A Blockchain Based Secure IoT Solution for Water Quality Management

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Abstract— **Water pollution is a major issue all over the world, and one of the great causes of water deterioration is industrial waste as the polluted water is being dumped into surface water such as seas, springs, and dams. Consequently, this will affect the whole planet, starting from destroying the agricultural crop up to the endangerment of humankind. There are plenty of industries all over Saudi Arabia, many of which are of a high category that generates dangerous fluids and other materials in their daily production activities. By discharging polluted components in water, the industry is considered to be violating the General Authority of Meteorology Environmental Protection (GAMEP)'s laws and regulations. It's a revolutionary step to stop establishments and industries from contributing to water pollution. Currently, industries violating these laws are difficult to identify due to the manual nature of measuring industrial water tanks. This produces difficulties in pulling out a sample to measure. To tackle the aforementioned issue, a system has been proposed as it is not only detecting water pollution but will take action in order to prevent the continuation of water pollution. The integration between two technologies has been introduced in this system. First, IoT (internet of things) is used to measure water components in industrial tanks and detect any violation. Second, blockchain is applied to the appropriate penalty of the violating industry and maintain the transparency, integrity, and reliability of the violation records. The system will be capable of measuring water quality in real-time and facilitate the instant detection of any violations to carry out the appropriate penalty. An introductory experiment shows prominent results that can be used to decrease the number of water violation cases to save the planet and secure a promising future.**

Keywords— water quality, IoT, blockchain, violation, industry

I. INTRODUCTION

The expansion of water pollution is a major issue all over the world in all its resources, especially in surface water, where most of the drainage of industrial waste ends up. Wastewater can endanger nature and it can go as far as endangering mankind. The GAMEP in Saudi Arabia has discharged 448 violations into the red sea water alone according to (GAMEP annual report 2018 [1]) due to the drainage of sewage water. From this perspective, we are proposing a system that integrates the use of IoT and blockchain technologies to solve the water pollution issue.

Water pollution is one of the critical issues that haunt green globalization. According to (UN WWAP 2003[2]) two million tons of industrial and sewage water waste is being discharged into the world's water every day. The impacts of this contaminated water include diseases, destruction of the ecosystem, and eutrophication that affects the aquatic life and the food chain. Governments are spending so much effort to monitor and manage the water pollution in their water resources. In the kingdom of Saudi Arabia, the oil and gas industries are consuming great amounts of water in their industrial activities. Consequently, insufficiency and failure of managing sewage causes chemical pollution which discharges carcinogens, toxic materials, and metals into the water. These industrial activities are monitored and controlled by the GAMEP. The GAMEP authority suffers from a lack of inspectors around all the regions in the kingdom. They also lack environmental laboratories to perform the necessary analysis. There is no proper system to accurately monitor all these violations in real-time to take proper reactions.

To tackle all these issues, the proposed system will help tremendously in the following:

- To control and restrict wastewater in industries based on GAMEP laws and regulations in Saudi Arabia.
- To measure impure industrial tank's water via sensors.
- Transparency of sharing data to all concerned parties via blockchain.
- To save time, effort and eliminating the manual work done by inspection campaigns.

The scope mainly focuses on industrial tanks where the IoT sensors are going to be placed to detect any water pollution that may occur. All the data collected by the sensors is going to be transferred to a blockchain platform to ensure transparency, security, and data sharing. The main idea is to focus on the industrial waste that reaches the surface water. The system works based on the GAMEP in Saudi Arabia laws & regulations on industries that pollutes water.

II. RELATED WORKS

Nowadays we face many issues in our society that threaten our lives, most importantly, water pollution. There are approximately 7630 industries all over Saudi Arabia and a large amount of those industries produce polluted water resulting from their daily production activities, like oil refineries, mine industries and so much more. This system has been developed to focus mainly on restricting industries from polluting the water and affecting marine life, agricultural crop, and human lives in general, and to save the planet from deterioration with the help of newly emerging technologies. The Internet of Things (IoT) provides the capability to measure water components in industries' tanks to determine the level of pollution in the water and whether it violates the laws and regulation followed by GAMEP. If the industry is considered violated then the appropriate penalty will be determined, applied, and uploaded. Since IoT lacks security whilst the penalty is being transmitted, and this may jeopardize the authenticity and integrity of it, using blockchain will provide the right solution for this issue as it helps to record transactions that are highly secured thanks to its encrypted and decentralized nature. Merging these two technologies will result in a great and reliable system to use in determining and restricting the cause of water pollution.

Many works have been proposed in the field of water pollution management. Starting with real-time water quality monitoring using the Internet of Things in SCADA [3], where they proposed a solution for detecting water pollution in real-time supervisory control and data acquisition systems that capture temperature, color, and turbidity through global systems for mobile communication. The system is composed of three modules, a sensor module to capture input, a processing module that process the data that comes from the sensor module to monitor water conditions parameters sent on Arduino UNO microcontroller, and the last module is a communication module that is used to communicate between the two previous modules with the help of GPRS modem which connect Arduino microcontroller to the internet. For this work, the data is sent to a centralized SCADA server. Centralized systems are using client-server architecture where many clients are connected to one central server. Centralized systems have been facing many problems over time:

- The highly dependent network connectivity which may cause system failure if the central server loses its network connection.
- The inability of data backup. If the server fails, then there is no possible way to backup the data.
- Difficult server maintenance. Since the data is only in one place when the server is down for maintenance, it can cause unavailable system problems.

Using a centralized system is inefficient since the water data is required to be measured in real-time. The energy consumption of the sensors is one of this system's challenges because it needs to operate 24/7. The proposed solution for the central system problem may be using blockchain as proposed in [4]. This work has given an overview of wastewater data collection, storing, and analyzing by creating a system that is open to all using Dissolved Oxygen, Temperature, TDS (Total Dissolved Solids), Turbidity, pH sensors. The transmission of the data will be using a (low-power wide-area network) LPWAN. Then, it will be stored on the blockchain that offers the solution for trustless systems. The use of blockchain also provides quality-credit to the parties involved in the system. The approach describes the use of Arduino based on an open-source and easy-to-use technology; however, it lacks power efficiency and security. The future work includes technical requirements: developing a blockchain where the makers write, as it is a permission-less Blockchain, the scalability of the system must be studied appropriately, and then stress tests need to be performed on the system to see how it reacts; creating smart contracts that execute an algorithm that maximize the profits of both players in the system.

In Raspberry Pi-based smart sensing platform for drinking-water quality monitoring system in [5] proposed a solution for detecting drinking water quality from various natural resources. The solution consists of a multi-sensor array (MSA). The selection of the parameters is based on the guidelines of the Central Pollution and Control Board (CPCB). MSA works with a software platform. The fuzzy model in python for a real-time calculation, after the data collection is done using Python libraries. The calibration of the sensors is time-consuming and requires a specific amount of time to be stabilized. So, an auto-calibrations system may solve this problem. The proposed system for water quality monitoring system based on IoT is designed to solve the problem of monitoring the quality of water manually by developing a low-cost real-time system that consists of several IoT sensors that measure the water quality parameter such as: temperature, pH, turbidity, flow. Then, the data is going to be sent to a web server when there is a proper internet connection. There are several challenges to this approach, as follows: the volume of data is going to be huge and difficult to process since the data is not structured. Moreover, there is no useful report generated from the data being gathered from the sensors and no useful result except the detection of pollution.

The proposed system in real-time, quality monitoring system for rivers [6] is focusing on remote monitoring of water (rivers and lakes), surveillance and notification system in real time. The system will measure water parameters based on international standards. Their objectives were to measure the quality of water, identify the degradation of water, identify major polluted areas, automation system, and guidelines and regulations, both for waste discharge and water usage. They also use solar power as a source of energy and finally send SMS messages to alert the authorities. They planned to design an efficient, cost effective, and a real time system to monitor the quality of water using a Wireless Sensor Network (WSN). They used different IoT sensors to measure different water parameters such as: temperature, pH, conductivity, dissolved oxygen, and turbidity. The data gathered from the sensors is placed in a server in the cloud via wireless channel and because of the structure of the data, the volume can increase over the time therefore they used Big Data Analytic applications to store and analyze data effectively. Then, the quality parameter is going to be evaluated and simulated for the finale step, where the SMS message is sent to authorized personnel to indicate the degree of pollution. One of the main issues faced this work is the security and privacy of data which can be solved using the Blockchain technique.

The proposed system in [7] for surface water pollution detection using IoT is based on World Health Organization (defines water quality metrics) and a prototype has been introduced. They gathered a sample of water measurements from different resources of water. Then, the data sent to cloud, both the data and water flow is monitored via app and dashboard uses IEEE protocol for sending data to cloud. Internet of things (IoT) in Marine environment Monitoring: A Review addressed the marine environment (ocean) [8]. They measure more parameters besides water quality. the devices take actions on receiving data after sending like: re-positioning, raising the temperature etc. They also used LAN, wireless sensor network, or mobile communication network, depending on solar energy harvesting.

Recently, wastewater from industries was discussed in [14]. They presented different case studies and explained the main requirements that are needed in order to incorporate the blockchain into wastewater management. Finally, they stated the direction of future works.

All the reviewed works share the exact same thing as the proposed system, which is using different IoT sensors to monitor water quality. However, there is a lack of solutions when it comes to security and privacy of data. This distinguishes the proposed system, as we introduce the integration of the blockchain with IoT sensors to solve this shortcoming.

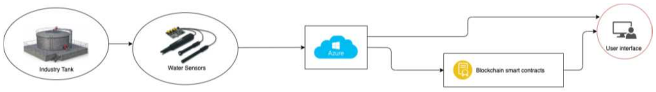

Figure 1: Architectural Design of the proposed system

III. PROPOSED SYSTEM

Figure 1 shows an architectural design of the proposed system. As the proposed system is a web application platform that integrates both technologies IoT and Blockchain, this section starts by introducing the main tools that are used to develop the system in terms of the IoT, blockchain, and the web application platform. These include the languages, the integration strategies alongside some of the algorithms, cloud services, sensors, IDEs, and hardware setups conducted to design the proposed system.

A. Internet of Things

Arduino is a ready to use microcontroller board, primarily designed for quick adaptation to digital devices, software or the environment [11] as shown in Figure 2. In our case, it is used for reading water parameters. So, it acts as the transmitter that reads and translates sensor information whether it's analog data or digital data to communicate with the water sensors. Arduino has many pins to connect sensors and other components through. These pins are divided into two types: digital pins that read and write single state value, or On/Off, which are used with the conductivity sensor, and analog pins that read range of values. It's more used for valuable fine-grained control. These pins are used in the proposed system with the pH and the dissolved oxygen sensor.

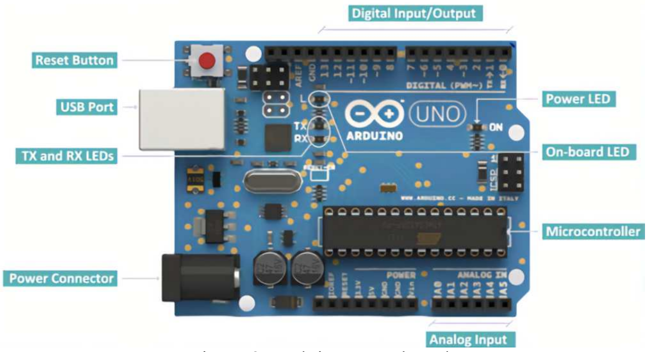

Figure 2: Arduino UNO board

In the proposed system different sensors are used to measure the water parameters as follows:

1– pH sensor: used to checks the behavior of the hydrogen ion in the water. There is the glass membrane at the end of a pH probe which allows the hydrogen ions from the water that is measured, to defuse into the glass's outer layer, whereas the larger hydrogen ions stay in the water. At that moment, a very small current is produced by the variation of the hydrogen ions concentration that is outside the probe and inside the probe. The created current corresponds to the hydrogen ions in the measured water. The analog pH Sensor reads the voltage signal from the probe and converts it into pH value. The equation for converting the voltage signal into pH is:

$$pH = (-5.6548 \text{ voltage}) + 15.509$$

2 – Dissolved Oxygen sensor: the dissolved oxygen probe used here consists of an anode bathed in an electrolyte, PTFE membrane, and a cathode. The oxygen is spread through the probe's membrane which will be at a constant rate with the help of membrane that will prevent the reaction from happening too fast. The oxygen will cross the membrane to the cathode where it will be reduced, and a small voltage is produced. If there are no oxygen molecules found, the probe will output 0 mV. The mV output will increase as the oxygen increases, and a unique voltage in the presence of oxygen will be produced from each probe. "0mV = 0" Oxygen is the only thing that is constant.

3 – Conductivity sensor: the electrical conductivity probe *3 – Conductivity sensor:* the electrical conductivity probe trials the electronical conductivity in a solution. It is frequently practiced in hydroponics, aquaculture, and freshwater schemes to keep under observation the quantity of nutrients, sodium chloride, or pollution in the water. Within the probe, two electrodes are placed across from one another, an AC voltage is put on the electrodes triggering cations to shift to the negatively charged electrode, whilst the anions shift to the positively electrode. The more free electrolyte the solution accommodates, the more the electrical conductivity is on an increase. The Conductivity circuit can be read with the following units:

$$\text{Conductivity} = \mu S/cm$$

Total dissolved solids = ppm
Salinity = PSU (ppt) 0.00 – 42.00
Specific gravity (sea water only) = 1.00 – 1.300

Finally, The Arduino Integrated Development Environment (IDE), a cross-platform framework, is used to write and submit compatible programs to the Arduino board.

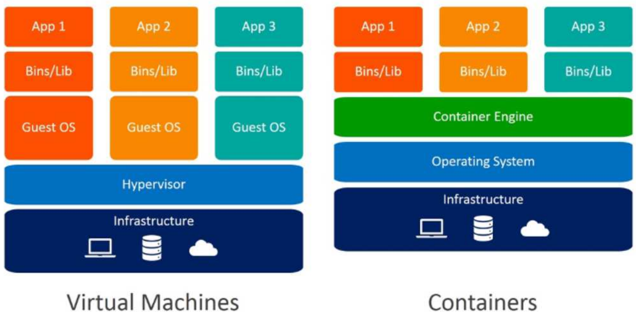

Figure 3: Containers versus the traditional application [9]

B. *Blockchain*

Private blockchain's biggest framework is Hyperledger Fabric, which is contributed by IBM, allowing enterprises to have their blockchain ledger without the need of money for miners to have stricter sharing of data on their network [12]. The fabric also allows the concept of subnetting the network, so not every node on the network can see the shared information ledger. These subnets are called channels. For the blockchain node members, Fabric makes it possible to be part of the network only if they were enrolled in the MSP - Membership Service Provider-Fabric code that runs the ledger is based on Chaincode -smart contract – The smart contract is a set of coding rules for the main business process. In our case, we will specify it for the water measures to decide when the violations have occurred.

The tools used in the system for the blockchain are as follow:

- Convector: Instead of using the Hyperledger fabric framework directly, which is a little complicated and needs previous Go language, we are using Convector. Convector is composed of Fabric development tools, but it uses a JavaScript-based Development Framework [10]. It has the features of making, developing, programming, deploying, and testing permissioned blockchain smart contracts.
- Hurley: Hurley is a development environment toolset for blockchain projects. It supports Fabric and other chain technologies [10]. In our case Hurly will act as the agent to create and manage the blockchain Fabric network.
- Docker: Docker is an open-source containerization platform. Docker enables applications to be packaged in a container which is standardized executable components [13]. Those components are combined in the application source code with all of the libraries and configurations of the operating system and dependencies required to run code in any environment the application will be working on. Containers make it possible by replacing the operating system; process isolation, and virtualization in making applications with enabling multiple application components to share the resources of a single instance of an OS kernel the same way that machine virtualization enables many virtual machines (VMs) to share their resources. Containers deliver all of VM's advantages such as isolation, good value with useful benefits, scalability, and availability as illustrated in Figure 3.

In our case the blockchain private network would be contained inside a docker container as a hyper ledger fabric image.

C. *Web Development*

In the web development process, stack technology has been used. It is essentially a set of frameworks and tools used together to develop an overall integrated software. There are a variety of stack technologies used for web development, but this project has been developed by using the full MERN stack.

The MERN stack is a web development framework. It contains multiple components that collectively help to build the software from the front end to the back-end and lastly to the database connection [14]. The components of the MERN stack as displays in Figure 4, help facilitate building the web application and can be summarized as follows:

- MongoDB: No-SQL database to store data needed for the application and to display required data. Stores data as JSON documents in collection with dynamic schemas.
- MongoDB Atlas: MongoDB Atlas is a cloud database which is completely managed. MongoDB Atlas is a cloud database which manages all the complexities of installing, maintaining, and deploying the applications on a specified cloud service platform. In this project, AWS service provider is used. Data in MongoDB is saved as JSON.
- ExpressJs: Fast and minimal Node.js web application server (Backend) framework. Instead of straight coding on Node.js and resulting in lots of Node modules, Express makes it easy to integrate the backend code all in one place.
- ReactJs: React is a JavaScript library which is used to create interfaces. Due to its ability to manage rapidly changing data, React is used for developing single-page applications. React creates developers code in JavasScript and build components for the UI.
- NodeJs: Node.js offers a JavaScript framework that enables the developer to run their code on the server. The pack manager for Node, which is npm, grants loads of free package options like Node Modules to choose from and use in the project.

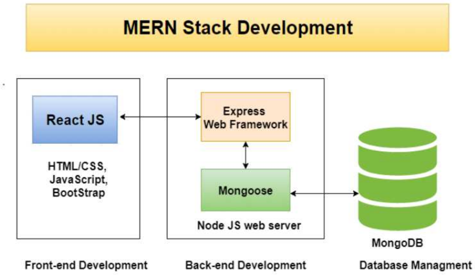

Figure 4: The main components of the MERN Stack

IV. EXPERIMENTAL RESULTS

This section demonstrates the framework experimental setup followed by the results of the conducted experiments.

A. *Experimental Setups:*

IoT hardware setup: When initializing the sensor readings to be captured through the Arduino serial monitor the first step always is setting the port which in our case is the 'cu.usbmodem143101' port and the port is changeable according to the different device ports. After setting the port we set the baud rate which define the rate of decoding signals bits coming from Arduino. All the sensors are working on 9600 baud rate which is the standard. The following present how the sensors' data were captured:

- Capturing conductivity sensor related parameters' measurement: The conductivity sensor reads the four parameters which are Electrical Conductivity, Total Dissolved Solids, Salinity and Gravity for the sea water.

```
#include "ph_grav.h"

Gravity_pH pH = Gravity_pH(A0);
uint8_t user_bytes_received = 0;
const uint8_t bufferlen = 32;
char user_data[bufferlen];

void setup() {
  Serial.begin(9600);
  delay(200);
  if (pH.begin()) {
    Serial.println("Loaded EEPROM");
  }
}

void loop() {
  if (Serial.available() > 0) {
    user_bytes_received = Serial.readBytesUntil(13, user_data, sizeof(user_data));
  }

  if (user_bytes_received) {
    parse_cmd(user_data);
    user_bytes_received = 0;
    memset(user_data, 0, sizeof(user_data));
  }
  Serial.print("pH:");
  Serial.println(pH.read_ph());
  delay(300000);
}
```

Figure 5: pH readings and capturing Arduino code

- Capturing pH measurement: The code in Figure 5 specifies the pins that is connected to the Arduino hardware A0 analog pin. The code also specifies that each 5 minutes which equals 300000 milliseconds the received measurements from the sensor would be sent to the serial monitor by using the read_ph() method in the ph_grav library.

```
#include "do_grav.h"

Gravity_DO DO = Gravity_DO(A0);

uint8_t user_bytes_received = 0;
const uint8_t bufferlen = 32;
char user_data[bufferlen];
}

void setup() {
  Serial.begin(9600);
  delay(1000);
  if(DO.begin()){
  }
}

void loop() {
  if (Serial.available() > 0) {
    user_bytes_received = Serial.readBytesUntil(13, user_data, sizeof(user_data));
  }

  if (user_bytes_received) {
    parse_cmd(user_data);
    user_bytes_received = 0;
    memset(user_data, 0, sizeof(user_data));
  }

  Serial.print("DO:");
  Serial.println(DO.read_do_percentage());
  delay(300000);
}
```

Figure 6: Dissolved Oxygen readings and capturing Arduino code

- Capturing Dissolved Oxygen measurement: The code in Figure 6 specifies the pins connected to the Arduino hardware which is A0 the analog pin. Like with dissolved oxygen, the specified duration to take readings is 5 minutes.

Blockchain setup: For the blockchain part, as specified previously, the convector to fabric ledger is used. The concept of convector is based on defining chain codes, which are the smart contracts. The smart contracts would let us define and deploy GAMEP terms and rules. Whenever a new violation is detected, that means it has been passed through signed and verified terms via the self-executing contract.

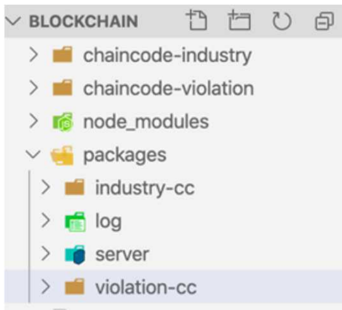

Figure 7: Blockchain project with the smart contracts

In convector, we defined a model for each smart contract which holds all the parameters that is saved onto the ledger. The work on smart contract is industry-cc and violation-cc as seen in Figure 7.

Controllers are defining the terms, and they control what goes into the ledger. In each term procedure's controller, there are three main phases that must exist:

1- Validation phase, which decides on whether the term is valid or not, this is the 'if statement' in the coming code.
2- Modification phase, which tells what should be done after validating.
3- Store phase, which updates and saves the data to the ledger.

We define GAME terms according to the existing sensors as the algorithm shown in Figure 8.

Algorithm 1 Detecting violation smart contract

> **INPUT** $x \leftarrow (pH, DO, EC, TDS)$
> **loop**
>   **if** Industry have no previous violation at the current month **then**
>   **if** $x >$ Allowable or $x <$ Allowable **then**
>   Add new violation with x saved
>   Pass violation to blockchain ledger
>   **else**
>   Don't pass any violation to the ledger
>   **end if**
>   Industry have previous violation at the current month
>   **if** $x >$ Allowable or $x <$ Allowable **then**
>   Update the industry's month violation
>   Pass violation updates to the blockchain ledger
>   **else**
>   Don't pass any violation to the blockchain ledger
>   **end if**
>   **end if**
> **end loop**

Figure 8: Detecting violation in the smart contract

Backend and Frontend setup: Collections were created for the project to store water measurements and information about industries and violations. In addition to storing data in the database, MongoDB Atlas has a service to chart stored collections called MongoDB Atlas Charts. At the backend, models are created to use mongoose and shape the MongoDB data. Whereas routes are created to connect the database with the backend and implement the CRUD operations. CRUD: Create, Read, Update and Delete on both the Violations and Industries collections.

For the frontend, Components is used to allow divide the user interface into separate, recyclable parts, and to work in isolation of each part. For connecting all the components and tools that are programmed together, the web services RESTful API is used that lets the components communicate with each other by using HTTP requests and responses in order to send data as Jason objects. The API is created and managed by express as shown in Figure 9.

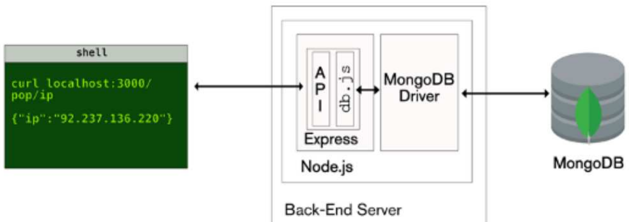

Figure 9: Express API concept

For the blockchain integration, convector Auto-generated API was used. It makes the smart contracts accessible through the HTTP request. The whole application integration phase is demonstrated in Figure 10.

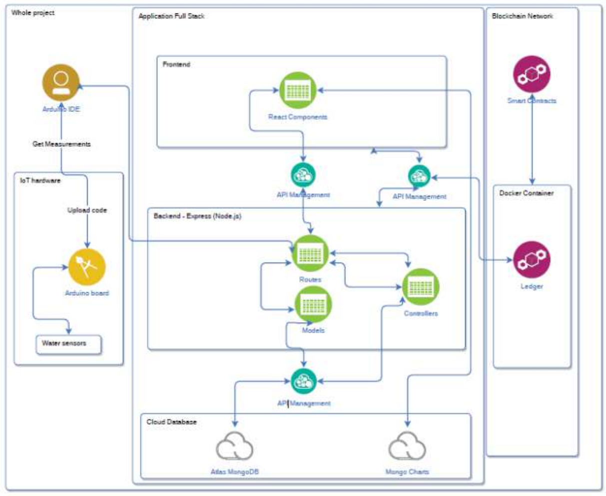

Figure 10: The System integration diagram

B. Testing and Results:

The system testing was supposed to be conducted on industry tanks in the industrial city of Medina, but due to the COVID-19 pandemic, entrance was restricted. As a result, during this current situation, we were not able to execute the planned test. Instead, chemical solutions were utilized to test the water parameters in the lab with the proposed system, as shown in Figure 11 and 12. Each solution with different measurements were used. The testing experiment was conducted on different water sources, like drinking water, tap water, bottled water, and solution water. The readings of each parameter were tested in different settings, for examples when these readings exceeded the limit of the allowable value, or when they met the GAMPE. The chemical solutions were used for pH and conductivity with different measures. The values and readings of the testing are specified in Table 1.

Figure 11: pH different testing solutions

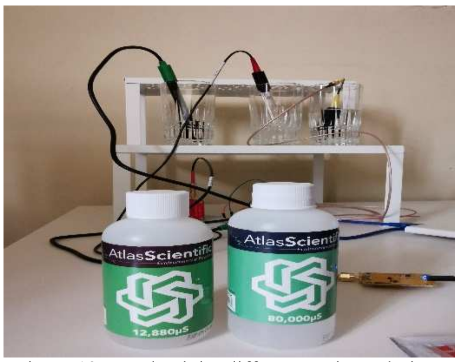

Figure 12: Conductivity different testing solutions

Captured Value	The kind of water	Solution Amount	Solution value	GAMEP Standads		Violation Detected
7.77	Tap water			Minimum Allowed	Maximum Allowed	
7.78	Tap water			6.5	8.5	✗
7.83	Tap water					✗
7.86	Tap water					✗
7.42	Drinking water					✗
7.44	Drinking water					✗
7.40	Drinking water					✗
6.57	Tap water	2.5ml	4.01 pH			✓
5.55	Tap water	2.5ml	4.01 pH			✓
5.54	Tap water	2.5ml	4.01 pH			✓
5.60	Tap water	2.5ml	4.01 pH			✓
5.58	Tap water	2.5ml	4.01 pH			✓
4.16	Solution water		4.01 pH			✓
4.05	Solution water		4.01 pH			✓
4.02	Solution water		4.01 pH			✓
3.99	Solution water		4.01 pH			✓
9.79	Solution water		10.01 pH			✓
9.82	Solution water		10.01 pH			✓
9.77	Solution water		10.01 pH			✓
10.36	Solution water		10.01 pH			✓

Table 1: The pH testing results

As shown in Table 1, the GAMPE standards for pH parameter range from 6.5 to 8.5 and when the detected value falls out this range, the violation is issued. It can be obviously noted that the smart sensor was successful in identifying the occurred violations. The same was measured for both dissolved Oxygen and conductivity parameters, as illustrated in Table 2 and 3. The violation was perfectly identified when it occurred from the captured values. However, the fault of some dissolved oxygen saturation values occurred due to the changes of the water movement and the deepness of the water, as well as the amount of the oxygen in the air.

Captured Value	The kind of water	Solution Amount	Solution value	GAMEP Standads		Violation Detected
166	Drinking water			Minimum Allowed	Maximum Allowed	✗
166	Drinking water			-	2500ppm	✗
166	Drinking water					✗
166	Drinking water					✗
351	Drinking water	2.5ml	1288			✗
379	Drinking water	2.5ml	12880			✗
391	Drinking water	2.5ml	12880			✗
924	Drinking water	10ml	12880			✗
988	Drinking water	10ml	12880			✗
2379	Drinking water	30ml	12880			✗
2382	Drinking water	30ml	12880			✗
2082	Drinking water	2.5ml	80000			✗
2073	Drinking water	2.5ml	80000			✗
5464	Drinking water	10ml	80000			✓
5429	Drinking water	10ml	80000			✓

Table 2: The dissolved oxygen testing results

Captured Value	The kind of water	Solution Amount	Solution value	GAMEP Standads		Violation Detected
307.7	Drinking water			Minimum Allowed	Maximum Allowed	✗
308	Drinking water			-	2500μS/cm	✗
307.8	Drinking water					✗
308.1	Drinking water					✗
649.7	Drinking water	2.5ml	1288			✗
701.3	Drinking water	2.5ml	12880			✗
724.6	Drinking water	2.5ml	12880			✗
1711	Drinking water	10ml	12880			✗
1829	Drinking water	10ml	12880			✗
4406	Drinking water	30ml	12880			✓
4410	Drinking water	30ml	12880			✓
3854	Drinking water	2.5ml	80000			✓
3838	Drinking water	2.5ml	80000			✓
10110	Drinking water	10ml	80000			✓
10050	Drinking water	10ml	80000			✓

Table 3: The Conductivity testing results

Once the parameters of the industry tank were measured, they were uploaded to the web platform, and when the violation is detected, the smart contract for that industry is updated. The web application interface is designed to serve GAMPE authority (the admin) by providing them with useful visual charts that help in decision-making, industries information, and list of detected violations. The admin can browse the list of the issued violations and approve their status as well as add the due fine based on their standards. Figure 13-15 show samples of the web platform interfaces. After the overall system testing, we can ensure that the system component from IoT sensors to the application and blockchain are communicating and are integrated properly. The sensors capture the water measures in real time, and whenever a sensor capture measured, it is fired to the other components. Additionally, whenever there an exceeding value or violation, it captures it. The smart contracts verify it by the admin and save it permanently, so that no person can alter these records later. The system is integrated with the cloud database in order to provide the best analysis and user-friendly representation.

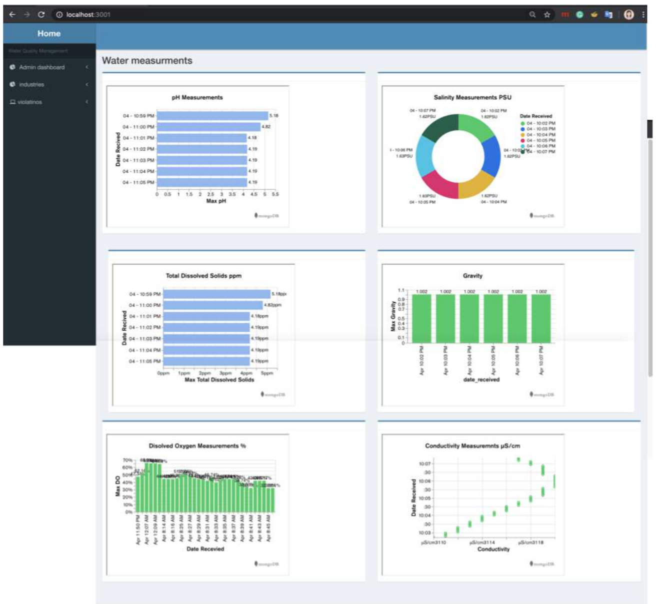

Figure 13: The admin dashboard interface

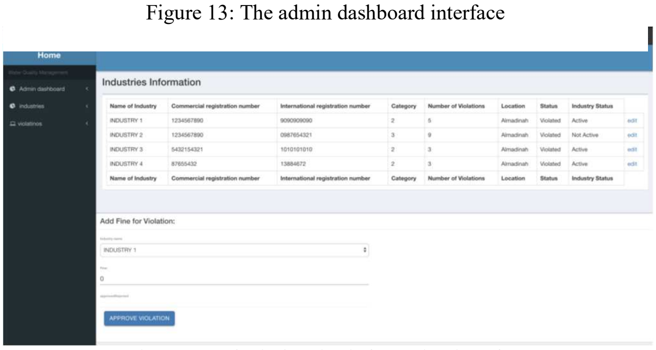

Figure 14: The industries information interface

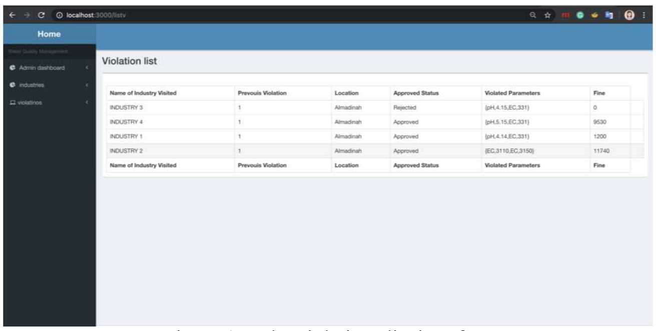

Figure 15: The violations list interface

V. CONCLUSIN AND FUTURE WORKS

In this paper, a new framework is proposed to solve a worldwide issue, i.e., facing the deterioration of all living creatures, and the best way is to start small with one of the largest sources causing water pollution, which are industries. The goal of this work is to detect water pollution in industrial discharge and evaluating whether it contains violated components against GAMPE standards through the use of

IoT sensors and blockchain to efficiently handle the security of violations. All of these components were integrated in a web application where the admin can access the platform to monitor the status of water measurements for registered industries and review the data related to water violation in easily-understood charts. It can be confidently said that most of our goals of detecting water pollution by IoT sensors, and sending violations in a secure manner through blockchain, and merging previous technologies into a web application, will solve all of the issues currently occurring in the Manuel process for GAMPE authority.

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