



GOBIERNO DE
MÉXICO



CONACYT
Consejo Nacional de Ciencia y Tecnología



Durango, DGO. March 13th, 2023

Attention to:
Editor of **Water**

Dear, Mr. Delwen Yan

Thank you very much for considering our manuscript, ***“Extension of LoRa coverage and integration of an unsupervised anomaly detection algorithm in an IoT water quality monitoring system”***, for publication in Water Journal.

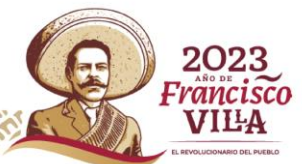
We appreciate your interest and the time taken by reviewers in providing constructive criticism for the manuscript. We have addressed the major concerns of the reviewers.

We have also included a point-by-point response the reviewers' comments. Changes to the text of the manuscript were made using the "Track Changes" function in Microsoft Word and are highlighted in green.

Best regards,

Dr. Diego Armando Martínez Cruz
Centro de Investigación en Materiales Avanzados, S.C. CIMAV Subsede Durango
Durango, Dgo. México.
E-mail: diego.martinez@cimav.edu.mx
Teléfono: (614) 4394898 Ext. 313

Calle CIMAV #110 Ejido Arroyo Seco, Durango, Dgo. México. C.P. 34147
Tel. 614 439 4898 cimav.edu.mx





Reviewer 1

Comments and Suggestions The changes requested are colored yellow	Answers The changes made are colored green
For instance, section 2.2.1, the module is not well explained, MCU has several meanings, explain what are PA6, PA7, ... Where is TTGO	Thank you so much for your observation. We add a more detailed explanation of the referred terms. For MCU: The node has as central unit an Arduino Uno board, which uses the AT-mega328P microcontroller unit (MCU). (Page 5, Lines: 165-166). For PA6, PA7. Using the chip's powerful storage and computing capabilities, set the PA6, PA7, PA8 analog PINS corresponding to the water quality sensor for analog to digital (A/D) acquisition, calculate the water quality PH value, temperature and TDS value, the data will be packaged and sent to the radio frequency module through the serial port. (Page 5, Lines: 168-172). For TTGO: The LoRa repeater uses a channel on the TTGO ESP32 development board, TTGO stands for "To be the best Go", which is a Chinese brand that produces various types of development boards based on the ESP32 chip [31]. (Page 5, Lines: 172-174).
Section 2.2.2 must explain in greater depth the componenmts. The amplifier for pH, what is it? What is the sensors consumption?	We add a more detailed explanation of the components: For Temperature: The module has a configurable 9 to 12-bit resolution and the data is transmitted through the 1-Wire interface, it also has a 64-bit unique identifier so that multiple sensors can share the same transmitting pin, the query time is less than 750 ms and the current consumption is less than 3 μA. (Page 6, Lines: 188-191). For pH sensor: The sensor can work in a voltage range of 3.3 to 5.5 V and handles an output signal of 0 to 3 V, with a current consumption of approximately 3 mA. The included software library allows calibration by the two-point method, automatically detecting when the electrode is immersed in pH 4 or 7

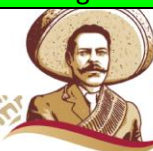




	solutions. The module has a response time of less than 1 minute and a probe lifetime of 6 months working 24 hours a day. (Page 6, Lines: 200-205). For pH, we specify the amplifier for pH: This signal is processed by an amplifier circuit based on the CA3140EZ operational amplifier, provided with the probe. This circuit amplifies the output signal of the PH electrode from millivolt voltage and converts it into the range of 0-5 V output voltage to reach the readable voltage required in the analogic input of the microcontroller. (Page 6, Lines: 174-177). For TDS: The operating voltage of the sensor is 3.3 to 5 V, with an output signal of 0 to 2.3 V and a current consumption between 3 and 6 mA. The measurement range is 0 to 1000 mg/L with an accuracy of $\pm 10\%$ at 25°C. The GravityTDS library was used for voltage to mg/L conversion of dissolved solids. The estimated value is compensated based on the temperature measurement obtained by the system temperature sensor. The library allows a one-point calibration of the sensor at 47 mg/L solution. (Page 6, Lines: 210-215). We specify the consumption of the sensor. For Temperature: less than 3 μA (Page 6, Line: 191). For pH: approximately 3 mA (Page 6, Line: 202). For TDS: between 3 and 6 mA (Page 6, Line: 211).
LoRa repeter and gateway are they always active or no? It is not clear which LoRa modules are used and where they are.	We add a more detailed explanation to specify the working cycle of the LoRa repeater and gateway: meanwhile the Gateway and LoRa repeater remain active in case data reception from other nodes is required. (Page 7, Lines: 284-285). Initially, it was thought to design the system with only one LoRa module. However, as the simulation and field tests showed, reaching the significant point of interest for monitoring "the ice dam" was impossible. For that reason, it was necessary to add to the system architecture of IoT-WQSM the lora repeater.



	We mentioned it in the text. A paragraph has been added to give more geographical context to the location of the LoRa modules and the transmission tests that were carried out. In Durango, Mexico, continuous, on-site, and real-time monitoring of the water quality of the city's dams, one of the primary sources of water supply in this arid city, is being sought. This objective motivated the development and implementation of the IoT WQSM. The project started with installing the node in "La presa de Hielo", located 6 km from the Gateway. The Gateway is located at the building of CIMAV DURANGO, which facilitates the Gateway's operation and the uploading of information to the server. Since it was impossible to access the node with a simple gateway due to the lack of a direct line, the initial architecture of the IoT WQSM was adjusted to add a LoRa repeater to the monitoring system (Figure 1). (Page 3, Lines: 114-122).
Section 2.2.4 what kind of converted is used to to convert 12 V to 5 V?	We use Mini 560 DC-AC Converter Voltage. The battery voltage is stepped down to 5V through the Mini 560 DC-AC Converter Voltage. The 5V powers the processor module and the wireless communication module. (Page 6, Lines: 226,228).
Section 2.3.3 has a confuse explanation, rewrite	We rewrite the paragraph: The server application consists of all those services installed on the virtual private server (VPS) necessary to perform real-time monitoring of the values sent from the node (Figure 1.a). The VPS was enabled on Amazon Web Services (AWS) (Copyright Amazon.com, Inc., Washington, USA). The database software is MySQL (Copyright Oracle, Corp., Texas, USA), and the control panel is Vesta CP (Copyright Vesta CP., California, USA). The server programs are mainly used for background procedures, including socket network communication, database connection, port upload data processing and storage, front-end interface loading, etc. EMQ X software, as the MQTT broker, coordinates the management of messages and devices. The server is the manager for





	the data collected by each terminal stored in their corresponding database using of Node.js algorithm that allows continuous connection to the broker and database. The user can monitor the terminal water quality parameters changes in real time through Grafana (Copyright Raintank, Inc., New York, U.S.A). (Page 7, Lines 287-299).
Figure 3 has 3 different pictures, explain what are the lower pictures.	We add a more detailed explanation in the description of Figure 3: a) PVC pipe structure with a pump for water recirculation for Indoor multi-node testing of IoT-WQMS, b) IoT multi-node designed for Indoor testing, c) OLED and LCD displays added for local verification of measurements. (Page 9, Lines 350-352).
Section 2.4.2 What is ADTK?	We add a more detailed explanation of the ADTK term: The Anomaly Detection Toolkit package (ADTK) (Copyright, Arundo Analytics, Inc., California, USA) (Page 10, Lines: 375-376).
Figure 4, explain.	We have added a paragraph to expand the explanation of the figure 4. The trained model was added to the general program, executed via Flask in the VPS. Figure(4) shows the program's stages for anomaly detection based on the unsupervised anomaly detection algorithm. This program allows a constant connection to the MQTT broker. Each time data is received from the node, it connects to the database to obtain and analyze the values through the anomaly detector. If the values are detected as anomalous, an alert message is sent via Telegram and is also displayed in the application control panel. On the other hand, if the data is correct, the system does not perform any action. (Page 10, Lines: 382-388).
Section 2.4.3, Describe in more detail the simulations, give more information about them and their results.	We modify a paragraph to expand the explanation of simulation: Because in the LoRa communication protocol, the quality of the transmission data depends on the characteristics of the transmitter and receiver antennas, terrain characteristics, transmitter operating power and receiver sensitivity. It is helpful to model the transmission coverage to design the architecture needed to achieve connectivity for LoRa-based IoT systems. The radiofrequency transmission was modeled using the SPLAT software (Copyright, SPLAT, John A. Magliacane, KD2BD) to visualize RSSI (Received Signal Strength Indication), according to the proposed transmitter and receiver





locations and the parameters presented in Table 1. It allows for determining the feasibility of the communication of LoRa in the area to be implemented IoT monitoring system. A spatial model is obtained with the RSSI gradient approximating the power received in the area of interest. In order to test LoRa layer of IoT-WQMS, the radio frequency performance of the system is verified in the field by detecting the 0-6 km system RSSI (received signal strength indication) and PLR [27, 28].

(Page 11-12, Lines: 397-409).

We add information about the simulation by adding a new Table: Table 1. Parameters used for radiofrequency studies in SPLAT (Page 12, Lines: 367-369).

We have added a paragraph to expand information about results: The modeling results can help assess the feasibility of different configuration options for LoRa-based IoT environmental monitoring networks in large areas or cities. They estimate if gateway localization provides scalability, signal coverage, and functionality for the planned IoT network. This study indicates that the localization of CIMAV-DGO to be located in a high and clear place could maximize coverage in the city. It has electrical power and Internet connectivity, and the gateway can be sheltered. The simulation, in this case, confirms that the building of CIMAV-DGO is a highly feasible place for the location of the gateway for a LoRa-based Wireless Sensor Network in IoT for monitoring water and air quality in Durango city.

(Page 15, Lines: 607-615).





Reviewer 2

Comments and Suggestions The changes requested are colored yellow	Answers The changes made are colored green
Interesting application of IOT to water sector together with LoRa. The results are not clearly defined so this appears to be an undergraduate report. Limited analysis of results	In the results section we expand the explanation for results in section 3.2, we add the type of anomalies detected: The anomalies detected by the program are of scalar type, which uses logical or Boolean values, i.e. a false-true (zero-one) classification, resulting in the data being divided into anomalous and normal. (Page 13, Lines: 508-510). We improved the quality of the figures 5 and 6, and the explanation of figure 6. The graphical output of the detection of the anomaly detection module integrated in IoT-WQSM are shown in (Figure 6), where the anomalous events detected by the model can be seen in the red lines, the blue, orange and green lines are the generated time series of TDS, Temp. and pH, respectively, during the experiment. (Page 13, Lines: 515-516). Figure 6. The graphical output of the anomaly detection module integrated with IoT-WQSM. Anomaly monitoring of a) pH (lower green line), b) Temperature (middle orange line), c) Total Dissolved Solids (TDS, upper blue line), detected anomalies (red vertical lines). (Page 14, Lines: 529-531). We extend the analysis of the results of section 3.2 Anomaly detection The anomalies detected by the program are of scalar type, which uses logical or Boolean values, i.e. a false-true (zero-one) classification, resulting in the data being divided into anomalous and normal. (Page 13, Lines: 508-510).



Only a few papers address anomaly detection in IoT systems for water quality monitoring. It is a complex task due to the many short- and long-term anomalies that may arise [44,45]. It is vital to address these issues because of the quality of the prediction and warning applications in water resources monitoring depends on the data generated in IoT-based water quality monitoring.

To address these issues, researchers can explore various anomaly detection techniques or their combinations, including statistical analysis, Machine learning algorithms techniques on historical water quality data to identify anomalies in real-time[34,44-46]. It is important to note that no single anomaly detection technique is suitable for all IoT-based water quality monitoring scenarios. Therefore, researchers should evaluate the performance of multiple techniques and select the one that best suits the specific use case. This IoT-WQSM offers the advantage of including both types of anomaly detection as Statistical Process Control (SPC) and an unsupervised anomaly detection algorithm. It is one of the advantages that allow the development of these ad hoc systems compared to similar commercial systems in which it is challenging and even illegal to incorporate various anomaly detection or modify the default configuration. (Page 14, Lines: 553-576).

We extend the analysis of the results of section 4.3 Outdoor long-distance communication test

The modeling results can help assess the feasibility of different configuration options for LoRa-based IoT environmental monitoring networks in large areas or cities. They estimate if gateway localization provides scalability, signal coverage, and functionality for the planned IoT network. This study indicates that the localization of CIMAV-DGO to be located in a high and clear place could maximize coverage in the city. It has





	electrical power and Internet connectivity, and the gateway can be sheltered. The simulation, in this case, confirms that the building of CIMAV-DGO is a highly feasible place for the location of the gateway for a LoRa-based Wireless Sensor Network in IoT for monitoring water and air quality in Durango city. (Page 15, Lines: 608-616). We mentioned it in the text, but now we emphasize Comparison of RSSI modeled with splat software and measurements obtained with two different LoRa configurations in table two,. Table 2. Comparison of RSSI modeled with splat software and measurements obtained with two different LoRa configurations at the sites of interest. (Page 16, Lines: 627).
Figures 5 and 6 need to be clearer, especially figure 5.	We improved the quality of the figures 5 (Page 13, Line:499). We improved the quality of the figures 6, and the explanation of figure 6. For figure 6, we add a more detailed explanation of the information in the chart: the blue, orange and green lines are the generated time series of TDS, Temp. and pH, respectively, during the experiment. (Page 13, Lines: 515-516). For figure 6, we add information to identify each data in the chart clearly: Figure 6. The graphical output of the anomaly detection module integrated with IoT-WQSM. Anomaly monitoring of a) pH (lower green line), b) Temperature (middle orange line), c) Total



	Dissolved Solids (TDS, upper blue line), detected anomalies (red vertical lines). (Page 14, Lines: 529).
Authors describe a short range and long range application of the system but no numerical definition given to these instances. Authors need to describe the range of the system in terms of distance.	We add the distance for each application: A close-range or WPAN allows transmission over 100 meters maximum, while a far-range or LPWAN allows transmission over 100 km. (Page 15, Lines: 595-596).
Robustness of the system, energy usage must be include	We add the energy usage and robustness of the system: The consumption of the entire system is 26 mA in active mode and 10 mA in sleep mode, which provides sufficient autonomy with the selected battery of approximately 30 days until it needs to be recharged. (Page 6, Lines: 230-232).