

II REVIEW OF LITERATURE

The review of literature pertaining to the study on *"Exploration of Domestic Water Management Practices and Paradigm Shift using IoT Enabled AI System for Devising Water Conservation in Ingenious Homes"* was presented in detail under the following headings:

A. Historical Perspective of Water

B. Residential Water Use

C. The Altering Water Quality Paradigm

D. An Overview of Water Conservation and

E. Futurism towards Smart Water Management Systems Using Artificial Intelligence

A. Historical Perspective of Water

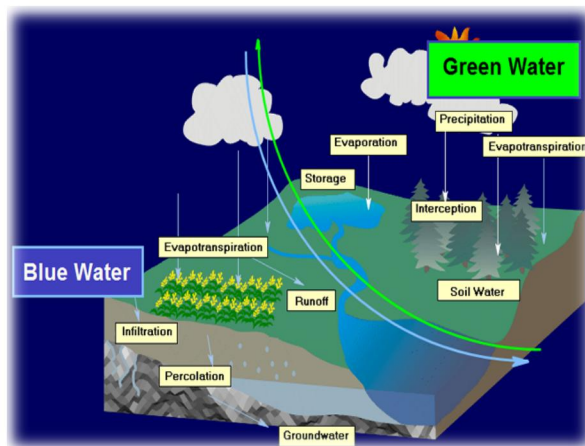


Figure 3: Blue and Green Water

Source: <http://ubclfs-wmc.landfood.ubc.ca>

Water has a legion of coloured faces. *"Blue water"*: exists as renewable groundwater in aquifers and as surface water in bodies. The term *"Green water"*: indicates the entire amount of water that is lost through evaporation during agricultural production. This includes both the evapotranspiration of plants as well as the loss of water through

evaporation from irrigation water.

"White water": people assessing the quality of water consider clean, clear tap water to be white. It can be collected from dams, lakes or rivers and has undergone treatment, making it fit for all uses, including drinking.

"Grey water": 38 per cent of the water used in the house is the clean wastewater from

Water is our most precious resource, a 'blue gold' to which more than 2 billion people do not have direct access. It is not only necessary for people to have it in order to survive, but it also plays an important part in the maintenance of public health, social relationships, and cultural traditions of human society.

UNESCO (2021)

Box 4: Water – Blue Gold

bathing, washing utensils, clothes, hand wash and other kitchen appliances is expressed as grey. "**Black water**": is sewage waste water, which must be treated before it is discharged into the environment. The quality of this treatment can be made by a simple septic tank in domestic sectors, according to Selinger and Barrow (2017).

“Water covers about 70 per cent of the planet and Earth is termed as the “**Blue Planet**” or the “**Water Planet**”. It fills oceans, lakes and rivers. It was estimated that 96.5 per cent of the total volume of water on the earth will be in oceans, with just a small percentage being fresh water. Nearly two per cent of the world’s freshwater is frozen as snow-covered ice sheets, glaciers, and mountain ranges of glacial terrain in Greenland, Antarctica, and other locations, whereas less than one per cent is accumulated as subterranean water in the water sources around the world. Water soaks into the ground into aquifers as stated by Olien (2005).

In the beginning of all, water owns countless exclusive properties; one of those is water the only compound that exists naturally as Ice (solid), Water (liquid), and Vapour (gas).

Spellman (2021) narrates the history of water detection as an early human, wandering alone from place to place, hunting and gathering to subsist, probably would have had little difficulty in obtaining drinking water, because such a person would-and-could only survive in an area where drinking water was available with little travail – that even the animals and many drank it from the same place as early humans. The search for clean, fresh and palatable water has been a human priority from the very beginning. It was stated that, when humans first walked on the Earth, many of the steps they took were in the direction of water. The foremost basis for water is the rain. When early humans were alone or in small numbers, finding drinking water was a constant priority, to be sure, but it is difficult for us to imagine today just how big a priority finding drinking water became as the number of humans proliferated.

வான்றின்று உலகம் வழங்கி வருதலால்
தான் அமிழ்தம் என்றுணரற் பாற்று

**'As the earth lives off the sky's bounty,
rain is praised as the nectar of
immortality'.**

- Thirukkural. Arathu Paal. Kural 11

Box 5: Nectar of Immortality – The Rain

Eventually, communities formed, and with their formation came the increasing need to find clean, fresh and potable drinking water and also to find a means of delivering it from the source to the point of use. Archaeological digs are replete with the remains of ancient water systems. For well over 2000 years, piped water supply systems have been in existence. One universal to the community needs of all humans: to deliver clean, fresh, potable water to where it was needed. These early systems lacked in two general areas a) water pressure – relied on gravity flow, since the means to pressurize the mains were not known at the time and b) sanitation – from the mid 1800s people realized that there is a connection between contaminated drinking water and disease. This had led to evolve scientific discoveries towards the development of technology for processing and disinfection of water. Drinking water standards were developed by health authorities, scientists and sanitary engineers. Due to the developed discoveries over time, that all is well with us – the problems related to providing clean, clear and fresh drinking water are problems of the past.

- Are they really problems of the past?
- Have we solved all the problems related to ensuring that our drinking water supply provides us clean, fresh and quality water?

Then why do we ignore water? Why do we abuse (pollute or waste) it?

1. Status of fresh water

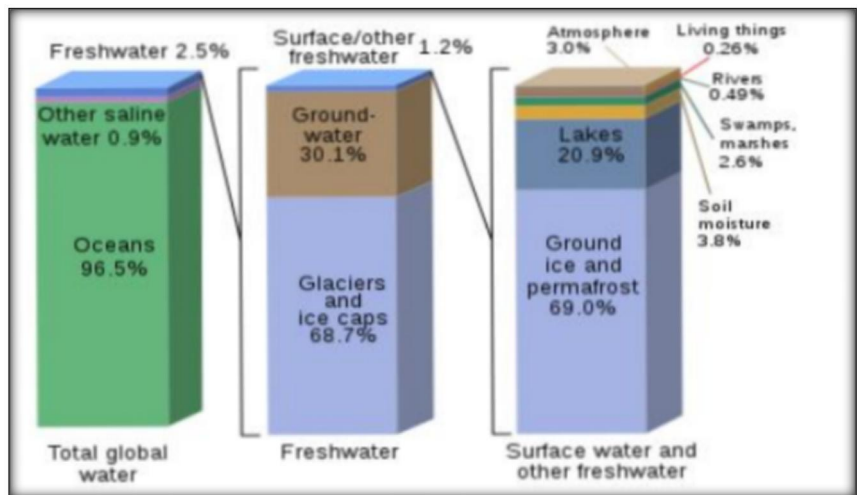
Water resources are sources of water that are potentially useful. The majority of human require fresh water for their consumption. Ninety seven per cent of the water on the Earth is salt water and only three per cent is freshwater; over two-thirds of this is frozen in glaciers and polar ice caps. The remaining unfrozen freshwater found mainly as groundwater, with only a small fraction present above ground or in the air as per Goswami and Bisht (2017) and Yadav *et al.* (2022). Figure: 5 portrays the status of fresh water.

Water has captivated the attention of every industrialist, business people, design developers, environmentalists, researchers and scientists, medical and engineering professionals, and even politicians with its supernatural characteristics. This indicates that water permeates in all phases of life as food, living medium, power generation, and the main component of life.

2. Water scarcity

According to Dehghani *et al.* (2021) water scarcity is described as a condition where water demand exceeds available water supply. A country or a region faces “water scarcity” when the availability of natural hygienic water falls below 1000 m³ per person per year.

According to Ramesh (2021) on an average, India gets a little over 1,100 mm of rain a year, mostly from the Indian monsoon. Summing this up over India’s entire land area translates to about 3,880 BCM (Billion Cubic Metres) of water a year. Now, a fraction of that rain water evaporates; some of it is retained by the soil, which leaves only about an estimated 2,000 BCM of this water to be ‘available’. Not all of the available water can be ‘used’ by humans. Only about 1,137 BCM can be used either from the water in rivers, lakes or ground water. Out of all uses water quality for drinking purpose is of paramount importance. It is therefore essential that quality guidelines and standards are prescribed by concerned authorities. The WHO, Bureau of Indian Standards (Government of India), European community and EPA(USA) are some of the prominent agencies which have formulated drinking water quality standards.



<https://www.usgs.gov/special-topics/water-science-school/science/where-earths-water>

Figure 4: Status of Fresh Water

Drinking Water — Drinking water is water intended for human consumption for drinking and cooking purposes from any source. It includes water (treated or untreated) supplied by any means for human consumption.

(<https://law.resource.org/pub/in/bis/S06/is.10500.2012.pdf>)

Box 6: Definition of Drinking water by BIS

Reed (2017) and Kumar (2018) stated that, today, water scarcity is

110 - that is the number of water taps that delivered the delectable Siruvani to the inhabitants of Coimbatore. It was on April 29, and the year was 1929. "In Race Course there were just six water connections". People offered flowers and worshipped the tap. It was Coimbatore's lifeline. When the siruvani water was first introduced to the town on April 26, 1929, it was due to the charisma and influence of Rathinasabapathy Mudaliar. Coimbatore experienced a resurgence.

- The Hindu (08.05.2015)

Source:<https://www.thehindu.com/features/metropolis/40year-struggle-to-bring-siruvani-water-to-coimbatore/article7185104.ece>

dangerously weakening vulnerable societies, creating fragile states. Lack of access to resources, in particular water, whether caused by mismanagement or inequitable distribution, is a major driver of poverty, conflict and extremism. The World Health Organization (WHO) estimates that a person needs more than 70 litres of water a day to live, while the Bureau of Indian Standards (BIS) recommends 135 litres per person per day as a lower limit.

According to Ramesh (2021) water availability per person is dependent on population of the country and for India, per capita water availability in the country is reducing due to increase in population.

Box 7: History of Siruvani Water in Coimbatore City

As per Ministry of Housing and Urban Affairs, 135 litre per capita per day has been suggested as the benchmark for urban water supply. For rural areas, a minimum service delivery of 55 LPCD has been fixed under Jal Jeevan Mission, which may be enhanced to higher level by states. This information was given by the Union Minister of State for Jal Shakti & Social Justice and Empowerment, Shri Rattan Lal Kataria in a written reply in Rajya Sabha on 02 March 2020 (<https://pib.gov.in/PressReleasePage.aspx?PRID=1604871>). The MOUD's (Ministry of Urban Development) benchmark for per capita water usage is 135 LPCD (liters per capita per day).

3. Water resources in India

Resource management, particularly water, is a key challenge to urban sustainability.

Singh *et al.* (2020) and Wang (2021) opined that water is present in various forms in nature and can be classified into different categories based on the amount of salt present in it (salt is one of the substances included in the determination of the

measurement total dissolved solids, or TDS in a water specimen). Water that is fit to drink has a TDS lying in the range of 100 to 300 ppm, while a Municipal supply would have a TDS between 300 and 500 ppm. Water used for medical and electronic purposes may have a very low TDS (<1 ppm). Sea water on the other hand has very high TDS values, in the range of 30000 to 40000 ppm.

4. Definition and scope of drinking water

Fryer (2012), referred to "Potable" water as water that is free of contaminants and safe for consumption. Consumption, cooking, and food preparation are all restricted by the use of non-potable water. When it comes to storing water for future use, there are a variety of reasons why people do so. The needs of each person are unique. When water is scarce, city dwellers may stockpile water in containers in case they need it in an emergency. Storing and collecting water are as follows:

- For emergencies, and
- For everyday use.

Chatterjee (2008) elucidated that potable water is derived mainly from two sources – surface and underground water. The surface water generally contains large quantities of sediments, organic matter and bacteria.

Committee on Environment and Public Works (2015) referred that WHO considers “drinking-water” should be “suitable for human consumption and for all usual domestic purposes including personal hygiene”. Drinking-water should therefore be suitable for consumption, washing/showering and domestic food preparation. In human health terms, exposure to water and its constituents can occur through ingestion, contact and aerosol inhalation. Drinking-waters should be safe for lifetime use. Piped drinking-water supplies typically involve source abstraction, treatment and distribution. The latter may include ancillary devices at domestic or institutional levels, such as softeners, activated carbon treatment, vending machines, dispensers, etc. People were in a situation to store the supplied water for a period upto 20 days based on their locality.

Halkman and Halkman (2014) and Ratna (2019) expressed that the control of faecal contamination in drinking-water systems and sources, where it occurs, is of primary importance. Faecal-specific indicator bacteria such as *E. coli* are the

parameters of first importance in monitoring faecal pollution. If only total coliform bacteria are detected in drinking water, the source is probably environmental. *Escherichia coli* is a subgroup of the fecal coliform group. Most *E. coli* are harmless and are found in great quantities in the intestines of people and warm-blooded animals. Some strains, however, may cause illness. The presence of *E. coli* in a drinking water sample almost always indicates recent fecal contamination—meaning that there is a greater risk that pathogens are present.

Herman and Gellasch (2021) quoted that, in the year 2000, the city of Walkerton, Ontario, Canada, experienced an *E. coli* outbreak caused by contaminated groundwater and resulting in several deaths. Investigation revealed that a combination of a shallow well, karst aquifer with thin soil, heavy rainfall, and livestock manure resulted in rapid movement of faecal contamination into the aquifer near a public supply well.

5. Details of water supply infrastructure

Weskamp *et al.* (2018) and Coimbatore City Municipal Corporation (2022) published that, at present, the drinking water is supplied to the extended areas of 11 Urban Local Bodies, now included in the Coimbatore Corporation by the Tamilnadu Water supply and Drainage Board through the Siruvani, Pillur Phase-I, Aliyaru and Bhavani scheme of water distribution. Total average quantity of 35.71 MLD (Million Litres Per Day) of water was drawn and this quantity gives only **66 litres (average) per capita per day** and distributed to the added areas once in 4 to 12 days.

Number of domestic meter connections	- 117673
Number of non-domestic meter connections	- 9787
Number of public fountains	- 2811

In the context of the project SWF India (Smart Water Future India Project), and Battenberg *et al.* (2019) Devasenadhipathi *et al.* (2016) even though there are raw water resources in high quality available in the dams situated in the mountains, the citizens of Coimbatore only receive water every 5 to 10 days. Insufficient infrastructure for treatment and supply as well as high water losses due to leakages are the reasons for this. Due to the irregular flow regime in the pipelines and the storage time in domestic tanks, the water quality at the point of consumption is

supposed to be much lower than at the water works. Mostly, water is not calculated for its flow using a water meter and users pay a very low flat rate. If the monsoon does not bring sufficient rain, the water supply for the city is endangered.

B. Residential Water Use

1. Water use and needs theory

Maslow (1943), Russo *et al.* (2014) and Crouch *et al.* (2021) quoted that Maslow's hierarchy of human needs is a useful framework in which to consider water-use requirements. Humans have different levels of needs, defined by Maslow in

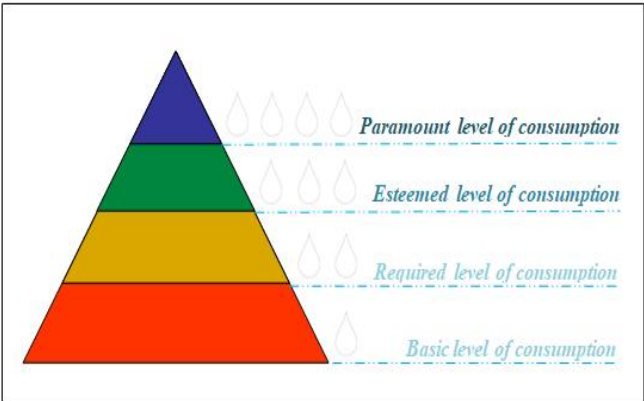


Figure 5: Graphical Representation of Water Use and Needs Theory

a hierarchy ranging from basic physiological needs, safety, love and belonging and esteem to the highest level of self-actualisation, which is defined as achieving one's full potential. Basic and the required level of water consumption to fulfill baseline physiological and

safety needs would include drinking water, cooking uses,

basic hygiene, and sanitation. Higher level needs for esteem and paramount would include additional water uses associated with sparkling clean homes and belongings, water-related sports or relaxation activities requiring swimming pools and hot tubs and irrigated gardens represented in Figure 5.

2. Worth of water

Gangwar (2013) explained that water is universally underpriced and undervalued. Very few governments, businesses or citizens are demanding that water is valued. Even though it is not always recognized by all, water clearly has value. In some perspectives the value of water is infinite, since life does not exist without it and there is no replacement for it. This is perhaps best exemplified by the recent elation in finding it on the Moon and Mars. The risks of undervaluing water are far too great to ignore.

As concluded by Zetland (2021) many a times, it is a challenge to provide water of desired quantity and quality at a desired place. At times, enough water may be available but the quality may be so poor that it is of no use without treatment. Olumana (2017) insisted that adequate, clean and safe drinking water supply has to be available for various end users importantly should be accessible by all.

Ali and Terfa (2012) listed factors influencing water consumption for domestic activities at household level. They are as follows: family size, income, nature of employment, education level, gender and topographical variation.

Browne *et al.* (2014) recorded that domestic water use is affected by a number of factors, including the age, occupation, cultural preferences, and household income of the individuals using water. Determining factors like climate, topography, culture, food habit, economic status and awareness about water was indicated by Rout and Ruth (2022).

It has been identified from the undertaken research that the primary challenge that the city residents may come across is to have adequate pressure of water during water supply. This is considered to be a major concern today. In addition to water pressure, water leakages from distribution pipes, water supply without intimation, and carrying water from water point inside the house were also included.

One of the greatest moves by the Coimbatore Corporation is that they posts water supply schedules a day in advance on social media. The change in timings left many residents clueless, especially office-goers who could not store water, as they were not at home during the supply time.

- Around one-third of all water is used for toilet flushing.
 - The average bath uses 80 litres of water.
 - Most washing machines are at least A-rated and use no more than 7 litres of water per kg of washing, compared to older models which use three times as much water.
 - Most A-rated dishwashers use less than 12 litres of water per cycle.
 - This typically saves around 70% of water compared to hand-washing
 - Standard taps use around 6 litres of water per minute.
 - Spray taps : 30 - 65% water saving
 - Self-closing : 20 - 50% water saving by timing water flow
 - Automatic shut-off taps: sensors need energy
- Pelsmakers, 2015

(<http://timesofindia.indiatimes.co>

[m/articleshow/90855248.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst](http://timesofindia.indiatimes.co/m/articleshow/90855248.cms?utm_source=contentofinterest&utm_medium=text&utm_campaign=cppst)). But for a normal layman it sounds difficult to understand the

Box 8: Minimum Essential Water Need in a House

information through social network. So such intimations on water supply can be made to reach all level of people around the city.

3. Minimal water requirements

Gangwar (2013) estimated that each day, a person drinks 2–4 litres of water and uses 10–15 litres for other needs. This is a governance problem. Globally only about 14% of all water use is for domestic needs (drinking, cooking, washing, etc.).

As per the International norms studied by Gupta and Deshmukh (2020) if per-capita water availability was less than 1700 m³ per year then the country was categorized as water stressed and if it is less than 1000 m³ per capita per year then the country was classified as water scarce. In India per capita surface water availability in the years 1991 and 2001 were 2309 and 1902 m³ and these were projected to reduce to 1401 and 1191 m³ by the years 2025 and 2050 respectively.

Sharma (2021) computed that on an average, the domestic consumption under normal conditions in an Indian city is expected to be around 135 litres/day person as per IS: 1172-1971. The breakup of 135 LPCD was given in Table 1.

Table 1: Per Capita Demand of water in Standard Indian Town and Domestic Consumption

S. No.	Per Capita Demand of Water in Standard Indian Town		Domestic Consumption	
	Purpose	Water Need	Domestic Use	Consumption in Liters per Day per Person
1.	Domestic Purposes	135 L	Bathing Requirement	55 L
			Washing Clothes	20 L
			Cooking	5 L
			Drinking	5 L
			Washing of Utensils	10 L
			Flushing of Latrines, etc.	30 L
			Washing and Cleaning of Houses and Entrance	10 L
			Total	135 LPCD

C. The Altering Water Quality Paradigm

1. Water quality challenges

Since water has the primary property as a *universal solvent*, it also holds impurities that are dissolved in the water. There are two ways by which the impurities get into contact with water:

- Natural, and
- Human activities/ handling.

Natural activities - like influence of atmospheric gases, bacteria, virus, particulate substances, turbidity by soil and natural debris, among others., and the next by

Human activities - handling of water like pollution by industrial and domestic wastes.

During the operation/journey from the water supply system to the consumer, water losses, pressure or flow reduction, and water quality deterioration may be caused by increasing concentrations of various organic, inorganic, or organometallic compounds and contaminants with various microorganisms stated Glavan (2018).

Omer (2020) classified water quality into four types. The most common scientific definitions of these types of water quality are as follows:

- ✚ Potable water – It is safe to drink, pleasant to taste, and usable for domestic purposes,
- ✚ Palatable water – It is aesthetically pleasing; it considers the presence of chemicals that do not cause a threat to human health,
- ✚ Contaminated (Polluted) water – It is that water containing physical, chemical, biological, or radiological substances, and it is unfit for drinking or domestic use, and
- ✚ Infected water – It is contaminated with pathogenic organism.

The UN-SDG 6 (Sustainable Development Goal) states that “Water Sustain Life but Safe, Clean, and Drinking Water Defines Civilization”.
- Dinka, 2018



Box 9: SDG - Clean Water and Sanitation


Sagasto *et al.* (2017) expressed that global attention has focused primarily on water quantity, water-use efficiency and allocation issues. Poor wastewater management has created serious water quality

problems in many parts of the world, worsening the water crisis. Water scarcity is caused not only by the physical scarcity of the resource but also by the progressive deterioration of water quality, reducing the quantity of water that is safe to use.

However, water scarcity and water quality degradation present major challenges in securing enough water of good quality to meet human, environmental, social and economic needs to support sustainable development of countries.

2. Water pollution and extanting water contaminants

Around 10% of the World's population, according to the WHO - World Health Organization estimation, does not have access to safe drinking water. Some chronic illnesses such as cancer and cardiovascular disease, reproductive problems and neuro development may result from exposure to chemicals in drinking water reports Levallois and Villanueva (2019).



Pollution is anything that goes against the Principle of Environment
– Srivastava, 2018

Box 10: Definition of Pollution

Quality and quantity of water should be given equal importance. Water is considered polluted when there is any physical, biological or chemical change in water quality that adversely affects living organisms or makes water unsuitable for use. It could be inferred that every process of human activity leads to the deterioration of water quality. The impact of water pollution is manifold and varied. It affects the health of the people, starting with all sorts of hepatitis disorders (diarrhoea, cholera, dysentery, jaundice, among others) and skin diseases, which ultimately lead to slow poisoning and cancer. Recycling water reduces water pollution and helps with water conservation (Chatterjee, 2008).

Singh *et al.* (2020) quoted water contaminants and the different water treatment technologies as follows:

The impurities present in water vary depending on their characteristics. Water if remained and treated may lead to various adverse physiological conditions. These can cause health problems at a smaller scale (affecting individuals) or a larger scale (affecting populations). Among the different kinds of contaminants present in water biological contaminants such as bacteria,

viruses, protozoa, among others, which can cause infectious diseases, are considered to be the most common and widespread health risk associated with drinking water.

3. Advances in water purification technologies

Chatterjee (2008) and Patrick *et al.* (2005) declared that as a result of large quantities of sediments, organic matter, bacteria, dissolved and colloidal impurities in drinking water, it requires necessary purification before consumption.

A single water purification technology cannot serve the purpose of obtaining consumable, purified drinking water. Water quality differ in different parts of the world and hence the technology employed for its purification also differs everywhere. Generally the aspects of water quality about which most regulations are concerned can be divided into five categories based on the presence of inorganic chemicals, organic chemicals, radioactive materials, physical parameters and microbiological parameters. There are several technologies available in the market today to treat these contaminants. Pradhan *et al.* (2018), research showed that majority of surveyed households (53.2%) consumed water directly from the source for drinking without any treatment. Treatment procedures such as boiling were used by 28.4 per cent of the people, membrane filters were used by 15.2 per cent of the people, and the other people utilised various alternative treatment methods.

4. Thermal (heat-based) technologies

Ahuja (2019) highlighted that the simplest method, boiling water used for drinking, is still a standard approach used in remote, undeveloped, or disaster-impacted situations, but also in technologically advanced settings when distribution systems are compromised: “boil water” advisories are routinely issued when pipe failures, storm flooding, or other factors cause contamination of public and private drinking water distribution systems. Boiling at ambient pressure is referred to as "pasteurization," and is effective at killing essentially all waterborne pathogens capable of causing human disease. Actual boiling temperatures are not required to kill or inactivate some waterborne pathogens, but public health advisories recommend bringing water to a rolling boil for at least one minute to ensure safety. Boiling remains the most common form of household-scale water treatment worldwide and is probably the oldest method of water treatment. Boiling does not reduce sediment or turbidity and it negatively affects taste.

5. Solar disinfection

Boyle *et al.* (2008) explained that solar energy is used for disinfection in various places. Some methods use solar radiation to deactivate microbes in either dark or opaque containers by relying on heat from sunlight. Others such as the SODIS (Solar Water Disinfection system) developed by the Swiss Federal Agency for Environmental Science and Technology, use clear plastic containers penetrated by UV radiation from sunlight and rely on the combined action of the UV radiation, oxidative activity associated with dissolved oxygen and heat other physical forms of solar radiation exposure system also employ combinations of these solar radiation effects in other types of containers such as UV-penetrable bags and Panels to improve the microbial quality of water.

6. UV Light technologies using lamps, including UV light-emitting diodes

As clarified by Nyhan *et al.* (2021), UV radiation is widely used as a germicidal treatment for water. The absorption of UV light by the DNA and proteins in microbial cells results in the inactivation of the microorganism. UV radiation has been used in drinking-water treatment for over hundred years. The technology has proven its effectiveness against chlorine-resistant protozoan pathogens, such as cryptosporidium and Giardia. The number of drinking-water treatment Technologies employ UV light radiation from UV lamps to inactive microbes. For household or small-scale water treatment low-pressure mercury arc lamps producing monochromatic UV radiation at a germicidal wavelength of 254 nm are mostly used.

7. Coagulation-flocculation or Sedimentation

Coagulation or precipitation is a method employing a natural or manufactured coagulant or precipitant to coagulate and or precipitate suspended particles including microbes to enhance their sedimentation. These methods may be used along with cloth or fibre media or as a straining step to remove the fore flocculated particles that have formed. This category includes simple sedimentation or that achieved without the use of a chemical coagulant. Some combination systems are commercial products in the form of granules, powders or tablets containing a chemical coagulant such as an iron or aluminium salt and a disinfectant such as chlorine. When added to water, these chemicals coagulate and flocculate impurities to promote their rapid and efficient sedimentation and to deliver the

chemical disinfectant (eg. Chlorine) to inactivate microbes. These combined coagulant-flocculant disinfectant products are added to specified volumes of water, allowed to react for floc formation, and mixed into to promote coagulation and flocculation. They are then allowed to remain unmixed for the floc to settle. The clarified supernatant water is then decanted off, usually through a cloth or other fine mesh medium to strain out remaining particles. The recovered supernatant is then stored for a period of time to allow for additional chemical reactions and disinfection to occur before the water is consumed (<https://www.mrwa.com/WaterWorksMnl/Chapter%2012%20Coagulation.pdf>).

8. Chemical disinfection

Talat (2020) explicated that the chemical disinfection of drinking water includes technologies that are based on the utilization of chemicals for disinfection. Chlorine/Iodine-based technologies, including chlorine dioxide as well as bromine, ozone, other oxidants, strong acids and bases, ferrates, and some antimicrobial metals such as silver and copper could be the methods involved:-

- a) Chlorination
- b) Disinfection with Iodine
- c) Ozone disinfection
- d) Disinfection by strong acids or bases
- e) Silver and copper-based disinfectants and
- f) Ion exchange.

9. Filtration

Point-of-use water filtration technologies include cloth or fibre filters, membrane filters, ceramic filters, carbon block filter, composite filters and similar technologies. Microbes by a combination of physical and chemical (and in some cases biological) processes including physical straining, sedimentation and absorption. Filtration technologies are finding increasing application in developing countries where chemical disinfection or boiling may not always be practical or effective. The WHO on the other hand reports that while they are common in developed countries, filtration technologies such as RO, micro filters, ultra filters,

nano filters and other membrane technologies are less prevalent in developing nations due to higher cost (Singh *et al.*, 2020).

- ✚ **Microfiltration** employs membranes that can filter particles down to 0.01 μ m diameter, effectively removing all microbes but not all solutes. The pore size for microfiltration ranges from 0.1 to 5 micrometers.
- ✚ **Ultra-filtration** employs semipermeable membranes that, in conjunction with pressure and concentration gradients, can remove particles and macromolecules leaving only water and small molecular solutes. A microfiltration filter has a pore size around 0.1 to 0.01 micron.
- ✚ **Nano-filtration** employs membrane or thin metal filters with very small pore sizes, typically a few nanometers(mm) in diameter, ability to separate a variety of contaminants, including hardness, natural organic material, micro-pollutants such as pesticides and volatile organic compounds, viruses, bacteria, salinity, nitrates, and arsenic. A nanofiltration filter has a pore size around 0.001 – 0.01 micron.
- ✚ **Reverse Osmosis** offers even greater selectivity than micro, ultra, and nano-filtration and has gained wider acceptance and use in recent years. Reverse Osmosis offers the additional advantage of removing essentially all dissolved chemical contaminants as well. Reverse Osmosis filters have a pore size around 0.0001 – 0.001 microns as identified by Ahuja (2019).
- ✚ **UV Treatment** – In the ultraviolet treatment, the water to be treated passes through germicidal ultraviolet (UV) light configured inside a low-pressure lamp. As the water passes the ultraviolet purifier, the biological contaminants are exposed to UV light, which damages the genetic components of the microbes. The microbes are killed this way using UV water treatment. This treatment is ineffective in the removal of dissolved chemicals and other particulate matter as opined by Sharma and Battarcharya (2017).

Chatterjee (2008) claimed that the usual practice for the destruction of bacteria is chlorine gas and for removing sediments by some methods of filtration. However, even then, the best method of water purification cannot fully purify water. Boiling water does not make it any better and the usual filtration processes that most households and municipalities use are not fully safe. Boiling of water practiced by

human beings from the dawn of civilization for germ killing is not found full proof. Even in boiled water micro-organisms will grow when water is cooled and kept for longer hours.

D. An Overview of Water Conservation

Hoque (2014) defined water conservation in Global perspective as limiting or modifying the use of water by human beings, so that our use of water does not cause fluctuations of water quantity and quality within any cycle beyond those fluctuations caused by natural events within the time-scale of human history.

According to Kumari and Singh (2016) water conservation meant

1. Any beneficial deduction in water loss, use, or waste,
2. A reduction in water use accomplished by implementation of water conservation or water efficiency measures, or
3. Improved water management practices that reduce or enhance the beneficial use of water conservation measure is an action, behavioral change, device, technology or improved design or process implemented to reduce water loss, waste or use.

“More to the point, I am thinking about thirst, dryness, dehydration, and the future need for liquid”

– Spellman.F.R, (2021)

Box 11: Future Need of Water

According to Tzanakakis *et al.* (2020), a major issue in water resources management is the reduction of water losses and the improvement of water use efficiency. This issue is becoming more challenging nowadays due to population growth, need for economic recovery, and climate change.

Water efficiency is a tool of water conservation that results in more efficient water use and thus reduces water demand. The value and cost-effectiveness of a water efficiency measure must be evaluated in relation to its effects on the use and cost of other natural resources, (e.g.energy or chemicals) as pointed out by Browne *et al.* (2014).

1. Goals of water conservation

Generally speaking, a water conservation measure is any act taken, behavioural alteration made, gadget installed, know-how developed, or better design or procedure implemented in order to cut down on the waste, water loss or

consumption. As a result, water is used more efficiently, resulting in a reduction in water demand.

The goals of water conservation efforts include:

- Sustainability - To ensure availability for future generations, the withdrawal of freshwater from an ecosystem should not exceed its natural replacement rate.
- Energy conservation - Water pumping, delivery and wastewater treatment facilities consume a significant amount of energy. In some regions (e.g. California) of the world over 15% of total electricity consumption is devoted to water management.
- Habitat conservation - Minimizing human water use helps to preserve fresh water habitats for local wildlife and migrating waterfowl, as well as reducing the need to build new dams and other water diversion infrastructure (<https://www.ecology.edu/water-conservation.html>).

2. Need for water conservation

Bansil (2004) observed that, the growing population has put a tremendous pressure on the existing civic services including the supply of water. Due to rapid urbanization there has been over-exploitation of ground water resources. It may be reiterated that unplanned and uncontrolled extraction of ground water has disturbed the hydrological balance, leading to decline in productivity of wells, rise in energy requirement and deterioration in quality of water with increase in salinity that has made it unfit for human consumption. In addition to over exploitation of groundwater, the uncontrolled disposal of effluents and sewage in the city has contaminated the groundwater levels. This precarious situation urgently calls for conservation of the limited fresh water that is available.

In this grave situation, the only solution is by establishing “A Water wise Home”. Allen (2015) recommended adopting water-wise home as they conserve and reuse water to create ecological and efficient water systems.

Features of a water-wise home:

- Use of efficient water fixtures and appliance,
- Reuse of water– water from sinks, showers and washing machines – is used for irrigation or toilet flushing,
- Use of potable water only for potable needs: drinking, cooking and showering,
- Collection of rain water and infiltrated into the landscape, and
- Awareness of fostered systems and stewardship of natural water systems.

Our homes interact with water in two main ways: how water arrives and how it leaves. Most homes have two common sources of water; the pipe flowing in with drinking water, and rain or snow that falls from the sky.

Also, water demand management and conservation efforts could lead to more efficient use of water, with related water reduction. However, such efficiency improvements are limited by aspects such as current practices, behaviour, available technology and affordability, recalled Crouch *et al.* (2021). Chatterjee (2008) concluded that a western style toilet can waste 500 litres of water a day. This is a criminal waste of water in today's water shortage. Therefore, we must use it efficiently, optimally, and with due care to avoid wastage.

3. Evaluation of water losses in quantitative terms

Gowri *et al.* (2015) reported that the overflow of tanks causes a significant amount of water to be wasted, which contributes significantly to the problem of water scarcity. In today's fast-paced world, manual monitoring of water filling in tanks appears to have difficulty turning on and off the motor, which is one of the causes of water waste. Although there are a variety of ways to prevent this waste using today's technology, these methods do not demonstrate a significant amount of impact on the prevention. Phipps *et al.* (2013) founded that one of the major activities which use water outside the house is car washing. The use of water in an individual domestic car wash varies and depends on a wide range of factors but principally car size and method of washing like power wash and hosepipe wash. For bucket wash the water use depends much more on the attitude and methodology of the individual. Water use in the initial trials ranged from 33 litres per wash to 123 litres per wash. The usage of the hose required maximum of 192 litres per wash.

The bucket bath is even more intriguing than yoga when it comes to India's contribution to the field of holistic health and wellness. In fact, the bucket needs to be adopted as the insignia of a worldwide movement for water conservation and, quite probably, of the brand-new Ministry of Jal Shakti as well. In many countries, the most significant instances of water misuse and waste occur in agricultural and industrial settings rather than in millions of individual bathrooms. However, installing a bucket and mug in every bathroom would at least serve as a reminder to each individual that every drop of water matters. It is said that a two-minute shower uses less water than a typical 25-liter bucket in India, yet, how many people time their ablutions, especially true in situations when severe temperatures or the need to "de-stress" lead individuals to take longer showers (The Economic Times) (2019).

Sadr *et al.* (2015) mentioned that the type of shower and the duration of taking a shower directly impact on the amount of water consumption. The heating mechanism of a shower, the kind of shower control (fixed vs adjustable), the spray pattern of the shower, and even the pressure of the water droplets on the skin may all affect the amount of water that is used during a shower.

Turn off the water while brushing – is a universal statement often referred to in water-related literature. Ha (2011) stated that we need only a cup of water to rinse out our mouth, toothbrush, and to clean the basin after brushing. Dishwashing by hand consumes 15 – 20 litres of water per load. It was also indicated by Chatterjee (2008) that to wash kitchen utensils, it is not necessary to open the tap fully. When utensils are cleaned shortly after use, much less water is required to get them cleaner than when they are left standing for an extended time.

Fardo *et al.* (2020) estimated that, up to 15 per cent of the water used by a household is wasted, either by leakage or simply not being used properly, and sent down the drain. According to the California Urban Water Conservation Council, leakage is the primary source of wasted water in the state. A leaking faucet is most likely the most prevalent kind of leak. Even a small leak has a high association with large wastes. It is estimated that a leak that only drips one time per second can waste over 3000 gallons (13,638 litres) annually. The faucet of a sink, tub, or laundry room is the most probable site of a water leak. Toilets are a silent area in which water leaks can occur around the valve that separates the tank from the bowl.

Kubba (2012) enunciated that one of the best ways to increase water efficiency in buildings is through plumbing fixture replacement and implementation of new technologies, particularly since significant water efficiency improvements over the conventional practice. When the field adjustment of the tank trim is set to its maximum water use setting, the maximum volume of water that may be discharged by the toilet should not exceed 1.68 GPF (Gallons Per Flush) (7.6 litres) for single flush fixtures; for dual-flush fixtures, it should not exceed 1.40 GPF (6.3 litres) in reduced-flush mode and 2.00 GPF (9 litres) in full-flush mode.

In The Times of India (2015), it is stated that for every litre of potable water produced by the RO purifier, 3-4 litres of wastewater go waste when they could have actually been used for non-drinking applications.

In The Economic Times (2021), it has been reported that the Bureau of Indian Standards has developed an Indian Standard (IS 16240: 2015) for drinking water purifying systems. This standard is expected to be technology-specific and will also detail the acceptable quality of the purified water, in addition to the recovery efficiency of the machine. It is believed that purification machines reject or waste somewhere between 70 and 80 per cent of the water that is brought in to be purified. As a result, purification tools now have a water recovery efficiency of approximately 20 per cent.

4. Water saving products and technologies for domestic use

Rola *et al.* (2018) informed that practical tips on monitoring daily water use, limiting water usage, and reusing water, stretches the previous water supply to provide everyone's water needs. Watering of plants should be done only when needed. Laundry ought to be washed only on a full load, and plumbing fixtures must be efficiently set up.

Technologies and efficient water use practices can be employed to reduce water use for domestic users. For domestic water use, some of the available devices and products are low-flow showerheads, shower flow restrictors, toilet-tank inserts, faucet aerators, low-flush toilets, dual-flush toilets, insulation of hot-water pipes, horizontal axis washing machines, low-pressure supply connections, pressure-reducing valves, water-efficient landscape designs, and irrigation practices.

a) Water saving appliances

Appleby (2011) felt that personal washing and toilet flushing dominate water consumption in households. Hence the attention on water saving has logically been on reducing water use from WCs and baths or showers. The challenge with the development and installation of water saving appliances is to achieve adequate performance at lower flow rates. For example, installing a low flush WC which has to be operated two or three times to clean the bowl. Similarly a low flow shower that provides only a dribble will both prolong the length of time required for an effective wash and create dissatisfaction and frustration amongst users.

b) Waterless urinals

Alternatively waterless urinals, that use a liquid which is lighter than water to provide both a seal that caps the outlet once the urine has drained away and masks the odour from the drain are available. These are obviously dependent upon good and regular housekeeping to ensure odour free operation.

c) Taps

The type of tap that offers the greatest water saving will depend on how it is to be used. A tap over a kitchen sink or bath will usually be used for filling things and hence the flow rate is probably not very important. Taps used primarily for washing hands however can perform well with low flow rates, provided their wetting capability is maximized. Hence aerated or spray taps are ideally suited to hand washing and can save up to 80 per cent of water consumption compared with a conventional bib tap.

d) Baths and showers

Showers should offer a significant saving on the water used in taking a bath. However, a lot depends on the shower type and the average length of shower taken. For example: a 'power shower' might use 16 litres /min which corresponds to 160 litres for a 10 minute shower. However, there are low flush shower heads which operate at between 4 and 8 litres /min and with aerating of the spray can provide excellent wetting and a high level of satisfaction amongst users.

e) White goods

A new washing machine uses approximately 50 per cent of the water and energy that is used by a typical 10 year old machine. Most new washing machine uses between 40 and 50 litres of water per 6 kg wash. Dishwashers are also becoming more water and energy efficient, with the most efficient machines using as little as 12 litres to wash 12 place settings. It should be noted that for the European market manufacturers have to quote water consumption on the Eco-label for each product.

5. Sustainable water conservation by rainwater harvesting

Tzanakakis *et al.* (2020) reviewed that rainwater harvesting (RWH) is a sustainable water management practice that has been adopted since the ancient times to augment water-potable and non-potable supplies in water-limited areas. Following a decline in the development of RWH systems in the last century, a renewed interest has emerged since the second half of the 20th century, driven mainly by rising water demands due to growing population, urbanization, climate variability, and by food security. The compiled information indicates a renewed concern for RWH systems on a global basis, either as a standalone or combined with conventional technologies to confront water scarcity. They successfully state: “Worldwide, rainwater harvesting has retrieved its importance as a valuable water resource, alternative or supplementary, in conjunction with more conventional water supply technologies. If rainwater harvesting is practiced more widely, many water shortages, actual or potential, can be alleviated”. They also underline the need for more research, investments, and public awareness on the importance of RWH; economic incentives (subsidies and tax exemptions); and the development and enactment of pertinent regulations to meet the full potential of RWH systems as a complementary water supply technology, not only in rural areas but in urbanized areas as well.

6. Crucial consideration of today’s hour – Water leakage and wastage

Lugoma, Van and Ilemobade (2012) investigated that On-site leakage is leakage that occurs on consumers premises. It includes leaks from water pouring elements such as pipes, fittings, taps, toilet cisterns and household appliances. The leakage incidence was higher for ‘Residential’ properties than other properties. Water loss and leakage occur in residential homes from time to time, where a number of water fixtures and plumbing can leak and often remain undetected.

Crouch *et al.* (2021) evaluated that every home and lifestyle level is subjected to a certain degree of water loss and leakage, as are the piped distribution networks which deliver water to households. Ageing infrastructure is a problem in many countries around the world and will exacerbate leakage. In many cases, the network leakage represents a volume similar to an individual's domestic water use. Efforts to promote water efficiency need to take a balanced approach that considers the impact on health and well being of consumers within the wider context of the water utility's supply and leakage situation. A well-said statement was made by Mohapatra and Rath (2019) that "The careless attitude of people also leads to substantial water wastage in today's scenario".

7. Approach to boost the interest in water conservation

According to Addo *et al.* (2019) awareness related to 'Water Conservation' and 'Safe drinking water' is extremely important and should be given adequate publicity. Recognizing the plethora benefits of domestic water management, it is crucial to raise awareness among homemakers so that they are aware of the problems and concerns related to water, as well as the appropriate technology behind water conservation and the benefits of doing so. Despite the fact that the government has implemented new policies and programmes to address the city's water crisis, they are still in a position to resolve the problem throughout the entire city. Because homemakers are the backbone of the water-handling industry, their involvement is regarded as a critical cause in the effective execution of any plan or strategy for domestic water management programmes. As a result, it is imperative to educate and encourage homemakers to espouse water conservation practices while also ensuring the quality of the water, which is a viable option for reducing residential water consumption which, in the long term, will show to be a much more sustainable solution to the world's major water shortage issue.

E. Futurism towards Smart Water Management Systems Using Artificial Intelligence

The intelligent systems such as IoT, deep learning and machine learning algorithms could be harnessed towards the process like leak management, flow monitoring, overuse, contamination and devising strategies towards acceptable water use.

Fryer (2012) and Kaushik *et al.* (2018) concluded that, to combat water shortages, some of the old-fashioned methods of dealing with them are regaining popularity. Modern technology has stepped into upgrade the methods and make them applicable to current lifestyles.

In the modern era, water can be saved by managing the water supply system in a smart way that paves the way for utilization of water resources optimally. The use of AI in smart water management system has several implications to improve the water management systems and to overcome challenges in water quality assessment, efficient service delivery and distribution systems. AI and Machine learning based models are demonstrated in water management applications such as wastewater treatment, water pollution control, smart agriculture, optimize water usage, automate critical water, water quality, water level monitoring and water conservation.

Yadav and Malik (2023) proposed that, through the adoption and implementation of flow restrictors and low flush toilets technology, the available water can be used more effectively as it has the potential to significantly reduce domestic water usage. Even though we may save a drop of water, our actions have the potential to create a ripple effect.

Krishnan *et al.* (2022), Pasika and Gandla (2020) portrayed the applications of IoT in various aspects in water management. There are various AI techniques pertaining to the wastewater treatment process. Some of the applications used for heavy metal detection, identification of pollutants in the water source, to examine the progression of water in each pipeline, level of the water in each tank, and expansion of water stream speed.

Residential water supplies are subject to contamination from pipe residues and silt, which causes cloudiness, a terrible taste, and an odor in the water. One of the key elements for determining the quality of water is turbidity, a measurement of water cloudiness. A cost efficient system, based on a light detecting device to gauge water cloudiness was proposed to overcome the above said issues by Ibrahim *et al.* (2018).

Nandhini *et al.* (2017) devised the automatic irrigation system that has been utilized to measure soil parameters, including soil moisture, pH, and humidity.

Jadhav and Pingle (2016) proposed automatic measurement and reporting system of water quality. This IoT-based developed model used the parameters such as temperature, turbidity and pH for analysing the water quality.

A model developed by Marjani *et al.* (2017) focussed on effective water supply management system to automatize the water management for domestic usage. It stored the information about water such as quality, leakage of water and amount of water consumed for various connection points. The proposed model contained several IoT devices and cloud services for efficient detection of pipe leakage. This model finds the amount of water leakage and wastage by deploying sensors in strategic locations.

Using the Internet of Things (IoT) platform, Alam *et al.* (2021) developed a low-cost embedded system device for real-time monitoring of water management systems. The requirement for water supply, distribution, and quality control is met by a novel system based on Internet of Things technology. Benefits of IoT for water management include real-time control, process optimization, service time reduction, new business models, resource conservation, and the ability to do all of these on a global scale.

The monitoring system described by Pasika and Gandla (2020) included a number of sensors that detect many quality characteristics, including turbidity, pH value, water level in the tank, humidity of the surrounding environment, and water temperature. The sensors are connected to the Micro controller Unit (MCU), and the personal computer does extra processing (PC). The Think Speak application based on the Internet of Things (IoT) will transmit the collected data to the cloud in order to monitor the quality of the water being tested.

Mukta *et al.* (2019) developed an IoT-based Smart Water Quality Monitoring (SWQM) system that enables the continuous assessment of water quality based on four distinct water quality indicators, including pH, temperature, turbidity, and electric conductivity. In order to detect the quality metrics, Arduino Uno is attached to four distinct sensors. The acquired data from all four sensors is sent to a desktop application built on the NET platform, and the retrieved data is compared to the standard values.

Using Internet of Things, Jeurkar *et al.* (2020) innovation involved a system that measures all parameters in real time and can be remotely viewed/controlled through smart phones (IOT). Using a capacitive level sensor, the device detects the water level. Currently, this device monitors three distinct water parameters for industrial and commercial uses, but it is possible to test other characteristics such as turbidity, pH, oxygen content and TDS.

In Nandi *et al.* (2019) the system comprised of three sensors: a water leakage sensor, a ph sensor, and a water level sensor. The water leakage sensor is installed close to pipeline-connected valves to detect water leakage, which then transmits output signals to prevent water leaking.

An Internet of Things (IoT) based design for water monitoring and control method has been described by Das *et al.* (2018). This strategy provides internet-based data collecting on a real-time basis in overcoming the water problem. Additionally, by using UV treatment, the quality of the water that was supplied to each family was significantly enhanced. Fluoride content level testing, together with hardness testing, is also done utilising relevant test metres by leveraging the technical utilisation of the IoT idea. This concurrently improves the drinking water's overall quality.

Yashaswini *et al.* (2021) developed the concept of Aquart - smart tap indicator with the intention of resolving the water issue by modelling, engineering, and producing a smart tap system that reduces water waste. A mechanical assembly was developed to monitor and control the usage of water with the aid of a mobile application, with a sensor interface that provides the data regarding the flow of water, total water consumption, and current output in Millilitres Per Second (ML/s), detecting if the threshold limit of water consumption is reached, and also generating a complete detail analysis of water consumption per day/week/month, allowing to determine the usage and wastage of water.

The above mentioned mobile application contains additional capabilities that allow us to determine the quantity of water now being used and the daily total amount of water consumed. The Aquart module may also be operated through the app, allowing to switch on or stop the water flow. Additionally, the app has a function that allows to establish a daily water consumption threshold. The user may specify the

daily water consumption limit/threshold value and will be alerted of the quantity of water used.

These emerging technologies in various aspects of water life cycle management would render brainstorming, an ideation process for addressing the current issue of the water crisis and to implement effective mechanisms to distribute better water quality to the consumers or the end-users. Homemakers are surrounded with valuable information about the concepts of water management at the household level, including how water consumption can be optimized and intentionally utilized to satisfy the requirements and expectations of an ever-expanding population. Homemakers would benefit from additional knowledge on tracking how much water is used by the family, unintentional water waste, failing to turn off water taps, and unattended water leakages in faucets and pipes, all of which result in a significant amount of water waste could be followed by installing modern tools and devices. Incorporating AI concepts into the development of new water management technology is a promising area of research.