Smart Water Quality Monitoring System

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***Abstract*— Nowadays Internet of Things (IoT) and Remote Sensing (RS) techniques are used in different area of research for monitoring, collecting and analysis data from remote locations. Due to the vast increase in global industrial output, rural to urban drift and the over-utilization of land and sea resources, the quality of water available to people has deteriorated greatly. The high use of fertilizers in farms and also other chemicals in sectors such as mining and construction have contributed immensely to the overall reduction of water quality globally. Water is an essential need for human survival and therefore there must be mechanisms put in place to vigorously test the quality of water that made available for drinking in town and city articulated supplies and as well as the rivers, creeks and shoreline that surround our towns and cities. The availability of good quality water is paramount in preventing outbreaks of water-borne diseases as well as improving the quality of life. Fiji Islands are located in the vast Pacific Ocean which requires a frequent data collecting network for the water quality monitoring and IoT and RS can improve the existing measurement. This paper presents a smart water quality monitoring system for Fiji, using IoT and remote sensing technology.**

Keywords—Smart Water Quality Monitoring; Internetof Things; Remote Sensing.

I. INTRODUCTION

Over the past few decades, waters in and around Fiji have gradually succumbed to a fair degree of pollution. Chemical waste and oil spills are the major, primary forms of water pollution threatening Fiji's waterways. For example, an article published in the Fiji Times on 24 December, 2014 reported on raw sewage seeping into the Samabula River at a rate of 200 liters per second due to broken pipes [1]. Eliminating pollution altogether may seem like an unfathomable notion but limiting its effects when it does happen is certainly possible. The primary objective of this project is to devise a method to monitor seawater quality in an effort to aid in water pollution control in Fiji with the help of IoT and RS technology.

The Smart Water Quality Monitoring System will measure the following water parameters for analysis; Potential Hydrogen (pH), Oxidation and Reduction Potential (ORP), Conductivity and Temperature using a RS technology. While monitoring these parameters, it is perceived that one should receive a stable set of results. Therefore a continuous series of anomalous measurements would indicate the potential introduction of a water pollutant and the user will be notified of this activity with the aid of IoT technology. False positives, such as anomalous readings over a short period of time, will be recorded but not treated as an alert. Hence, with the successful implementation of this monitoring approach, a water pollution early warning system can be achieved with a fully realized system utilising multiple monitoring stations.

II. BACKGROUND

Initiatives have been taken all over the globe to develop projects based on sampling water to aid in controlling marine environments. It may not be specific to water pollution monitoring but similar concepts are involved.

Libeliums Smart Water device monitors the status of an aquarium's health in Europe [2]. It specifically monitors parameters like pH, electro conductivity, oxidation/reduction potential (ORP) and temperature. A cloud based solution is developed to help in monitoring data in real time providing a fast and effective reaction in case of rising abnormalities.

A similar example to that of this project can be seen in the coastal water pollution monitoring initiative in the Gulf of Kachchh [3] with the only difference being in terms of it having a much larger scope and vastly more expensive protocols deployed to counter the effects of the industrial development.

Furthermore, locally there have been projects based around the conservation of the coral reefs. The Mamanuca Environment society's (MES) Biannual Sea Water Monitoring Program has been around for 4 years whereby tests are carried out on seawater for faecal coliform (FC) bacteria, salinity and nutrients which helps in ascertaining the health of the surrounding reefs [4].

Research indicates that projects of this nature are developed on a large scale with generous funding from reputable organizations. There is little indication of small-scale and inexpensive projects that have a similar role in places like marine jetties, cities and industrial rivers to preserve aquaculture and public health. By applying a strategic, cheap and methodical technique this project hopes to achieve this in an effort to sanitize our oceans.

III. INTERNET OF THINGS

The internet of Things (IoT) is a revolutionary new concept that has the potential to turn virtually anything "smart". A Thing in this context could be defined as an object such as a cardiac monitor to a temperature sensor. This extraordinary event has captured the attention of millions. Why is this so big today? So imagine a world where machines function without any notion of human interaction. A future where machines communicate with other machines and make decisions based on the data collected and all independent of an end user.

To understand how this revolution took shape we have to travel back to the 1900's with a profound prediction from a well renowned inventor Nicolai Tesla in which he stated that the world will be wirelessly connected to a

single brain. Every invention starts with a simple thought, that's all it takes to define history. Alan Turing, the inventor of the computer, spoke about machines having sensors and humans teaching the machines, what we know today as Artificial Intelligence (AI). Then came the World Wide Web (www), the flow of information that is available to the public and this was exactly what was missing to realise Teslas prediction. The term itself "internet of things" was coined in 1999 by Kevin Ashton for linking the idea of sensors with the internet [5]. The IoT journey has taken over a century to see light and it will undoubtedly not stop here.

Fig. 1: The proposed schematic diagram of the smart water quality monitoring system.

It might be difficult to see the significance of the IoT but every advancement made is to make everyday life simpler and safer. Examples of these are a baby monitor to keep track of a baby's health in real time [6], an IoT for caregivers which collects behavioral data to improve care [7] and a heart monitoring system that collects biometrics data to track an aging patient's health [8]. These are just a few examples of how IoT projects can improve the way of life. Fig. 1 shows the proposed schematic diagram of the smart water quality monitoring system using the IoT concept.

IV. Approach

The first task and a very integral one was to determine which water parameters would provide a close indication for water pollution. Through extensive research [9-11] the parameters were chosen to be composed of pH, oxidation and reduction potential (ORP) and temperature. The reasoning behind these selections is discussed in section V – Water Parameters.

Independently these parameters provide very little information in terms of how polluted the seawater actually is. Therefore, analysis will consider collective parameter behavior in order to generate a valid output, which is either polluted or not unpolluted. To put this into perspective, a drop in pH of tap water alone is not a valid indication of pollution, this only indicates a formation of acids but it may still be consumable (e.g adding lemon juice to tap water).

The second step was the selection of locales that will provide useful data. The area in question should be susceptible to some chemical fluctuations by either marine life or human interference since performing data readings on clean, untouched waters would produce known results. Therefore, the locations were narrowed down to industrial areas, marine jetties, sewer waste openings and city lines where human interference had a considerable impact. Given that security was a factor, the site was chosen as the USP jetty since the area is completely secure from theft and vandals.

The third obstacle was which form of data logging would produce an acceptable format. An FTP solution was developed initially on a local network, however without the intervention of local Internet Service Providers this seemed like the least convenient option. A cloud server has also been considered to act as an intuitive and a more permanent solution. Work is still in progress on this matter. Moving on, since the equipment has an SD storage option, data logging was ultimately done on the hardware itself in text format which can easily be read by practically any application.

The final step was to decide on an acceptable, proficient and accurate form of analysis. Seeing as the sea contains a vast number of unknowns which will imminently chemically alter the properties being measured. This will in turn present erroneous readings. As previously mentioned, changes in one measured parameter may be no indication of the sea water actually being in the presence of pollutants. The collective measured results had to be consistent over period of time to be treated as a possible threat. Moreover, to overcome this obstacle an intelligent analytical system had to be designed in the manner of a Neural Network model.

V. Water Parameters

A. *Temperature*

It is important to record temperature alongside the other parameters as this will be useful in behavioral analysis of the parameters being measured. Relating to temperature-relation theories, pH and conductivity have an undesirable effect with large temperature changes. In addition to this, extreme temperatures for pacific island climates is of understandable concern.

B. *pH*

The pH of a solution is the measure of the acidity or alkalinity of that solution. The pH scale is a logarithmic scale whose range is from 0-14 with a neutral point being 7. Values above 7 indicate a basic or alkaline solution and values below 7 would indicate an acidic solution. The majority of aquatic life prefers a pH level of 6.5 – 9.0. Anything outside of this optimum range is considered fatal to the marine ecosystem. Extreme pH values also increase solubility of elements and compounds making them toxic and therefore more likely to be absorbed by marine life. Furthermore, temperature has an inverse relationship with pH that is, as temperature increases pH levels decrease and vice versa.

C. *Oxidation- Reduction Potential*

Oxidation-Reduction Potential is the measure of a solutions oxidizing power. In simple terms it can be described as the potential of a solutions ability to sanitize itself. Higher ORP values would indicate more oxidizers present. Likewise lower ORP equals more reducers present.

It is understood that a typical good value for aquatic life should be in the vicinity of 100 mV to 200 mV. Anything outside these limits is a case to be investigated. The same can be said about tap water whose ORP levels are very high, usually in the high 600 mV because of the use of disinfectants such as chlorine. Anything outside this range should be investigated.

D. *Conductivity*

Conductivity signifies the ionic strength of a solution. In other words it is the ability of a solution to conduct electricity with the typical unit for measurement being micro-Siemens per centimeter (uS/cm). As the dissolved ions increase in the water, conductivity increases. Therefore, the conductivity of tap water is perceptibly low at around 100 uS/cm. On the other hand, expected values for sea water are 55000-60000 uS/cm due to its high ionic content. Any further increase in the conductivity value may be indicative of polluted waters, such as sewer leaks or chemical wastes flooding into the water.

Moreover, conductivity is directly related to salinity that is conductivity improves with high salinity. Conductivity values outside of the optimum levels indicate a possible negative scenario. Dead Sea is a prime example of lethal concentrations of salt.

The temperature relation with conductivity is a proportional one. A general assumption of a temperature-conductivity relation is taken to be linear in nature with a deviation of 2%/°C.

VI. Overall Structure

The main concept behind this project can be described in a simple block diagram shown in Fig. 2 and Fig. 3 Shows the setup with the sensors and Waspmote microcontroller board.

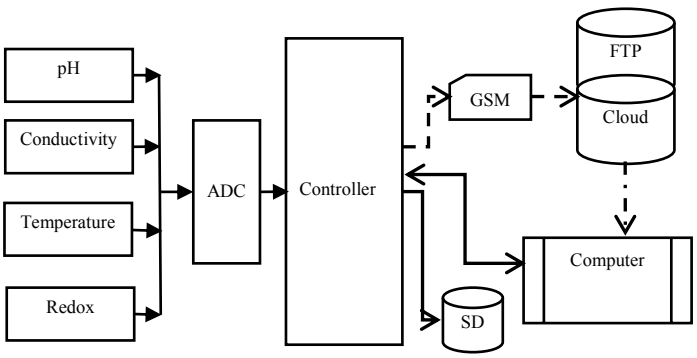

Fig. 2 : Shows the overall block diagram of system operation.

The system as a whole comprises of sensors, an analogue to digital convertor (ADC), a microcontroller, an SD storage and a GSM module. The data collected can either be stored onboard via the SD card or sent to a File Transfer Protocol (FTP) server or a cloud server. In the case of this project, a cloud server in conjunction with a local machine is utilised for data analysis.

A complete bundled set provided by Libelium [6] was used for this project and included the sensors, microcontroller and GSM communication. Furthermore, since the deployment duration is expected to run for months or even years, power conservation is imperative. To achieve this, the system design incorporates sleep mode i.e the system gets a 15 minutes sleep time after an hour of continuous readings. To further extend battery life any idle modules have been set to off mode. For instance, when an SD card operation has finished the SD module switches off. The same is realized with the GSM and serial communication. Further to this, alerts have been set to notify the user of certain conditions such as battery life and progress report.

Fig. 3: Deployment Setup with the sensors and Waspmote microcontroller board.

VII. Experimental Results

Four water samples from different water sources were tested to establish a reference on the parameters for each water type. The chosen water types were seawater, surface water, Tap water and polluted creek water.

The four water samples were tested simultaneously with four separate, identical systems at indoor ambient temperature. Readings were taken at 1 hour intervals for a total period of 12 hours. For security reasons the systems were not deployed in the specific areas of interest, instead water samples were collected and tested in a safe controlled environment. However, the tap water sample was changed every hour to see the consistency of Fiji tap water (supplied by Fiji Water Authority) readings.

A. *Reference for tap water*

Fig. 4-7 shown the trends of the acquired data and are consistent with the globally accepted values for pH, conductivity and ORP. The temperature effect on pH and conductivity is clearly observed.

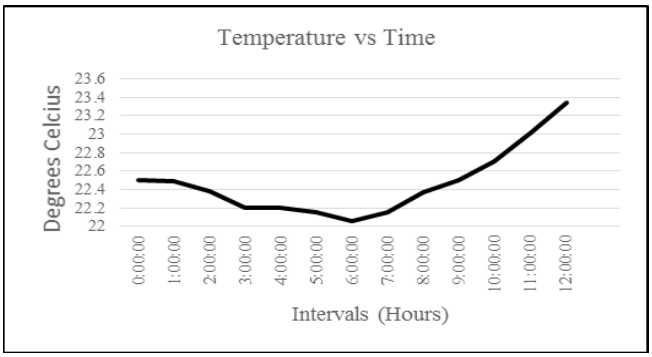

Fig. 4: Graph of the solutions ambient temperature.

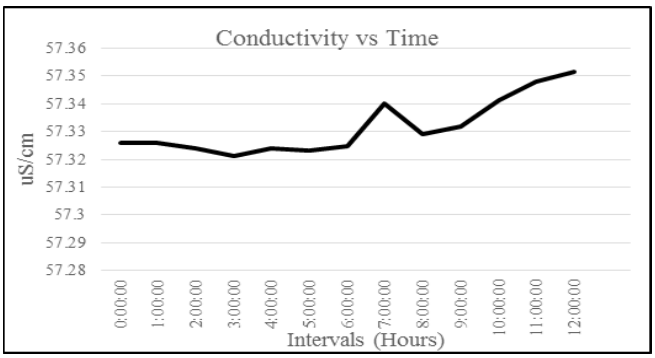

Fig. 5: Conductivity for tap water is shown.

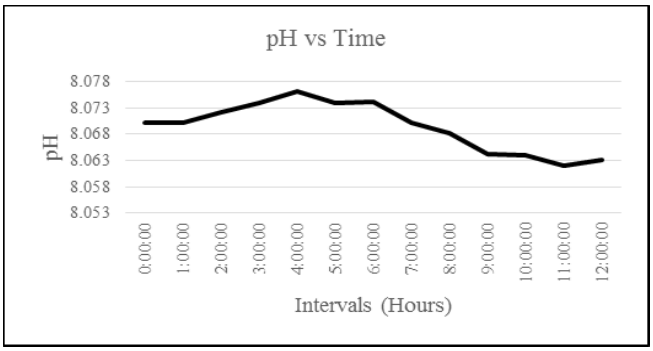

Fig. 6: PH trend for tap water.

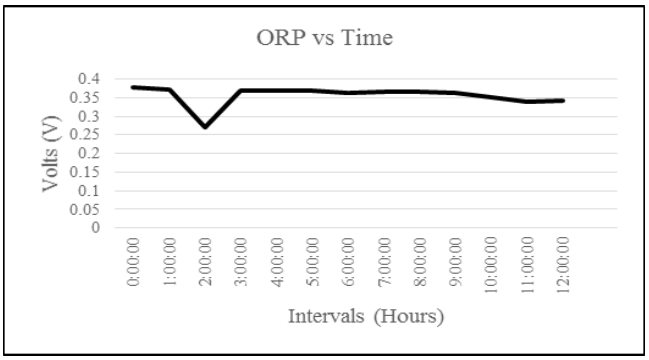

Fig. 7: ORP trend for tap water.

In addition, Temperature- Conductivity relation can be seen to be linearly proportional.

B. Reference on sea water

A sample of fresh seawater, collected from the shores of Sigatoka, was tested to provide a reference on healthy sea water with little to no contamination.

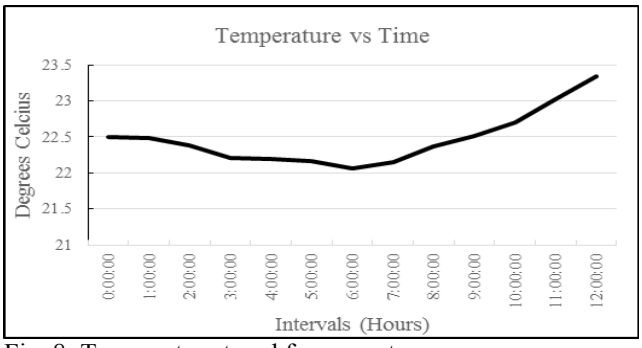

Fig. 8: Temperature trend for seawater.

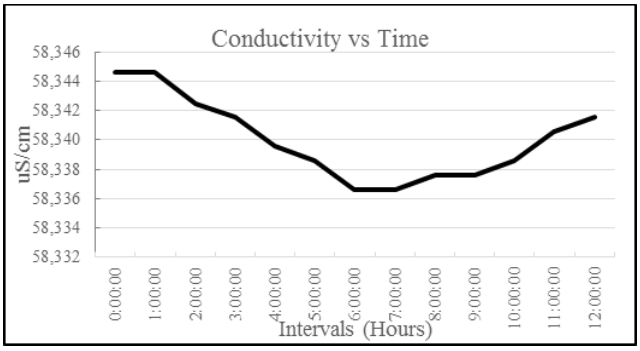

Fig. 9: Conductivity trend for seawater.

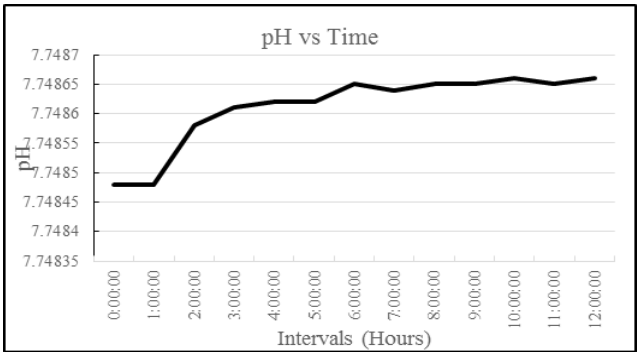

Fig. 10: PH trend for seawater.

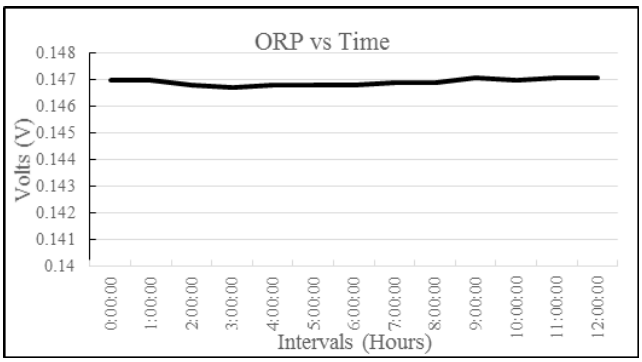

Fig. 11: ORP trend for seawater.

The results shown in Fig. 8-11 indicate values that are near to the researched data for acceptable sea water parameters that can sustain aquaculture [9].

C. Reference on surface water

A sample of water was taken from Rewa River (Suva, Fiji) to provide a reference on surface water. The results obtained (Fig. 12-15) from Rewa River were also consistent with the researched data available on acceptable surface water parameters [10].

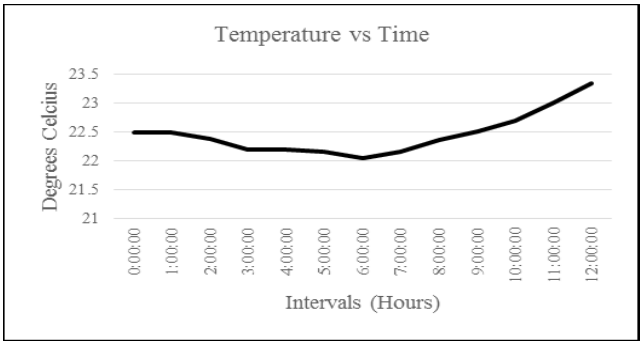

Fig. 12: Temperature trend for Surface water.

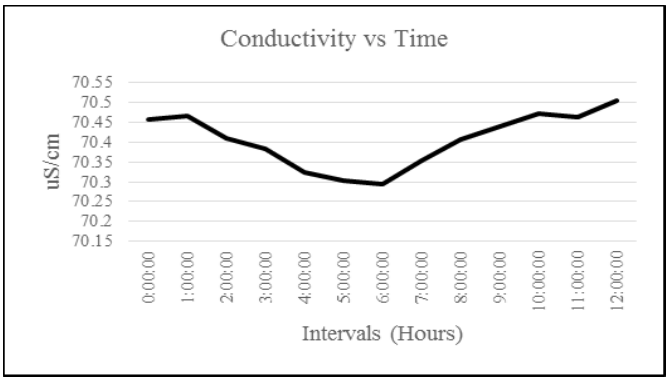

Fig. 13: Conductivity trend for surface water.

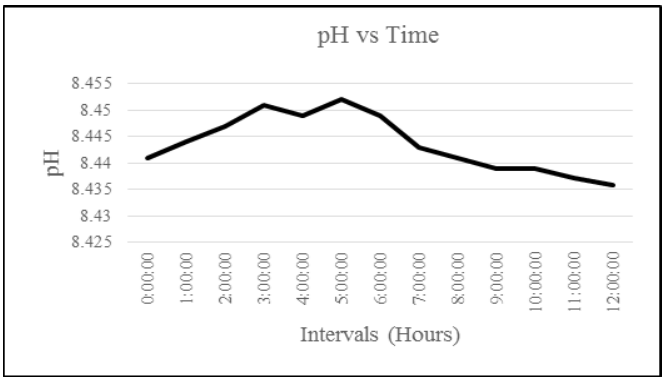

Fig. 14: PH trend for surface water.

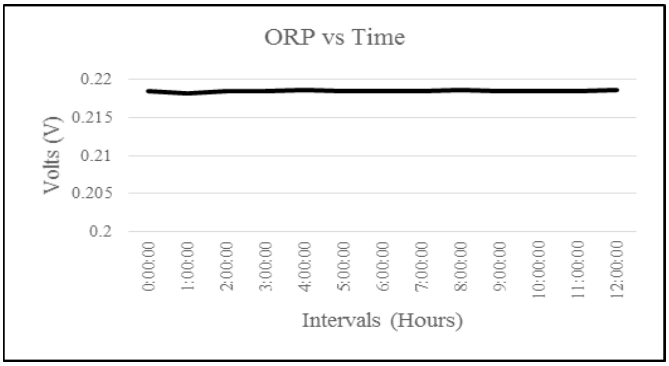

Fig. 25: ORP trend for surface water.

D. Polluted water test

To get a fair idea of how the parameters of polluted water should look a sample of water was collected from the Nabukalou Creek an extremely polluted waterway in the heart of Suva City. The results are shown in Fig. 16-19.

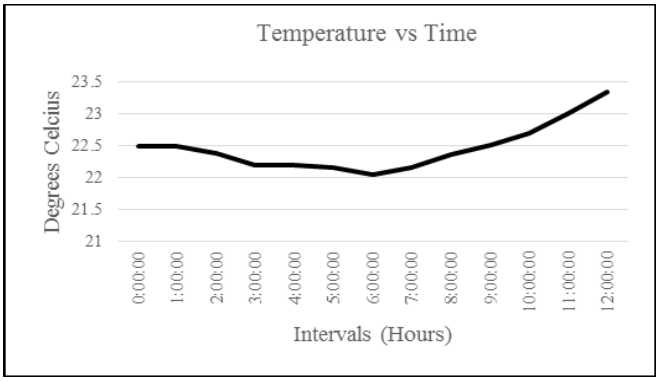

Fig. 36: Temperature trend for Nabukulau creek.

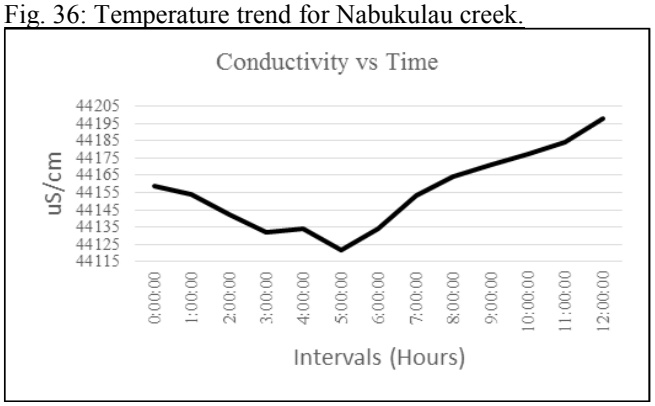

Fig. 47: Conductivity trend for Nabukalou Creek.

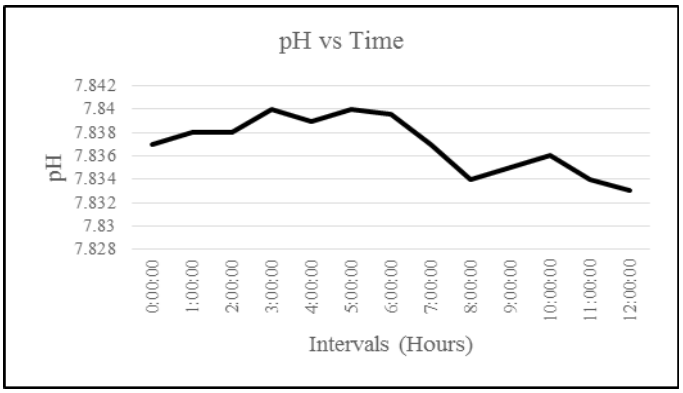

Fig. 58: PH trend for Nabukalou Creek

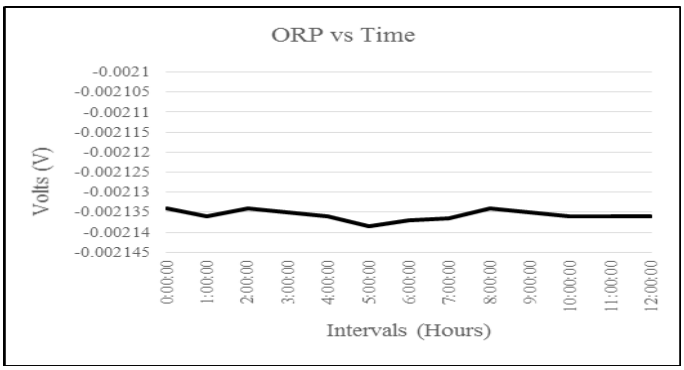

Fig. 69: ORP trend for Nabukulau Creek.

E. Summary of the tested properties between the water samples

A comparison can be made with the collected data between tap water, river water, seawater and polluted creek water. The pH levels for all were fairly similar with the only change being in relation with temperature.

Conductivity for the water samples differed significantly because of the different salinity concentrations for different water types. The highest conductivity being 58000 uS/cm for sea water and the lowest being that of tap water with conductivity value of 58 uS/cm. ORP for sea water and river water were similar with results being in the low 100-200mV range. ORP for tap water was observed to be 350 mV which is fine considering that the acceptable range is from 300-650mV.

The data obtained for polluted water has some interesting values for ORP and conductivity. A very low ORP value was observed, averaging at -2mV which is an indication of overpowering reductants. This is an expected value considering the background of Nabukalou Creek having waste lines connected to the creek. The conductivity value was in the 40000 range indicating that water samples likely contained traces of pollution. A summary is also presented in table format shown in Table I.

TABLE **I. SUMMARIZED RESULTS**

Source	***Readings***			
	Temperature	***pH***	***ORP***	***Conductivity***
Rewa River	20-30 °C	7.7-8.2 pH	190-220 mV	70-80 uS/cm
Central Tap water	20-30 °C	7.7-8.1 pH	300-600 mV	55-70 uS/cm
Sigatoka coast	20-30 °C	7.7-7.9 pH	100-150 mV	50-60 mS/cm
Nabukulau Creek	20-30 C	7.7-7.9 pH	0 to -3mV	42-45 mS/cm

VIII. CONCLUSION

This research demonstrates a smart water quality monitoring system. Four different water sources were tested within a period of 12 hours at hourly intervals to validate the system measurement accuracy. The results obtained matched with the expected results obtained through research. The temperature relation with pH and conductivity were also observed for all the water samples. GSM technology has been successfully implemented to send alarm based on reference parameter to the ultimate user for immediate action to ensure water quality. Additionally, the parameter references obtained from all the different water sources will be used to build classifiers which will be used to perform automated water analysis in the form of Neural Network Analysis.

In a nutshell, the system has proved its worth by delivering accurate and consistent data throughout the testing period and with the added feature of incorporating IoT platforms for real time water monitoring, this should be an excellent contender in real time water monitoring solutions.

ACKNOWLEDGMENT

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