LoRaWAN Monitoring System for Emergency Vital Signs in Pusu River

https://doi.org/10.3991/ijim.v16i15.30117

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Abstract—Sungai Pusu is the river that passes through the IIUM Gombak campus. The river has been having a cloudy appearance for years hence it is needed to quantify the vital signs such as pH, temperature, and turbidity because these are the vital signs indicating the health of a river. Currently, there a lot of monitoring systems however the available monitoring systems do not support long-range communication and consume a lot of power. The data need to be transmitted at a long-range as it is being monitored remotely at a long distance. Therefore, a river pollution monitoring system must be developed to track the emergency vital signs (EVSs) of the river water The EVs include pH, temperature as well as turbidity. This project capitalizes on the long-range communication and low power consumption LoRaWAN system. The prototype monitoring station design can read the important EVSs of the river such as temperature, pH level, and turbidity. The sensors are connected to a microcontroller board. The readings of the EVSs are transmitted by the LoRa gateway which is forwarding the data to The Things Network Server. A graphical representation of the data is displayed on Ubidots. The results attained quantify the contribution of the IIUM populace to Sungai Pusu Pollution and raise awareness. It is also important to discuss the possibilities to the pollution of the river to see how one's action could contribute to it. A statistical data of the results is as important so that an overall result can be deduced. Based on the results, the pH is decreased 1.32 pH, the temperature is increased by 2.29°C, and turbidity is decreased by 0.44 NTU throughout the monitoring period. In the future, six more monitoring stations will be added to accommodate KL River of Life (RoL) EVSs too.

Keywords—component, formatting, style, styling, insert

1 Introduction

River pollution is not something new, but a very important issue to be raised. In 2019, the issue of Kim Kim River toxic pollution became the talk. It was extremely serious and had destroyed the life underwater as well as affecting the health of people nearby the river. People had difficulties in breathing and some needed to be admitted to the hospital. Having a river pollution monitoring system that includes IoT devices will help to solve the issues. A communication technology called Low Power Wide Area Network (LPWAN) is one of the technologies that is commonly used in IoT devices and this includes Long Range (LoRa) network introduced by Semtech. LoRaWAN is the communication protocol for LoRa and it can transmit data from 1km up to 10km [1]. Wireless Sensor Networks (WSNs) is referring to a group of sensors integrated with wireless technology to monitor a certain environment or condition. These sensors assist users with data collection and communication remotely [2]. It is usually used for monitoring an environment wirelessly for example pollution monitoring. The sensors can attain the important parameters of a river that indicate the water quality. It is important to have these characteristics of WSNs which are low power consumption, resilience, and user-friendly. There are many advantages of WSNs that needed to be noted including easy network setups, minimal wiring, flexible, and low-cost implementation [3]. There are other applications of WNSs including process management, healthcare monitoring, fire detection, and so many others. However, the only focus in this project is pollution monitoring which is river pollution monitoring.

2 Literature review

2.1 LoRa and LoRaWAN technologies

LoRa is an RF modulation that makes the physical layer of the OSI reference model. The only LoRa integrated circuit producer, Semtech had developed this technology since 2015 [4]. An area with hundreds of square kilometres can be covered by a single gateway depending on the obstacles of a geographical location. The main factor in determining the range is the link budget [5]. LoRa works over the ISM Band (868–915 MHz) which is very convenient as that range of frequency is free to use anywhere in the world, be it rural or indoors, therefore there is no need for licensing. The gateway also allows communication and broadcasting to be done bidirectionally. It uses 128 AES encryption for its security which can take a billion years to decode the key, as a result, making it highly secure.

LoRaWAN is a MAC layer standard that coordinates the medium [1]. The communication protocol and system architecture are defined by LoRaWAN and determiners of cell lifespan of nodes, network capacity, the quality of service, and security [5]. LoRaWAN network is typically based on a star network topology. Star network works by having all connected devices connected to nodes that are acting as a gateway [6]. Each of the end-nodes passing the data in which the end-nodes connected directly communicate with gateways [5]. LoRaWAN receives data transferring via a nearby gateway which means the data can be transferred to any gateway without handover. Adaptive Data Rate (ADR) and multichannel multi-modem transceiver in gateways are used in LoRaWAN [4]. LoRaWAN has three classes by which Class A is the default and all end devices must support this class. Class A creates downlink windows. Class B is an optional class that has a role like class A with additional scheduled receive slots. Class C is also an optional class that listens when it is not transmitting.

The link budget is the measure of the quality of the transmission channel. It can be computed by simply summing up the transmit power, receiver sensitivity, antenna gain, and free space path loss [6]. The amount of energy lost in free space between the transmitter and receiver is called path loss. The energy gets lower as the distance between transmitter and receiver gets further. It is typically represented in this form of the equation:

$$\mathrm{FSPL} = \frac{44\pi \mathrm{d}}{\lambda} = \frac{44\pi \mathrm{df}}{c}2 \quad (1)$$

It can also be represented in the form of a logarithmic equation:

$$\mathrm{FSPL} = 20\log_{10}(\mathrm{d}) + 20\log_{10}(\mathrm{f}) - 147.55 \quad (2)$$

The link budget is affected by the value of the receiver sensitivity. The receiver sensitivity is the minimum possible reception power and tolerance for thermal noise, and the equation is represented as:

$$\mathrm{RX\,sensitivity} = -174 + 10\log_{10}(\mathrm{BW}) + \mathrm{NF} + \mathrm{SNR} \quad (3)$$

Since LoRaWAN has a more sensitive power receiver hence it outperforms WiFi. Equation (2–4) is the equation when there is no antenna gain and other types of free space loss due to severe path loss.

$$\mathrm{Link\ Budget} = \mathrm{max.RX\ sensitivity\,(dB)} - \mathrm{maxTxpower\,(dB)} \quad (4)$$

2.2 Important parameters of a river

There are some parameters required to monitor the quality of a river and these parameters cannot be neglected in a river monitoring system. These parameters include temperature, pH, and turbidity.

pH. pH indicates the hydrogen ion concentration of a river, and some factors are affecting the pH of the river. The factors include acid rain, waste from industries, and carbonic decomposition [8]. Acid rain causes the river to be acidic. Organisms like fish and plants are affected as it shows a decline in number at places that experience acidic rain [13]. Besides that, carbonic decomposition causes the river to be acidic too that is due to agricultural fertilizers [14]. These organisms have different tolerance of acidity; hence some might survive, and some might not. pH value is affected when industrial waste is dumped in the river by which increases the alkalinity of the river. The alkalinity will cause extreme distress to the aquatic organisms [15]. This means any living organism in the river is exposed to toxins that could harm their life and explicitly affects human life. A pH sensor is an essential sensor to be in the river monitoring system because aquatic organisms can live in the river with only a certain range of pH which is 6.5 to 8.5 [19]. When the water gets too acidic it can cause toxic heavy metals to be released into the water by which will affect the aquatic organisms. Hence, monitoring the pH of the river is a must. pH sensors are the combination of pH electrode and signal conditioning circuit which measure the pH value to determine if the water is acidic or alkali. 0 pH, 7 pH, or 14 pH shows that the water is strongly acidic, neutral, or strong alkali, respectively [20–21].

Temperature. The temperature of a river is affected by some factors including air temperature, pollution as well as shading like trees that cover the river [8]. Gas can be absorbed in warm water better than in cold water. This means that hazardous gas can be eliminated in water however if the gas is too much, it will contaminate the river. Changes in air temperature influence the river temperature but only if the changes are severe [9]. Luckily, Malaysia does not experience extreme weather as it is either sunny or rainy. Power stations that released excess heat as cooling water to the river are known as thermal pollution [10]. This pollution affects the river temperature as well as the aquatic organisms. Raptis [11] conducted research regarding which country emitted the excess heat. He found that the United States and Europe emitted the most cooling water. Shading is also a factor in the changes in river temperature. A publication [12] stated that the different size of the river has different exposure to the light by which directly affects the river temperature. In analyzing the quality of a river, the temperature of the river is measured because it affects the aquatic creatures in many ways. Fish can live within the range of 27°C–30°C. The aquatic organisms' body temperature is like the water temperature and it has a narrow tolerance as they cannot live when the temperature drastically changes, either too high or too low. Metabolism, reproduction, and the emergence of aquatic organisms are also affected by temperature. The photosynthesis rate of aquatic plants is affected when the temperature changes consequently affecting the aquatic food web as well [19]. Therefore, it is important to have a temperature sensor in a river monitoring system.

Turbidity. Turbidity is the murkiness of the river caused by tiny particles that cannot be seen with eyes. Factors that influence the turbidity of a river include soil erosion and industrial waste [8]. Soil erosion is a global phenomenon, it happens almost everywhere. Soil erosion that goes into the river will increase the river turbidity as well as disturbing the aquatic life which decreases the quality of the ecosystem [16]. It is also physically unpleasant to see a cloudy river. Industrial waste that is dumped into the river legally or illegally has caused an impact on the river. It is also the source of metals that degrades the quality of the water as well as the appearance of the river [17]. Turbidity is essential in determining water quality. The normal turbidity of a river is less than 10 NTU. When the river has high turbidity, the sunlight cannot penetrate the water which will eventually slow down the photosynthesis rate of aquatic plants consequently increasing the death rate of aquatic organisms as the result of lacking oxygen. Turbidity affects the temperature of the river as the level of turbidity increases the temperature rises. Turbidity absorbs heat from solar radiation efficiently more than water. Thus, a turbidity sensor must be in a river monitoring system. The sensor will provide data in the form of analog voltage for processing.

2.3 Related works

In designing this river monitoring system, other related works have been reviewed so that the design will serve its purposes at its best capacity. There are various ways of designing river monitoring systems models as it depends on the parameters, budget, and quality of the devices hence different publication has a different designing method. Some of the parameters are turbidity, pH, temperature, and dissolved oxygen.

By reviewing all these works, a river monitoring system for the Sungai Pusu River can be designed to monitor the parameters mentioned. Ahmad and Kumar [7] established a smart water monitoring system called IoT based smart River Monitoring System by which the information will be delivered to the database using TCP protocol. The system will notify the authorities by if this then this (IFFTT) via Twitter API push notification when it exceeds the tolerable limit. However, it uses a microcontroller board rather than LoRa by which LoRa can send data from afar with less power consumption. A similar method was proposed by Chowdbury [8] but to serve a different purpose. It is to help reducing pollution in Bangladesh by sending the data using the ESP8266 Wi-Fi Module. Server PC is used to display data collected with the assist of Spark streaming analysis through Spark MLlib. The method proposed in monitoring the water quality is using deep learning neural network models. The system will notify the authorities through an SMS. Likewise, the authors in [9] used the same Wi-Fi module. Thingspeak is used to attain the data using the Local Area Network (LAN). Since these authors are using a LAN network, the data can only be transmitted in a small area. A portable water monitoring system was invented five years back by Schneider, Schultz, Mancha, Hicks, and Smith [10] to monitor the Animas River. The portable water monitoring system is attached to water transport like rafts and kayaks. This allows the monitoring system to monitor the water by continuously moving the raft or kayak to float along the river. Although the method is simple and cheap, it cannot be monitored remotely. A quite similar project was developed in Indonesia to monitor a certain area in the country. The authors [11] claimed that the system aims to overcome and reduce river water pollution. The goal of the project is to help the farmers in monitoring the area. An Android-based operating system (OS) helps the farmers to monitor the water quality remotely. However, the authors mentioned having some difficulties in notifying the users. Similarly, Kadir, Irie, and Rosa [12] shared the same goal as the previous authors but have a distinguished method of doing so. The authors stated that their method used Wireless Sensor Networks (WSNs) to gather data from the sensors. Despite the low-cost and low power consumption of the device, its coverage area is smaller than that of LoRaWAN. Aziz, Sarosa, and Rohadi [13] used a nodeMCU microcontroller for data collection. Then the data is stored on the database server that is sent through a wireless connection. The authors monitored the results using an application that is available on the Android operating system. Similarly, Ismail and Mohammed [14] used the same method however they used a different microcontroller which is Arduino. Some publications [15], [16] have used an approach of using ZigBee as the communication protocol due to its low cost and low power consumption. ZigBee acts as a transmitter as well as a receiver. ZigBee is able to transmit data from a distance of 10 meters up to 100 meters. It is a practical approach if the data transmission does not require long-range communication. However, long-range communication is required hence ZigBee is not the best approach for this project. There is another publication [17] using an RF ZigBee module. The author used an FPGA board to monitor the result. FPGA consumes high power, and the programming is quite challenging, hence it is not a good option as our project requires as low power as possible.

3 Methodology

LoRa nodes are the first part that collects the data and sends it to the LoRa gateway. LoRa nodes consist of a few other parts which are the LoRa module, Arduino UNO microcontroller, and sensors. The sensors are connected to the Arduino UNO and Arduino UNO received the data in analog and converts it to digital. The LoRa shield is stacked on top of the microcontroller to send the data to the gateway. LoRa gateway received the data sent from the LoRa nodes. LoRa gateway is stacked on top of Raspberry Pi 2. This gateway acted as both receiver and transmitter. Raspberry Pi is a simple computer that is needed in this project to provide a connection of the LoRa gateway between The Things Network and LoRa shield. Then, the gateway transmitted the data to the network server and the data is displayed on Ubidots.

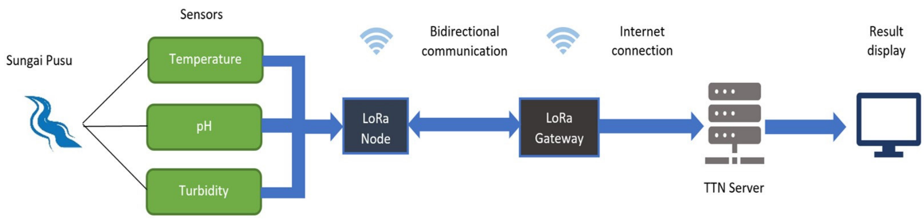

Fig. 1. System overview

3.1 Hardware setup

The connection of LoRa nodes is shown in Figure 1. The sensors measured the vital signs which are temperature, pH, and turbidity of a river. All these sensors are connected to the Arduino UNO. Arduino UNO collected the data from the sensors in form of an analog signal and it converted it into digital data and transmitted it to the LoRa shield. LoRa shield transmitted the data to the LoRa gateway. The solar power source is used to power up the nodes. The LoRa Hat is stacked on top of the Raspberry Pi 3. The SMA Antenna is connected to the LoRa Gateway. SD card is inserted into to SD card slot. Then, the image is installed using a modified Raspberry Jessie Lite image with the LoRa gateway pre-installed software. The initial system design has been reported in [18].

3.2 Software setup

The Things Network is the IoT platform used to monitor the results. The devices are registered on The Things Network (TTN) Server The results are shared in the network server that can be accessed with an internet connection. The server is then integrated with Ubidots to display the data and TTN Data Storage to retrieve the stored data withing the last 7 days.

3.3 Nodes and gateway location

Figure 2 shows the physical location of the nodes as well as the gateway on the maps.

Fig. 2. Nodes and gateway location

The first node was placed at the entrance when the river started to flow in the IIUM campus and the other was placed at the exit of the river when it started to flow out of the IIUM campus. Figure 2 shows the map location of the gateway and the nodes while Figure 3 shows the photos of the nodes been placed at their respective locations.

Fig. 3. Node 1 at low tide, node 2 at low tide

4 Results and discussions

4.1 Data collection

During the monitoring period some sensors were not functioning well and were replaced as soon as possible. The parameters monitored are the river's pH, temperature, and turbidity. Figures 4 and 5 show the overall results obtained from Ubidots. There are two ranges of monitoring period because in between the gap, the TTN server was down.

Fig. 4. Ubidots data from Oct 18th–December 1st, 2020

Fig. 5. Ubidots data from December 9th–23rd, 2020

4.2 Discussion

pH parameter. One of the most vital signs of polluted river water is pH hence it has been monitored and the daily average pH level is shown in Figure 6. pH is important to indicate the river water is either acidic, neutral, or basic.

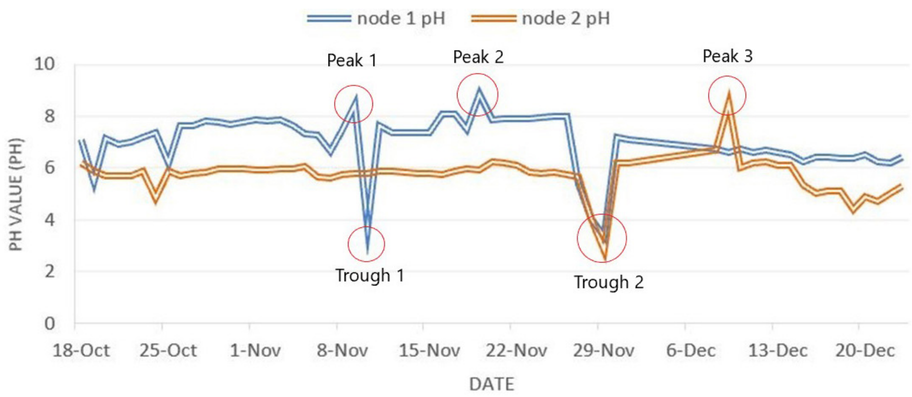

Fig. 6. Daily average of pH value

The daily average pH level for node 1 is generally higher than the daily average pH level for node 2. The daily average of pH is in the range of 3.38 pH to 8.1 pH and 2.85 pH to 8.48 pH for node 1 and node 2, respectively. The river water of node 1 was usually more than pH 7 while the river water of node 2 is usually less than pH 6. This indicated that the river water at the entrance where it started to flow in the IIUM campus was alkali and as it was about to leave the IIUM campus was slightly inclined to acidic. The ideal pH level for a river is about 7.4. This shows that the river water is already less than it should be when it started to flow on the IIUM campus. Based on the daily average of pH obtained, it can be said that something was happening between node 1 and node 2. The drops in pH throughout the monitoring could be due to carbon dioxide. Respiration of aquatic living may contribute to the carbon dioxide level in the water which causes the water to become acidic. During Peak 1 and Peak 2, the pH was basic that could be due to limestone as limestone is widely found in Malaysia especially in a river however the alkalinity level is still acceptable as it was no more than pH of 9. The unanticipated drop of pH at Trough 1 could be caused by acidic chemicals spilled before it started to flow in the IIUM campus. On November 29, the sudden decline at Trough 2 of pH for both node 1 and node 2 could be caused by the acidic rain. For the rain to be classified as acidic it must be in the range of pH between 1.5 to 5.5. This acidic rain had possibly affected the pH level by lowering the reading. Acidic rain affects the aquatic life by jeopardizing the ecosystem of the river. Aquatic species, insects, plants, and microorganisms are sensitive to the rapid changes of acid and will decrease in population that will eventually cause an extinction while moss and algae will breed even more in the acidic condition Excessive amount of algae will clog water intakes. Some fish cannot survive rapid changes in acidity of the river due to aluminum poisoning and as for frogs, they will have problem to breed. The rapid rise in pH at Peak 3 was possibly because of the presence of phosphates. The overall changes between node 1 and node 2 were perhaps caused by acidic domestic wastes dumping or leakage in water tanks in the IIUM campus that may contribute to the increase of the river acidity.

Temperature parameter. Aquatic organisms can only live in a certain range of temperature. Too high in temperature will cause the river to have less oxygen that affects the breathing of aquatic organisms. The temperature daily average is quantified as in Figure 7. The daily average temperature of the river between node 1 and node 2 is almost consistent throughout the monitoring period however, there is some spike happening in temperature in some days that occurred between December 11 to December 21, 2020. The daily average temperature for node 1 and 2 are between 26°C to 34°C and 22.65°C to 41°C, respectively. Healthy river water can never be more than 40 °C to be at an acceptable range. The temperature of the river was generally higher during the days and lower at night. Based on the results obtained, the spike in temperature between December 10–December 14, 2020, which was during Peak 1 and Peak 2 may be due to the spill of waste or chemicals that caused a temperature rise. Waste or chemical spill is acidic that might affect the temperature of the river. It is important to know the changes in temperature because it will decide which organisms get to live. During the temperature spike, bacteria died as the temperature (41°C) was more than 35°C that directly affected the increase in ammonia spike. The spike affected the aquatic living by burning the gills of the fish and as for algae, they were affected as well as algae could only live between 20–35°C. Trough 1 (between Peak 1 and 2) was probably due to the heavy rain that occurred on that day which contributed to the decline of the pH value.

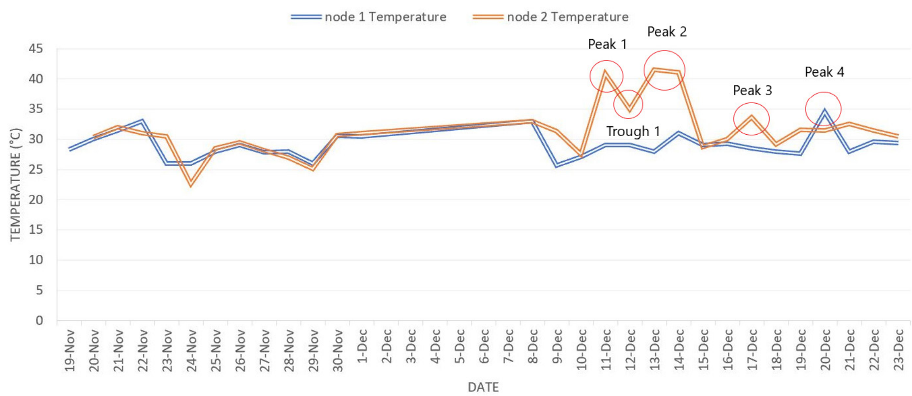

Fig. 7. Daily average of temperature

The difference in temperature on November 23, December 16–December 19, and December 21 which was during Peak 3 could be due to shallow water. This shallow water is affected especially on sunny days due to solar absorption. Based on the graph, it is known to be a sunny day as the average temperature of those days were above 31°C. When the river first entered node 1, the river had quite a lot of shading as many trees around them but as it flowed through the IIUM campus, it was more open where it was more exposed to sunlight. On December 21, which was during Peak 4, the temperature of node 1 is higher compared to node 2, this could be due to the river water from upstream tributaries. When the upstream water was more exposed to the sun, the temperature went higher so as it flowed through the IIUM campus, it was less exposed compared to the upstream which resulted in a decrease in temperature on that day.

Turbidity parameter. The turbidity parameter is important to indicate the cloudiness of the river. Generally seen, Sungai Pusu seems cloudy and it is a vital sign for us to find out the value of the turbidity. High turbidity will affect the temperature of the river as the small particles absorb the light which causes a temperature rise and eventually affect the aquatic organisms. The turbidity of the river, shown in Figure 8, fluctuated throughout the monitoring period. It can be noted that the turbidity of node 1 spiked between November 15 to November 22, 2020. This could be due to the heavy rain that was occurring on that duration. The turbidity daily average range was between 0.58 NTU to 6.48 NTU and 0.26 NTU to 4.95 NTU for node 1 and node 2, respectively.

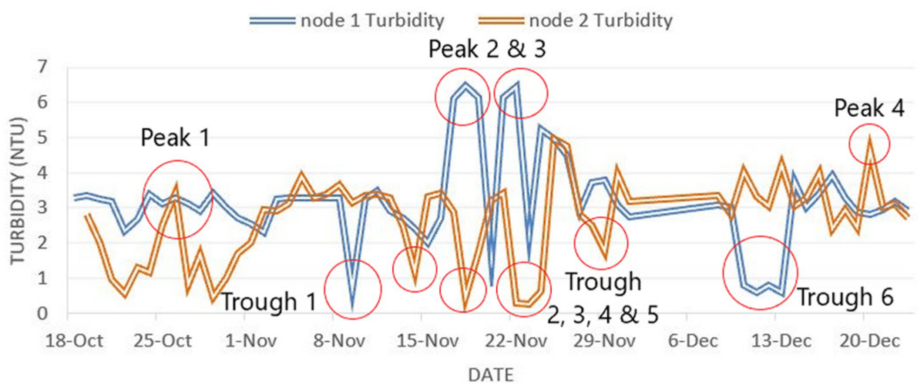

Fig. 8. Daily average of turbidity

Generally, the river was clearer when it had lesser NTU reading which when it was sunny, and it higher NTU reading when the day was rainy. Based on the data, Peak 1 and Peak 4 occurred probably due to soil that was mixed up with the particles that made the turbidity high. The sudden dip at Trough 1 was perhaps they were fewer particles and was not experiencing any soil erosion before it entered the IIUM campus. Peak 2 and 3 showed that the river had probably flowed from a heavy rain condition as it was the rainy season during that time. When it was raining the particles from the soil surface were washed into the river and joined the preexistent particles which made the colour appeared even more cloudy (yellowish) during the spike. The sudden dips of 2, 3, 4, and 5 were probably because there was no soil erosion occurring as it flowed through the IIUM campus. The unforeseen drop of Trough 6 was probably because the river had flowed through areas that did not experience any rainfall before it flowed through the IIUM river. The unpredicted rise at Peak 4 was probably because it started to rain after it flowed through from node 1 to node 2.

4.3 Statistical analysis

Based on the data obtained, statistical data is formed. The overall statistical data can be summarized as shown in the Table 1 and Table 2 below.

Table 1. Statistical data of node 1

	Node 1		
	pH level (pH)	Temperature (°C)	Turbidity (NTU)
Average	7.05	29.29	3.21
Variance	1.18	4.67	1.84
Standard deviation	1.08	2.16	1.36
Variance coefficient	0.15	0.07	0.42

Table 2. Statistical data of node 2

	Node 2		
	pH level (pH)	Temperature (°C)	Turbidity (NTU)
Average	5.73	31.58	2.77
Variance	0.53	14.17	1.29
Standard deviation	0.73	3.76	1.15
Variance coefficient	0.13	0.12	0.42

pH parameter. The overall pH average of node 1 is higher than the overall pH average of node 2. This means the water turned acidic as it flowed through the IIUM campus. The acidification of water could be due to a few reasons and that include organic acids. The variance of the pH of node 1 is bigger than the variance of pH of node 2, this means the data value of pH at the first node is more spread out compared to the second node however the variance coefficient of pH for both node 1 and 2 are relatively low because they are all less than one. Based on the statistical data obtained, it can be concluded that the river pH level range (5.73–7.05 pH) is safe to be inhabited by the aquatic organisms like bacteria, algae and fish can live within the pH range calculated, however, if the pH level continues to decrease, it will affect the aquatic organisms hence actions like adding limestone in the river to increase the pH level can be done.

Temperature parameter. The overall temperature average of node 2 is higher than the overall temperature average of node 1. The river water had increased in temperature by 2.29°C. The rise in water temperature could be due to acidification of the river that has been mentioned in the previous subsection. The data temperature of node 2 is more spread out than node 1 as the node has a higher temperature variance compared to node 1. Bacteria can live up to 35°C, algae can live within 20°C–35°C, and fish can live within 27°C–30°C. By producing the statistical range of temperature (29.29°C–31.58°C), it can be said the river is safe to live by both bacteria and algae however it is an alarming sign that fish may not survive the sudden change of temperature.

Turbidity parameter. The average turbidity of the first node is higher than the turbidity of the second node. This means the river water was getting clearer (less cloudy) as it flowed from node 1 to node 2 as it is decreased by 0.44 NTU. The turbidity of node 1 is more spread out compared to the turbidity of node 2. The acceptable value of turbidity of a river is less than 10 NTU. Therefore, the Sungai Pusu River has an acceptable reading of turbidity. Even though the variance coefficient turbidity of node 1 and node 2 are the same, node 1 is cloudier as it has higher average turbidity. The statistical data of turbidity indicates that the river's turbidity can support the aquatic organisms because the range of turbidity is considered safe. This is also a good sign as the algae are just enough to feed the aquatic organisms which means it is not dominant that could be harmful to the aquatic life.

4.4 IIUM Gombak community's contribution to Sungai Pusu river

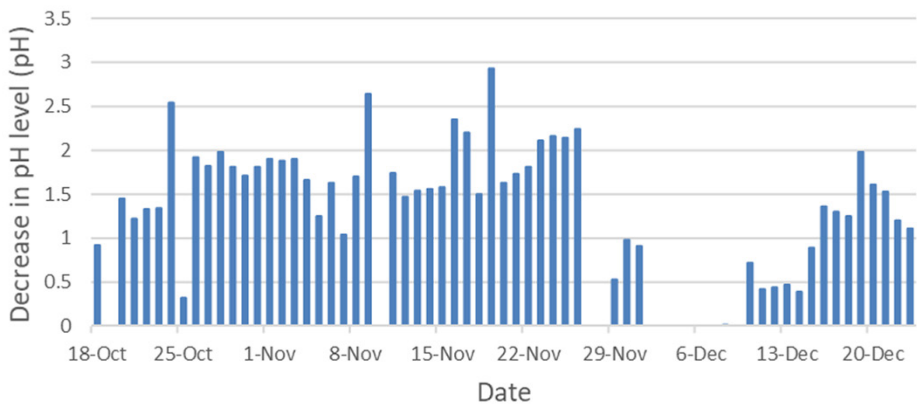

Fig. 9. Daily increase in acidity

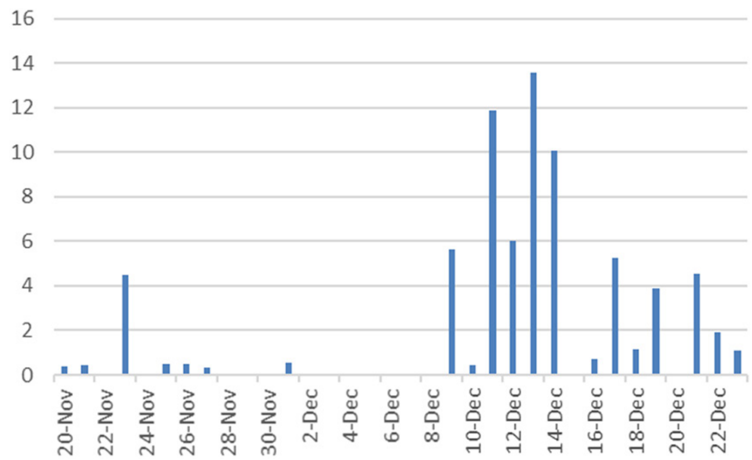

Fig. 10. Daily increase in temperature

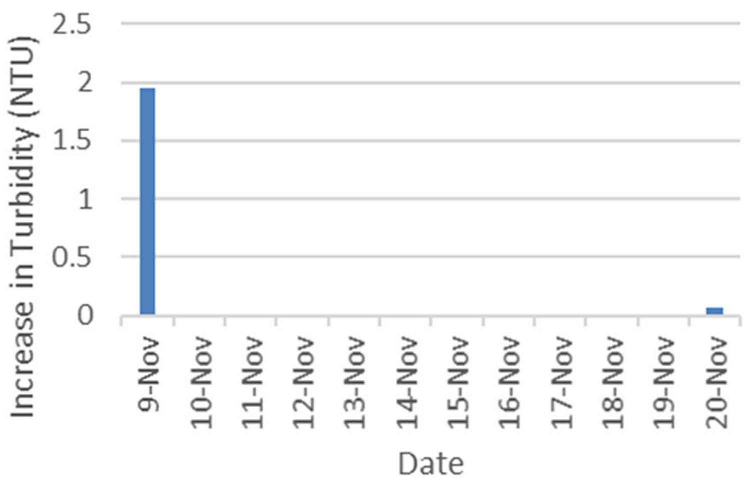

Fig. 11. Daily increase in turbidity

The three figures (Figures 9, 10 and 11) above show that before the river flowed through node 1 it had a certain value of parameters and when it was about to leave the IIUM campus, the value of the parameters decreased for pH level and increased for the temperature and turbidity. The decrease in pH indicates that the water became acidic as it flowed through the IIUM campus. These changes indicate the contribution of the IIUM community to the pollution of Sungai Pusu. An increase in temperature indicates that the river water had gone through a polluted area and worsening the turbidity possibly because it had experienced soil erosion during the trip from node 1 to node 2.

Based on the charts above, all these changes in parameters occurred inside the IIUM campus. This means the pollution was internally contaminated either a natural cause or a man-made cause. The changes in readings indicate that perhaps it was polluted by some irresponsible bodies or individuals among the IIUM community. Since the river flowed through a lot of canteens, it could be the dumping of gray water into the river that caused the changes in the readings of the parameter. The highest decrease in pH throughout the monitoring was 2.93 pH on November 19, followed by 2.64 pH and 2.54 pH on November 9 and October 24, respectively. The highest increase in temperature and turbidity was 13.57°C on December 13 and 1.95 on November 9. The sudden changes throughout the monitoring period could be due to waste dumping internally. Waste dumping usually contains dangerous and harmful substances that could affect the death of aquatic life. It will not only increase the turbidity reading but will also increase the temperature reading as well as affecting the pH level of the river. As discussed previously, aquatic microorganisms, plants, species can only live in a certain range of the parameters hence sudden changes will affect their habitat which will eventually cause in loss of the balanced ecosystem.

4.5 IIUM contribution to better river water quality of Sungai Pusu

The three figures above (Figures 12, 13, and 14) show that the daily decrease of parameters as it flowed through the IIUM Gombak campus. The river was highly polluted before it started to enter the IIUM campus, and as it flowed through the campus, the readings of the parameters have changed to better reading. The highly polluted water could come from the upstream settlements and villages dumping their gray water. Besides, construction is currently ongoing nearby the river, this could be the contribution to the high pollution of the river water before it started to flow in the campus. One of the ways that construction companies could have contributed to the river is by digging the soil that caused soil erosion and affected not just the aesthetic appearance of the river but as well as the temperature and the acidity of the river. Dumping construction materials could also have been the cause of the increase in river water pollution. It could also possibly irresponsible individuals who sneak up upstream of the river and throw waste into the river. The sudden changes have affected aquatic life the most including insects, plants, microorganisms, fish, and the life nearby the river like frogs. However, as it passed through the IIUM campus, the water became better as the readings were showing the river water has improved.

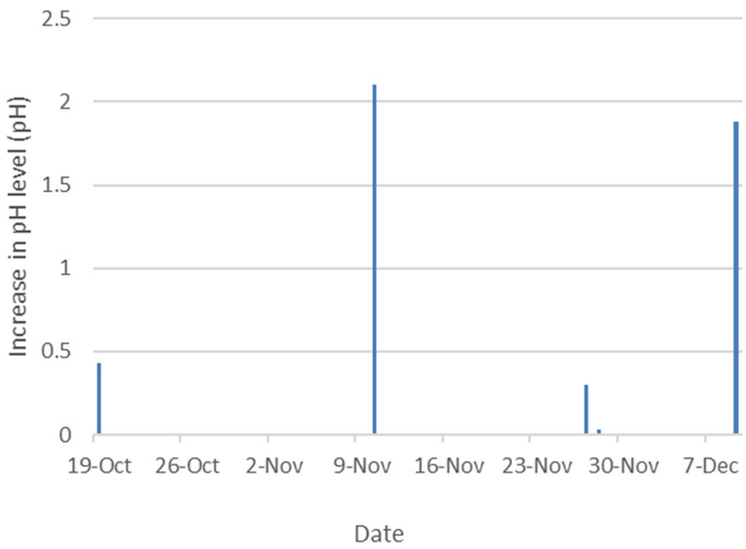

Fig. 12. Daily increase in alkalinity

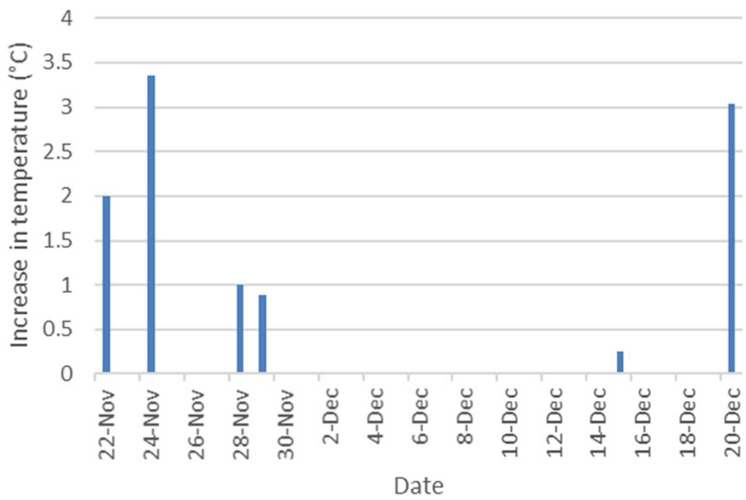

Fig. 13. Daily decrease in temperature

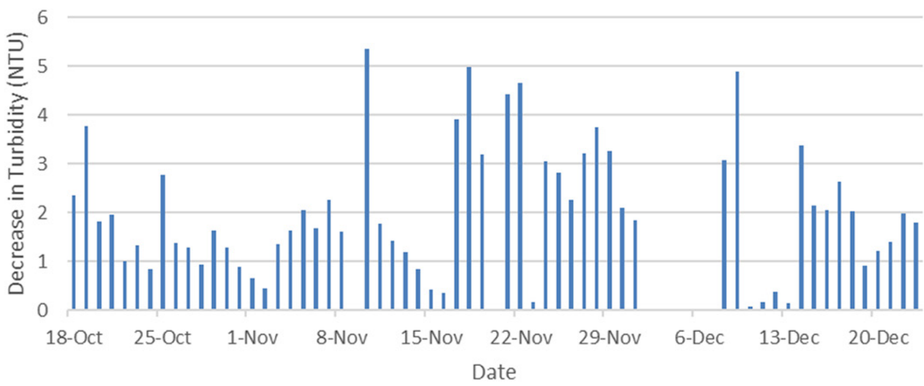

Fig. 14. Daily decrease in turbidity

This is because the water volume had become more and averaged the changes of the polluted water and mitigated out. The highest decrease in acidity, temperature, and turbidity was 1.88 pH on December 9, 3.35°C on November 24, and 5.36 NTU on November 10. The decrease of acidity in pH would help the fish life to be in a better condition as it is within the acceptable range. However sudden changes will affect fish the most as they are sensitive to changes in pH level. High acidity or alkalinity causes the death of fish as it burns the gills and the skin of the fish.

4.6 Raising awareness for greater Gombak

By doing this analysis the condition of the river has been noted in terms of the parameters that are pH, temperature, and turbidity. Without this project, no one would have known how much individuals or bodies do have contributed to the pollution of the river. The purpose of raising the awareness is to have a community that is aware of their mother Earth and that includes every nature around them especially IIUM Sungai Pusu river. It is a must for people to understand how important a river is to humankind, ecosystem and how it balances the cycle of life. The river is a living source for all living things. River water has been used for drinking water food sources, aquatic habitat, farming, fishing, and many more. The river carries water and nutrients all around the Earth.

5 Conclusion

In this work, a river emergency vital signs (EVSs) monitoring system using LoRaWAN has been developed. The developed monitoring system can monitor several physical streams such as the pH level, turbidity and temperature of the river. The feature of this system is the long range advantage given by LoRaWAN radios and the real-time data availability. Results demonstrated that the river can be monitored in real-time for a long periods of time while the deterioration in Sungai Pusu EVSs, caused by the IIUM community, can be quantified. As the river flows from river entry node 1 to river exit node 2, the pH decreased by 1.32 pH, the temperature increased by 2.29°C, and turbidity decreased by 0.44 NTU on average throughout the monitoring period. The monitoring period has been greatly affected by movement restrictions due to COVID-19 pandemic but the results still demonstrate a community-contributed deterioration in the river EVSs.

6 Acknowledgement

This work is partially sponsored by IIUM Publication Research Initiative Grant Scheme P-RIGS18-003-0003.

7 References

[1] M. A. Ertürk, M. A. Aydın, M. T. Büyükakkaşlar, and H. Evirgen, "A Survey on LoRaWAN Architecture, Protocol and Technologies," *Futur. Internet*, vol. 11, no. 10, p. 216, 2019, https://doi.org/10.3390/fi11100216

[2] U. Farooq, "Wireless Sensor Network Challenges and Solutions Android Operating System Architecture View project Wireless Sensor Network Challenges and Solutions," no. February, pp. 1–6, 2019, 10.13140/RG.2.2.22191.59043

[3] J. M. Marais, R. Malekian, and A. M. Abu-Mahfouz, "LoRa and LoRaWAN testbeds: A review," *2017 IEEE AFRICON Sci. Technol. Innov. Africa, AFRICON 2017*, pp. 1496–1501, 2017, https://doi.org/10.1109/AFRCON.2017.8095703

[4] T. M. Workgroup, "A Technical Overview of LoRa® and LoRaWAN TM What is it?," no. November, 2015.

[5] Di. M. Ibrahim, "Internet of Things Technology based on LoRaWAN Revolution," *2019 10th Int. Conf. Inf. Commun. Syst. ICICS 2019*, no. June, pp. 234–237, 2019, https://doi.org/10.1109/IACS.2019.8809176

[6] "LoRaWAN Range, Part 1: The Most Important Factors for a Good LoRaWAN Signal Range (Updated) – Industrial IoT Solutions – SmartMakers." [Online]. Available: https://smartmakers.io/en/lorawan-range-part-1-the-most-important-factors-for-a-good-lorawan-signal-range/. [Accessed: 04-Jun-2020].

[7] D. Ahmad and A. Kumar, "IOT Based Smart River Monitoring System," *Int. J. Adv. Res. Ideas Innov. Technol.*, vol. 4, no. 2, pp. 60–64, 2018.

[8] M. S. U. Chowdury et al., "IoT Based Real-Time River Water Quality Monitoring System," *Procedia Comput. Sci.*, vol. 155, pp. 161–168, 2019, https://doi.org/10.1016/j.procs.2019.08.025

[9] G. V. Vinod, A. V. Peter, I. S. Rao, S. Sailaja, and Y. S. N. Babu, "IoT Based Water Quality Monitoring System using WSN," *Indian J. Public Heal. Res. Dev.*, vol. 9, no. 12, pp. 1575–1578, 2018, https://doi.org/10.5958/0976-5506.2018.02082.X

[10] J. Schneider, L. E. Schultz, S. Mancha, E. Hicks, and R. N. Smith, "Development of a Portable Water Quality Sensor for River Monitoring from Small Rafts," *Ocean. 2016 MTS/IEEE Monterey, OCE 2016*, pp. 1–10, https://doi.org/10.1109/OCEANS.2016.7761392

[11] R. Sulistyowati, A. Suryowinoto, A. Fahruzi, and M. Faisal, "Prototype of the Monitoring System and Prevention of River Water Pollution Based on Android," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 462, no. 1, 2019, https://doi.org/10.1088/1757-899X/462/1/012028

[12] E. A. Kadir, H. Irie, and S. L. Rosa, "River Water Pollution Monitoring using Multiple Sensor System of WSNs (Case: Siak River, Indonesia)," pp. 75–79, 2020, https://doi.org/10.23919/EECSI48112.2019.8976991

[13] F. A. Aziz, M. Sarosa, and E. Rohadi, "Monitoring System Water pH Rate, Turbidity, and Temperature of River Water," *IOP Conf. Ser. Mater. Sci. Eng.*, vol. 732, p. 012106, 2020, https://doi.org/10.1088/1757-899X/732/1/012106

[14] S. F. Ismail and H. A. Mohammed, "Design and Implementation of Remotely Tigris River Water Monitoring System in Baghdad," *Int. J. Eng. Technol.*, vol. 7, no. 4, pp. 2784–2788, 2018, https://doi.org/10.14419/ijet.v7i4.16699

[15] B. Das and P. C. Jain, "Real-time Water Quality Monitoring System using Internet of Things," *2017 Int. Conf. Comput. Commun. Electron. COMPTELIX 2017*, pp. 78–82, 2017, https://doi.org/10.1109/COMPTELIX.2017.8003942

[16] N. A. Cloete, R. Malekian, and L. Nair, "Design of Smart Sensors for Real-Time Water Quality Monitoring," *IEEE Access*, vol. 4, pp. 3975–3990, 2016, https://doi.org/10.1109/ACCESS.2016.2592958

[17] C. Z. Myint, L. Gopal, and Y. L. Aung, "WSN-Based Reconfigurable Water Quality Monitoring System in IoT Environment," *ECTI-CON 2017–2017 14th Int. Conf. Electr. Eng. Comput. Telecommun. Inf. Technol.*, pp. 741–744, 2017, https://doi.org/10.1109/ECTICon.2017.8096345

[18] N. S. Kosnin, S. F. Y. Hasan, M. H. Habaebi and M. R. Islam, "Sungai Pusu River Emergency Vital Signs Monitoring Using LoRaWAN," 2021 8th International Conference on Computer and Communication Engineering (ICCCE), 2021, pp. 49–52, https://doi.org/10.1109/ICCCE50029.2021.9467252

[19] "Mendapan Asid." [Online]. Available: https://www.met.gov.my/pendidikan/sainsatmosfera/mendapanasid. [Accessed: 09-Feb-2021].

[20] Fouzi Lezzar, Djamel Benmerzoug, Ilham Kitouni, "IoT for Monitoring and Control of Water Quality Parameters," International Journal of Interactive Mobile Technology (iJIM), vol. 14, no. 16, pp. 4–19, 2020, https://doi.org/10.3991/ijim.v14i16.15783

[21] Jinfeng Li, Shun Cao, "A Low-Cost Wireless Water Quality Auto-Monitoring System", International Journal of Online and Biomedical Engineering (iJOE), vol. 11, no. 3, pp. 37–41, 2015, https://doi.org/10.3991/ijoe.v11i3.4488

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Article submitted 2022-02-10. Resubmitted 2022-06-13. Final acceptance 2022-06-25. Final version published as submitted by the authors.