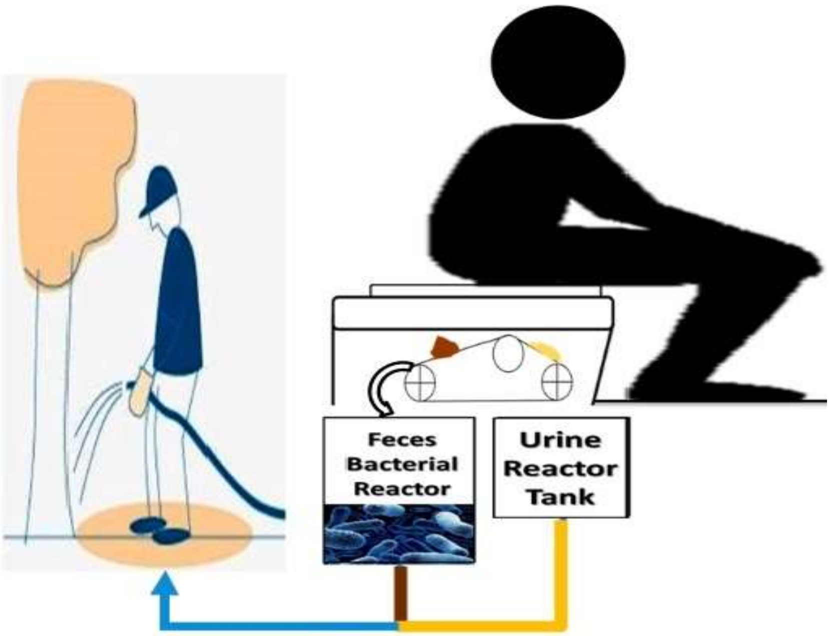

Figure 7. Bi-sloped conveyor belt toilet for separation and recycling purposes.

To understand and evaluate the progress of WASH program and its strategies the interviews of 22 stakeholders like leaders, users, volunteers etc were conducted. The target of the interview was to determine whether the system was working well or not. If 80% of the system was working then the system was successful or otherwise. @Nvivo qualitative software was used to code the all interviews using keywords[19].

Initiatives taken for prevention of disease transmission and promotion of WASH strategies were studied by Mulopo and Chimbari. In order to design intervention strategy data was collected from all the stakeholders. Here 5 different categories of people are selected like 2 nurses, 2 community caregivers, 2 teachers, 2 village headmen and all households with children below 5 years of age. Knowledge about the WASH was the criterion to select the stakeholders. Group discussions and interviews were conducted to collect the data from the members of the community participating in the program. Data was collected during a dry season from August 2018 to November 2018. Role of stakeholders, provision of WASH services, and local experience with WASH issues were the themes of interviews. These interviews were recorded on Audio recorder[20].

As mentioned earlier in the study conducted by O'Reillyn and Louis, to understand the successful sanitation strategy in India, three legs are considered like political will, social pressure and political ecology. The study used a mixed method of data collection. The study has chosen the two villages each from Himachal Pradesh and West Bengal that have received recognition as Clean Village Award (Nirmal Gram Puraskar). The field work was done in 16 person-months. Minimum 600 people selected for study. To determine the quantitative data passive latrine use monitors (PLUM) were used which records the number of times the toilet has been used. Themes of the interviews were awareness about sanitation, toilet use, and social pressure etc.[21].

A low cost membrane-based waterless urinal odor trap, which was not patented and was manufactured by Shital Ceramics in India, was chosen for evaluation of odor control efficiency, of low density polyethylene, was the raw material used for the membrane in the form of tube with open ends. One end of the membrane was fixed to the pipe while the other end was fixed to the pipe which was connected with the waste collector. A bell-mouth adapter on top of the circular odor trap body enables fixing of the odor trap to the outlet of urinals at the bottom. Odor control was nothing but the ammonia control efficiency. Ammonia over the urinal pan was measured.

Ammonia in the range of 0.2 ppm to 78 ppm measured in the gas detection tubes. To understand the resistance to the clogging arrangements for continuous flow of water were made, cigarette buttes with length

38 ± 2.5 mm were flushed in every cycle. For every cycle, to remove the 20 cigarette butts, 5 liters of water are used for flushing. To determine the maximum size of particles which can pass through the trap, a particle flow experiment was performed. During the experiment particles of particular size were placed in the pan and water was allowed to flow over it (0.5 liters per minute) water was supplied until everything came out. The water flushed was stored in a container[29].

Use of urine diverting toilet (UDT) used on pilot basis in Uganda. In order to understand the success in the application of UDT, an evaluation was conducted. For this two schools of Kalisizo were selected. The project was monitored by brick by brick Uganda (NGO). For the assessment an evaluation guide was prepared. All the stakeholders of the program like construction workers, teachers, skilled and unskilled laborers were interviewed after every month over the ten month period. The change in attitude and knowledge was observed before the installation and after installation i.e. 6 months assessment was done in two phases; in the first phase 58 students and their parent's feedbacks were recorded. While phase 2,59 students were assessed, those were students only. Two third of all participants used UDTs. The qualitative aspect was assessed with pH, temperature, moisture content[30].

To measure the outcomes and quality of implementation a survey was conducted in cluster areas of SHEWA-B. Survey focused on demonstrations and spot checks of health behaviors. Promoters were interviewed by staff to assess whether they recall the key messages or not. For program implementation, an index was created using various variables from the survey. To avoid the bias the survey items of promoters were included. The Delphi method was used to collect the data from the feedback of 12 UNICEF staff. Depending upon the performance of participants points were assigned (1 = weak measure of implementation quality, 5 = strong measure of implementation quality). The weight age of every point was decided on the basis of its average points. Then the index was scaled from 0 to 100. When promoters never met participants '0' given and when '100' for a good promoter[22].

Sinha et al. conducted a study as mentioned in **Table 2** in an Endeavour to determine the gap between assessment methods. The study was conducted in puri district of odisha out of 46 eligible villages 25 villages were selected. Functional latrines were found in all the selected villages. Assessment period was 14 days in which questions were asked to participants manually. Data from PLUM were collected over the MYSQL server[23].

Table 2. Questions and methods used for assessing reported use of latrines and the corresponding PLUM-recorded estimation approaches for four comparison categories[23].

Parameter	Survey questions	Approach to estimate reported use	Corresponding PLUM recorded estimation
"Usual" or average daily reported latrine use	Among your family members who use the latrine, can you please tell me how many times in the day they usually use the latrine?	Average daily reported use for a given household: sum of "usual" reported latrine use per day for all latrine using household members	Average daily PLUM-recorded use for a given household: sum of PLUM recorded defecation events over 14 days/14 days (for households without any reported visitors) or sum of PLUM-recorded defecation events over 12 days/12 days (for households reporting visitors on days 13 and 14
Reported latrine use for "yesterday" (day 14)	For each member of your household, please tell us which members used the latrine for defecation "yesterday" and the approximate time of day they used it. If they used the latrine, tell us the number of times they used it (based on four dis aggregated parts of the day. Visual aids depicting the parts of the day and household members used to facilitate recall).	Sum of reported latrine events across all parts of the day for all household members for "yesterday" in a given household	Sum of PLUM-recorded defecation events for the same day in the same household

Table 2. (*Continued*).

Parameter	Survey questions	Approach to estimate reported use	Corresponding PLUM recorded estimation
Reported latrine use for the "day before yesterday" (day 13)	For each member of your household, please tell us which members used the latrine for defecation the "day before yesterday" and the approximate time of day they used it. If they used the latrine, tell us the number of times they used it (based on four dis-aggregated parts of the day. Visual aids depicting the parts of the day and household members used to facilitate recall)	Sum of reported latrine events across all parts of the day for all household members for the "day before yesterday" in a given household	Sum of PLUM-recorded defecation events for the same day in the same household
Reported latrine use−48-hour recall	No separate question asked	Sum of total reported use for "yesterday" and the "day before yesterday"/2: to estimate average reported use based on prior 48-hour	Average daily PLUM-recorded use for a given household based on the 14-day (or 12-day) monitoring period

7. Analysis of water consumption

Koelman et al. reviewed the 50 studies while 55 records were studied on the drinking or its fresh water resources. 9 criterions were used for the reliability of the data like Sample size, Sampling methods, Lab preparation, Sample processing and storage, Clean air conditions, Negative controls, Sample treatment, Polymer ID, Positive controls, Total Accumulated Score (TAS, max.18). Scores were given like 2 for reliable data, 1 for reliable to limited data and 0 for non reliable data. Final reliability score shows the reliability of the data and the study which was quantifiable data[31].

To understand the effect ships boarding on the harbor Froude number was used. Depth Froude number (Fh), used to distinguish different waves propagating from the ship hulls expressed as follows,

$$Fh = Vs(gh)^{-0.5} \tag{1}$$

where, g is the gravitational acceleration, Vs is the ship speed and h is the water depth. In shallow water, the limited ship speed Vs leads to Fh less than 1. This effect of Froude number less than 1 depends on the ratio of ship cross sectional area to waterway cross-sectional area.

$$m = As/Aw \tag{2}$$

due to displacement ships and planning ships the waves like primary and secondary waves were generated. Ships which sails slowly like displacement ships e.g. Cargo ships. Displaying less volume results in a primary wave. High speed ships like planning ships producing secondary waves. Wave height, wave velocity, Froude number under normal conditions were field measurements data used during study. Using wave height during the passage of ships water level fluctuations were measured. Three dimensional water current velocities measured using two NORTEK acoustic Doppler velocimetry (ADVs). Data were recorded at 25 cm height above the river bed at 6 m and 40 distances from riverbank[32].

The study to determine the water quality, first completed the field work where the data was collected for about 30 min. By using conductivity, temperature, and depth (CTD) probes, water quality parameters like salinity, turbidity, and dissolved oxygen concentration were measured at each station laboratory methods were used to determine the Particulate organic matter and suspended salt. To determine the concentration of salt dissolved oxygen, the Mass balance method is used[33]. While determining the water forecasting, mathematical models have been implemented, the past data collected on time scale, functional variables like income, weather conditions, resident population, indoor/outdoor use considered[42]. In some studies daily water supply capacity[43], daily groundwater pumping[44] is considered as variable. Multi scale relevance vector regression approach uses stationary wavelet transform to decompose historical time series water data. While NRMSE, MAPE, correlation coefficients (CC) are used for performance analysis[43]. Autoregressive integrated moving averages (ARIMA) which is a linear model in time series used for short term forecasting, for nonlinear functions artificial neural network (ANN) used. R-square, RMSE, MAPE, MAE used for optimization and prediction of the best model[44].

8. Scope of IOT and AI for water conservation

It is seen from the review that various investigators have used traditional methods for collection of data of water use and subsequent predictions of water pattern. The water reduction technologies are generally used in toilets to reduce use of water for flushing. A few investigators have implemented IOT based systems to monitor water consumption. Saranya et al. have used IOY for data collection and real time control of water systems. They focused on domestic areas such as hostels, colleges and hotels for installing IOT systems. They have used Proteus software for simulation and analysis along with IOT based systems that inform the users about excess use of water[45]. Sidula et al. developed an information system by utilization of smart sensors and IOT. They claim to have developed a novel idea of collecting and sharing water use data to a central command center using far field communication. The central command center then takes a decision to operate dams by closing or opening of the doors of the dam[46]. Suciu et al. in their paper, presented the approach of the Water-M project that developed a new business model by making use of smart water chains as no-loss and holistic water management systems[47]. Ascencao et al. have done a comprehensive review of smart management systems. They have categorized various systems into groups according to their efficacy[48]. Similarly a vast body of literature available for application of smart meters in water management. However, most of the IoT based systems are used for water use patterns and management using micro-controllers such as Arduino etc. A standard protocol for an IOT based system for domestic water consumption is missing. Recent paper by Jenny et al. discusses a data driven approach for water management. They have come up with predictive, forecasting and prescriptive AI tools for water management.

9. Further discussions

Studies being conducted at global level to find out the water consumption pattern and technological development to reduce water consumption, here we will discuss the results of some previous studies. The study on water consumption done by TERI, India. The sectoral water consumption distribution was determined using rainfall data collected annually and data for agriculture, industry and households were collected by the PODIUM SIM model. It was found that industry consumes the largest portion of water at least upto 80% while domestic and agricultural water consumption stood around 10% each. As per the report rural domestic water consumption was 30 LPCD while for urban it was around 130 LPCD in 2011[1].

Hasnat et al.[8] attempted to understand the presence of arsenic load present in potable water in the villages affected by arsenic pollution in Bangladesh. 640 participants were taken for study. Shallow tube wells were used by all participants for drinking while for cooking it was used by 97.34% of all the participants. Tube wells were used as a source of water for washing purposes by 89.22% people (participants) and for irrigation tube wells were used by 79.40% participants, these tube wells were either hand operated or machine operated. Water consumption found was 3.53 litres per capita per day. For cooking it was 6.71 liters daily per person per day. For bathing 27.26, for washing 12.18, cattle feeding and toilets 12.75 in litres per person per day. So overall consumption was 62.47 litres[8] Rehman et al. studied the average water intake which was for agriculture labor found as high as 9.17 litres. Seasonal variation was observed with 3.44, 3.21, 2.72 litres per day for summer, monsoon and winter respectively. Gender wise was seen with females consuming average water of 2.8 litres and for male it was 3.42 litres per day. The weather and habits of the population about intake of foods also affects the water consumption. Age groups also affected the water consumption. The age group below 15 years consumes more water than the 16–60 age group which consumes water of 3.5 litres per day while the age group above 60 age consumes water of 2.25 litres per day[9].

It was found that in the city of jaipur, india out of all study group population 80% use underground water. It was observed that one third of all participants consumes water of 20–40 litres while only 20 litres per day is consumed by 50% of the population. Average consumption was 3.53 litres for all age groups per day. For LIG 114.1, lower MIG 120, upper MIG 141.8, HIG 139.3 per person per day. It was observed that with the income group water consumption also increases. Reason for higher consumption was the use of more household appliances. In HIG gardening consumes a considerable amount of water raising the total consumption[10]. The study which was conducted in 7 cities of India for water consumption a benchmark of 100 liter per capita per day taken. Water consumption was found as 91.56 LPCD for individuals and 389.3 LPCD for households. It was seen that average water consumed was less than that recommended by Bureau of Indian standards. Consumption varies with income group as HIG areas consume more water than LIG areas. It was noted that of all the population 35 % of people consume more than 100 LPCD[11].

Water use and human activity was linked by Fogarassy to determine the water footprint using water allowance coefficient. Water use is determined in monetary values. To determine the requirement of water, per ton of wheat crop production was chosen. In the regions of hungary water allowance coefficient ranges between 1114–1612. Average water footprint of 1268 in m^3/ton, 63659 was the average consumer price.(HUF/ha) adjusted water value was 1941211 billion HUF which was national aggregate water value (AWV). This AWV demonstrates the total value of water and its types[12]. A study on water consumed in tourism was studied by Beckan using only local water for reference. The data over the 22 countries was provided by earth check dataset shows that water consumption varies as per the countries. Water consumption ranges from 37 litres to 2461 litres per day. To understand the difference in the water consumption between the tourist and local people, a water disparity indicator (WDI) was used. It was seen that tourist water consumption exceeds the local water consumption by 8.3–8.5 in Fiji and Sri Lanka. Philippines, China, Indonesia, India show higher disparity in level of consumption. Water use of 101,335,527 m^3 per annum which amounts to 0.2% of the total supply of municipal water. The presence of swimming pools increases the water consumption in the tourism industry[13].

Water need model uses the method which tells us about the requirement of water for every tonincrease. Water needs model variations due to changes in four independent variables. For the first variable, the variable will increase by 0.1 MCM for every ton increase in production of wheat crop. For the third variable the increase was 0.006 MCM and for the fourth it was 0.35 MCM[15].

Impact of climate was observed on water consumption in the study conducted in, Lima regions of Peru. The increased temperature causes more water to consume in summer than winter. Seasonal variation of 26%, 21%, 22% was seen in Isidro, Brena and Villa el Salvador respectively. The size of the family affects the overall level of water consumption of the household. Larger the family, the more was the consumption. Gender wise consumption varies as women consume less water than men. The difference was 1.6, 19, 37 in Isidro, villa el Salvador and Brena respectively. Water use efficiency was proportional to level education; lower consumption was observed in higher educated groups. Some contradictions are also seen as higher education gives highly paid jobs so household appliances use increases the water consumption[17].

The level of groundwater was determined by water table fluctuation (WTF) method where levels of aquifers confined to particular areas were identified and change in water level was multiplied by specific yield of soil in those regions. This method is simple as compared to methods in which movement of water was taken into account. The method was easy to use and implement. The method can be applied to any wells which taps the water. no assumptions were required for compensating the movement of water from or over the surface. Use of method was not restricted by the presence of flows. The method’s values were applied to areas larger in the size i.e. more than thousands of square meters. The study was conducted in 14 mandals of the Tirupati revenue division of Andhra Pradesh, India. The specific yield was found around 8865 MCM with fluctuation of average 9.44 m of groundwater levels. This method was useful only when the water going inside the aquifer was larger than the water leaving over the surface.

As per the analysis, mandals level of exploitation denoted by GEC norms. As shown in **Table 3**, it was found that out of 14 mandals 7 were in safe zones while the number of semi-critical mandals were 6 and tirupati mandal was found over exploited[16].

Table 3. Classification according to GEC norms and number of mandals.

Classification according to GEC Norms No. of mandals	
Safe < 70% of net available resources	07
Semi critical (70%–90%)	06
Critical (90%–100%)	00
Over exploited (> 100%)	01
Total	14

The automatic flush system for urinals show that only 1.2 litres per flush used[25] while in smart flush system by Atta water consumption was reduced by 50% with only 3.75 litres per flush which uses pH sensor for determining the purity of water used with microcontroller for the system[26]. Hashemi et al. suggested new smart sanitation equipment. By improved siphon system flushing could be possible in only 4.5 litres[28].

Water quality of the estuary was measured by Mao during ebb tide when water was receding at the rate of 0.66 m/sec towards sea. For the whole cycle salinity varies within the range of 0.1 to 0.9 and 0.1 to 7.1. Concentration of SS reduces from (70–80 mg/L) to less than 20 mg/L due to rain which brings fresh flow. The dissolved oxygen (DO) was found varying from top to bottom as 9.28–10.96 and 5.69–11.18 mg/L respectively[33]. Li and Zhai developed the nickel adsorbent with pore size with the diameter of 19.6 nm of synthesized MCF. When conditions were optimized the rate of adsorption reached to 96.10% and adsorption capacity 7.69 mg/g adsorption of NI was an exothermic reaction with temperature between 25 to 45[36].

The study in scour profile suggested that the scour profile in water flow was affected by the Froude number, bed slope and angle of buried plates. The result was good when a single plate was placed at 45 cm with 90° angle. The depth and the maximum length decreased by 46.3% and 50%. When the distance was 30 cm and plate angle was 50°, the base was non erodible. Here the possible reduction was 54.7% and 50%[34]. When the bend of 120° is given to flow passage at a section before the bend. The water depth found increasing, so before the bend, when discharge was low the water depth increased. Water depth decreases after the bend[35].

Modification in the design of combined sewer overflow (CSO) detention tank was suggested. The model was prepared to analyze the situation by considering the rainfall event and rainfall data with more than 1 mm. The interception capacity of the interception downstream pipeline was calculated around 0.45 m^3/s using an interception multiplication factor of 3. This volume flow was for dry days. It was presumed that the intercepted water first gets collected into the detention tank through the pipeline and overflow happens when the detention tank is full. The redesign of detention size was to 10 mm so the reduction in the rate of overflow reaches to 50%–60%. This is the value which was recommended[27]. The study on water wave impact on sea harbors due to the influx of heavy ships was studied by Mao. The results of the studies show that water level fluctuates due to heavy ships and current velocities also change. due to heavy shipping activities waves from ships always get superimposed. To analyze the condition data for 220 ships were recorded and 27 passing barrages also analyzed. MATLAB was used to simulate the result to find out the regular pattern. When ships were passing through the water channel the current speeds were measured using the ADVs which were placed at the bottom of water. Due to constant shipping actions the ship induced waves of higher heights (Hm) increases with depth. With Froude number wave height also increases. When a single ship was passing then current velocities were

9 times the when no sailing was happening. But when multiple ships were sailing current velocity was 6 time of the no sailing condition[32].

To evaluate the strategies and success of strategies implemented by Marshall and Kaminsky. 22 stakeholders were interviewed about 218 strategies. 70 were found successful and 148 were unsuccessful. Analyses of the strategies were done so as to understand whether the strategies were aligned with the motivation factor or not. It was seen that self esteem was more successful motivation rather than health issues. When any strategy focused on multiple motivations the chances of its success was more. To motivate people to use the improved sanitation facilities and good health infrastructure increases the ease of access and quantity of infrastructure. So health benefits could be achieved. The successful strategies were mostly higher order as shown in **Table 4**[19].

Table 4. Maslow's theory of motivation (1943)—definition of motivations and applied coding dictionary for sustainable rural water delivery[19].

Motivation	definition from Maslow's theory for WASH related	WASH applications
Local self actualization	Helping local people become who they really want to be; fulfill potential.	Strategies that make life more convenient; looks at bigger picture—not just health and water; focuses on development of local people—including capacity building; focuses on long-term development—often at expense of immediate short-term outcomes
Outside self actualization	Helping outside organizations become who they really want to be; fulfill potential.	Baseline measurement of actualization—every organization has some purpose/mission they are trying to fulfill. For purposes of coding, any mention of water and/or health in a quote was coded as outside actualization.
Excessive outside actualization	Focusing on outside organization's needs at expense of long term results/local needs	Evidence that long-term results or fulfillment of local needs fails or suffers as a result of excessive focus on: outside interests—(budget, schedule); narrow approaches that focus on own goals and expertise—e.g., WASH only, health only, engineering only approaches; short-cuts to achieve things cheaper, faster, easier; short-term focus
Self-esteem	Stable, firmly based high evaluation of oneself.	Respect—listening to local priorities, preferences; buying, hiring, and building local. Reputation—pressure on providers to succeed/not make mistakes and desire for good quality items and services
Love and belonging	Connection to people through loving relationships and belonging to a group.	'A place in his/her group'–belonging, the need and desire to be part of a group – connected, i.e., involving local people in decisions. Strategies that help people stay connected and foster loving, meaningful relationships. Takes into consideration issues like community dynamics
Safety and security	Preference for a predictable orderly world.	Formal and informal research—data, monitoring, evaluations. Preference for using familiar methods. Freedom from division, injustice, and inequality
Physiology	Homeostasis (balance) of chemicals in blood	Thirst, water quantity. Not water quality

In order to prevent the spread of schistosomiasis using WASH initiative, Mulopo and Moses J. Chimbari, used a ground theory approach with data collection. For the thematic analysis 2 major themes were considered in 6 steps. These Themes were used as the guiding principles for identification of problems as shown in **Table 5**.

The result of the study shows that reliable and safe access for water sources to the community was not provided. Contaminated water was collected from unprotected sources by people. Less awareness and less education about sanitation was seen in participants regarding the products of water treatment. People lacks the knowledge of transmission of schistosomiasis[20].

Toilet tripod or sanitation tripod studied by O'Reillyn and Louis shows that for better implementation the need of political will, social pressure and political ecology were important. The experiences of the people as obtained from their interviews suggests that improved facilities of common sanitation, sewage and drainage systems encourage people to use it. These all were elements of political ecology which allowed the funding to be invested in sanitation facilities, building more toilets. Social pressure affects the living of people as improved income allows people to spend on improving standard of living and creates shame for going outside for the toilets and using the toilet they built or provided by the community services. Political will allow the policy to be formulated which shows the willingness of the authorities and views towards the sanitation. So to conclude the three factors as mentioned above forms the 3 legs of toilet tripod which are interdependent[21].

Table 5. Steps in thematic analysis.

Theme I	Access to facilities	Water source and practices Access to primary health care Basic sanitation facilities
Theme II	Knowledge about diseases	Health education and hygiene Hand washing among preschool going children. Knowledge about WASH

The study on waterless urinals which used a mechanism for odor control and blockages shows that ammonia gas was reduced by 98.3% when odor trap mechanism was used. The results were as shown in **Table 6**. The study also reveals that blockages at start were not formed but over the time with scum formation blockages may be formed[30].

Table 6. Ammonia odor control efficiency of the low-cost membrane based waterless urinal odor trap.

Experiment No.	Quantity of urine stored in tank (litres)	Ammonia measured at storage tank (ppm)	Ammonia leakage from odour trap (ppm)	Ammonia control efficiency
1	1	>75	0.44	>99.4
2	5	>75	1.31	>98.3
3	10	>75	0.66	>99.2
4	15	>75	0.88	>98.9
	Avg.		0.8	
Standard deviation			0.4	
C.V.			45.1	

The study over the use of urine diverting toilet demonstration facilities shows that there was less knowledge about UDTs. After demonstration facilities installed and opened for use, knowledge and attitude of the people has changed. The economic aspect of UDTs was also understood by the people that though initial cost was high but long term gains were many. Study suggests the effective school awareness program for students, teachers, parents for effective involvement and use[30].

The study of UNICEF about the SHEWA-B program in Bangladesh where 33,027 households were involved in the survey conducted in 33,134 houses which were distributed in 1182 clusters so the99.7% was the response rate. It was seen that out of respondents 96% were mothers. 50% of all participants did not remember the meeting called by promoters; it means access to the program was affected. Health behaviors of participants were similar whether improved facilities were provided or not. The analysis on impact of quality on outcomes suggests that higher quality results in higher outcomes. To increase the effectiveness of the program the redesign was needed in SHEWA-B. Target-like reduction in defecation rate was dropped as suggested by UNICEF. But as quality was low or implementation strategy was faulty the health and behaviors may not meet the goals. It was observed that the cases of child diarrhea, respiratory illness dropped but no significant reduction was seen; which shows the less impact of the program on health. The lethargic nature of promoters might have affected the program implementation[22].

The average water use over the household and individual using PLUM was done and data analysis was performed using EPI data 3.1. Data was processed using STATA 12. The assessment of PLUMs recorded events was done for every 48 hours and the study conducted surveillance of data for 14 days for every household. 4088 household-days data was reported with 2035 individuals. The "usual" daily latrine use events recorded were 7.09, while PLUM recorded events were 3.62. The 6.74 was the average household size with standard deviation of 3.2[23].

The result of the study for reliability of studies conducted by Kolman says that none of the criteria was reliable. The average score was lower than 2. Therefore significant improvement is needed in reporting of data. **Table 7** shows the criteria wise score[31].

Table 7. Criteria wise score.

Criteria	Sampling methods	Sample size	Sample processing and storage	Lab preparation	Clean air conditions	Negative controls	Positive controls	Sample treatment	Polymer ID	Total Accumulated Scoreb (TAS, max¼18
Score	1.57	1.02	1.20	0.77	0.64	1.18	0.21	0.93	0.89	8.41

10. Conclusions

Water conservation is the need of the hour. Robust, economic and smart technologies need to be developed that consume less water. It needs accurate data on water consumption patterns and its spatial, temporal variations. Water consumption in various sectors like agriculture, industrial, domestic use needs to be determined by using scientific data collection methods using new technologies like internet of things, sensors, actuators and smart sanitation equipment will be produced. Smart sanitation will open the doors of economy and also employability. Furthermore, its value could be worth at least US $12 trillion per year in market opportunities and generate up to 380 million new jobs by 2030. The sanitation economy is a US $32 Billion per year market in India in 2017 and is set to double to an estimated US $62 billion by 2025. While implementing there is more focus given to the toilet tripod i.e., effect of political will, social pressure and political ecology for better implementation of strategies. There is a need for a bottom up approach to WASH and WASH Promotion. More emphasis must be given awareness and its relation with the disease transmission must be given wide promotion. Similar emphasis was given to the promotion in the study of UDDTs. Waterless urinals can be good candidates for water saving equipment as study showed that it can be efficient by minimum 90%. Also cost effective and less maintenance is required. There is a gap between the assessment processes so while conducting any assessment there is a need to select an accurate method. The need of the hour is better forecasting of water demand, judicious consumption, water saving habits and technology. Since IOT based systems have become technologically mature and availability of cloud at low cost, domestic water systems can be IOT enabled for better water management and conservation. AI based systems can monitor water quality, pattern, and consumption autonomously and have good potential to save water in domestic settings.

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Conflict of interest

The authors declare no conflict of interest.

References

1. TERI. Study On Assessment Of Water Footprints Of India's Long Term Energy Scenarios. New Delhi And NITI Aayog; 2017.
2. World Health Organization. Domestic Water Quantity, Service, Level And Health. World Health Organization; 2003
3. Bureau Of Indian Standards. Code Of Basic Requirements For Water Supply, Drainage And Sanitation, 4th ed. Bureau Of Indian Standards; 1993.
4. Cosgrove WJ, Loucks DP. Water Management: Current And Future Challenges & Research. Water Resource Research. 2015.
5. Luo T, Young R, Reig P. Aqueduct Projected Water Stress Country Ranking. World Resource Institute. 2015.
6. UN Human Settlement Programme. Global Report On Human Settlements 2011- Cities And Climate Change. UN Human Settlement Programme; 2011
7. FAO. The State Of Food And Agriculture, Climate Change. Agriculture & Food Security. 2016.
8. Milton AH, Rahman H, Smith W, Shrestha R, Dear K. Water consumption patterns in rural Bangladesh: are we underestimating total arsenic load? J Water Health. 2006 Dec;4(4):431-6.
9. Hossain MA, Rahman MM, Murrill M, Das B, Roy B, Dey S, Maity D, Chakraborti D. Water consumption patterns and factors contributing to water consumption in the arsenic affected population of rural West Bengal, India. Sci Total Environ. 2013 Oct 1;463-464:1217-24. doi: 10.1016/j.scitotenv.2012.06.057. Epub 2012 Aug 2. PMID: 22858413; PMCID: PMC4089211.
10. Jethoo AS, Poonia. Water Consumption Pattern Of Jaipur City (India). International Journal Of Environmental Science And Development. 2011; 2(2).
11. Shaban A, Sharma RN. Water Consumption Pattern In Domestic Households In Major Indian Cities. Economic And Political Weekly. 2007.
12. Fogarassy Cs, Neubauer É, Böröcz Bakosné M, et al. Water footprint based water allowance coefficient. Water Resources and Industry. 2014; 7-8: 1-8. doi: 10.1016/j.wri.2014.08.001
13. Becken S. Water equity—Contrasting tourism water use with that of the local community. Water Resources and Industry. 2014; 7-8: 9-22. doi: 10.1016/j.wri.2014.09.002
14. The Toilet Board. The Sanitation Economy In India, Market Estimates & Insights. The Toilet Board; 2017.
15. Hamdar B, Hamdan A. Economic Modeling of Water Need Determination in Lebanon: Implication for Lebanon's Agriculture. American Journal of Water Science and Engineering. 2020; 6(1): 31. doi: 10.11648/j.ajwse.20200601.14
16. Gorantla S, Kumar Yadiki Y, Pandla J. Quantification of Groundwater Resources using Water Table Fluctuation Method in Tirupati Division, Andhra Pradesh State, India. American Journal of Water Science and Engineering. 2020; 6(2): 65. doi: 10.11648/j.ajwse.20200602.12
17. Rondinel-Oviedo DR, Sarmiento-Pastor JM. Water: consumption, usage patterns, and residential infrastructure. A comparative analysis of three regions in the Lima metropolitan area. Water International. 2020; 45(7-8): 824-846. doi: 10.1080/02508060.2020.1830360
18. Bich-Ngoc N, Teller J. A Review of Residential Water Consumption Determinants. In: Computational Science and Its Applications. CRC Press; 2018. doi: 10.1007/978-3-319-95174-4_52
19. Marshall L, Kaminsky J. When behavior changes fails: evidence for building WASH strategies on existing motivations. Journal Of Water Sanitation And Hygiene For Development. 2016.
20. Mulopo C, Cjimabari MJ. Water sanitation and hygiene for schistosomiasis prevention: A qualitative analysis of experiments of stakeholders in rural Kwazulu Natal. Journal Of Water Sanitation and Hygiene. 2021.
21. O'Reilly K, Louis E. The toilet tripod: Understanding successful sanitation in rural India. Health & Place. 2014; 29: 43-51.
22. Benjamin-Chung J, Sultana S, Halder AK, et al. Scaling Up a Water, Sanitation, and Hygiene Program in Rural Bangladesh: The Role of Program Implementation. Am J Public Health. 2017; 107(5): 694-701.
23. Sinha A, Nagel CL, Thomas E, et al. Assessing Latrine Use in Rural India: A Cross-Sectional Study Comparing Reported Use and Passive Latrine Use Monitors. The American Journal of Tropical Medicine and Hygiene. 2016; 95(3): 720-727.
24. Rafa N, Uddin SMN, Staddon C. Exploring challenges in safe water availability and accessibility in preventing COVID-19 in refugee settlements. Water International. 2020; 45(7-8): 710-715.Sarode PM, Ijrbat. Design And Implementation of Automatic Flush System For Sanitation In Public Toilets. 2015; 7: 56-58.
25. Atta RM. Purity Sensor Activated Smart Toilet Flushing System. International Journal Of Water Resources And Arid Environments. 2013; 2(1): 51-55.
26. Lei T, Shuhui J, Weiwei W, et al. Research on Design Method Optimization of Combined Sewer Overflow Detention Tank. American Journal of Water Science and Engineering. 2020; 6(1): 1.
27. Hashemi S, Han M, Kim T, Kim Y. Innovative Toilet Technologies For Smart And Green Cities. 8th Conference Of The International Forum On Urbanism. 2015.
28. Sakthivel SR, Azizurrahaman M, Ganesh Prabhu V, Chariar VM. Performance evaluation of low cost odor trap installed in waterless urinals. Journal Of Water Sanitation And Hygiene For Development. 2016.

29. Trimmer JT, Nakyanjo N, Ssekubugu R, et al. Assessing the promotion of urine-diverting dry toilets through school-based demonstration facilities in Kalisizo, Uganda.
30. Koelmans AA, Mohamed Nor NH, Hermsen E, et al. Microplastics in freshwaters and drinking water: Critical review and assessment of data quality. Water Research. 2019; 155: 410-422. doi: 10.1016/j.watres.2019.02.054
31. Mao L, Chen Y, Li X. Characterizing ship-induced hydrodynamics in a heavy shipping traffic waterway via intensified field measurements. Water Science and Engineering. 2020; 13(4): 329-338. doi: 10.1016/j.wse.2020.11.001
32. Casila JC, Azhikodan G, Yokoyama K. Quantifying water quality and flow in multi-branched urban estuaries for a rainfall event with mass balance method. Water Science and Engineering. 2020; 13(4): 317-328. doi: 10.1016/j.wse.2020.12.002
33. Abbaspour A, Parvini S, Hosseinzadeh Dalir A. Effect of buried plates on scour profiles downstream of hydraulic jump in open channels with horizontal and reverse bed slopes. Water Science and Engineering. 2016; 9(4): 329-335. doi: 10.1016/j.wse.2017.01.003
34. Gholami A, Bonakdari H, Akhtari AA. Assessment of water depth change patterns in 120° sharp bend using numerical model. Water Science and Engineering. 2016; 9(4): 336-344. doi: 10.1016/j.wse.2017.01.004
35. Li X, Zhai Q. Nano mesocellular foam silica (MCFs): An effective adsorbent for removing Ni2+ from aqueous solution. Water Science and Engineering. 2019; 12(4): 298-306.
36. Hamner S, Tripathi A, Mishra RK, et al. The role of water use patterns and sewage pollution in incidence of water borne or enteric diseases along the Ganges river in Varanasi, India. International Journal of Environmental Health Research. 2007.
37. Basua M, Hoshino S, Hashimoto S, Gupta RD. Determinants of water consumption: A cross-sectional household study in drought-prone rural India. International Journal of Disaster Risk Reduction. 2017.
38. Liu J, Li YP, Huang GH. Mathematical Modeling for Water Quality Management under Interval and Fuzzy Uncertainties. Journal of Applied Mathematics. 2013; 2013: 1-14. doi: 10.1155/2013/731568
39. Sislian R, Silva FVd, Gedraite R, et al. Mathematical Modeling and Development of a Low Cost Fuzzy Gain Schedule Neutralization Control System. Engineering Letters. 2016.
40. Castillo AFd, Garibay MV, Senés-Guerrero C, et al. Mathematical Modeling of a Domestic Wastewater Treatment System Combining a Septic Tank, an Up Flow Anaerobic Filter, and a Constructed Wetland. Water. 2020.
41. Arbues F, Garcıa-Valinasab MÁ, Martınez-Espineir R. Estimation of residential water demand: a state-of-the-art review. Journal of Socio-Economics. 2003.
42. Bai Y, Wang P, Li C, et al. A multiscale relevance vector regression approach for daily urban water demand forecasting. Journal of hydrology. 2014.
43. Kofinas D, Mellios N, Papageorgiou E, Lasipadou C. Urban water demand forecast for the island of Skiathos. Proceeding Engineering. 2014.
44. Saranya P, Reddy B, Vani B, Durgesh S. Iot Automatic Water Conservation System. IOP Conf. Series: Materials Science and Engineering. 2021.
45. Siddula SS, Babu P, Jain PC. Water Level Monitoring and Management of Dams using IoT. 3rd International Conference On Internet of Things Smart Innovation and Usages. 2018.
46. Suciu G, Bezdedeanu L, Vasilescu A. Unified Intelligent Water Management Using Cyber Infrastructures Based on Cloud Computing and IoT. International Conference on Control Systems and Computer Science. 2017.
47. Ascencao E, MAriangelo F, Almeida C, et al. Applications of Smart Water Management Systems: A Literature Review. Water. 2023
48. Jenny H, Alonso EG, Wang Y, Minguez R. Using Artificial Intelligence for Smart Water Management Systems. ADB Briefs. 2020.