2022 4th International Conference on Sustainable Technologies for Industry 4.0 (STI), 17-18 December, Dhaka

Internet of Things (IoT) for Water Quality Monitoring and Consumption Management

Mehedi Hasan Jewel*, Abdullah Al Mamun†,
* Department of Computer Science and Engineering, United International University, Bangladesh
†Department of Electrical and Electronic Engineering, Bangladesh Army International University of Science and Technology, Bangladesh
Email: jewel.mehedi7@gmail.com, mamun.jeddah1996@gmail.com

2022 4th International Conference on Sustainable Technologies for Industry 4.0 (STI) | 978-1-6654-9045-0/22/$31.00 ©2022 IEEE | DOI: 10.1109/STI56238.2022.10103355

Abstract—**This paper describes the design, development and implementation of an IoT-based water consumption metering and water quality monitoring System. Water is one of the natural resources found in nature and an essential part of life. Two of the major issues related to consumption of water, especially in Bangladesh are, huge amount of water waste due to lack of proper water management system and another one is poor quality of the drinking water. From the perspective of Bangladesh, the drinking water quality has been a huge issue but there are very few to no ways to monitor the quality of the water that is being consumed by the people. In this paper, we have proposed a solution to the problem by developing a mobile smart water metering system and integrated water quality monitoring where the quality of the tap water in households is constantly measured in real-time and can be monitored using a web/mobile application. In the meantime, the daily/monthly consumption of water is measured and recorded in the database for billing purposes. The daily consumption record is the key to decreasing water wastage. Our system will be able to reduce unnecessary water wastage by consumption metering and ensure the quality of water by quality monitoring. The metering, monitoring, bill payment, etc. are done remotely, and online using the Internet of things (IoT). The proposed solution integrates the IoT, hardware and software which results in healthy/safe drinking water and reduces water wastage which contributes to the sustainability of the environment.**

Keywords— IoT, Water Quality, Water Metering, pH, Remote Monitoring

I. INTRODUCTION

Water is a natural resource that is a gift to the planet and an integral element of our daily life. Every part of our existence requires water, from freshwater for drinking to water for farming, industry, etc. We would not exist without water. According to UNICEF, 38.3% of the total Bangladeshi population still drink contaminated water [1]. In the case of wastage, Dhaka city has the highest water wastage percentage than any other cities [2]. By 2050, the World Water Development Report of the United Nations projects that there will be a shortage of clean drinking water for around 6 billion people [3]. Bangladesh's drinking water condition too has issues and concerns. Despite improvements in drinking water quality, approximately 40% of the population still drinks contaminated water from sources that are infected with bacteria. About 20 million people continued to use water contaminated with arsenic as of 2012 [4]. It will be extremely difficult to provide this vast population with equitable and cheap access to clean water. In contrast, only 12% of Bangladesh's total water supply is used for domestic purposes, while 86% of it is used for agricultural [5]. Among those who use piped water, 86% of those in Chittagong and 70% of those in Dhaka are metered. A survey conducted by earlier studies revealed that 50% of people who used metered water drank it straight from the faucet without first boiling it [6].

In this research, we have presented a system wherein, in addition to measuring water consumption for improved water management, the quality of the water being drunk will also be assessed and monitored via a website and/or mobile application. We have employed a variety of sensors to measure the TDS (total dissolved solids), pH, and turbidity of the water. We measured and calculated the total usage using a flow meter. All of the sensor data was processed by a microprocessor and sent to a database that also computed monthly bills. 2.4 GHz Wi-Fi technology has been utilized by us to connect to the Internet of Things network.

II. LITERATURE REVIEW

Water quality monitoring has drawn increased attention from academics in the twenty-first century. Numerous studies are being conducted on this subject, each concentrating on a different element. The creation of a safe, economical system for monitoring water quality in real-time was the overarching goal of each project. Below is a quick summary of earlier, related works.

The research conducted in [7] focuses on the water quality of Dhaka City. This research includes water sampling and analysis making up a traditional method of monitoring a system. The researchers selected a zone and collected water samples for this research. After sample collection, physicochemical analysis, heavy metal determination, and biological analysis were carried on. The drawback of this research is that the quality assessment of the water done in this paper was focused on economic and biological analysis. There was no proper direction of technologies used to measure the water health and no monitoring section for the consumers.

In [8] researchers proposed a complex system that is integrated with processors and sensors. The proposed system uses four sensors which are pH, Turbidity, Ultrasonic, etc. & the processor is used to collect data from these sensors. In addition, an ESP8266 Wi-Fi module is used for sending data to the cloud for data visualization. But the proposed system has a couple of limitations. In this system, there is no power backup system to power up the devices. For data sending, they use a Wi-Fi module but in the context of real-world Wi-Fi may not be available everywhere. Both research [9] and [10] came up with solutions similar to [8]. But solutions that researchers came up with lack feasibility as [9] uses Wi-Fi as the primary mean of wireless connectivity and [10] used GSM network.

978-1-6654-9045-0/22/$31.00 ©2022 IEEE

The Wi-Fi network lacks portability and the GSM network is high power-consuming technology. Both systems ignored the power management for the proposed system.

Researchers at [11] took a different approach and used Zigbee and Raspberry pi-based system. This system has pH, Turbidity, DO, Temperature sensor. All sensor is connected with a Main Controlling unit which collects data from the sensor. The proposed system has real time water quality system with RF network technology. But it has some limitations such as cost-effectiveness. The system network is based upon the ZigBee technology which cost more than the other technologies. Moreover, the wireless connectivity of the ZigBee modules is short ranged.

Another research conducted by [12] designed and implemented real-time water quality monitoring using the Internet of Things (IoT) at a low-cost framework. The system which consists of multiple sensors, is used to measure the water's physical and chemical parameters including the Temperature, pH, turbidity, and the TDS (total dissolved solids) of the water. The whole system is controlled by an Arduino. This work is highly focused on the quality parameter of the canal water of Dhaka City and does not address the drinking water quality in households, generally provided by the authority.

Our research work focuses on the monitoring of drinking water quality in general households. The developed system can be implemented in the underground reservoir or the overhead tanks. Both of the systems will use similar wireless technology and quality measurement sensors but will be different in the area of power management systems. The main outcome of this research is real-time monitoring of drinking water quality parameters and periodic monitoring of water consumption.

III. PROPOSED SYSTEM & ARCHITECTURE

Dhaka is an unplanned, heavily crowded metropolis. The infrastructure of this city is so complex which raises many challenges with the integrity and robustness of our proposed system. Some of the features that have been used in our system in order to ensure stability and longevity of devices are as followed:

- Low powered microcontroller which can enter into “light/deep sleep” mode when not in use to save battery.
- A Battery Management System (BMS) to ensure continuous supply of power to the system.
- Precise sensors to collect water health parameter data.
- Data Storage system in order to store the water consumption values and health parameter values
- Internet connectivity for real time monitoring and water consumption assessment.

In our proposed system, we have used ARM-Cortex based low-power microprocessor which is used as the primary data gathering and computing device connected with various sensors used to collect water data.

Below “Fig. 1” shows the proposed architectural block diagram:

The whole system divides into three blocks

A. End-user Node
B. Intermediate Device (Local Gateway)
C. Cloud Server/ Storage System

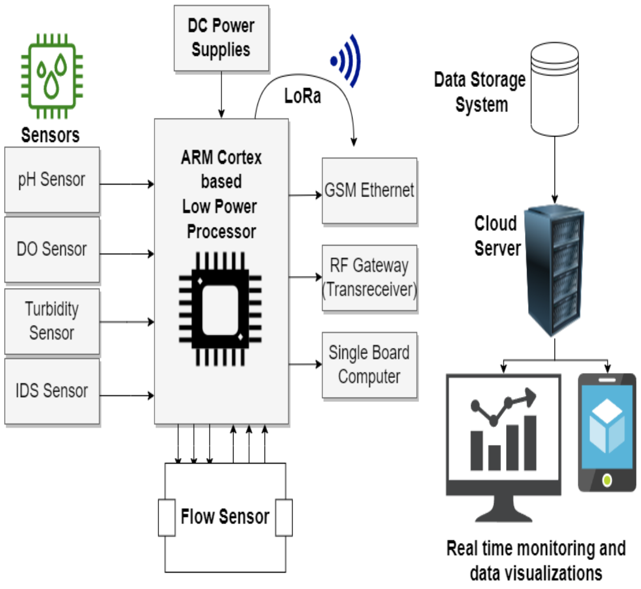

Fig. 1. Proposed System Architecture

A. *End-User Node:*

The end-user (Consumer) side is where this node is situated. This device's primary function is to gather sensor data and send it to the gateway it is linked to. There are three sections in this unit. Sensor Junction, Solar System Module and Battery Management System (BMS).

1) Sensor Junction: pH, turbidity, and dissolved oxygen are among the water parameters that are measured by sensor junction units. TDS Sensor for assessing water quality and flow Water consumption measurement sensor.

a) pH Sensor:

The acidity of the water is determined using the pH sensor. Water has a pH of 7 naturally from its source. The pH range for water that is deemed acceptable to drink is 6.5 to 9.5, whereas in Bangladesh, the requirements are 6.4 to 7.4. Acidic water is indicated by a result higher than 7. Extreme pH values also make elements and compounds more soluble, which makes them hazardous.

b) Turbidity Sensor

Water's turbidity is a gauge of how cloudy it is. The turbidity sensor has shown the extent of the water's clarity loss. It is regarded as a reliable indicator of the water's quality.

c) TDS Sensor

Total Dissolved Solids (TDS) is a measurement of the total dissolved content of all inorganic and organic components in a suspended acidic, ionized, or micro-granular (colloidal sol) liquid. TDS is made up of sulfates, bicarbonates, calcium, magnesium, potassium, sodium, and chlorine. Total Suspended Solids are calculated as follows: Total Suspended Solids (TSS) = Total Solids (TS) [12]

d) Flow Meter

The flow sensor is used to measure the amount of fluid passing through it. A rotor and a hall effect sensor are included in the inflow sensor. The electrical pulse is produced by the hall effect sensor with each rotation of the pinwheel rotor. We can determine how much water is present by utilizing this flow meter.

2) Battery Management System and Solar System Module

Battery backup is necessary to run all the devices. A strong Battery Management system is necessary for battery backup. We used a Li-ion battery in our suggested setup. BMS is required in order to charge these unique batteries. The BMS shields the battery from discharge while simultaneously preserving its long-term health. In the method we've suggested, some modules are located on the roof of the building while others are located closer to the water reservoir. As a result, there are two ways to charge a battery: AC-DC charging and DC charging. BMS features a small solar panel for outdoor systems and uses AC to recharge the battery in inside systems. At dawn, this module can use the buck converter to charge the battery.

3) Radio Frequency (RF) Network connectivity

This system is compatible with a wide range of networking and communication protocols, including WiMAX, Wi-Fi, cellular, ZigBee, and LoRa. The LoRa (Long Range) radio network, a spread spectrum modulation approach evolved from chirps spread spectrum (CSS) technology, is what we've chosen for our suggested solution [13]. The comparison of various wireless communications technologies is provided in Table 2.

Table 2 shows that LoRa has the longest range and lowest power consumption of all the technologies, and its data rate is ideal for transmitting sensor data to an intermediary system. We chose the Lora network for the communication system to achieve this.

B. *Intermediate Device (Gateway)*

An intermediary gateway (local server) is required for communication with the cloud server and utilized node devices in our suggested approach. This gateway gadget can communicate in both directions. This gateway device consists of a single-board computer coupled to a LoRa trans receiver chip (Raspberry Pi). Additionally, this gateway has internet access, allowing it to communicate the data it has gathered from node users to the server. More than a thousand node devices can be handled by this intermediate gateway. The MQTT protocol is used by the intermediate server to communicate with the server.

C. *Cloud Server and Storage System:*

The end-user data is gathered and analyzed for each user's water quality and metering system using a cloud-based server. For the purpose of gathering end-user node data, a gateway is in communication with a third-party broker. This independent broker has means of encryption. Additionally, this server contains a SQL-based database system for storing gathered data and doing user-specific data analysis. A web-based system has been created in this server so that a user can simply access and check the water quality of his or her building. Users and consumers can access their periodic water consumption data such as weekly, monthly, yearly report and asses their water usage which will ultimately result in reduction in water wastage.

TABLE I: COMPARISON OF DIFFERENT RF TECHNOLOGIES

Ref No	Tech.	Freq.	Range	Power	Data Rate
[14]	***Bluetooth***	2.4GHz	50-150m	Low power	1Mbps
[15]	***Wi-Fi***	2.4GHz and 5GHz	Approx.: 50m	Medium power	150-200Mbps, 600 Mbps
[16]	***ZigBee***	2.4GHz	50-100m	Low power	250kbps
[17]	***Cell***	900/1800/ 1900/ 2100MHz	35km (GSM)200km (HSPA)	Band depended on the power	35-170kps (GPRS), 120-384kbps (EDGE), 384Kbps-2Mbps (UMTS),
[16]	***LoRa***	433MHz, 868 MHz, 915 MHz	more than 10 Km	Low Power	<50kbps

IV. METHODOLOGY

The architecture of the IoT-based water quality monitoring system is depicted in "Fig. 2". There are multiple nodes on the figure's right side. These nodes are used to gather water sensor data. Each node features three different types of sensors: flow, TDS, pH, and turbidity. Every sensor has a DC 5V connector to power it up. All ADC readings from the sensor are collected using a 32-bit base microcontroller. The microcontroller must convert in order to collect data from the sensor because it has a 12-bit ADC input but a 10-bit ADC output. The microcontroller is also connected to a LoRa SX1276 chip. This chip can be used to send sensor data via SPI connection. The LoRa SX1276 chip-based microcontroller unit, which is located on the receiving side, also gathers all the nodes' data. After receiving node data, the procedure for sending data to the MQTT broker begins. When the MQTT broker receives data, a Python script is launched in the background and adds all of the node data into its data table while also displaying the sensor value on the online dashboard. The whole process can be seen in flow diagram below in "Fig. 3"

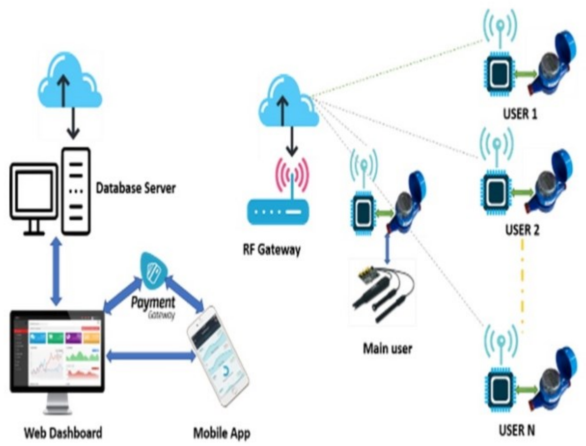

Fig. 2. Proposed Architectural Diagram of Water Metering and Monitoring System

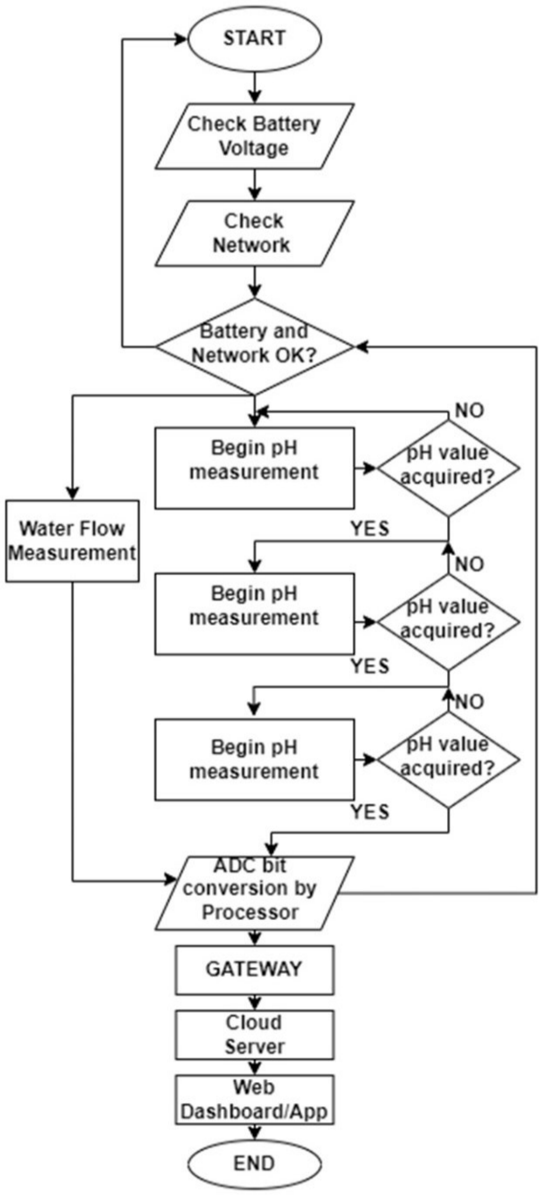

Fig. 3. Flow diagram of Working Principle of the proposed water quality and consumption monitoring system.

V. Results and Discussion

In order to implement our proposed system for water quality measurement and monitoring, we have designed and developed a circuit which houses all the necessary components including the sensors, microprocessors and battery management system. The Node device and the Gateway device can be seen in the "Fig. 4". The whole package is contained in a waterproof container. The various sensors for collecting the necessary data are connected to the main processing board for data acquisition.

In order to properly assess the water quality of the tap water used in our homes, we have developed and assembled 5 sensor nodes as shown in "Fig. 4." and 1 gateway in 5 different household within 1 KM of distance. The nodes-network setup is seen in "Fig. 5". 5 sensor nodes are connected to a primary gateway in a star topology. The gateway is responsible for collecting the data and sending the data to the cloud server.

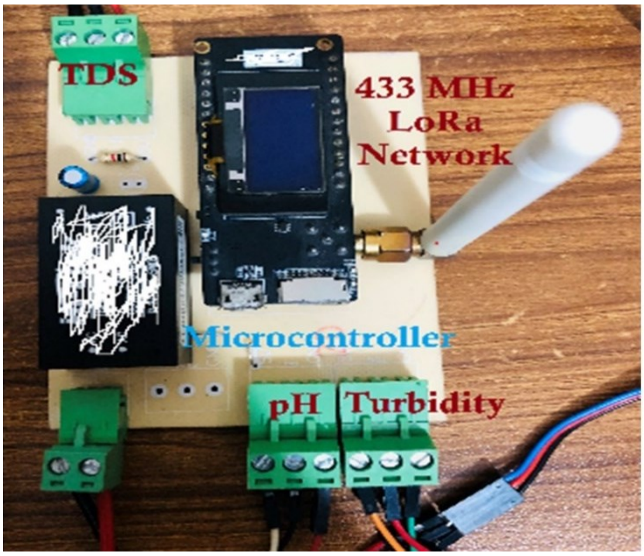

Fig. 4. Node devices for collecting water quality data and health parameters

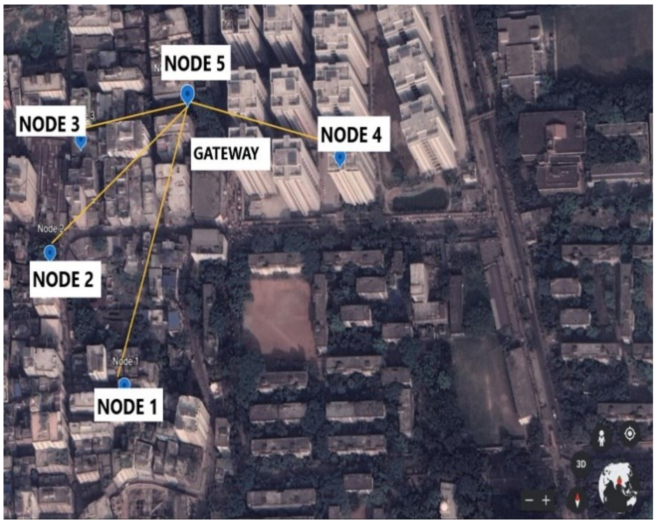

Fig. 5. Location of 5 sensor nodes and gateway

The real time data can be seen any time using the web dashboard available to the consumers. The real time data includes current water consumption, weekly/monthly/yearly water consumption, water quality assessment, bill calculation

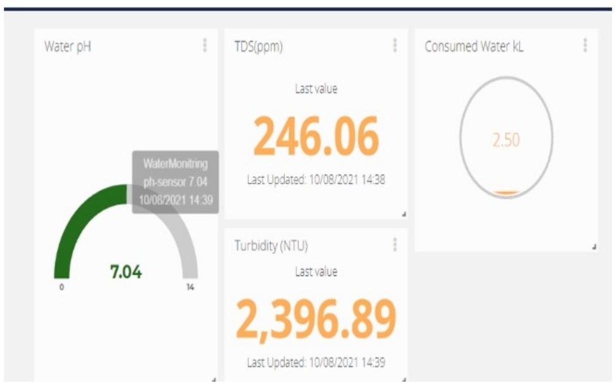

Fig. 6. Web Dashboard for real time water quality and consumption monitoring

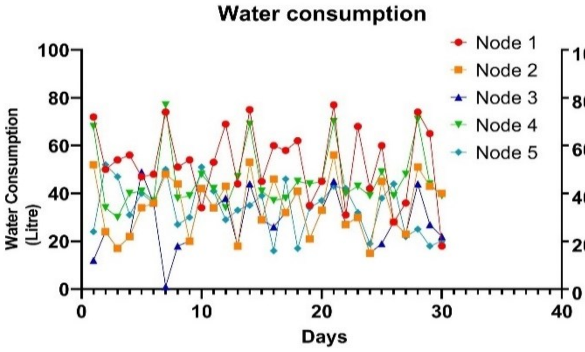

Fig. 7. Daily water consumption data obtained from the server

and payment system. In “Fig. 6”, we can see the live dashboard containing important water data.

We collected water data from the 5 nodes as seen in “Fig. 5” for a time period of 30 days. All the data were stored in the MySQL database. The data was subsequently examined to determine the typical turbidity, TDS, and pH values of the sampled water, as well as the average daily water consumption for each household. In a month, more than 150 samples of water flow data and about 2250 samples of water quality data were gathered. The data are compiled in the graphs below, which are labeled "Fig. 7" and "Fig. 8."

From “Fig. 7” we can see that every household uses a comparatively high amount of water on the weekends and it remains average for the rest of the week.

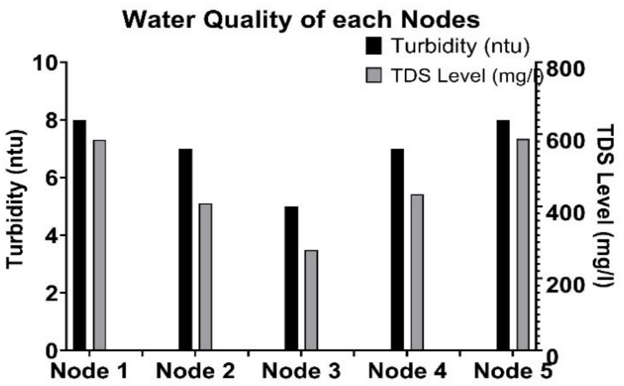

Fig. 8. Average Turbidity and TDS in water sampled from the 5 nodes

From “Fig. 8.”, we can see the average TDS level and the average Turbidity level in the water sampled from each node. For node 1, we found that the TDS level was between 585 to 632. For node 1, the value was from 408-501, node 3 had a value from 272 to 308, node 4 was similar to node 2 and node 5 was similar to node 1. The pH value was not included in the graph as it remained almost the same and within the safe value throughout the testing period, which was 7.0 – 7.6. The TDS level for the households varied between 290 mg/l to 600 mg/l.

VI. CONCLUSIONS

Monitoring water quality is essential since it has a direct impact on health. We must make sure that the drinking water is of the highest quality possible while also minimizing water waste. In order to measure the water quality and record consumption information at the same time, our proposed solution calls for the usage of a low-cost and low-powered microcontroller-based system. The consumption metering system keeps track of users' daily and monthly consumption, and quality measuring helps us to drink healthier water. Our proposed system is very user friendly, can be installed and used by the consumers without any hassle. Utilizing this approach will eliminate unnecessary water waste and encourage people to drink clean water. In order to fully justify the quality of the water, we have planned to add more water quality parameter measuring sensors to the system in our future work.

REFERENCES

[1] *“Better access to safe drinking water Quality, equitable access and sustainability” Unicef* [Online] Available: https://www.unicef.org/bangladesh/en/better-access-safe-drinking-water.. (Accessed December 20, 2021)

[2] “How we waste Water” *The Financial Express* [Online] https://thefinancialexpress.com.bd/views/how-we-waste-water-1633528417. (Accessed December 22, 2021)

[3] Boretti, A., Rosa, L. Reassessing the projections of the World Water Development Report. npj *Clean Water* 2, 15 (2019).

[4] “Drinking Water Quality in Bangladesh”. *Unicef* [Online] Available: https://www.unicef.org/bangladesh/sites/unicef.org. Bangladesh/files/2018-10/Drinking%20Water%20Quality%20in%20|Bangladesh.pdf. (Accessed December 21, 2021)

[5] “Water Resources and Freshwater Ecosystems, Country Profile – Bangladesh” *World Resources Institute.* [Online] Available: https://web.archive.org/web/20040909180844/http://earthtrends.wri.org/text/water-resources/country-profile-14.html.(Accessed December 21, 2021)

[6] Water Supply and Sanitation in Bangladesh” *Wikipedia* [Online] https://en.wikipedia.org/wiki/Water_supply_and_sanitation_in_Bangladesh#Water_use.. (Accessed December 22, 2021)

[7] A. K. M. M. Z. H. M. S. H. A. A. N. Mohammad Khabir Uddin Sarker1, "Assessment Of Inland Water Quality Parameters Of Dhaka City," *Environment & Ecosystem Science*, p. 4, 2019

[8] S. T. G. Satish Pasika, "Smart water quality monitoring system with cost-effective using IoT," *Heliyon*, vol. X, no. X, p. 9, 2020

[9] V. G. M. G. M. B. D. S. W. Ankira Taware, "Water Quality Monitoring System using IoT," *International Journal of Advanced Research and Publications*, vol. 4, no. 6, p. 7, 2020.

[10] KAMFRIHHAN, P. (2015). Smart Water Quality Monitoring System. *In Asia-Pacific World Congress on Computer Science and Engineering (APWC on CSE)*, Osaka, Japan.

[11] J. Bhatt And J. Patoliya, "Iot Based Water Quality Monitoring System," *International Journal of Industrial Electronics and Electrical Engineering,* p. 5, 2016.

[12] Hasan, I., Mukherjee, M., Halder, R., Rubina, F. Y., & Razzak, M. A. (2022, June). Development of an IoT-Based Low-Cost Multi-Sensor Buoy for Real-Time Monitoring of Dhaka Canal Water Condition. In 2022 *IEEE International IOT, Electronics and Mechatronics Conference (IEMTRONICS)* (pp. 1-6). IEEE.

[13] Total suspended solids. (2022). *Wikipedia* [Online} https://en.wikipedia.org/wiki/Total_suspended_solids (Accessed August 5, 2022)

[14] Alam, M. N., Saiam, M., Al Mamun, A., Rahman, M. M., & Hany, U. (2021, November). A Prototype of Multi-Functional Rescue Robot Using Wireless Communication. In *2021 5th International Conference on Electrical Engineering and Information & Communication Technology (ICEEICT)* (pp. 1-5). IEEE.

[15] “Bluetooth”. (2022). *Wikipedia* [Online] https://en.wikipedia.org/wiki/bluetooth. (Accessed October 23, 2022)

[16] “Wi-Fi”. (2022). *Wikipedia* [Online] https://en.wikipedia.org/wiki/Wi-Fi#Performance.. (Accessed October 23, 2022)

[17] Ali, A. I., Partal, S. Z., Kepke, S., & Partal, H. P. (2019, June). ZigBee and LoRa based wireless sensors for smart environment and IoT applications. In *2019 1st Global Power, Energy and Communication Conference (GPECOM)* (pp. 19-23). IEEE.

[18] “Cellular network”. (2022) *Wikipedia* [Online]. https://en.wikipedia.org/wiki/Cellular_network. (Accessed October 24, 2022)