

e-ISSN: 2319-8753 | p-ISSN: 2347-6710

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International Journal of Innovative Research in SCIENCE | ENGINEERING | TECHNOLOGY

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN SCIENCE | ENGINEERING | TECHNOLOGY

Volume 13, Issue 2, February 2024

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 8.423

9940 572 462

6381 907 438

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|e-ISSN: 2319-8753, p-ISSN: 2347-6710| www.ijirset.com | Impact Factor: 8.423| A Monthly Peer Reviewed & Referred Journal |

Volume 13, Issue 2, February 2024

DOI:10.15680/IJIRSET.2024.1302056

Restoration of Water by Integrating Sensor Acquired Lab Analyzer Data and Text Mining Data in BIoT Environment for Smart City

Dr.K.Mala

Professor, Department of Computer Science and Engineering, Mepco Schlenk Engineering College (Autonomous),

Sivakasi, Tamilnadu, India

ABSTRACT: Water quality monitoring plays a significant role in protecting ecosystems and maintaining the health of human. Currently, water quality is maintained by periodical checking with human intervention procedure. Hence, the process is automated with the required infrastructure design. Data are collected from the field-testing kit placed in various water sources. Sampling locations are strategically chosen to represent different areas and sources of water supply. They are aggregated using network components and processed. The results are transmitted to the laboratory for recording, further analysis and follow up. Processed data in the laboratory is updated by blockchain updation module in IoT Peer (Server). Laboratory reports, restoration reports, consumer complaint logs and enquiry messages available as text information are processed by text mining module and the prediction status are updated in the server. Data available are used by Restoration Control Module for further follow up of restoration of water bodies or removing encroachments like activities and creating awareness among public by generating action plan.

KEYWORDS: Water quality, BIoT environment, Smart city, health care Introduction

I. INTRODUCTION

Water is one of our most vital resources, and ensuring its quality is essential for human health, environmental sustainability, and various industries. Water quality management is a critical component of effective water resource management. Ensuring the safety of water for both human consumption and environmental well-being is paramount. Conventional approaches to monitor water quality frequently involve manual processes that are labour-intensive and do not offer instantaneous data. Blockchain technology offers a promising solution for real-time water quality monitoring, establishing a transparent and secure system for recording water quality data at various stages of the supply chain. By integrating cutting-edge technologies like the Internet of Things (IoT), blockchain, and machine learning, we can establish a potent system for the real-time monitoring and e-governance of water quality.

The integration of blockchain technology into various aspects of water management has shown promise in addressing some of the challenges in water supply, allocation, and traceability. Dogo et al. [1] and Pahontu et al. [2] have explored the use of blockchain technology to manage water supply systems. Blockchain can enhance the transparency and security of data related to water supply, including water quality monitoring, infrastructure maintenance, and billing. Blockchain can provide a transparent and immutable ledger for recording water allocation rights, making it easier to manage and enforce allocations among different stakeholders. Mahmoud et al. [3] proposed a smart meter data aggregation mechanism for water supply systems. Smart meters equipped with blockchain technology can securely record and transmit water consumption data, enabling efficient billing and resource management.

An Internet of Things (IoT) water quality monitoring system comprises a network of sensors and internet-connected devices engineered to consistently gauge and transmit real-time data pertaining to diverse water quality metrics. These parameters can include:

- **Physical Parameters:** Temperature, pH level, turbidity (cloudiness), conductivity, dissolved oxygen, and water level.
- Chemical Parameters: Concentrations of various chemicals such as nutrients, heavy metals, and contaminants.
- **Biological Parameters:** Presence of microorganisms and pathogens.



e-ISSN: 2319-8753, p-ISSN: 2347-6710 www.ijirset.com | Impact Factor: 8.423 | A Monthly Peer Reviewed & Referred Journal |

|| Volume 13, Issue 2, February 2024 ||

DOI:10.15680/LJIRSET.2024.1302056

The water quality parameters collected through IoT devises are processed, analysed and the transactions are sent to blockchain updation module for validation and storage in blockchain. Machine learning models of restoration module in combination with IoT can analyse data from various sensors and devices to detect anomalies, predict water quality changes, and to optimize the water treatment processes. This integrated system combines the strengths of blockchain's data security and transparency, IoT's real-time data collection, and machine learning's analytical capabilities to provide a robust solution for monitoring and managing water quality.

Paper is organized as follows. Section II surveys the related work, Section III demonstrates the Proposed System infrastructure, Section IV discusses the results and Section V concludes the work with future enhancements.

II. RELATED WORK

In the realm of water quality maintenance using Blockchain Internet of Things (BIoT), each transaction is scrupulously recorded to support subsequent analysis and data mining activities. Smart city implementations [4,5] are reviewed to know the state of art works. Blockchain technology is a component of a group of technologies referred to as Distributed Ledger Technologies (DLTs). These DLTs have the capability to store data from various devices located in different places, thereby eliminating the necessity for a centralized cloud system. Qingping Chi et al. [6] employed CPLD (Complex Programmable Logic Device), which is well-suited for high-speed real-time data acquisition in IoT environments. CPLD serves as the central controller for the interface device, intelligently managing data acquisition, processing, and transmission, as well as conducting preliminary data pre-processing. In a separate study, K. Yogendra et al. [7] conducted an investigation into Water Quality Index (WQI), using the criteria for drinking water quality as recommended by organizations such as the World Health Organization (WHO), Bureau of Indian Standards (BIS), and Indian Council for Medical Research (ICMR).

C.R. Ramakrishnaiah et al. [8] investigated and found that elevated WQI values are primarily attributed to higher concentrations of iron, nitrate, total dissolved solids, hardness, fluorides, bicarbonate, and manganese in groundwater. These analytical findings have been used to propose models for predicting water quality. According to Hiren B. Soni and Sheju Thomas [9], the Water Quality Index is utilized to conduct a comprehensive evaluation of water quality across various levels that impact a watercourse's ability to support aquatic life. It also serves as a tool to assess the overall quality of a water body when facing potential threats. Megha Agarwal and Animesh Agarwal's study [10] highlights the recurring issue of industrial and domestic waste consistently entering the River Kasi, resulting in water pollution.

The conventional centralized water information systems suffer from inadequate data security [11]. They are vulnerable to data manipulation and distortion, and accessing information is often sluggish due to network congestion. Furthermore, various government departments are involved in managing water resources, and a lack of trust among these departments leads to the creation of isolated information silos, hindering effective business coordination and diminishing operational efficiency.

The implementation of Blockchain IoT offers a comprehensive solution for addressing multiple challenges in data management. It ensures data security, safeguards privacy, mitigates the risk of single node failures, prevents data tampering, and enables automation using smart contracts, all while maintaining transparency.

Blockchain technology offers solutions to these challenges. Specifically, it enhances the reliability of data and the efficiency of data transmission through its robust network infrastructure [12,13]. Firstly, the blockchain's distributed storage network empowers each component to swiftly access water data, ensuring rapid responses and informed decision-making in the event of emergencies. This prevents unilateral decisions by participants based on their individual data. Secondly, encryption technology safeguards data integrity and makes it exceedingly difficult to tamper with the information. Moreover, blockchain technology fosters trust and enables secure information sharing at a minimal cost. Lastly, the innovative decentralized information management model enhances operational efficiency in water resource management.

India faces significant challenges in ensuring water quality due to contamination and infrastructure limitations. However, there have been notable advancements in technology and monitoring systems, particularly in urban areas and smart cities. Ongoing efforts by government agencies, research institutions, and civil society aim to address these challenges and improve water quality monitoring and management across the country. Based on this systematic study,



e-ISSN: 2319-8753, p-ISSN: 2347-6710 www.ijirset.com | Impact Factor: 8.423 | A Monthly Peer Reviewed & Referred Journal |

Volume 13, Issue 2, February 2024

DOI:10.15680/IJIRSET.2024.1302056

BloT based water quality maintenance system is proposed to maintain public health in smart city by combing with text mining techniques.

III. PROPOSED METHODOLOGY

The Proposed System Architecture is given in Fig. 1 and different modules in the proposed methodology are presented. The 13 water quality parameters for observation considered are namely Electrical Conductivity(EC), Total Dissolved Soldis(TDS), Total Alkalinity(T.Alk), Total Hardness(TH), potential of Hydrogen(pH), Iron(Fe), Chloride(Cl), Sulphate(SO4), Maganese(Mn), Nitrate(NO3), Floride(F), Residual Chloride(Res.Cl) and Fecal Colifonum(FC). Calculated parameter is Water Quality Index(WQI). Field testing kit enclosed by plastic shell, consists of sensors for water quality parameters observation, RF receiver and transmitter connected to Arduino IDE, is placed in the water sources. The water parameters read from the sensors are sent to RF transmitter after appropriate data format conversion and then to RF receiver. For example, for monitoring water temperature, Arduino AT Mega 2560 Board connected with Sensor (DS18b20 Water Temperature Sensor) is used with RF transmitter (WSTx01) and RF receiver (WSRx02). All the required sensors and components are placed with Arduino inside the Water proof Plastic shell. The data from the RF transmitter are received by Data Concentrator (RF DCU) and the aggregated data are sent to the server periodically. Data concentrator RF DCU has ARM Cortex M4 Processor operates up to 72 MHz with communication interface ZigBee / 6LoWPAN. It gathers data from connected RF transmitters and uploaded to server connected with Redundant Array of Disks (RAID).



Fig. 1. Proposed System for Water restoration in BIOT Environment for Smart city

The Laboratory employees remotely monitor the water quality parameters. Also they take samples from water sources when required for water analysis in laboratory. When the Water Quality Index exceeds ISO 10500,2012 standards, LED will blink and creates an alert.

Laboratory analysis is done to ensure whether the water quality is compliance with rules and regulations and the results are used for Public Health (especially for Drinking water) and Industrial Use. It is done based on the 3 methods 1) Water Quality Index (WQI), 2) Correlation Analysis and 3) Multiple Regression Analysis. For calculation of water quality index (WQI), laboratory monitors 13 water quality parameters.

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WQI is the best tool to calculate the pollution ranges of the water bodies. WQI is described in single number, which is used to describe the total water quality for a specific location and time, based on the water quality parameters. It is calculated for 3 types of sectors namely a) Surface Water (Reservoirs), b) Ground Water, c) Industrial Effluents.

WQI for **Surface Water (Reservoirs)** is calculated using 2 parameters named Quality Rating (QR) and Unit Weight (UW).

Quality Rating (QR) is used to measure how much ratio of water is polluted based on the standards with respect to water parameters and is calculated by using equation (1).

(1)

$$QR = \frac{100(Ob_n - I_{io})}{(SV_n - I_{io})}$$

QR – Quality rating for the water parameter

Ob_n- Observed value of the water quality parameter at a Specific water body

SV_n– Standard permissible value of the water parameter

I_{io}– Ideal value of the water parameter

Unit Weight (UW): Unit Weight is calculated from the proportionality constant (K) and Standard Value (SV_n) using the equation (2).

(2)

$$K = UW * SV$$

Then total WQI for surface water is calculated by using the equation 3.

$$WQI = \frac{\sum QR * UW}{UW} \tag{3}$$

The WQI for Ground water is calculated from Weight (W_t), Relative Weight (RW), Quality Rating (qr) and Sub Index(SX).

Weight (W_t) is assigned to the 13 parameters with respect to its contribution to the total quality of water for drinking use. The maximum weight 5 is given to the parameter called nitrate, because it's more contributing to fix the WQI. The Minimum weight 1 is given to the parameter called magnesium, because it's less contributing to fix the WQI.

Relative Weight (**RW**_i) is calculated by weight of the water quality parameter (w_t) multiplied by summation of total weights of the water quality parameter.

$$\boldsymbol{R}\boldsymbol{W}_{i} = \frac{\boldsymbol{W}_{t}}{\sum_{i=1}^{n} \boldsymbol{W}_{t}}$$
(4)

Quality Rating (qr) is calculated by observed value of the water quality parameter divided by the standard value of the BIS 10500, 2012 (Bureau of Indian Standards) and the result multiplied by 100.

$$qr_{i} = (\frac{Ob_{i}}{SV_{i}}) * 100$$
(5)

Sub Index (SX is calculated using the equation (6).

$$SX_{i} = RW_{i}^{*} qr_{i}$$
⁽⁶⁾

WQI is calculated by summation of Sub Index (SX_i).

$$WQI = \sum SX_i \tag{7}$$

WQI for **Industrial Effluents** is calculated using equation 3.

RAID technique uses combination of multiple disks instead of using a single disk for increased performance, data redundancy or both. Data redundancy adds to disk / reliability. In case of disk failure, since the data is backed up onto another disk, the data is retrieved and go on with the operation.

In the laboratory, observed and calculated 14 parameters are daily monitored. The 14 parameters are passed to Block chain updation module periodically for updation in distributed ledger using the function *SendParam()* for record keeping and protected permissible participants view to follow up action. News, Laboratory reports and messages represented and mined using *MineDoc()* in Text Mining module in proper format are received using function *GetInfo()* and passed to Block chain updation module using *SendInfo()*.

The updated block chain data are monitored using *GenerateRepo()* in Restoration Control Module to generate Action Plan for further follow up actions to

IJIRSET

|e-ISSN: 2319-8753, p-ISSN: 2347-6710| www.ijirset.com | Impact Factor: 8.423| A Monthly Peer Reviewed & Referred Journal |

Volume 13, Issue 2, February 2024

| DOI:10.15680/IJIRSET.2024.1302056 |

- Create awareness among public
- Remove encroachments near water bodies and
- Take necessary water restoration steps.

Hence block chain is used to monitor and verify the transactions between the IoT devices and providers. Blockchain is a data structure that chains all the mined blocks in a chronological order. This chain is immutable. Here for study purpose, python blockchain is used.

First block in the block chain is the 'Genesis' block and initiated by the creator of the block chain. The transactions are signed using SHA algorithm. The sha256 function takes a message as a parameter, generates a hexadecimal digest and returns a value. Block chain explorer is used to access the data. Validators in the block chain are Junior water analyst, Chief Water Analyst, Executive Engineer, Chief Engineer, Local body and Policy maker. Validation is done by using their authorization code using *PoAuth()* algorithm. After validation, time stamped blocks is added to the permissible blockchain.

Laboratory reports, restoration reports, consumer complaint logs and enquiry messages are available as text information. These documents, collectively known as corpus, are taken as input for text mining module. Text Mining Module uses the algorithm to implement as given below.

Algorithm *MineDoc()*

Get the Corpus as input

- 1. Apply "Bag of Words" approach to identify the words or terms
- 2. Calculate Term Frequency (TF) as word count
- Calculate Inverse Document Frequency for the term t IDF(t) = 1 + log (total no of documents / number of documents containing t)
- 4. Calculate TFIDF for the term t and document d as TFIDF(t,d) = TF(t,d) X IDF(t)
- 5. Extract features as (TF, IDF, TFIDF) and quality scale
- 6. Build Machine Learning Model using Logistic Regression Algorithm using the extracted features for Prediction

The build model is used with incoming documents represented as feature vector (TF, IDF,TFIDF). The predicted value represents the quality of the water as per the document bag of word contents represented in a scale. These data represented in a required proper format are given to restoration control module through server for further processing. Laboratory Analyzer data, Mined News Documnet, Information and orders received from Restoration Control Module are used to generate Action plan. Then the Water maintenance government department can execute the appropriate services to restore water in an effective and efficient manner periodically and on need basis

IV. RESULTS AND DISCUSSION

First data collection is done. In the experimental setup, 13 water quality parameters are observed. Also Dataset which contain observed values of water quality parameters were gathered from TWAD Board, Virudhunagar for 2 years (2012-13 & 2013-14) for study and analysis. Sample documents for mining are given in Fig. 2.

News Document1:

Central Water Commission is monitoring water quality at 552 key locations (519 water quality sites and 33 water quality sampling stations) covering all the major river basins of India. CWC is also maintaining a three-tier laboratory system for analysis of the parameters.

News Document2:

Significant increase in Yamuna pollution since 2017: Delhi government report **Water**-borne diseases impact around 37.7 mn Indians annually say experts **India**'s conservation efforts for tortoises, fresh **water** turtles earn support at CITES CoP19 Ambala, Rohtak, Faridabad best performers under Jal Jeevan Mission and Swatch Bharat Mission



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For the observed values and the documents collected, experiments are conducted and some of the results are presented for discussion. R tool is used for analysis. Correlation analyses among parameters are done and **screen shot** is shown in Fig. 3.

Correlation Matrix														
		EC	TDS	рН	T.Alk	тн	Fe	Mn	NO3	CL	F	SO4	R.Cl2	FC
EC	Pearson Correlation	1	.974	.019	.714	.961	.191	. ^D	.015	.959	.093	.966**	014	.436
	Sig. (2-		0.000	.091	0.000	0.000	.000		.170	0.000	.000	0.000	.215	0.000
	N	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143
TDS	Pearson	.974**	1	.022	.711**	.989**	.193**	. ^ь	.027*	.984**	.102**	.997**	013	.424
	Sig. (2-	0.000		.044	0.000	0.000	.000		.014	0.000	.000	0.000	.223	0.000
	N N	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143
рН	Pearson Correlation	.019	.022*	1	.006	.021	.007	.•	018	.025	.022	.023*	.003	.010
	Sig. (2- tailed)	.091	.044		.618	.058	.521		.106	.023	.046	.038	.812	.381
	N	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143
T.AK	Pearson	.714**	.711"	.006	1	.717**	.190**	. ^ь	.034**	.588**	.072**	.709**	025*	.164**
	Sig. (2-	0.000	0.000	.618		0.000	.000		.002	0.000	.000	0.000	.021	.000
	N N	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143
тн	Pearson	.961**	.989.	.021	.717**	1	.191**	. ^ь	.030**	.970**	.101**	.987**	013	.389**
	Sig. (2-	0.000	0.000	.058	0.000		.000		.008	0.000	.000	0.000	.224	.000
	N	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143
Fe	Pearson	.191**	.193**	.007	.190**	.191**	1	. ^ь	.014	.175**	.019	.193**	003	.081**
	Sig. (2-	.000	.000	.521	.000	.000			.195	.000	.091	.000	.790	.000
	N N	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143
Mn	Pearson Correlation	· •	. ^ь	·•	. ^ь	. В		. ^ь	. ^ь	. ^ь	. ^ь		. ^ь	-
	Sig. (2-													
	N	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143
NO3	Pearson	.015	.027*	018	.034**	.030**	.014	. ь	1	.024*	.016	.030**	003	023*
	Correlation	170	014	106	002	008	105			029	144	007	796	037
	tailed)		.014	.100	.002	.000	.135			.023		.007	.730	.007
	N	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143
CL	Pearson	.959**	.984**	.025*	.588**	.970**	.175**	. ь	.024*	1	.098**	.980**	010	.471**
	Sig. (2-	0.000	0.000	.023	0.000	0.000	.000		.029		.000	0.000	.375	0.000
	tailed)	0142	0142	0142	0142	9143	0142	0142	0142	0142	0142	0142	0142	0142
	N De e ve e ve	0143	8143	0143	8143	8143	0143	6143 b	0143	8143	0143	8143	8143	8143
F	Correlation	.093	.102	.022	.072	.101	.019		.016	.098		.102	002	.025
	Sig. (2-	.000	.000	.046	.000	.000	.091		.144	.000		.000	.861	.021
	N	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143
SO4	Pearson	.966**	.997**	.023*	.709**	.987**	.193**	. ь	.030**	.980**	.102**	1	013	.420**
	Correlation	0.000	0.000	038	0.000	0.000	000		007	0.000	000		227	0.000
	tailed)	0.000	0.000	.000	0.000	0.000	.000		.007	0.000	.000			0.000
	N	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143
R.CI 2	Pearson	014	013	.003	025*	013	003	."	003	010	002	013	1	001
	Sig. (2- tailed)	.215	.223	.812	.021	.224	.790		.796	.375	.861	.227		.955
	Ň	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143
FC	Pearson Correlation	.436**	.424**	.010	.164**	.389**	.081**	.ь	023*	.471**	.025*	.420**	001	1
	Sig. (2- tailed)	0.000	0.000	.381	.000	.000	.000		.037	0.000	.021	0.000	.955	
	Ň	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143	8143

Fig. 3. Correlation Matrix – Among the Parameters (EC, TDS, T.Alk, TH, Fe, Mn, NO3, Cl, F, SO4, Res.Cl, FC) for TWAD data (Tamilnadu Water supply and Drainage Board)

For the collected data, correlation analysis of 13 parameters with WQI shows that Water Quality Parameters like Total Dissolved Solids(TDS), Total Alkalinity(T.Alk), Total Hardness(TH), Chloride(Cl) and Sulphate(SO4) are observed with values (.974, .714, .961, .959, .966), which is nearer to 1. It means that those parameters are highly contributed to determine the water quality index value of the water. Water Quality Parameters like Potential of Hydrogen(pH), Iron(Fe), Floride(F), Residual Chlorine (Res.Cl), Fecal Coliform(FC) and Manganese(Mn) are observed with values (.019, .191, .093, -0.14, .436, .0) which is nearer to 0. It means that those parameters are less contributed to fix the water quality index of the water. Further analysis is done in laboratory if we transmit the data to the server in the laboratory. In the laboratory, Junior Water Analyst will perform the test and validated by Chief Water Analyst in the Water Maintenance Board of Government.

For various water quality parameters namely EC, TDS, T.Alk, TH, Fe, Cl, SO4, FC, pH, Fe, Mn, NO3, F and Res. Cl, scatter plots are drawn using R tool. In Scatter Diagram, water quality index is represented in x-axis and water quality parameters are plotted in y-axis. As a sample, Scatter Plot between Cl and WQI is given in Fig. 4.

|e-ISSN: 2319-8753, p-ISSN: 2347-6710| www.ijirset.com | Impact Factor: 8.423| A Monthly Peer Reviewed & Referred Journal |



Volume 13, Issue 2, February 2024

DOI:10.15680/IJIRSET.2024.1302056



Fig. 4. Scatter Plot between Cl and WQI for TWAD data (Tamilnadu Water supply and Drainage Board)

In the above scatter plot given in Fig. 4, WQI is plotted in x-axis, ranges from 0 to 400. The Chloride(Cl) is plotted in y-axis, ranges from 0 to 10000. The observed values of Chloride(Cl) is plotted in the ranges of **20-60**. It describes that water is good quality, not contaminated and potable for drinking. Some of the points are scattered around the plots ie., above WQI>100, means that water is not good quality, contaminated and not-potable for drinking. The \mathbf{R}^2 Linear Value is 0.468. It means that Chloride(Cl) Parameter is more contributed to ensure that whether water is good for drinking or not. Similarly other parameters are analysed.



Fig. 5. Scatter Plot between F and WQI for TWAD data (Tamilnadu Water supply and Drainage Board)

In the above scatter plot given in Fig. 5. WQI is plotted in x-axis, ranges from 0 to 400. The Floride(F) is plotted in y-axis, ranges from 0 to 2.5. The observed values of Floride(F) is plotted in the ranges of 20-60. Some of the points are scattered around the plots i.e., above WQI>100, means that water is not good quality, contaminated and not-potable for drinking. The **R2 Linear Value is 0.023**. It means that Floride(F) Parameter is **not contributed** to ensure that whether water is good for drinking or not.

The 13 water quality parameters are plotted from starting observed values to maximum observed values as parallel coordinates. The water quality parameters of Total Alkalinity (T.Alk), Chloride (Cl), Total Hardness (TH), Nitrate (NO3), Sulphate (SO4), Total Dissolved Solids (TDS) are highly correlated and those parameters are highly contributed to fix the water quality index, which is shown in Fig. 6

(JUSN: 2319-8753, p-ISN: 2347-6710 www.ijirset.com | Impact Factor: 8.423 | A Monthly Peer Reviewed & Referred Journal | || Volume 13, Issue 2, February 2024 || | DOI:10.15680/IJIRSET.2024.1302056 | || Unit of the state of the

Fig. 6. Correlation - Parallel Coordinates

Hence, experiments proved that the observed water quality parameters sensed using sensors are significant for water quality analysis.

Sensor data are combined with Lab analyser data and Text mined data. Fig. 2. Shows one news in social media data and one consumer complaint log data. The Validators, Junior water analyst, Chief Water Analyst, Executive Engineer and Chief Engineer validating the data and are made available to view by Local body and Policy maker. The Restoration Control Module does the necessary follow up action by generating Action Plan. Sample Action Plans are:

- Remove encroachments
- Create Awareness among public not to pollute water
- Restore water after pollution
- Take necessary action for industrial waste deposit
- Take water from water resources for laboratory analysis

The experimental results show that the proposed BIoT solution for water quality maintenance system design ensures transparent secured service to keep public using safety potable water.

In water supply management, a traceability encoding system is established to provide water users with access to water information. This system encodes water data, which can then be integrated into the data analysis platform for water resources. This integration enables the tracking of water consumption patterns across various geographical areas. On the blockchain platform, each water user has the capability to retrieve traceability information, such as the origin of the water details regarding the water quality at its source and treatment facility.

V. CONCLUSION

Water quality monitoring and restoration service system based on BIOT is proposed for Water Supply and Drainage system of government. The water quality monitoring sensors gather data from water, and forward that data to Arduino IDE. The Arduino IDE forwards that data to RF Receiver, Transmitter module. Then Data Concentrator aggregates sensor data and send to the TWAD server located in the testing Laboratory. This reduces human intervention. The validated mined data by Proof of Authorization, *PoAuth()* regarding water quality are processed securely and transparent, immutable data stored in the block chain is used to generate action plan for execution and thereby maintaining Smart city water quality by smart restoration.

ACKNOWLEDGEMENT

Author would like to thank the Management and the Principal of the Mepco Schlenk Engineering College (Autonomous), Sivakasi for providing facilities and necessary infrastructure for carrying out this work.



e-ISSN: 2319-8753, p-ISSN: 2347-6710| www.ijirset.com | Impact Factor: 8.423| A Monthly Peer Reviewed & Referred Journal |

Volume 13, Issue 2, February 2024

| DOI:10.15680/IJIRSET.2024.1302056 |

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