SNSP-3

by Evizal Abdul Kadir

Submission date: 29-Sep-2019 11:58PM (UTC+0800)
Submission ID: 1182230844
File name: SNSP_2019_revise_v.1.docx (1.93M)
Word count: 4429
Character count: 23199

Remote Monitoring of River Water Pollution Using Multiple Sensor System of WSNs and IoT

Evizal Abdul Kadir
Department of Informatics Engineering
Universitas Islam Riau
Pekanbaru, Indonesia 28284
evizal@eng.uir.ac.id

Hitoshi Irie
Center for Environmental Remote Sensing (CEReS)
Chiba University, Chiba, Japan
hitoshi.irie@chiba-u.jp

Sri Listia Rosa
Department of Informatics Engineering
Universitas Islam Riau
Pekanbaru, Indonesia 28284
srilistiarosa@eng.uir.ac.id

Bahruddin Saad
Fundamental Applied Science Dept.
Universiti Teknologi Petronas
Seri Iskandar, Perak, Malaysia 32610
bahruddin.saad@utp.edu.my

Sharul Kamal Abdul Rahim
Wireless Communication Centre
Universiti Teknologi Malaysia
Johor Bahru, Johor, Malaysia 81310
sharulkamal@fke.utm.my

Mahmod Othman
Fundamental Applied Science Dept.
Universiti Teknologi Petronas
Seri Iskandar, Perak, Malaysia 32610
mahmod.othman@utp.edu.my

Corresponding author
evizal@eng.uir.ac.id

Abstract — The river is a natural phenomenon that commonly available in the tropical region because of rain intensity. Many peoples and community like to live along the riverside for a few decades ago. The river has a significant role by the community for transportation and daily activities use river water. This research aim to design and develop system with multiple sensor to monitor river water pollution because most of the community use river water in daily activities. In this design and development of system, Wireless Sensor Networks (WSNs) applied because of the advantages, multiple sensor nodes installed for detection of water pollution such as temperature, Electrical Conductivity (EC), pH and Dissolved Oxygen (DO). The system designed to monitor river water pollution parameters and send the information to the data center (backend system). Arduino microcontroller used to process and filtering the data before sending to the backend system, only valid information to collect and keep in the database. Results show system be able to detect polluted water with indicating parameters and shows in a graph. Based on analysis can be concluded that polluted water indicator mostly from residence waste and industry. Furthermore, WSNs sensors will deploy in some of area then compare the results each other as well as use Internet of Things (IoT) technology for data sharing and communication.

Keywords—Multiple sensor, WSNs, River water, Pollution, Monitoring

I. Introduction

Water pollution is one of the issues has been raised in some of the areas in Indonesia. This research take case in Siak River located in Riau Province because of the issue of polluted river occur since a few years and until now not yet have a significant solution by the respective authority. Riau province is located in central of Sumatera Island in Indonesia, this province has 5 rives known long and deep river, as well as one of the rivers as the deepest among river in Indonesia. Along the Siak rivers, many companies are operating and the big company is pulp and paper beside other small companies. Sometimes the companies emit the pollution to the river then makes river contaminate with pollution. Contaminate river water may come various of caused such as industries waste, chemical spill, community and residence waste then because of flooding and others disaster might be polluted to the river. This research aims to do a monitoring system with 4 basics sensing system which temperature, dissolved oxygen (DO), pH, and electrical conductivity.

The conventional technique to measure quality of water did by several method as discussed in [1-4]. The method can collect information to the water quality than test in the laboratory including biological, chemical contents and physical of the water. Normally very hard to differentiate and do the measure along the river but some sample to the point can be done. Real-time water quality monitoring system using WSNs are popular in recent year because of the advantages of technology to collect data and information through the sensor node. The requirement for continuous data monitoring for water quality in a real-time system to establish the trend and predict to determine behavior from the history as discussed in [5-9].

A biological sensing system for detection water quality is a method to detect bacteria using a computer vision system in analysis, the water pollutant with chemical contamination be able to analysis as discussed in [10-12]. The use of multi-sensor for the water pollutant detection system for the basic parameter with the limit to a few parameters, the use of localhost for collection of the data to monitoring system has limited access as elaborated [13-16]. Image processing contributed to the remote sensor in analyzing and monitoring with long-distance of water quality. In the previous research, the maximum distance is 10 meters used image analysis [17, 18]. In the deep-

water or river, the use of the robotic system for water quality detection system has the advantages. Another scenario is in the ocean with the aid of mobile communication assist in the detection of water quality but the cost may concern. Others research conducted uses the method for polluted water detection but ineffective way to the permanent system, furthermore the case of the area as discussed in [19-22].

In this research propose a new method to detect water quality by analysis the samples, the analysis can be done either water quality or polluted water. Multiple sensors propose to achieve a better analysis of data by compare value of detection in each sensor. The basic parameter propose are temperature, pH, electrical conductivity and DO. The research gain in this method for knowledge and invention to a technique for polluted river monitoring and collect all the information from the sensing system as well as a new design of sensors. Propose model of data transfer system between WSNs nodes to a node sink for smooth data communication is a part of the objective in this work. This case of research at one of the long and deep rivers in Riau Province, Indonesia which is Siak River.

II. Multiple Sensor System of WSNs

The proposed design multiple sensor systems for water quality monitoring using WSNs based on a case study at Siak river in Riau Province Indonesia. The river is very long with more than 200 km along to the end at the seaside, most of community and rural resident lives on the riverside and doing daily activities use river water. According to a preliminary survey on the river and study on geographic on the river then come out with the design of the sensing system for detection of the river. Figure 1 shows a type of geographic of Siak river located in Riau Province, Indonesia. The river compact with the residence of community in some of the area then highly polluted into river water from the housing waste as well as unhealthy community residence. Furthermore, in the raining season become worst because some of the area flooding and all of the rubbish and waste go into the river through the canal.

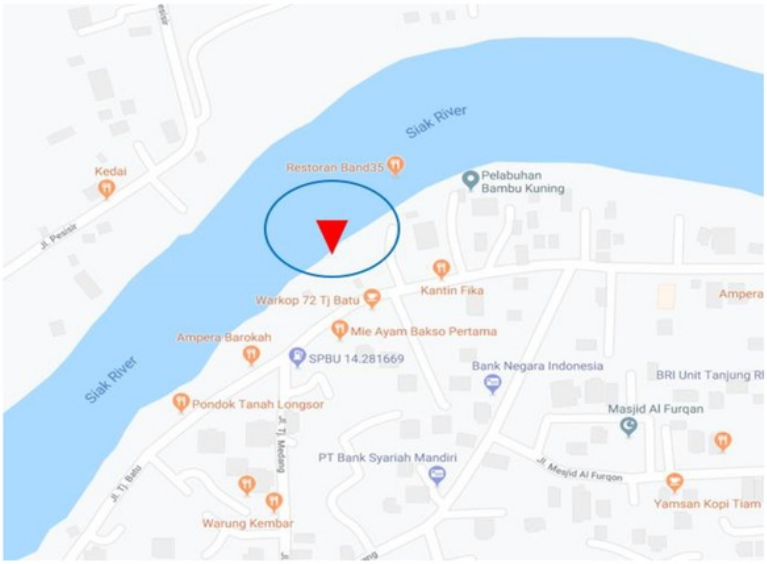

Fig. 1. A scene of Siak river and the testing location

Based on the early survey the actual condition of the river and water is highly polluted water with various contamination because the river is not only for the residents live along the riverside but more than that is for transportation, many vessel, and wooden ship through the river with carrying various material including people which high-speed boat. Furthermore, many companies operating along the river as well because of easy transportation and water supply, some of the company spilled the chemical waste and material to the river. In figure 2 shows a scene of polluted river water indicated by water color and contain of various material and chemical. Based on the early survey and visual observation then multi-sensors is required for detection water contamination and analysis to determine of chemical contained in the river. River water collected as a sample to analysis and results shows many materials contaminated in the water then to decide the type of sensors need to install to the system for detection such as temperature, DO, pH and electrical conductivity as well as other parameters possibility for the future.

Fig. 2. Actual scene of Siak river in Riau, Indonesia

Multiple sensors system design into four parameters for detection of river water pollutant index, the detection results of all sensor analyzed and determine the polluted water contain. A complete diagram block of WSNs system for water detection as shows in figure 3. Which Arduino Uno used as sensor signal conditioning, then Raspberry Pi 3 for Microcontroller Unit (MCU) as data processing and Radio Frequency (RF) transceiver Texas Instrument module CC1310 for RF communication among sensor nodes. In the last step of system block diagram an antenna to transmit the signal and information to the other sensor node and send the information to the data center. The complete expected indicator of measurement and range of the results in the unit as well as the accuracy shows in the table 1.

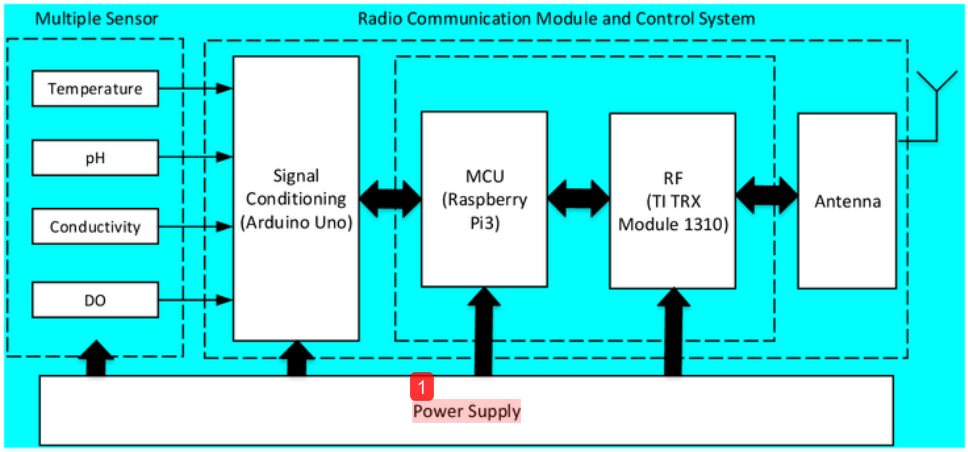

Fig. 3. Block diagram of multiple sensor system

Table 1. Design Specification of the multiple sensor system

Parameter	Range	Accuracy	Method
pH	0 to 14	± 0.1	Glass Electrode
Temperature	0 to 16 ° C	± 0.5 ° C	Thermistor
DO	0 to 20 mg/L	± 0.5 mg/L	Polarography
Electrical Conductivity	0 to 50	± 0.5	Conductivity Measurement

III. System Design for Polluted Water Detection

Proposed design of the multiple sensing systems for polluted water used four parameters of the sensor as mention in early, every sensor contributed the data to collect and do the analyses in the system. To detect common polluted water in time then sensing system must deploy on the river at any time. Solar system is required for supply the power to the system because remote location with no electricity available. In this case a set of solar panel system with backup battery is provided base on the capacity of sensing system that have been tested. In the monitoring of polluted river water system, there are several external factor need to consideration such as environmental, whether, temperature, etc. Based on early testing some of parameter is increasing abnormal with exponential curve, this is because of some of sensing contact to the obstacle with contribute high polluted chemical but only in short time.

Design of multiple sensor use several model of sensing and one of it is used temperature sensor which contributed of thermistor product with non-linear parameter between temperature and internal resistance. The range of temperature sensor is from 0°C to 40°C. The scale of temperature is selected based on early measurement and average temperature of Siak river water as well environmental in Pekanbaru city in Riau Province. In common use the thermistor uses valid for high temperature which is more than 300°C, thus low range of temperature is better in detection in avoid counteracting the nonlinearity. The resistance of sensor be able to scaled using general formula as invented in Steinhart-Hart thermistor third order approximation can be write as in equation 1 [2]:

$$\frac{1}{T} = \mathrm{A} + \mathrm{B}\,.\ln(R) + C\,.\ (\ln(R))^3 \qquad (1)$$

While T indicate the temperature of water detected in degree kelvin and R is the measured resistance in Ohm. While the parameters of A, B, and C standard constants fabricate from the manufacturer, these parameters determine the reading of the sensor. When the sensor powered then induce a voltage across the thermistor at the fed point and go into an operational amplifier to gain and fine-tune the off-set signal. Value of voltage out from the sensor is in analog then must convert to digital to match with the WSNs system which used Arduino microcontroller. The value of thermistor internal resistance is depending on manufacturer, in common the resistance for room temperature for example 25°C with 20k ohm then the characteristics can write as in equation 2:

$$R_T = |R_0\,.\ e^{\beta.\ \frac{1}{T} - \frac{1}{T_0}} \qquad (2)$$

Where RT is the resistance of the thermistor at T and the temperature is in Kelvin. While the value of T_0 is 298.15°K (or 25°C) and the value of beta based on manufacturer datasheet and specification. Equation 3 used to calculate the temperature based on manufacturer datasheet as a comparison to the actual value detected in testing. The results of temperature based on the analysis used formula as equation 3 are required for the calibration of the temperature detected by the sensor.

$$T = \frac{\beta}{\ln\frac{R}{r_\infty}} \qquad (3)$$

Where:

$$r_\infty = R_0\,.\ e^{-\beta/T_0} \qquad (4)$$

A. Multiple Sensor System

The design of multiple sensors system has been done in a prototype as well as tested in the laboratory scale. Sensor for detection of river water pollutant as specification shows in table 1 is fabricated to connect to the microcontroller. Figure 4 shows the fabricated system and tested with a mini scale, results show the system able to read all the parameters of water contain then shows in the LCD display. Next step is to test the prototype after improving the casing according to the field at the riverside.

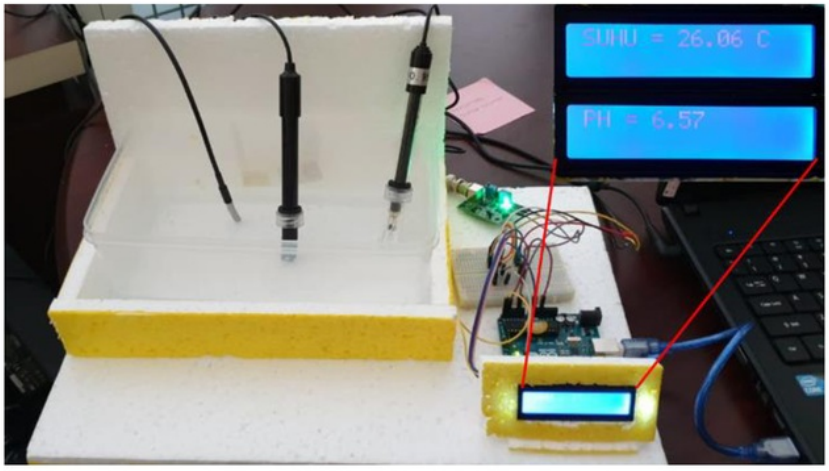

Fig. 4. Prototype of multiple sensors for detection water pollutant.

The testing has been done in the laboratory for a long time to check the performance of the system. Results show the reading in the various parameter of detection of polluted water gives accurate results to the calibration with the manual or conventional system. The used of multiple systems for detection is good because gives a various indicator of polluted water to analyze than the final result for determining of polluted water more accurate. Furthermore, introducing an intelligent system on microcontroller programming assist the accuracy of the decision on the results.

B. WSNs Sensing Commnication

Communication to the backend system is one of the requirement to pull data to the server and monitoring system. In actual condition sensor system located on the site which at the riverside and several sensors connected each other for data sharing and a system used as a gateway for communication to the backend system. Based on the survey the distance of site location more than 30 km to the backend system. Figure 5 shows a design of data transfer to the remote monitoring, every sensors node represented water pollutant sensing system has their individual sink for data collection and keep in site localhost before sending to the monitoring system. The proposed multiple sensing for water pollutant apply in 4G as a network for communicating from sink node to backend which is database or data center for faster transfer of data as well as real-time monitoring, which in the most of area currently have coverage by network in latest technology such as 4G.

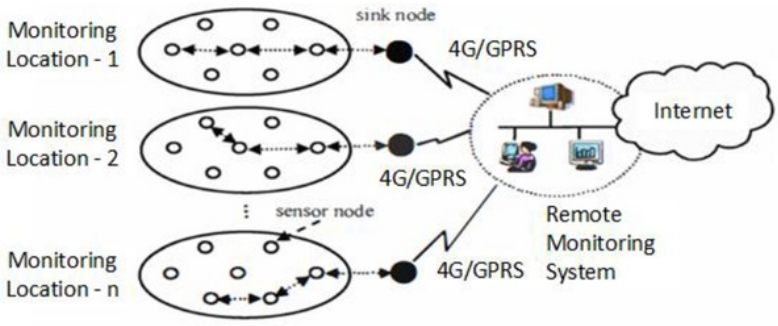

Fig. 5. WSNs nodes communication to sink node and monitoring system

The system design with real-time monitoring system thus detected data from the sensors mush be transfer immediately with low delay. A block diagram applied in this system for communication to the backend as shows in figure 6. While Fourth Generation (4G) technology or General Package Radio Services (GPRS) used then river water pollution data collected in an interval of time to minimize dumb and useless data that can be waste in local memory. Universal Asynchronous Receiver/Transmitter (UART) unit use as interface between MCU to the 4G communicaiton unit.

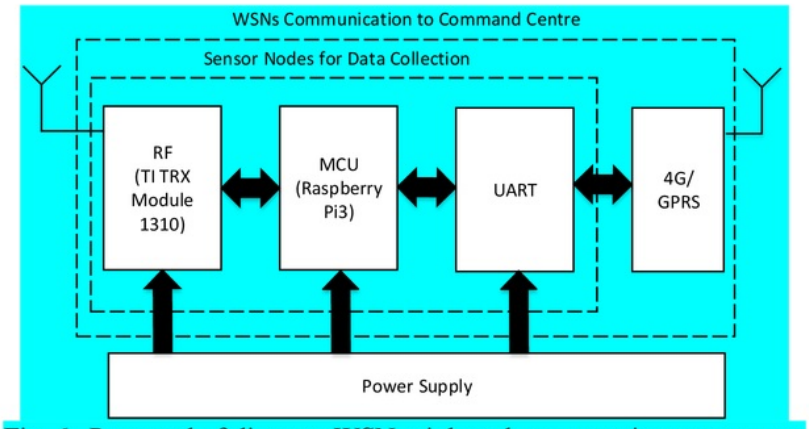

Fig. 6. Proposed of diagram WSNs sink node communicate to sensors

The design of multiple sensors system consists of four parameters which common indicator in polluted water but the sensor node for WSNs ability to serve sensing system up to fifty nodes or location in 10 of a sink node. The distance of sensing system node from a location to others according to site survey effectively not more than 500 meters because the longer distance between sensing system then the results is low accuracy because the river water flow is very high especially in raining season. The system supplied with independence power system from the solar panel because of some location very far away from the electrical utility. Figure 7 shows an actual scan of Siak River located in the capital of Riau Province. While a set of sensor under testing onsite to get the reading for analysis and calibration to the actual value. Many activities on the river create the pollution to the river and effected to the sensor reading. The polluted river water very hazardous to the community when consume or use it for daily activities.

Fig. 7. A set of sensor under testing to obtain the results

C. IoT System and Commnication

Internet of Things is a technology used as support in this case with integration to WSNs system, the design scenario of sensing system for effective communiation and data transfer in order to achieve good response of sensors in the location. Combination between WSNs ssytem and IoT proposed in this design for optimum data colletion from every sensors and keep in buffer memory in sink node of WSNs. Figure 8 shows a network architecture of IoT and WSNs integration.

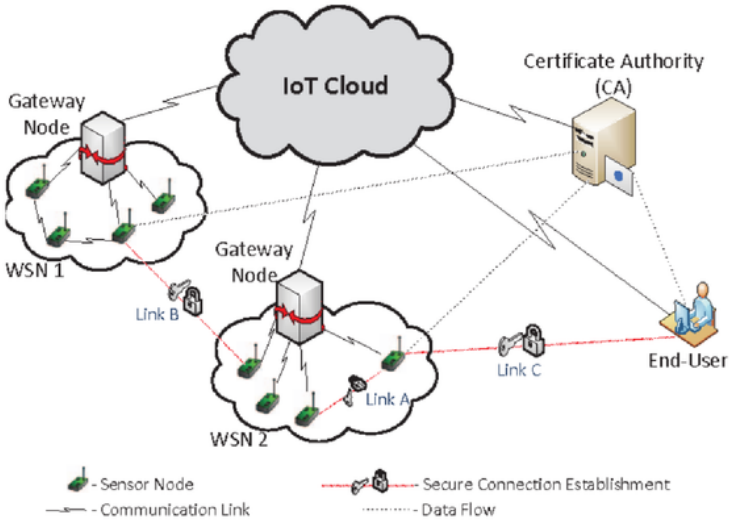

Fig. 8. An architecture of WSNs and IoT system integration.

Once the sensors collecting and store in memroy in sink node then follow by next process which is to provide usefull data information to IoT application. In addition, integration of WSNs and IoT can be as such properties.

- The placement of the sensor nodes of IoT and sink nodes WSNs is in static locations.
- Because of the sensor nodes location is fix then the distance of each sensor nodes and sink nodes can be determine by calculated as equation in (5).

$$dist = \sqrt{(x_1 - x_2)^2 + (y_1 - y_2)^2} \quad (5)$$

where $(x_1; y_1)$ is the location of the first node, and $(x_1; y_1)$ is the location of the second node. The distance calculated based on effective communication of WSNs node to transfer the data.

- The power of transmission for each sensor nodes set as required, although the distance is same but every sink nodes has different path loss and environemnatl effect.

IV. Simulation Results and Discussion

The results system based on in house testing which in the laboratory for several sensors such as temperature, water pH and electrical conductivity and do calibration to the manual (conventional) system which manually measured to the tested water. The preliminary testing is very important to make sure the reading of the sensing system is accurate to the actual condition. To do a comparison and some of the results from the sensors compare to other datasheet and literature in reference [2].

The results of this testing of temperature achieve reading in the sensing and comparison to the conventional measurement unit. Figure 9 shows the measurement of temperature by thermometer to compare to the temperature sensor setup in the sensing system. The rate of deviation between sensing system temperature to the reading of manual thermometer is very minimum which 0.071°C to 1°C in maximum.

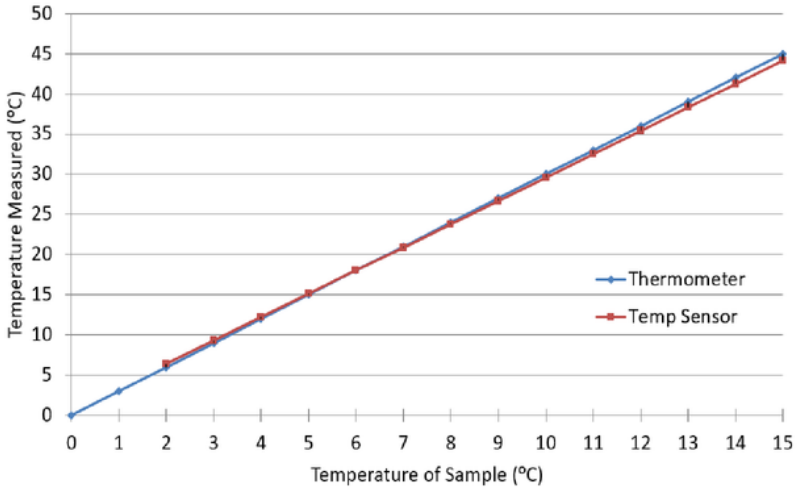

Fig. 9. The results of temperature sensing compare to thermometer

In the polluted water, electrical conductivity index is one of the indicators have to do a measurement to achieve complete water pollutant, based on the design with sensor occupied 2-electrode. Low error on results based on testing for the electrical conductivity is expected to get high accuracy in the determination of polluted water. Normally error rate for this measurement is not more than 15%, similar to other indicators of polluted water. In figure 10 shows testing results of comparison between reading of simulated electrical conductivity to the actual signal conditioning and have a similar trend for both of parameters result.

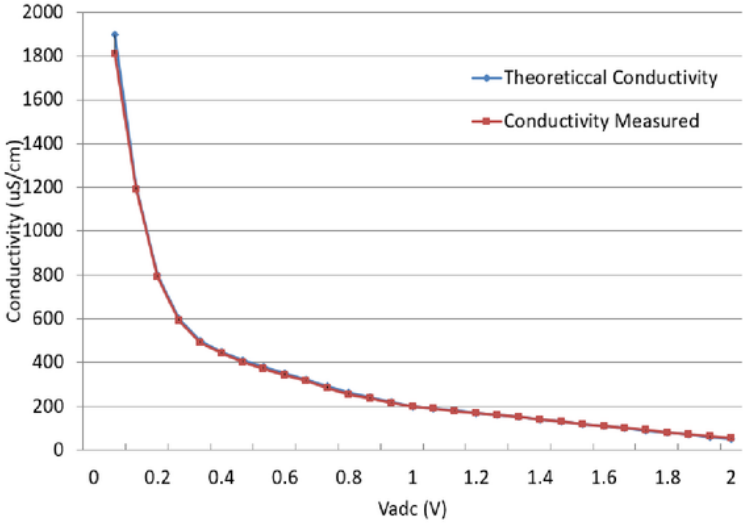

Fig. 10. Test results of the electrical conductivity of the sensor node

Another common indicator to measure water quality is water pH, this indicator is very important to determine polluted water. Sensing system for detection of water pH designed integrated to others sensor and measurement results analyze into the same microcontroller. Refer to the table, the specification of pH within the range from 0 to 14 with 0.1 accuracies. Figure 11 shows the results of measurement water pH theoretical analysis.

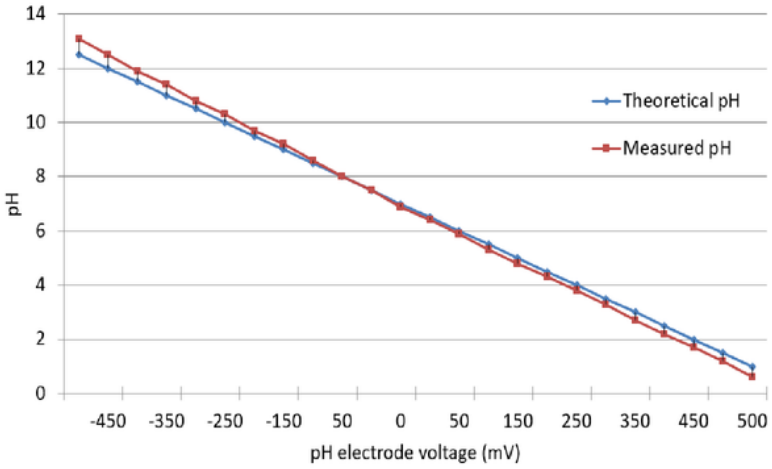

Fig. 11. Water pH test results versus theoritical analysis

According to the initial testing in the laboratory, all the sensor for good function and be able to detect water parameters as indicate then display the value to output in an LCD. Further action is required to install and to do testing at the actual site as the proposed system. The results expected to achieve high accuracy based on actual contain polluted water. Figure 12 shows the results of water flow meter between manual and sensing system.

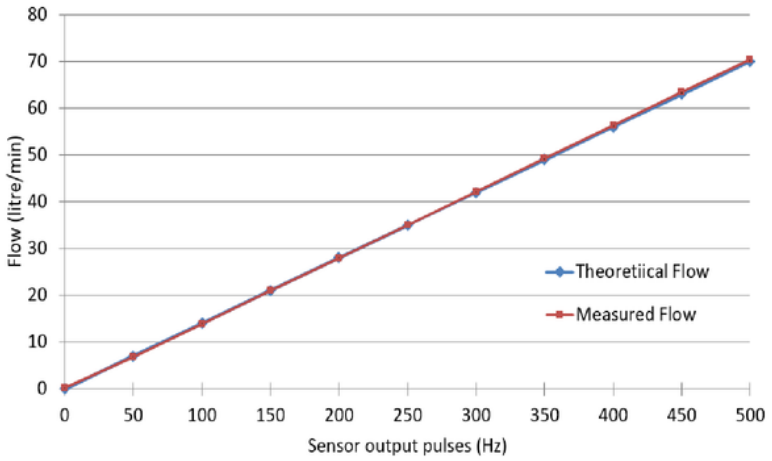

Fig. 12. Water Flow meter test versus theoritical analysis

According to the initial testing in the laboratory for all the parameters of the water, pollutant achieved good results between conventional measurement unit to the sensing systems. Thus the proposed system has a significant impact on the community and further step continue to test onsite

with real environmental. All the data in the real location of the river for water pollutant collected to analysis and compare to the other reading results. As the proposed design, the system uses both of WSNs and IoT technology apply in this monitoring, this integration in the location have different design according to the real environment and field on the location. Distance between sensing node is one of the consideration to the field to achieve good and representative reading of the sensing system.

V. Conclusion

Propose design of polluted water using multiple sensors have a design, fabricated and tested in mini scale which is laboratory as well as initial testing on the site. Results show good agreement between measured compared to analysis and manual (conventional) measurement. Four main indicators in sensing system such as water pH, temperature, DO and electrical conductivity is measured to determine and gives the decision on the quality of river water either polluted or not. The proposed system applied intelligent system as well in programming the microcontroller to achieve high accuracy in the final decision based on detected value. The results from the sensor reading is good agreement to the actual value in the water pollutant parameters. Further action to get a sensing system beneficially to the community then, a water level and flow are required to include into an integrated sensing system then warning for flooding can be implemented. In final, to make sensing system is smart then intelligent algorithm should apply into microcontroller programming because of various type of material and chemical flow into the water.

Acknowledgment

Appreciation to the Ministry of Research, Technology and Higher Education (KEMENRISTEKDIKTI) of Indonesia for funding this research project and Universitas Islam Riau, Indonesia to support the facilities as well as Chiba University, Japan, Universiti Teknologi Malaysia and Universiti Teknologi Petronas, Malaysia.

References

[1] Y. Guo *et al.*, "An Inversion-Based Fusion Method for Inland Water Remote Monitoring," *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing,* vol. 9, no. 12, pp. 5599-5611, 2016.

[2] 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.

[3] Y. Wang, S. M. S. M. Rajib, C. Collins, and B. Grieve, "Low-Cost Turbidity Sensor for Low-Power Wireless Monitoring of Fresh-Water Courses," *IEEE Sensors Journal,* vol. 18, no. 11, pp. 4689-4696, 2018.

[4] MarjolijnWoutersen *et al.*, "Development and Validation of an On-LineWater Toxicity Sensor with Immobilized Luminescent Bacteria for On-Line Surface Water Monitoring," *MDPI Sensor,* vol. 17, no. 2682, pp. 1-14, 2017.

[5] L. Y. Li, H. Jaafar, and N. H. Ramli, "Preliminary Study of Water Quality Monitoring Based on WSN Technology," in *2018 International Conference on Computational Approach in Smart Systems Design and Applications (ICASSDA)*, 2018, pp. 1-7.

[6] E. A. Kadir, S. L. Rosa, and A. Yulianti, "Application of WSNs for Detection Land and Forest Fire in Riau Province Indonesia," in *2018 International Conference on Electrical Engineering and Computer Science (ICECOS)*, 2018, pp. 25-28.

[7] G. Lockridge, B. Dzwonkowski, R. Nelson, and S. Powers, "Development of a Low-Cost Arduino-Based Sonde for Coastal Applications," *MDPI Sensor,* vol. 16, no. 528, pp. 1-16, 2016.

[8] T. Islam and Y. K. Lee, "A Two-Stage Localization Scheme with Partition Handling for Data Tagging in Underwater Acoustic Sensor Networks," *MDPI Sensor,* vol. 19, no. 2135, pp. 1-27, 2019.

[9] E. A. Kadir, A. Siswanto, S. L. Rosa, A. Syukur, H. Irie, and M. Othman, "Smart Sensor Node of WSNs for River Water Pollution Monitoring System," in *2019 International Conference on Advanced Communication Technologies and Networking (CommNet)*, 2019, pp. 1-5.

[10] F. Yuan, Y. Huang, X. Chen, and E. Cheng, "A Biological Sensor System Using Computer Vision for Water Quality Monitoring," *IEEE Access,* vol. 6, pp. 61535-61546, 2018.

[11] W.-C. Lin, K. Brondum, C. W. Monroe, and M. A. Burns, "MultifunctionalWater Sensors for pH, ORP, and Conductivity Using Only Microfabricated Platinum Electrodes," *MDPI Sensor,* vol. 17, no. 1655, pp. 1-9, 2017.

[12] Y. Lu, D. Macias, Z. S. Dean, N. R. Kreger, and P. K. Wong*, "A UAV-Mounted Whole Cell Biosensor System for Environmental Monitoring Applications," *IEEE Transactions on NanoBioscience,* vol. 14, no. 8, pp. 811-817, 2015.

[13] T. P. Lambrou, C. C. Anastasiou, C. G. Panayiotou, and M. M. Polycarpou, "A Low-Cost Sensor Network for Real-Time Monitoring and Contamination Detection in Drinking Water Distribution Systems," *IEEE Sensors Journal,* vol. 14, no. 8, pp. 2765-2772, 2014.

[14] J. Tian and Y. Wang, "A novel water pollution monitoring approach based on 3s technique," in *2010 International Conference on E-Health Networking Digital Ecosystems and Technologies (EDT)*, 2010, vol. 1, pp. 288-290.

[15] M. Grossi, R. Lazzarini, M. Lanzoni, A. Pompei, D. Matteuzzi, and B. Riccò, "A Portable Sensor With Disposable Electrodes for Water Bacterial Quality Assessment," *IEEE Sensors Journal,* vol. 13, no. 5, pp. 1775-1782, 2013.

[16] E. A. Kadir;, A. Efendi, and S. L. Rosa, "Application of LoRa WAN Sensor and IoT for Environmental Monitoring in Riau Province Indonesia," in *5th International Conference on Electrical Engineering, Computer Science and Informatics (EECSI 2018)*, Malang, 2018: IEEE.

[17] C. Doña, J. M. Sánchez, V. Caselles, J. A. Domínguez, and A. Camacho, "Empirical relationships for monitoring water quality of lakes and reservoirs through multispectral images," *IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing,* vol. 7, no. 5, pp. 1632-1641, 2014.

[18] S. Olatinwo and T.-H. Joubert, "Optimizing the Energy and Throughput of a Water-Quality Monitoring System," *Sensors,* vol. 18, no. 4, p. 1198, 2018.

[19] P. Teixidó, J. Gómez-Galán, F. Gómez-Bravo, T. Sánchez-Rodríguez, J. Alcina, and J. Aponte, "Low-Power Low-Cost Wireless Flood Sensor for Smart Home Systems," *Sensors,* vol. 18, no. 11, p. 3817, 2018.

[20] F. D. V. B. Luna, E. d. l. R. Aguilar, J. S. Naranjo, and J. G. Jagüey, "Robotic System for Automation of Water Quality Monitoring and Feeding in Aquaculture Shadehouse," *IEEE*

Transactions on Systems, Man, and Cybernetics: Systems, vol. 47, no. 7, pp. 1575-1589, 2017.

[21] Z. Wu, J. Liu, J. Yu, and H. Fang, "Development of a Novel Robotic Dolphin and Its Application to Water Quality Monitoring," *IEEE/ASME Transactions on Mechatronics,* vol. 22, no. 5, pp. 2130-2140, 2017.

[22] E. O'Connor, A. F. Smeaton, N. E. O'Connor, and F. Regan, "A Neural Network Approach to Smarter Sensor Networks for Water Quality Monitoring," *MDPI Sensor,* vol. 12, pp. 4605-4632, 2012.

SNSP-3

ORIGINALITY REPORT

4%	1%	4%	1%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Evizal Abdul Kadir, Apri Siswanto, Sri Listia Rosa, Abdul Syukur, Hitoshi Irie, Mahmod Othman. "Smart Sensor Node of WSNs for River Water Pollution Monitoring System", 2019 International Conference on Advanced Communication Technologies and Networking (CommNet), 2019 Publication	4%
2	repository.up.ac.za Internet Source	1%

Exclude quotes	On	Exclude matches	< 1%
Exclude bibliography	On		