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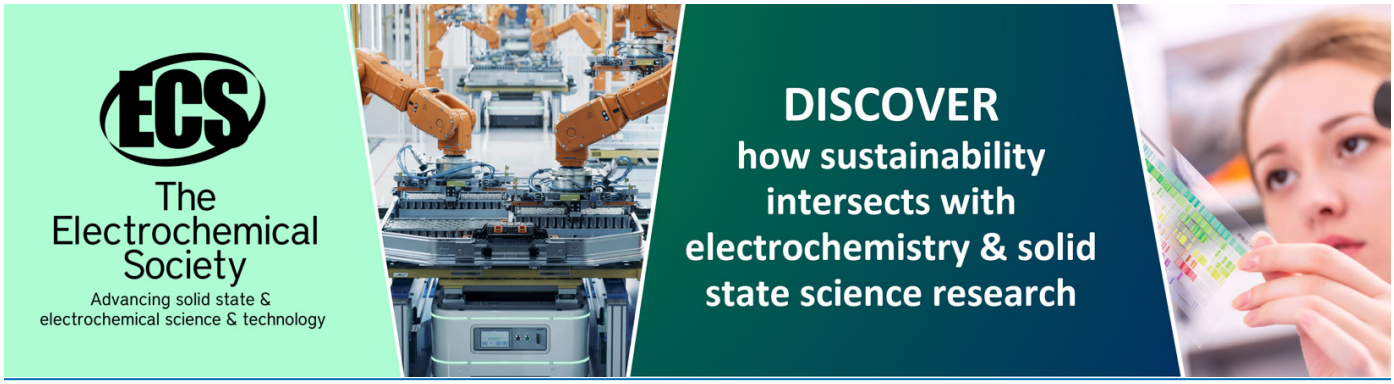

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Harnessing technology for mitigating water woes in the city of Bengaluru

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Abstract: Industrialization has caused most of the world's environmental problems like climate change, water security issues, biodiversity issues among others. Water-related issues like water scarcity, lack of water quality, water sanitation issues, lack of proper water resources management are some of them. Urbanization, population increase, pollution has led to an increase in water demand. Water being the elixir of life, is essential for the day-to-day living of an individual. The Fourth Industrial Revolution technologies like AI, IoT, Blockchain, Machine Learning have the capability of bringing solutions to these issues. The current study focuses on the water woes of Bengaluru, a fast-growing urban city, due to its migrating population. The woes are also due to the irresponsible behaviour of builders converting lakes into real estate infrastructure leading to clogged drains, excess sewage creation and flooding. A huge mismatch between demand and supply of water is created due to these issues. Before the city hits the Day Zero – no water day, it is significant to set up water infrastructure along with technology implementation which will help resolve this burning issue at the earliest.

1 Introduction

The present world is caught up with environmental problems like climate change, extreme levels of air pollution, uncontrollable waste generation on land and in oceans due to rapid industrialization [1]. With the Fourth Industrial Revolution gathering pace, emerging technologies like the Internet of Things (IoT), virtual reality (VR) and Artificial Intelligence (AI) have come into the rescue of these problems. The technologies have enabled societal shifts by impacting economies and identifying multiple possibilities for future generations. These technologies have collaborated with policy-makers, scientists and investors to address the environmental issues which needs immediate attention of all stakeholders concerned. It is estimated by The International Union for Conservation of Nature (IUCN) that, by 2050, demands for water, energy, and food will increase by 55%, 80%, and 60%, respectively. Among these three essentials, water, being the elixir of life, takes the top-most priority.

Among the top five global risk factors, water issues have been the most spoken about since the past seven consecutive years. It is expected that by 2050, the expected gap between global water supply and demand would be around 40%. Efficient water management is significant, as it is a finite resource among multiple competing users with increasing demand. Balancing between the supply and demand of water requires an understanding of the demand in terms of water availability through multiple sources, and water quality. The projected water demand is expected to be (Figure 1) in the areas of agriculture, energy generation, drinking purposes, and industrial use. Across the globe, currently, about 4 billion people live in water-scarce regions. Out of this more than 2 billion people still live without access to safe drinking water and basic sanitation services.

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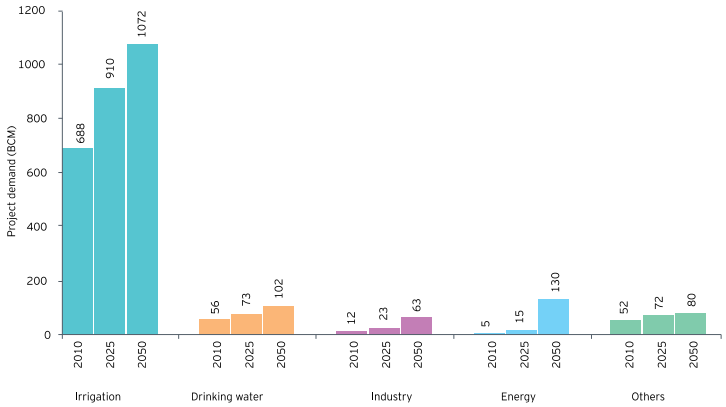

Figure 1: Projected Water Demand by different sectors
Source: Wastewater production, treatment and use in India (EY, Assocham, 2019)

All the facts and figures indicate that the conservative approaches of water management may not be relevant to this pertinent problem. There is a need to harness technologies represented by the Fourth Industrial Revolution to find a long-term solution [1]. These technologies are capable of identifying data sources, ensuring data sharing thus making it transparent among stakeholders of supply and demand. We observe that satellite imagery and other earth observation tools have provided insights on water supply across the globe. According to NASA, by 2021, a satellite would be capable of surveying at least 90% of the Earth, by studying lakes, rivers, reservoirs, and oceans. Apart from this, measurement of water quality and distribution of water balancing between supply and demand is possible through technologies provided by Industry 4.0. These interventions are valuable because they help generate huge amount of data that is essential for solving problems related to water. The current study focuses on four major issues related to water namely - Water Security, Water Quality, Water Sanitation, and Water Management.

1.1 Water Security

Water Security is defined as the capacity of a population to safeguard sustainable access to water for human well-being and socio-economic development. This must ensure protection against water-borne pollution and water-related disasters to bring peace and political stability in communities [2]. Technology has played a significant role in improving transparency and decision making related to the Water Security issues. Insurers, organizations, and communities are some of the possible stakeholders who could reap benefits due to the adoption of technologies [3]. One of the popular technologies, Artificial Intelligence is capable of optimizing the process of water management with effective decision making [4]. By soliciting dynamic feedback from the field, systems are created to integrate computer modelling with local authority planning, policy interventions, and decision making. Technologies could lengthen the lives of water assets, reduce water leaks, and lower water expenditure and loss. In a world where only .05% of the earth's water is readily available for human consumption, increased demands need to be met with new sources of supply.

1.2 Water Quality

There is a need to have good water quality for human health, socio economic development, and the entire ecosystem. As the population grows, ensuring sufficient and safe water for every one becomes a challenge. It is important to manage water at every part of its cycle: from fresh water abstraction, pre-treatment, distribution, usage, collection and post-treatment. Water quality can be improved by reducing pollution and improvement of the way we manage waste-water [5]. IoT enabled monitoring systems could be deployed to ensure water quality. Artificial Intelligence and Machine Learning techniques help predict leakages, pipe replacement thus optimizing capital, revenue, operating costs and services.

City corporations and town municipalities can record water distribution and consumption in real time through Blockchain technology. It is also possible to monitor water quality through this technique. In coastal environments, computer simulated models are deployed to measure water quality. Water filtration systems are used to ensure high quality water thus minimizing water loss. Predictive maintenance techniques deployed in water plants ensure quick and effective way of analysing factors leading to likelihood of failure of water pipes. These techniques also estimate pipe corrosion and deterioration by ensuring high-quality. Risk scores are assigned to individual water mains on a map by using machine learning models. Due this, city planners can prioritize the maintenance and infrastructure replacement to maintain better water quality [6].

1.3 Water Sanitation

Improved sanitation and adherence to good hygiene practices would lead to improved access to drinking water source. Access to WASH – Water, Sanitation and Hygiene has a wider socio-economic impact for large communities. WASH is the subject of dedicated targets within the Sustainable Development Goals with focus on public health [5]. The process of water sanitation services in cities could be disrupted through the application of Artificial Intelligence and other advanced technologies.

As urban needs expand due to increased population, it is significant to retrofit cities to become more resilient while designing basic service delivery systems. In Pune, India, the Toilet Board Coalition has brought in a workaround called 'digitization of sanitation'. This involves integration of sensors and wi-fi into toilet networks. This leads to generation of huge amount of valuable data and information on public health and their behaviour. The data also helps in the improvement of quality of maintenance systems and route optimization for waste collection and transport [7]. Sensors deployed in water bodies allow experts to detect issues related to water contamination in wastewater treatment plants. Artificial Intelligence is deployed in municipal wastewater treatment plants by improving ultrafiltration membranes. These algorithms intelligently choose the perfect cleaning intensity thus ensuring reduction in the total energy and resources used.

1.4 Water resource management

The process of coordinated development and management of water, land and related resources to maximize economic, and social welfare without compromising the sustainability of ecosystems is known as Integrated Water Resources Management (IWRM). The traditional, fragmented approach has led to poor services and unsustainable water resource use. IWRM is built on the premise that, water as a natural resource is meant for social and economic good. Water is in high demand for agriculture leading to less water availability for drinking or industrial use. Ecosystems are threatened due to contamination from industrial and municipal wastewater. Implementing IWRM ensures protection of world's environment, fosters economic growth and sustains agricultural development thus improving human health. Across the globe, water policy management means the reflection of fundamentally interconnected nature of hydrological resources [8].

In some of the metro cities, households have been fitted with smart meters which produce large volumes of data. This data is used to predict water demand, spotting of inconsistencies and support in setting up decentralized energy systems. A combination of Machine Learning, Internet of Things and Block Chain helps set up an efficient decentralized water system. These systems help the corporations measure consumption, enable data-driven pricing, and provide incentives for water conservation [6]. Blockchain technology is capable of transforming the way water resources are managed and traded. It supports peer-to-peer trading of water rights in a specific location. Consumers can trade this important resource among each other instead of relying on a Central Authority. A combination of Block Chain and precision farming would help farmers decide to trade their water allocations based on the latest weather data, crop prices, market trends and long-term climate trends through their hand-held devices. The key issue here would be the availability of data across resources, stakeholders and consumers.

The current study focusses on the four aspects of water related issues – Water Security, Water Quality, Water Sanitation and Water Resources Management in the city of Bengaluru. Technology solutions are proposed to resolve the pertinent problems of the city which is inching towards 'No water day' in a matter of few years.

2 Literature Review

One of the significant issues faced by developing countries is the availability of safe drinking water and adequate sanitation for all. Resolving this issue would reduce spread of disease and save lives. A comparative study conducted between Spain and Nigeria investigates water resource management practices in both the countries. The study brings out the lessons that need to be taken to ensure clean water supplies to consumers [9]. According to the United Nations, across the globe, about 2.8 billion people live in river basins with some form of water scarcity.

The study by the American Society of Civil Engineers reveals that one of the major causes of disappearance of clean, treated drinking water is old, leaky pipes and mains. There has been a huge wastage of money and priceless natural and energy resources for future generations due to this cause. A research group led by the Illinois State Water Survey in collaboration with the Department of Mechanical Engineering at North Western University developed a 'Smart Pipe' prototype [10]. Nanotechnology is used to monitor the water flow as well as the water quality. Smart Pipes are installed in critical sections of a public water system. The flow rate, pipe pressure, stagnant points, slow flow sections, pipe leakage, backflow and water quality are measured regularly. This cost-effective technology has helped small/rural public water systems in rule implementation, capacity development, and water systems operations.

One of the major problems in Water Management is that the surface water bodies are highly polluted [11]. The waste generated from Industrial facilities which use chemicals as raw materials have been the cause of this air and water pollution. The cause of deterioration is also due to the dumping and littering of solid wastes in rivers, lakes, and oceans. Some of the items are Cardboard, Styrofoam, aluminium, plastic, and glass. The insoluble oil forms a thick sludge thus causing water pollution. Sewage from toilets cause water pollution too, where chemicals and pharmaceutical substances are flushed in by the users. This needs a behavioural change. A Water and Air Monitoring system has been designed to help authorities in crisis management to discover and anticipate contamination of water and air.

An advanced automation technology is proposed by Itron, Inc. to help address water conservation and efficiency efforts in India [12]. The company is slated to provide an advanced metering solution to the Delhi Jal Board in association with Larsen & Toubro. This solution would include setting up of 120,000 advanced automated meters, 40,000 standard meters, mobile collection equipment, and software. Delhi Jal Board intends to collect, measure and analyse the water usage by consumers. With thousands of employees supporting nearly 8,000 utilities in more than 100 countries, Itron is all set to spearhead the cause of efficient energy and water resource management.

The performance measure of an Artificial Neural Network model was done by applying it to the observed time series of the Pawana reservoir in Upper Bhima River Basin, Maharashtra, India [13]. By comparing this model with the Auto-Regressive Integrated Moving Average model and Time Lagged Recurrent Networks, it is found that the Neural Network model performs better and provides improved accuracy. This being a Machine Learning technique, adopts the Backpropagation method by iterative learning models. The findings of this study reveal that using mathematical filters to bring out the long term and seasonal variations in the data could be extremely useful in solving problem.

A smart city integrates multiple Information and Communication Technology (ICT), Big Data and Internet of Things (IoT) solutions in a secure fashion. The objective of this integration is to manage

a city's assets for sustainability, resilience, and liveability [14]. Nowadays, we observe that monitoring of water quality has been carried out and is ready to be part of the wireless sensor network-based solutions. The smart city infrastructure – Bristol Is Open was utilized to provide a plug & play platform for the monitoring system. This system not only benefits the entire wireless network covering area but also integrates with the Urban Water Management System to achieve improved efficiency.

In order to ensure the safe supply of drinking water, it is significant to monitor the water quality in real-time [15]. The research has designed and developed a low-cost system for real-time monitoring of water quality using Internet of Things (IoT). The system measures the various physical and chemical parameters of water such as temperature, PH, turbidity, conductivity, dissolved oxygen of the water, etc. through sensors. This system is cost-effective, efficient, and is capable of processing, analysing sending and viewing the data on the cloud. This is used in environmental monitoring and ecosystem monitoring.

The report [16] highlights the following benefits of digitization to solve issues related to water.

Table 1: Benefits of Digitization

Water Utility Business Challenges	**How Digital Technology can help**
Demand Forecasting, Asset Failure	Improvement of weather-related data through Machine Learning techniques, Improved predictions of asset failure
Cost Optimization in Water treatment	Improved data visibility through Industrial Internet of Things and Smart sensors
Customer Consumption & Billing Patterns	Identifying anomalies in consumption and billing by conducting outlier analysis based on cluster algorithms
Water Production Planning	Optimization of water production planning through Cognition-based situational intelligence
Aging infrastructure	Assessment of the condition of wastewater pipeline through robotics

Source: Cognizant 20-20 Insights

Smart metering in households provide multiple utilities. The digital water utility measures the water consumption by individual households. Once the water is distributed through a network, the pressure is continuously monitored. This leads to better transparency in the water distribution process. The digital water utility also ensures when and how much water is consumed by the users. This helps in the streamlining of various initiatives taken by authorities through uninterrupted water supply [17]. Electricity and Water utilities generate huge volumes of data across their organizations. This includes status or condition of operational assets, customer behaviour and history. This is enabled through devices like smart metering and connected homes which generates data. The challenge is to turn this raw data into insight [18].

In both developed and emerging economies, there are issues related to water infrastructure which need immediate attention. Digitization of water is one of the solutions. It improves operating efficiency and help support in the adoption of distributed, decentralized water treatment technologies. It is used in improved water use in agriculture and overall water management. These digital technologies have enabled water utilities and industries across the world in improving the legacy water infrastructure and have a positive impact in water conservation and water distribution [19]. It is imperative and urgent to include digital transformation in utility companies. They have to change with the fast-changing times. It is significant to modernize the infrastructure to improve efficiency. Due to the huge burst of data generation and availability, companies must have strategies to manage data efficiently by deploying digital technologies [20].

As we observe, digital technologies have been used for water security, water sanitation, water quality and water resource management across various countries and organizations. With the world moving towards over consumption and less water availability, it is important that we conserve water and make better use of this significant resource, nature has given us. Some of the major cities of India

have been facing water shortage and one of the prominent ones is Bengaluru, which is the capital of the state of Karnataka. The study focusses on the water resources of this city and its increasing demand due to urbanization.

3 Methodology

The study follows a qualitative method by taking up four parameters to measure the water related issues in the city of Bengaluru. Both the demand and supply of water into the city are considered for the discussion. Multiple surface water resources like rivers and reservoirs are considered as sources of water supply to the city. Demand from the consumers are considered and focus is towards the management of the available water resource effectively. The study focusses on the data perspective where technologies could be used to collect water related data, ensure organized distribution and ensure optimum level of water quality.

Data from various reports published by authorized agencies and refereed journals are considered as input for this study. Status of Bengaluru is compared with other urban cities across the globe and discussions are carried out. Solutions are proposed based on the already available remedies which are implemented in various countries through private or Government agencies. The study looks at the solutions provided by Industry 4.0 which has the capability of arriving at solutions for water related issues, whenever relevant data is available.

3.1 Scope and Limitations

The scope of the study is limited to the city of Bengaluru as this city is staring at the reality of nearing the 'Day Zero' where water availability for consumers are expected to be limited. The city attracts large number of migrants from other states due to the climate and job opportunities it provides. With average rainfall being above normal this year, one can expect authorities to save water for the future use. The discussions would be related to the technology solutions for water issues from multiple identified perspectives based on United Nations Sustainable Development Goals.

Technology interventions are possible only if enough data is available in the domain in order to provide implementable solutions. The study would highlight the need for data collection through sensors and automated devices. Data thus collected could be available in public domain so that primary data related studies can be conducted to arrive at specific solutions for domestic and industry consumers.

4 Discussions

The current study discusses the various water sources of the city of Bengaluru, the issues related to water and the possible solutions provided by technologies related to Industry 4.0. The city is growing at a rapid pace leading to increased demand for this important resource for human survival. The discussion would be around the fact whether technologies could be used optimally to find solutions to water issues.

4.1 Water Sources of Bengaluru

Being one of the fastest-growing cities, Bengaluru, also known as the Silicon Valley of India has spearheaded the growth of Information and Communication Technology in India. It is a cosmopolitan city attracting people and businesses alike leading to an exponential growth in the migrant population. The city enjoys a pleasant and salubrious climate throughout the year. Bengaluru is situated at an altitude of 920 meters above mean sea level. The city enjoys a mean annual total rainfall of about 880 mm. The city is located over ridges delineating four watersheds, viz. Hebbal, Koramangala, Challaghatta and Vrishabhavathi. A large number of tanks were created for traditional uses of irrigation, drinking, fishing and washing by the visionaries Kempe Gowda and Wodeyar dynasty in the early 1900s in Bangalore. Due to urbanization and the consequent infrastructural need, there has been a sharp decline of 58% in the existence of surface water bodies in the city [21].

4.2 Water Woes of Bengaluru

Urban activities require infrastructural support from the Government. Water, being one of the significant needs for human survival takes priority. For the urban economy to thrive, there is a dire need to have the infrastructure of water supply, wastewater treatment, stormwater drainage systems, solid waste management, and transportation network in place. Bangalore Water Supply and Sewerage Boards (BWSSB) is the agency responsible for drinking water supply and wastewater collection and treatment for the city of Bangalore. Drinking water is pumped from the river Cauvery, the lifeline of Karnataka from a distance of about 100 km over an elevation of 500 m. Apart from the river supply, groundwater and water from the river Arkavathy also feeds the city. Though drinking water is distributed completely in Greater Bangalore, the yester city corporation limits only 20% of the households. It remains a challenge to distribute water to the remaining areas. BWSSB remains the nodal agency concerning the collection and treatment of wastewater in Bengaluru with three major treatment plants with a total capacity of 450 MLD.

Water demand per person in the city of Bengaluru is estimated at 150 to 200 lpcd (liters per capita per day) as per the BWSSB. However, the average supply is only about 100-125 lpcd. As we observe, water demand has gone up due to growing population in the city. Population density has gone up to about 147.2 persons per hectare. The estimated generation of wastewater is 700 MLD and the treatment capacity of the plants is stressed. Frequent clogging of stormwater drains results in the pollution of natural water bodies. In early 2018, the water problem in Bengaluru was highlighted by BBC naming it as the second most likely city in the world behind Cape Town to run out of drinking water shortly. The city's largest lake caught fire multiple times due to the abundant toxins and debris that were dumped into it.

4.3 Increased water woes

To mitigate water stress in rapidly growing cities like Bengaluru, it is important to adapt wastewater reuse. It is, however, easier said than done as the river Vrishabhavathy, which is the tributary of Cauvery carries almost half of the city's wastewater. The Sewage Treatment Plant does not function efficiently and there is no impact of effluent discharge on river water quality. Bengaluru needs decentralized wastewater treatment which is expected to be more cost-effective. The water management in Bengaluru requires techno-institutional integration [22]. As the population of Bengaluru increased to 8 million it started developing problems of megacities including water supply challenges [23]. The film 'Water and City' made by Swati Danker in 2010, describes the relationship between the city and its dwellers with water. Bengaluru is struggling with an immense water supply shortage. This has led to informal groundwater extraction, tanker and pots water business. These 'water mafias' are supported by local authorities too. No citizen has 24 hours water access as there is huge amount of disparity in the water distribution across the city. Therefore, the storage facility plays a crucial role in household water availability. World Health Organization (WHO) has set a minimum standard of per capita water requirement as 50 litres per day; however, the city has access to only 16 litres of water per day which is well below WHO standards. The wastewater treatment facility in the city treats only 60% of the city's sewage. The rest ends in hinterlands where it contaminates water bodies causing economic losses such as death of fish and water pollution. Without sufficient rainwater harvesting facilities, the city is flooded with rainwater while the water could have been used to fill the gap between areas which are water scarce and abundance.

Water that flows out of the city of Bangalore is only wastewater. Unfortunately, farmers are compelled to use this water to irrigate their fields. By the time water reaches a field, it is mixed with industrial pollutants and other wastewater dump thus polluting the water and making it unpotable. The series of events leading up to large-scale pollution and privatization of the city's lakes have impacted the resilience of the city. In the early 1970s, a highly centralized managed infrastructure was existing. Leaders expanded the city with the promise of abundant river water supply which was never kept [24].

4.4 Tracing the History

Bengaluru was known as 'Land of Lakes' during the regime of Kings and the Colonial rule. These lakes were constructed to store water for domestic and irrigation purposes. Due to industrialization and globalization, after independence, the city gained a name called 'Silicon Valley' due to growth in science and technology. This has led to loss of lakes and increased need for urban infrastructure related to real estate. Encroachment of lakes and storm water drains have caused decline in ground water table also leading to flooding. Dumping of solid waste in the drains is also a cause of flooding. Uncontrollable pollution due to increased vehicular traffic and water resources being tampered with industrial effluents have caused damage to the water quality in the city.

Some of the solutions which are suggested in various reports by agencies have not been implemented. These include – water harvesting through surface water bodies by rejuvenating lakes, interconnectivity of lakes within the city, setting up of sewage treatment plants which are decentralized, re-use of treated sewage water. Few of the reasons could be due to bureaucracy, lack of motivation to solve citizen related issues by Government agencies [25].

4.5 Technology solutions for water woes of Bengaluru

From the discussions so far, we observe that the major issues plaguing Bengaluru Water woes are related to Water Security, Water Quality, Water Sanitation, and Water Resource Management. It is possible to group all the water related issues under these categories. Advanced technologies are capable of providing a solution to these issues provided the Government is prepared to invest in Water Infrastructure for the city. Pricing policy has to be devised so that people are responsible for water consumption for Industrial, Domestic and Irrigation purposes. Some of the technology solutions which have been successfully implemented across the globe in various organizations and countries have been taken as a benchmark to propose the solution given here under the four perspectives related to water.

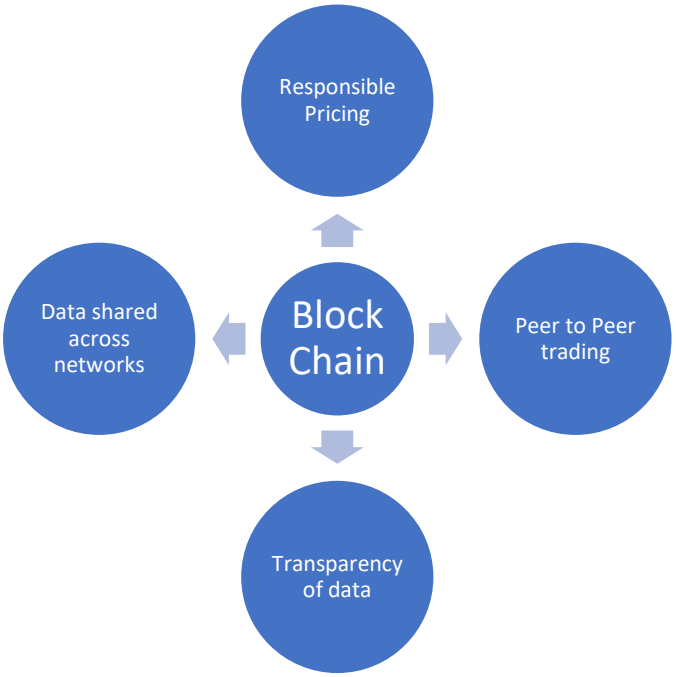

Figure 2: Technologies to solve water woes of Bengaluru – Block Chain

4.5.1 Technologies to solve water woes of Bengaluru – Block Chain

Block Chain can be extensively used with respect to data generation and sharing. The data could be collected by installing smart meters in households. This would be help in the right pricing for the right person instead of inflated bills. With water trading coming into play, Block Chain will play a major role in the responsible pricing aspect. As data is shared across networks for water consumption and wastewater re-use the technology brings in data transparency too.

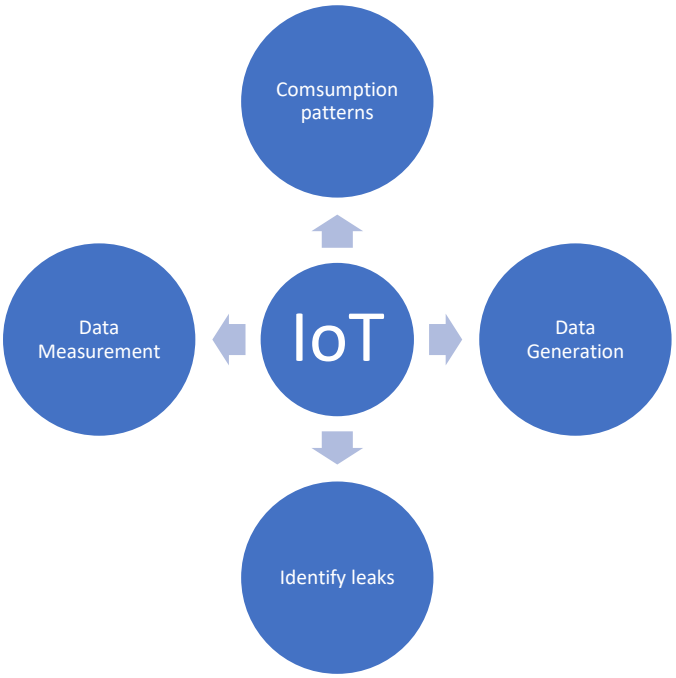

Figure 3: Technologies to solve water woes of Bengaluru – IoT

4.5.2 Technologies to solve water woes of Bengaluru – IoT

Sensors fitted in various devices and pipes will help the consumers as well as authorities to identify locations where water leak could happen. IoT devices are the origin of data generation and data measurement. These sensors ensure right measurement of consumption of individual consumers and can enable the pricing strategies based on over consumption or shortage. Due to excess rain, if there is a need to store water sensors could be activated to rationalize the storage process across locations leading to water sharing.

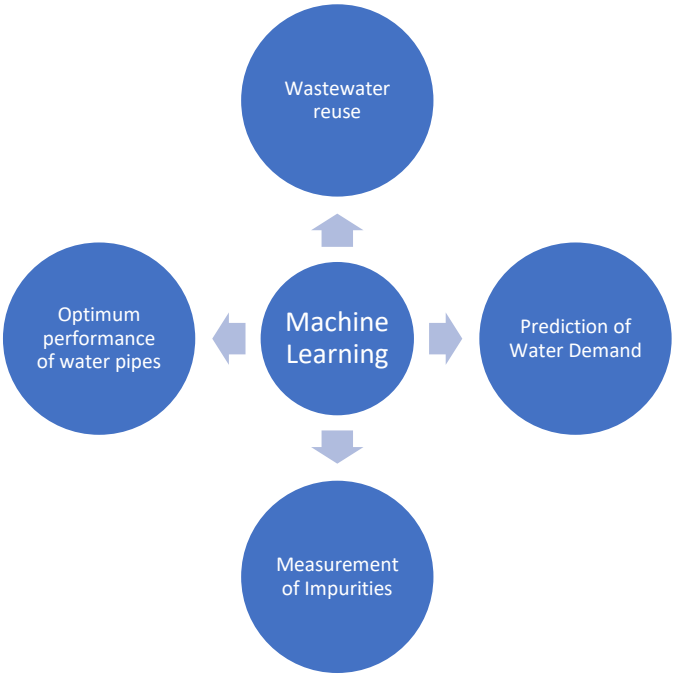

Figure 4: Technologies to solve water woes of Bengaluru – Machine Learning

4.5.3 Technologies to solve water woes of Bengaluru – Machine Learning
Machine Learning is one of the most important concepts under Industry 4.0. These techniques help authorities predict water demand in multiple locations. There is a disparity between water availability across geographical regions and through optimization techniques this can be sorted out. Measuring the amount of wastewater and the impurities would help authorities ensure water purification before sending it as a supply to the consumer. Water pipes which are interlinked across the city can be tuned for their optimum performance through machine learning models.

5 Conclusion

In the fast-changing global scenario, it is observed that water resources are under serious threat. This is applicable especially to the surface water bodies which are exploited by humans. Water availability, poor water quality, and lack of sufficient wastewater treatment systems are some of the greatest challenges being faced by the consumers. The groundwater withdrawal rate as compared to available supplies is extremely high due to the population growth and rapid industrialization [26]. To address the growing concern, there is an urgent need to develop water infrastructure. Along with that, advanced technologies need to be deployed for measuring consumption leading to responsible pricing, peer-to-peer trading to bridge the gap between supply and demand. This will enable participatory water management to achieve sustainable water reuse and recycling. Since water has become an issue that cannot be neglected, policymakers need to adopt best practices and technologies to address this at the earliest. Another significant solution could be privatising the water management leading to better technology implementation.

Water scarcity, being a global issue needs to have a common solution at the global level as it impacts economical, political and health of the citizens. Water Security, Water Sanitation, Water Quality and Water Resource Management must be the focus area of all developing countries. The conflict between supply and demand of water is in need of a governing body leading to good governance taking into account the benefits of all parties involved. Future solutions related to Water issues is expected to

be towards water being treated as a commodity. As a commodity, water trading would lead to water being sold and bought at a price instead of it being taken for granted [27].

Future research in this topic could be conducted based on the primary data collected from the consumers once the technology implementation is done. Research could be on data transparency on water resource management, water quality and sanitation issues as consumers are entitled to this. This would lead to responsible water consumption, storage and harvesting leading to a safe water economy.

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