Role of Information and Communication technology in Water Quality Monitoring and Water Management

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Abstract - **Water Quality Monitoring and Water Resource Management are significant for solving the problem of water crisis and procuring clean and safe water to the public. Smart solutions for water quality monitoring are of paramount importance and it has got significance with the advancement of communication technology. In modern times, the applications of Information and Communication Technology (ICTs) play a vital role in water management sectors. The water monitoring sensors assist in detecting the pollutants that cause adverse effect on aquatic life and human health. There are many countries where water resources are inadequate to meet domestic, economic and environmental needs. Therefore, this is the need of the hour that something should be done to curb this alarming problem. The basic objective of this paper is to emphasize how ICT tools can overcome water quality monitoring and water management challenges faced in different sectors in order to provide clean and safe water. ICTs have high potential to improve the current water situation. Satellite Remote Sensing, Geographical Information System, Global Position Sensor, Real Time Monitoring Sensor are some shining examples that are employed for information tracking, forecasting and of course identifying new sources of fresh water. This paper also puts forth a detailed overview of recent works carried out in the field of smart water quality monitoring as well as water resource management.**

keywords - **Water Quality Monitoring, Water Resource Management, Information and Communication Technology(ICT's), Monitoring Sensors, Rainwater Harvesting**

1. INTRODUCTION

1.1 WATER QUALITY MONITORING:

Water Quality Monitoring helps in determining the quality of water and provides sound objectives in order to manage water quality today and in the future. It also alerts towards the ongoing and emerging problems. It provides a wide spectrum of information from the local level up to the national and global levels. Clean and reliable fresh water is a very fundamental element to human life and economy. Access to clean and safe water for drinking and sanitation purposes are still a problem to a large amount of the global population. If water quality is poor, it affects not only aquatic life but the surrounding ecosystem as well. Thus, monitoring is required to make sound decisions to manage water quality [29].

In the 21st century Water Quality Monitoring is a big challenge because of the large number of chemicals used in our day to day life which make their way into our waters [17]. Also, with the introduction of IOT (Introduction of Things) in the modern world, several problems can be resolved quickly [6]. Assessments based on monitoring data help law makers and water managers to ensure the effectiveness of water policies, determine whether water quality is getting better or worse, and formulate new policies to protect human health and the environment to a great extent.

1.2 WATER RESOURCE MANAGEMENT:

Water scarcity affects more than 40% of the global population. The global population is growing fast, and data shows that within current practices, the world will face a 40% shortfall between demand and availability of water by 2030. It is an essential component to sustain life for humans, plants and animals. Our country is blessed with vast water resources but they are not distributed properly. Hence it is the need of the hour that more focus should be drawn towards the water resource management [5]. Water resource management is a practice of making decisions and taking actions while considering multiple viewpoints of how water should be managed. These decisions and actions relate to situations such as task forces, planning of new capital facilities, controlling reservoir releases, regulating flood plains and developing new laws and regulations. The water resource management includes the quantitative and qualitative exploration of water resources. There are several water management techniques which have numerous benefits as they can prevent flooding in the area, store lots of water for future use (26,9,10].

2. Information and Communication Technology (ICTs) tools and techniques used for Water Quality Monitoring and Water Resource Management:

1. **Wireless Sensor Local Area Networks(LANs):**
   It improves field measurement by allowing more flexibility for site measurement like soil moisture, salinity etc.
2. **Global Position Sensor(GPS), Geographic Information Sensor(GIS):**
   These techniques help in the assessment, exploration, evaluation, analysis, monitoring and management of groundwater. They provide data to hydrologists / hydraulic engineer to evaluate the earth's surface and other specific features [3, 28].
3. **Remote Sensing:**
   It includes geophysical surveys which offers the possibility of exploring underneath information of the earth. It has an advantage over other techniques in terms of spatial, spectral and temporal data availability. It has several applications in:
   - Exploration and assessment
   - Groundwater pollution hazard assessment
   - Pollution modelling
   - Estimation of natural recharge distribution
   - Detection of local and regional flow of groundwater [3].
4. **Sensing Technology for Water Quality Monitoring**
   i. **Physical Monitoring Sensors:**
   These sensors have been used for years to measure physical parameters such as oxygen, CO_2 in sea water, conductivity, depth, temperature and turbidity.
   ii. **Chemical Monitoring Sensors:**
   They are used to monitor several chemical parameters. They can be monitored through automatic water samplers. They help in determining whether the water sample is acidic or basic.
   iii. **Electrochemical Sensors and Biosensors:**
   These are the viable methods for water quality monitoring. These instruments have a wide range of applications in clinical, environmental and agricultural fields. Electrochemical Sensors use conductometric electrodes to measure salinity, Ag_2S electrodes to measure sulfur and potentiometric methods to detect oxygen and nitrous oxide.
   Biosensor is an analytic device, used for detecting a chemical substance that combines with a biological component.
   iv. **Optical Remote Sensors:**
   These sensors work by direct solar radiation entering the water column. The radiation is reflected in the atmosphere and is passively recorded by the sensor. It provides information on sediment particles and also helps to understand the growth and maintenance of suspended and benthic (layer closer to the bottom of the plant life) plant life [13].
5. **Real-Time Monitoring Sensors:**
   These sensors are applied in various fields such as drinking-water supply systems, river and lake management and water resource distribution. They also provide parameters measured with sensing technology for proper management of water quality. They also help in flood forecasting and several warning systems [3, 13, 28].
6. **Water Quality Sensing in Water Distribution System:**
   Water Quality Sensors are used for decision-making on a variety of management issues such as regulating water quality requirements, identifying non-regulatory water quality for critical users, verifying water quality modelling, implementing a contamination warning system etc. [3]
7. **Novel Monitoring Systems for municipal water pipes:**
   If there is any leakage of water pipes in remote areas then it's difficult to trace and repair the leakage within a short span of time. It usually takes two to three days to locate the leakage and repair it. During this time a lot of water is wasted. Thus, Novel Monitoring System helps in detecting the leakage in no time.
8. **Robotic and autonomous hydraulic information monitoring infrastructures:**
   It uses an autonomous sensor-based system called SPAMMS (Sensor-based Pipeline Autonomous Monitoring and Managing Systems) which combines robot agent based technologies with sensing technologies to efficiently locate and monitor several pipelines and infrastructures used for water conservation. It is cost-effective, scalable and customizable [14].

3. Need and Scope of ICTs:

Information Technology refers to the creation, gathering, processing, storage, presentation and dissemination of information. It is a combination of technology and programming to communicate information through digital systems. Today it plays a significant role in every sphere of life. Several companies and industries rely on IT due to its high quality accuracy, consistency and uniqueness. The ICT sector has grown much faster globally. The growth is due to increase in application of Information Technology in almost every field. ICT is growing tremendously with every passing year. Starting from the 20th century, Information and Communication Technology (ICT) tools have been increasingly used in several sectors.

- It plays a major role in water sector by monitoring the water quality and by providing several technologies for water resource management. There is a great need of ICTs in water supply and irrigation management. The applications of

advanced technologies in water resource management provide a remarkably efficient use of water, mainly in the areas exposed to severe water scarcity. It is apparent that there are fundamental flaws in the nation's water and wastewater management infrastructure (pipe systems, facilities and equipment) that result in environmental damage and the loss of millions of gallons of water every year. Hence it can be asserted that there is a great need of Information Technology in water sector, as the population is rapidly increasing globally which has led to water crisis in several areas. Today all water utilities have begun to adopt smart technology solutions to streamline their operations and proactively address issues with the nation's water infrastructure [21].

- ICTs can be used to solve climate-induced water management challenges in prediction, monitoring, adaption and strategy formulation. It helps in Laboratory Information Management System (LIMS) for water quality [21].
- ICTs also help in maintaining the client-server connection. There are several ICT tools ranging from simple mobile telephony to advanced sensors which are helpful in several ways [21].
- ICTs have a great scope in the coming future. The technologies are developing day by day. Today all water utilities have begun to adopt smart technology solutions to streamline their operations and address issues with the nation's water infrastructure [21]. The fast growth in technology has made world a better and fast moving place. In the coming future Information and Communication Technology (ICT) is expected to play a key role in developing and managing the nation's water resources [13].
- 'Water is Life' (saying by unknown). This shows how water is essential for all organisms. The ICTs provide a better means to measure and control water resource management and water quality monitoring through its various applications and tools.

4. Applications of ICTs in Water Quality Monitoring and Water Resource Management:

ICTs play a key role in water monitoring with the assistance of several sensors and different monitoring technologies. Information Technology helps in the management of water resources by facilitating the collection and analysis of data. It provides improved data for decision making in both rural and urban areas. It also helps in mapping of water resources, climate changes and flood management etc. Several suspended and dissolved matter in water streams can be investigated directly or indirectly through water monitoring. In the irrigation and agricultural sector, water monitoring is required to determine and measure the water quality parameters viz. physical, chemical, microbial such as the salt concentration, pH, conductivity, soil moisture etc [18].

- People have been planning, designing and developing infrastructure and policies for the water quality monitoring and management of water resources with the assistance of ICT.Information and Communication Technology (ICT) makes use of appropriate technology so that decision makers have the information about the water resources and demands to make right decision. Certain technologies are there which act as an environment indicator and check climate changes and IT helps in alerting the center operators and the appropriate agencies responsible for taking management actions [28].
- It also provides the information with appropriate accuracy and reliability so that the decision maker is well informed. It also helps in the assessment of flood areas and also helps in determining the leak detection centers.
- The conventional use of field sampling (e.g., point sampling at a single location) and laboratory analysis requires considerable labor and time (several hours to weeks), and are therefore labor-intensive, time-consuming and costly, further hindering the ability to gather a synoptic (general view of a whole) view of the water source. . Today Information Technology has made it more simpler and easier. Today Information Technology has made it simpler and easier.
- A sensor known as LoRaWAN has enabled smart water management solution, with the help of this, a gate can be remotely opened or closed or a pump can be turned on or off to adjust the flow of water through the water transport system which is really helpful to reduce wastage of water.
- There are several sensors which can monitor the indications of failure of several equipment or the need to replace or repair them. This more detailed and timely information allows utilities to improve service delivery and enhance customer engagement around water conservation.
- The introduction of various contaminants such as organic matter, hazardous chemicals and nutrients from domestic, industrial and agricultural activities to natural water systems has caused harmful effects on drinking water supply systems like lakes and rivers [17]. Thus, appropriate water-quality monitoring technologies are needed in order to develop an effective water-resource management strategies. ICT helps to overcome that type of challenges. Several efforts have been made to develop a robust water monitoring system using the appropriate application of ICT.
- Several devices and techniques such as remote sensing helps in monitoring the intoxicants present in water and informs the related authority about it. Sometimes field-deployed analyzers and portable sensors are used to measure the water quality parameters such as quantities of disinfectant, pH level, turbidity, conductivity, temperature etc. It also helps in indicating the acidity of water. Poor water in general can slow the plant growth. Water with too high pH level could be harmful to some plants, making it difficult for them to absorb nutrients.
- The smart water quality monitoring system can help in determining the salinity in water because some plants can tolerate high salinity while others can't. Sensors are significant in monitoring the drinking water quality, determining amount of oxidation-reduction potential (ORP) etc.

5. ICTs used by different countries in Water Quality Monitoring and Water Resource Management:

Canada: In Canada "Smart Water" technology is used to provide safe and clean water to indigenous communities. **The Internet of Things (IoT)** offers many benefits for water management. IoT sensors can collect real time data on water quality for water and waste water treatment plants. Water meters and intelligent sensors can work together to gather information about total dissolved solids (TDSs), bacteria, chlorine and electrical conductivity. IoT sensors can also monitor water quality through each stage of disinfection treatment such as chemical labels during chlorination or when water is treated with ultraviolet (UV) rays [30].

China: China is facing severe water problems due to urbanization and socioeconomic developments. The water shortage problems in China are further exacerbated by water pollution, not only for the inland fresh water but also for the coastal water resources. With the widespread water pollution the application of **remote sensing techniques** for water quality assessment has become increasingly popular in China. (Ministry of Ecology and Environment of the People's Republic of China, 2018). According to the most recent national survey in 2017, bad quality surface freshwater accounted for 22.1% of total freshwater resources in China. In addition, of the total 109 assessed lakes, 33 (30.3%) were experiencing eutrophication. For coastal water resources, only 34.5% was reported to be clean with little pollution [16].

UK : Bio-Electrochemical System(BES) technology has the potential to reduce the discharge of pollutants from treatment facilities. **BES Sensors** are the Real Time Water Quality Monitoring Technology. This technology is popular in UK and also applicable to –

- Wastewater Treatment Facilities
- Rivers
- Industrial Waste
- Marine Pipelines

In BES electrogenic bacteria forms a bio-film on an electrode surface and donate electrons which generate electricity. With a multi-stage BES device it is possible to extend the dynamic range of the sensor [20].

Malaysia: A **Water Quality Simulation Model** for **Maong River,** which flows through Kuching city in Malaysia was explored with a focus on predicting the dissolved oxygen parameters. The water Quality Model was developed to simulate the inflow water conditions and estimate the dissolved oxygen level at various locations. It was observed that dissolved oxygen concentration were clearly affected as the river flowed downstream. The use of **Remote Sensing** and **GIS** is also popular in Malaysia. They are widely used in monitoring water quality parameters such as- suspended matter, phytoplankton, turbidity and dissolved organic matter [23].

Philippines: Stationary and portable water quality monitoring and a mobile surface vehicle are employed to measure the quality of water. The overall system comprises a commercial water quality **sensor**, a **GSM** and **Zigbee module** for a wireless communication system. During testing all captured data like water quality parameters, location, and other essential parameters are collected, processed and stored in a database system [4].

6. Policies and Schemes of Government of India for Water Resource Management:

Water is a prime natural resource. It is not only a basic human need but a precious national asset as well. We cannot live without water. It is very essential for all living beings on the earth [22]. India accounts for 18% of the world population and about 4% of the world's water resource. Water distribution is uneven and several areas are deficient in rain as well as groundwater. Unequal distribution of water in major parts of India makes most of the population face water shortage. Around 2 lakh people die in India every year because of immense water shortage and 600 million people of this country and 1.2 billion people across the world don't have access to clean drinking water [28]. It has become very important to protect all possible water resources. Conservation and management of water resources is necessary to meet current and future human demand.

There are several schemes and policies formulated by the government of India so as to manage and conserve the water resources. Few of them are listed below:

- **National Water Policy:**
  The first National Water Policy was adopted in September 1987. It was reviewed and updated in 2002 and later in 2012. It is formulated by the Ministry of Water Resources of the Government of India to govern the planning and development of water resources and their optimum utilization. It aims at making the water available to water short areas, resource planning, recycling for providing maximum availability and regulates exploitation of ground water. It provides guidelines for the safety of storage dams and other water related structures [19].
- **Jal Shakti Abhiyan:**
  It was a time-bounded, mission-mode water conservation campaign which ran in two phases. Phase 1 form 1st july to 15 september 2019, Phase 2 from 1st October to 30th November 2019. It focused on five aspects-
  a. water conservation and rain water harvesting
  b. renovation of traditional and other water bodies
  c. reuse of water and recharging of structures
  d. watershed development
  e. intensive afforestation [12].
- **Jal Jeevan Mission:**

This mission began in 1972 and was renamed as National Rural Drinking Water Programme (NRDWP) in 2009. It aims to ensure access of piped water for every household in India. According to a report only 3.27 crore out of the total 17.87 crore households in the country, have piped water connection. The mission's goal is to provide all households in rural India with safe and adequate water through individual household tap connections by 2024 (Wikipedia).

- **Swajal Scheme:**
  The government of India has launched Swajal Scheme to ensure regular supply of clean drinking water in rural areas. These rural areas usually receive contaminated and harsh water which, on consumption, has led to many illness. The Swajal Scheme is launched on around 115 rural districts in India to provide clean drinking water (India Today).
- **National Rural Drinking Water Programme (NRDWP):**
  It was launched in 2009-10 with the objective of bringing various programme together. It aims at prevention and recharging of ground water table and introduces to rain water harvesting.
- **Amrita Water Distribution System:**
  It aims to build water distribution for more effective water use and effective management. The project began in Kerala in April 2015 and in Rajasthan and Odisha in July 2015.
- **'Nal se Jal Scheme':**
  It aims to provide potable water to 18 lakh rural household. It will be based on a unique model water under which villagers will themselves decide how much to pay for water they consume (Wikipedia).
- **National Water Mission:**
  The government of India has established National Water Mission as one of the eight National Missions under the National Action Plan on climate change. It was established on 6th April, 2011. Its main objective is conservation of water, minimizing wastage and ensuring its more equitable distribution both across and within states through integrated water resources development and management [24].

7. Water Management Techniques in Hilly Regions of India:

Water is the most vital element for sustaining life. As world is facing a serious threat from climate change, the importance of water has become more relevant for sustaining life particularly in the developing countries like India.

The inhabitants of hilly areas, are completely dependent on rain for several purposes. Also they are at high risk due to highly vulnerable changes in seasonal climatic patterns. The people in hilly areas depend on natural water springs for drinking water supply, household activities, but in recent times most of the springs have either become seasonal or have been extinct due to ecological imbalances. Let's take an example of Uttarakhand state which is situated in North-East of India. There have been several cases of people leaving their homes across Uttarakhand and migrating to cities because of scarcity of water in their area [27]. About 70% people living in mountainous region of Uttarakhand State mostly depend on agriculture for their livelihood, but various climatic, geographical constraints have led to low agricultural productivity in the region. Agriculture is largely rainfed, and the farmers generally face severe soil-moisture stress at germination stage. Heavy rainfall in first half of July improves the situation but the relief is only temporary. A major part of state's rural population depends only on springs & mountain streams, it is important to work on protection of sources [2]. A number of natural water bodies across Uttarakhand have dried up leading to a virtual crisis in villages especially in summer. According to estimates, almost 60% of all water sources have dried up in hills. Therefore, the only option in the present circumstances is to collect and store all forms of water resources such as direct surface runoff water or runoff through roof-tops of house [25]. Residents have complains that authorities did lay pipelines but the water is very irregular and half of the water pipes remain defunct (non-functioning) [27]. Water scarcity in some districts like Uttarkashi, Rudraprayag (India) has been so acute that it has driven villagers to sit on protests demanding that something should be urgently done to solve water crisis. There are several hill stations of India like Shimla, Mussorrie, Ooty which are facing acute shortage of water [15].

India has traditionally been a country of **dharas (springs), gadheras (small river tributaries), naulas (little depression aquifier), guls (traditional irrigation canals), chal and khal (artificial ponds on hill tops)** many of which are at verge of extinction. Water Management Techniques adopted by India for its Hilly Regions can be beneficial for some other countries too. Some of these techniques are as follows:

1. **Bamboo drip irrigation:**
   It is a method in which stream and spring water are transported with the help of bamboo pipes without any leakage. It is a very cheap and efficient way to conserve, transport and store water. It is so perfect that about 18-20 liters of water entering the bamboo pipe system per minute gets transported over several 100 meters.
2. **Spiti's Kul Irrigation:**
   This is a process which is used in Himanchal Pradesh (India). Through this process water is transported from glacier to villages lined with stones to prevent clogging and seepage. The water then leads to a huge circular tank from which the water can be regulated and then can be further transported to the villagers.
3. **Development of Naulas and Dharas:**
   Naula is a naturally occurring water aquifier. It is a stoned lined tank which catches dripping water from springs and streams. It looks like a temple from outside and is equally regarded as such. Naulas and Dharas are also considered as sacred in Uttrakhand's (India's) tradition and culture. Naulas and Dharas are always prevented from being polluted. The entrance of Naula is always made small and this was done to prevent animals from entering it and to ensure that only one person can enter at one time. On the other hand, Dharas are mostly protected by constructing boundary walls.
4. **Construction of Chals and Khals:**

These are small artificial ponds which are not only the traditional methods of rainwater harvesting which help in maintaining the groundwater level but also provide water to domestic and wild animals in forests.

5. Construction of Guls:

These are the channels built by people in hilly areas. They are made and used for the purpose of irrigation. These are diversion channels which provide water to several agricultural fields. They serve a very important purpose and special care should be taken while construction and maintenance [7].

ICTs play a major role here. There are several sensors such as **Remote Sensing** and **Global Positioning Sensor (GIS)** which can help in tracking the location and giving the information about the availability of water which can be used to conserve it by making naulas, gadheras etc.

8. Rainwater Harvesting and its advantages:

Rain water harvesting is a sustainable process that helps in preserving water for future needs. Water scarcity is a major concern in today's scenario. The process of rainwater harvesting is a good way to conserve water. In this process rainwater is collected and redirected to a tank or a reservoir. It can be used for watering lawns, gardens, flushing toilets, rinsing vegetables, irrigation and domestic use [1]. It can also be used for cooking and drinking purposes after examining it properly with the help of several **ICT tools** and **monitoring devices**. **UV Filtration Device** makes the water adequate for consumption. Rainwater harvesting was also common in Roman Empire.

This is a very common practice done in several countries such as **India, Sri Lanka, South Africa, China** etc. (Wikipedia, Rainwater Harvesting). It is a cheap method. It reduces flooding and erosion. It increases the groundwater level and quality. It decreases the demand of water and promotes both water and energy conservation.

8.1 The Impact of Rain Water Harvesting on Local Cropping System of Bangladesh:

An **experiment** was conducted in hill tracts of **Bangladesh** which is predominantly rain fed with an average 2210mm monsoonal rain, but rainfall during dry winter period (December-February) is inadequate for winter crop production and other purposes. The geographical feature of these hilly areas is considerably different from the plain land. Bangladesh has the highest per capita fresh water available among South Asian countries, i.e. annually 795,000m^3 of water through surface flow and about 2030mm of rainfall. However, it can hardly make proper use of the resources due to poor internal water management practices. Hence it affects water supply for domestic, crop production and other purposes.

Then a study was conducted to investigate the potential of **rainwater harvesting** and its impact on **local cropping system**. It was concluded that harvesting rainwater during monsoon and its proper use and management can develop a better farming system with increased crop production, cropping intensity and also it fulfilled several other domestic purposes. The study was conducted at a hill station Khagrachari. The elevation of the site ranges from 56 to 85m relative to mean sea level [11].

8.2 Methodology:

The experimental site consisted of a cross dam, spillway, gate valve, pump, storage tank, water conveying channel, pipe networking and risers.

A cross dam between two hills collects surface runoff during rainy season from June to November. The overland runoff part of rainfall was not treated because it was enriched with wash load including silts and clay particles and was suitable for irrigation. An evaporation pan was installed at the reservoir which was used to measure the evaporation, seepage and percolation losses. Considering all the losses a storage volume of reservoir was designed so as to meet the water demands. As water was stored at upstream of the valley, the potential energy of reservoir was enough to make gravity flow irrigation to the lower valley land. A gate valve was used to regulate water flow to the downstream channel, which involved no energy cost [11]. A simplified sketch is shown below:

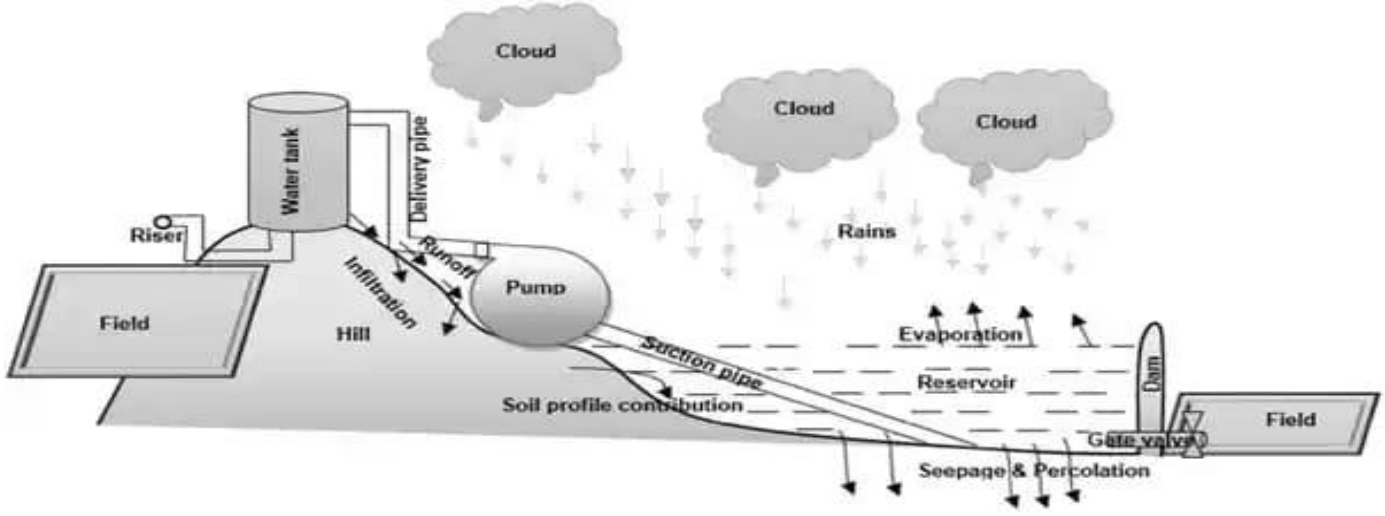

FIG.1 Rainwater Harvesting Model

The economic benefit of the system was calculated based on the gross benefits obtained from different outputs of the cultivated area and costs for the input of the system. Benefit-cost ratio was calculated on the basis of annual benefit and cost

of the system. The items included for benefit calculation were the outputs for agronomic and horticulture crops. For cost calculation the items were labour, seed/seedling, fertilizer, manure etc [11].
This method was made at large scale which can be beneficial for a large amount of people.
Also, a similar model at small scale can also be made which can be easily adopted by every household as shown below:

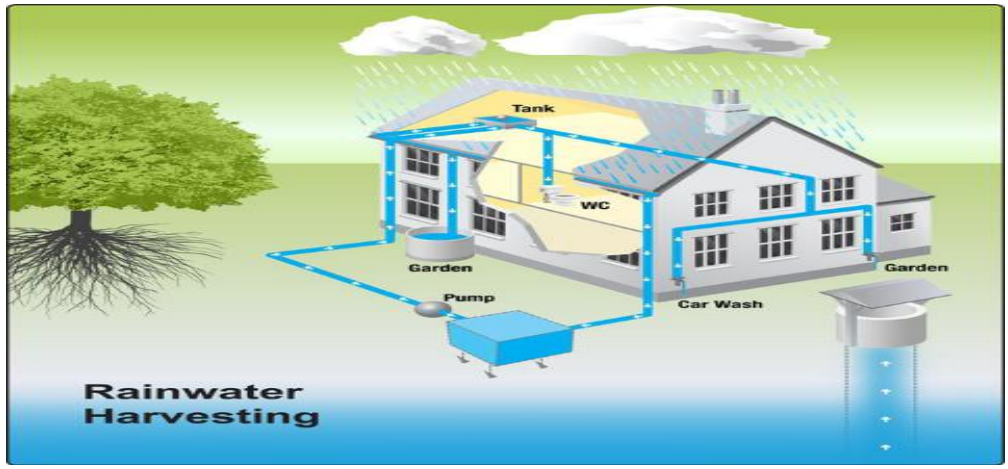

FIG.2 Simple Model of Rainwater Harvesting

This is a small scale rain water harvesting method which can help in the conservation of rain water. The rainwater will be collected in a tank made at the roof top of the house. The rainwater can be monitored with the help of **(ICTs) several sensors** which will give the information whether the water is safe for use or not.

8.3 Results and discussion:

In this method a series of steps were completed for investigating the rainwater harvesting potential to improve the farming system performance of crops.

8.3.1 Effect on farming system: Before this water management system, most of the land remained barren during the dry season due to the lack of irrigation facility. A comparison of cropping pattern between with and without rainwater harvesting is shown as under:

Without Rainwater Harvesting Facility			**With Rainwater Harvesting Facility**		
RABI	**KHARIF-1**	**KHARIF-2**	**RABI**	**KHARIF-1**	**KHARIF-2**
Fallow	Aroid	Aroid	Cabbage	Chilli	Aroid
Fallow	Yard Long Bean	Brinjal	Raishak	Chilli	Aroid
Fallow	Jum RICE	Sesame	Potato	Red Amarnath	Yard Long Bean
Fallow	Chorovaiti	Sesame	Onion	Red Amarnath	Yard Long Bean
Fallow	Rice/maize	Fallow	Red Amarnath	Maize	Aroid

Source: Water Resource Planning Organization, Bangladesh

8.3.2 Performance of crops: There was a great change in the performance of crops. Different crops studied under the rain water harvesting system is shown as under:

Crop	**Yield (t/ha)**	**WU(Water Usage) (mm)**	**WP(Water Productivity) (kg/ha/mm)**	**Total Benefit**	**Total Cost**	**Net Benefit**	**Benefit-Cost**
Sweet Gouard Leaf	60	340	176.5	140	35	105	4
Chilli	14.8	290	51.03	444	188	257	2.36
Red Amarnath	14	270	51.8	260	140	120	1.86
Cucumber	15	370	40.5	300	125	175	2.4
Black Cumin	1	250	4	200	100	100	2
Raishak	30.6	270	113.3	517	277	240	1.87
Cabbage	60	310	193.5	600	300	300	2
Onion	20	335	59.6	-	-	-	-
Bottle Gourd	66.9	345	193.8	669	345	324	1.94
Country	2	310	6.45	600	238	363	2.52

Bean							
Tomato	20	370	55.55	-	-	-	-
Malze Cob	14.5	360	53.8	167	43	124	3.88
Maize Grain	3.5	270	7.1	65	46	19	1.41
BRRI Dhan-28	4	490	1.4	40	29	1	1.38
BRRI Dhan-29	4.5	1250	1.2	45	38	8	1.18

Source: Water Resource Planning Organization, Bangladesh

In this method several information technology sensors (ICTs) play a vital role as they assist
in weather forecasting and detecting the problems occurring during the whole process so that everything could be solved as soon as possible.

Conclusion:

Water crisis is increasing day by day and the foregoing study exhibits that every country is facing high scarcity of water. The problem is getting multiplied by low rainfall, floods and climate change. The analysis which has been formulated from the present study is that – water once an abundant natural resource has become a more valuable commodity due to droughts and overuse. Due to increasing population, pollution, deterioration in quality, the monitoring of water quality and water resource management has become the need of the hour.

The present study has tried to find out the role of Information and Communication Technology (ICTs) in the monitoring of water quality as well as water management system. An attempt has also been made to exhibit several (ICTs) tools and techniques employed by different countries. The study is also an attempt to show that ICTs play a vital role in making sound decisions regarding water resources. The objectives of water management and water quality monitoring are to perform and predict future trends of water quality more efficiently. ICTs bring enormous benefits to water authorities by helping them in mapping and monitoring natural water resources as well as in forecasting river flows and giving advance warning for water related emergencies such as flooding. In future, the use of ICT technology would provide promising solutions for the advanced management of water resources. Also, the water conservation method (rainwater harvesting) used during rainy season exhibits that it has high potential for performance of crops and domestic use. It is expected that in the years to come, every country will certainly experience a huge shortage of water leading to several problems. There are several small scale water management techniques as discussed in this study which can be followed. A concerted effort is needed to solve and curb this very problem as it cannot be solved with immediate effect.

References:

[1] Bailin. S (16August, 2017), "Application In Rainwater Harvesting".
[2] Chakrabarty, (15 August, 2016), "Parched Hills: Issue of down to earth magazine''.
[3] Charalampos et al., (25th July 2018), "Information-Communication Techonologies as an Integrated Water Resource Management (IWRM) Tool for Sustainable Development'', pp.7-14, DOI:10.55772/intechopen.74700.
[4] Demetillo A.T, Taboada E.B (April 2019), Volume:9/Issue2/Pages3959-3964.
[5] Dr. Lal Bansari, Dr.Ahamad Shahid (December 1, 2014)."Water Management in Hilly Areas''. Journal of Advertising Research, editorial article, news.statetimes.in.
[6] Doni Ashiwini, M.V, Chidananda Murthy, Kurian M.Z (2018),"Survey on multi sensor based air and water quality monitoring using IOT'', pp.1-2, Department of Electronics and Communication Engineering, SSIT, Tumakuru.
[7] Er Garg. B. A (11Feb, 2018). "Water Management in Hilly Regions''. Source: www.teachstgs.org.
[8] Government launches schemes to provide clean water to rural districts. Source: India Today.
[9] Horne. J (12May, 2015). "Water Information as a tool to enhance Sustainable Water Management-The Australian Experience'', pp.1, doi:10.3390/w7052161.
[10] slam Zahidul, (April 2011)."A Review on Water Resources Management Modelling'', pp.2, Department of Environmental and Civil Engineering, University of Alberta. DOI: 10.13140/2.1.3496.0168. Source: Research Gate.
[11] Islam Tarqul, Ullah Mohabbat, Sahadat Hossain (2017),"Rainwater Harvesing Potential for Forming System Development in a Hilly Watershed of Bangladesh'', pp.1-8, DOI 10.1007/s13201-016-0444-x. Source: Springerlink.com.
[12] 'Jal Shakti Abhiyan': Government launches water conservation campaign (1July, 2019). Source: m.economictimes.com.
[13] Jungsu Park, Keug Tae Kim and Woo Hyoung Lee (12Feb2020)."Recent Advances in Information and Communicatiom Technology for Monitoring Water Quality'', pp.3-16. Department of Civil, Environmental and Construction Engineering, University of Central Florida, Water 2020, 12(20), 510; https:/doi.org/10.3390/w12020510.
[14] Kim Hoon-Jong, Sharma Gokarna, Boudriga. N, Iyengar. S. Sheena (February 2010). "SPAMMS: A Sensor Based Pipeline Autonomous Monitoring and Maintenance Sytem'', pp.1-3. Department of Computer Science, Louisiana State University, USA. DOI:10.1109/COMSNETS.2010.5432015. Source: IEEE Xplore.
[15] Majumdar. K (29 May, 2018), "One of India's top hill station running out of water''. Source: BUSINESS INSIDER.
[16] "Ministry of Ecology and Environment of the People's Republic of China", 2018.

[17] Moses. K. D, (April, 2016), "A review paper on Industrial Waste Water Treatment Process'', pp.2-3, University of Nigeria, NSUKKA.
[18] Mukherjee et al., (2011), "Managing the flow of Monitoring Information to improve the rural sanitation in East Java, water sanitation program'', pp.1-2.
[19] National Water Policy. Source: Wikipedia, en.m.wikipedia.org.
[20]Newcastle University, NE1 7RU, United Kingdom.
[21] Otuke (April2016),"Role of Information Communication Technologies in Water Management'', pp.16-47.
[22] Raina. N. Y., Alam Pervez (November 2014). ''Waste Water Treatment and management in rural areas- A Case Study of Rajouri District, Jammu & Kashmir, India'', pp.1-2, http:/www.journalijdr.com.
[23] S Said, DYSMah, P. Sumok, SH Lai(2009), "Preceedings of the institution of Civil Engineers-Water Management", 162(1), pp.35-40.
[24] Schemes: National Water Mission (13 May, 20190. Department of Water Resources, RD&GR, Government of India, nwm.gov.in.
[25] Sharma. S (19 May, 2016), "Hills Face Acute Water Shortage''. Source: Times of India.
[26] Singh. A, Dr. Ram. S (2014), "Water Management in Hilly Areas: Indian Context'', pp.1, Madan Malaciya University of Technology, Gorakhpur, India.
[27] Singh. V (8Feb, 2019). "Water and hopes down to a trickle in Uttarakhand's hilly areas as residents ignored by state abandon their homes''. Source: Firstpost, www-firstpost-com.cdn.ampproject.org.
[28] Solomon. H. G (9June 2014). "The Role of Information and Communication Technology (ICI) in Water Resource Management'', pp.1-24, https://www.recearchgate.net/publication/279852273.
[29] William J. Cosgrove and Loucks P. Daniel (28June2015)."Water Management: Current and Future Challenges and Research Directions'', pp.24.
[30](www.canadianconsultingengineer.com).