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Submission date: 26-Dec-2022 10:14PM (UTC+0700)
Submission ID: 1986723189
File name: ICITACEE_v.3.pdf (5.24M)
Word count: 4535
Character count: 23583

Water Pollution Source Identification Based on Real-Time Monitoring System in Siak River

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***Abstract*—Water is a natural resource that is required for basic human life, the pollution of water become more serious in major sources such as in the river, sea, lake, etc. This research analyzed and identified the exact source of pollution sources, due to the length of the river and many industrial and other potential sources of pollution. A system of water pollution detection installed and deploy in measurement points along the river that potential to contribute to pollution especially surrounding industrial emit their chemical and wastewater. Data collected from the sensor analyzed use algorithm to find and check the abnorm and behavior data changing by the time. There 6 sets of detection systems deployed around the river, especially in the heavy residential and industrial areas. Due to the longest r r, this research only analyzed and identified the source of polluted water around the city of Pekanbaru which many people used the water including water supply companies. Location of sources pollution identified and the exact location found at the sensor node number 2 and 4 which indicated by abnormal reading data, various kind of material contained into river detected by the sensors system. To get the accuracy of the location due to many factors then improve the algori m by training data and doing many iterations as well as increasing data from the sensor and repeat for many times to determine the source coordinate as in the map.**

Keywords—water pollution, source identification sensor, algorithm, smart system, siak river

I. Introduction

Water is a basic need for living things in the world especially for human life, water also has the primary role of maintaining and sustainability the environment on the earth. The resource of water is originally from natural such as in the sea, river, lake or under the ground. In the recent decade, due to development and exploration by humans, many water resources got polluted and contaminated by chemical or damage of environmental then impacted to the water resources. Many efforts have been done to protect environmental and water resources but some areas or regions have difficulties due to rules and regulations given by authority or local government. As well as, many people are not responsible for damage to the environment by cutting the trees and illegal exploration so that they make the environment polluted. Indonesia is one of the tropical countries in the South East Asia Region which is rich in tropical trees and high intensity of rainfall. Riau Province has five big rivers and some others small or sub rivers scattering around the region. River water is one of the main sources of water supply in most houses and industries in Indonesia, especially the community that living surrounding the river. River is part of their daily life and most of the activities use rivers such as cleaning and washing, showering, fishing, transportation, etc. Recently the water got contaminated with the dangerous chemical to human health and need immediate action to prevent become worst.

Natural water is one of the basic needs for human life and other living things on earth, in the recent decade, the pollution water source became seriously damage the source due to the development of cities and others aspect from human activities. Installing of water quality monitoring system at source of water for example river, lake, or other sources needed to know the status of water quality [1]. The use of Water Distribution Network (WDN) in the identification and analysis of water contamination discussed two types of WDN in the analysis of a problem which are the transient state conditions and the steady. The use of WDN to achieve continuous water contamination as presented. An approach to estimate the magnitude of concentratio and the sources of water contamination applied [2]. The use of a multi-functional miniaturized to monitor Water Quality Monitoring System (WQMS) that consist of continuous monitoring of water quality as well as simultaneously used o the wireless communication system. The electrodes sensor integrated with polydimethylsiloxane flow channels were applied in the system as a basic compound sensor [3].

A machine-learning algorithm to identify water supply pollution sources is discussed in [4] while using a parallel processing system. The algorithm combining Artificial Neural Networks (ANN) to classify the water pollution sources by used analysis of Random Forests regression to determine the significance of variables a water contamination event for example start and end time as well as the concentration of the chemical contaminant. Furthermore, a two-stage inversion framework discussed for advance enhances the stability of LASSO to address inade e situ samples circumstance. With this framework, the two different schemes applied to handle the band arithmetic terms information propagation between the two stages, for which two new algorithms [5]. A method of coupling machine learning applied in solving of water contamination problem in water dist ution network supply, which are includes determination of the exact source of water contamination, start and end times of an event for every node individually. Two algorithmic in different meworks were constructed, both of algorithmic maximize the Random Forest algorithm for classification of the main source of water contamination in a node candidate, while another one of the frameworks used the stochastic fireworks optimization to determine the water contamination start and end time [6].

Method to identify water supply contamination source in a network based on an algorithm of random forest classifying used in this discussion [7-8]. The algorithm was tested in two kinds of different water benchmark distribution networks with different locations of sensor placement to achieve accurate data collection. In each network consider the number of contaminated amounts in random scenarios as well as random simulation parameters of water quality in time series.

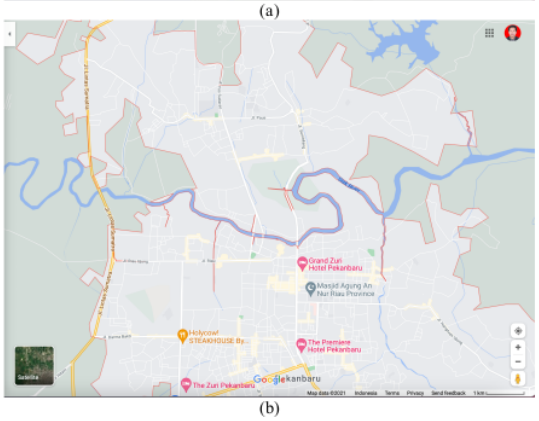
Identification of water source contamination used Genetic Algorithm (GA) as discussed, the first method to obtain the rough source of water contamination by release analyzing time to the double peak typical phenomenon in region and then presenting the rough position of water source by using Lagrange tracing scheme [9]. Calculation and measurement results show the correlation of the concentration at water contamination measurement point, high resolution, and mass optimization model applies to improve and the results and repeat several times alternatively. Another discussion on the use of GA to identify water pollutant sources in river water supply by implement intelligent and optimization methods to overcome the weakness of accuracy in identify location [10].

Pollution management and incident of surface water is an emergency issue to protect the environment, method to identified and localized the source of pollution water is a crucial and urgent matter to do in quick response to protect the environment and water supply. A multi-sensor water quality monitoring system for water pollution sources identification and localization based on Wireless Sensor Networks (WSNs) system. The multi-sensors system is embedded into two types of sensor nodes to send the information to WSNs sink (gateway) as elaborated in [11-14]. A coarse method of the location based on the land contour is used for advanced water pollution identification and localization for better diffusion models and detailed analysis of source contaminated water. The simulation and experiment model results compare to check the accuracy and determination of the final contaminated location for further action [15-16]. While both dynamic and static sources of pollution related to the binary hypotheses, specific inspection, and test statistics are given high attention and apply in this case. Experiment and simulation results of detection give a test feedback to illustrate the source of water pollution and contamination as well as large of the area contaminated [17-19].

II. Method and Data Collection

Siak river is located in the capital of Riau Province, which is in the city of Pekanbaru. The River is a main role and is very important not only for the community but for the Riau economy, where the Siak river is a transportation line to connect the city of Pekanbaru to others cities besides land transportation. The use of the river as main transportation is more effective compare to others. The total length of rivers is more than 200 km from the upstream to the downstream which is added to the sea. Along the river which quite long that many obstacles and potential contaminated to the river's water, thus detecting and monitoring of river water is very important urgent thing have to do because the river water has been badly contaminated. Furthermore, operating of several industrial and factories surrounding and along the river contribute the water pollution is become worst, besides waste from the community and others trash around the river. Fig. 1 shows the map of Riau Province and fig.1(a) location of the Siak river in the hearth of Pekanbaru city while fig.1(b) the specific of the river roots that has several branches crossing the city of Pekanbaru. Siak river divides the city of the Pekanbaru between the north and south part, as the river crossing in the center of the city, has a high impact on the daily activities for the city and communities. Thus, potential river water gets contaminated from the pollution is very high as the busy area.

(a)



(b)

Fig. 1. Location of Siak river (a) map of Riau province which center of Sumatera (b) Siak river cross Pekanbaru city

A. Water pollution sensing system

In normal conditions, water has several parameters that can be measure either by observation or using measurement tools such as sensors or probes. While the water gets contaminated the value of water parameters changes according to the amount of material or chemical contaminating into the water, how much the amount of material can be measure, and check the changes. There are several common values of water can be measure either in normal condition or when contaminated. Table 1 shows the common parameters in most of the water. The most common parameters in the water are temperature and pH, these two parameters as the basic have to measure and are very closely related to the quality of water. Additional parameters to support and make accuracy in measurement are water Dissolved Oxygen (DO) and content of Electrical Conductivity (EC) in the water. All of those parameters have a strong justification to determine water get polluted as well as the type of chemical-based or intensity measured.

TABLE I. Water Polltuion Sensing Parameters

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

In this research a set of sensing systems was designed and developed to do detection of river water parameters, several sensors have been used according to the water parameters. Fig. 2 and Fig.2(a) show a block diagram of a river water sensing system designed, where temperature, pH, DO and EC sensors were installed. The signal from the sensor-based of detection commonly has a noise, thus a signal conditioning process is required before going to the Main Control Unit (MCU), wh Radio Frequency (RF) and antenna system are ed to transmit the data to the WSN node station. Fig.2(b) shows a block diagram of th VSN gateway system to collect data from sensor nodes then send to the data center (backend system) for analysis.

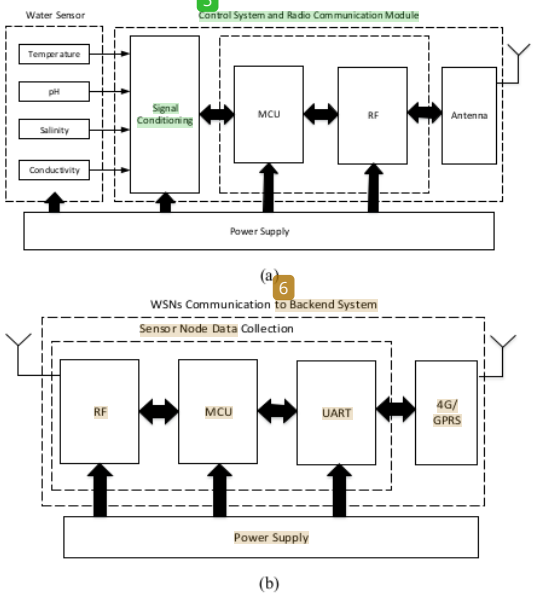


Fig. 2. Sensing syste, block diagram (a) water polltuion sensors for detection (b) sensor gate way to send data to data center

B. *Real-time detection and monitoring system*

Detection of water pollution location and monitoring the status is very important to achieve accurate data and location, due to the length of the river to monitor then several sensor nodes deploy at the potential area that water gets polluted. Fig.3 shows a sensor network to connect several sensor nodes deploy on-site for detection of river water pollution. Detected water parameters data stored in the buffer memory in WSN sink node for temporary before forwarding to the data center using cellular data communication or Global System for Mobile Communication (GSM) modem. All the data analyzed in a central unit at the monitoring system to determine pollution.

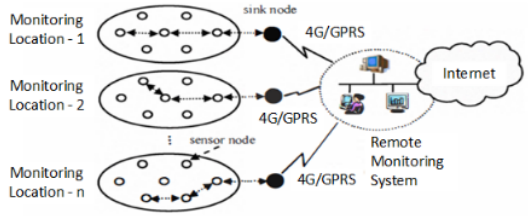


Fig. 3. WSN nodes monitoring and network system

Designed water pollution sensing system has been fabricated and initial testing conducted in a laboratory to obtain preliminary data as well as to calibrate all the sensors to the ideal value of sense. Fig. 4 shows a set of fabricated sensing systems set up in a container which consists of water, to check the functionality of sensor then water contamination simulated to various of value for example temperature sensor by heat up the water then back to the normal temperature and colling down the water by putting ice or other material. Similar concepts have been done for other parameters to check and make sure the sensor is working and detection values changing.

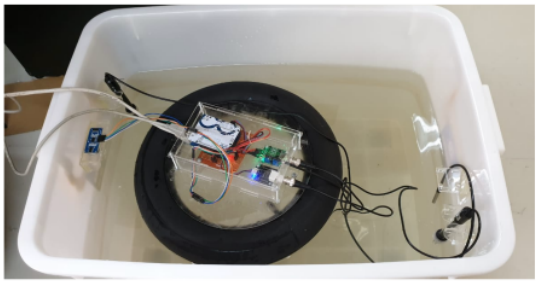


Fig. 4. Initial testing of water pollution in laboratory

Prototype of sensor system fabricated based on actual condition in river water, several numbers of sensor used as mention in early section to detect actual values of water in the river. Fig.5 shows an actual prototype of the sensor system Fig.5(a) shows testing conducted in a river with a floating tube and Fig.5(b) shows a solar panel installed at the system as a power supply for sensors and other components. All the detected data sending to the data center through cellular communication as a GSM antenna installed at the side of the box.

(a) (b)

Fig. 5. Prototype of water polltuion sensing system (a) front side which is control unit and (b) solar panel as power supply the sensor system

C. *Data collection and analysis*

The Siak river is located at the coordi te 0°32'27.9"N 101°26'15.8"E in central of Pekanbaru City in Riau Province, the river divided the city into two parts which north and south part. To collect the data of water quality and to analyze how the pollution concentration in the water and find the location,

the scenarios which sketch the river as shown in fig. 1(b) in early to draw a new map which only main river and tributary as shows in fig. 6. The river consists of six tributaries or sub rivers that potentially contribute and contaminate river water due to the branches are come from the were community residential and industrial operation. While the main body of the river with wide about 100-150 meters and the depth starting from 20 meters to more than 100 meters is one of the deepest rivers in Indonesia. Deployment of sensor nodes have to carefully consider because of typical of the river is deep and has fast river flow especially during raining and flooding season.

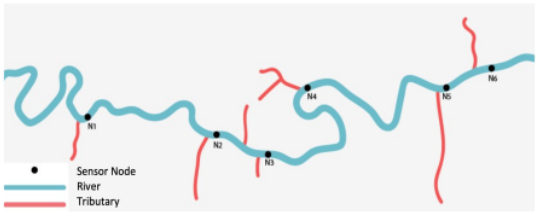


Fig. 6. River with sensor nodes installed the measuremtn point

Water pollution data collected from the sensor nodes deployed to the field, there are 6 sensor nodes as monitoring point installed and each node located at the specific location which is based on a preliminary survey that high potential to contribute contamination and polluted the river water. Table 2 shows the detailed coordinate of those sensor node's locations, all the nodes installed after the river branch or tributary to obtain accurate water pollution data, as mention in the early placement of sensors after the branch then will get detailed water pollution data. All the detected data from sensor nodes sending to the backend system through the WSN sink gateway to continue the next process which is filtering and analyze the data using an artificial intelligence algorithm to achieve and identify the correct location of sources water pollution.

TABLE II. SENSOR NODES DEPLOYMENT LOCATION

Sensor Node	Deployment Coordinate
1	0°32'57.1"N 101°24'59.4"E
2	0°32'40.8"N 101°25'50.9"E
3	0°32'27.9"N 101°26'15.8"E
4	0°33'09.5"N 101°26'50.5"E
5	0°32'48.2"N 101°28'09.7"E
6	0°33'34.9"N 101°29'25.3"E

To identify water pollution source location based on the common normal river which the water flow moves from upstream to the downstream which normal speed from 0 to 20 km/hour. The pollution source location can be modeling refer to the topology of the river as shown in fig.6, by using a mathematical model as shown in equation (1) to find the coordinate of *L* and *Co*.

$$F = \max_{k-1,..,N_s} \left\{ \sum_{t-1}^{T} \left(C_k^{obs}(t) - C_k^* L, C_0, t \right)^2 \right\} \quad (1)$$

where F is representing of the error of prediction and L represents to point of locating the source of pollution C_0 is representing of the water pollution concentration, t is the current step time and T is representing of the total number of monitored analyzed data time, k represents the location of the sensor nodes N_s represent of total number sensor deployed, C_k^{obs} is represent of the correct number of cumulative concentration data at the sensor location k, and $C_k^* L, C_0$ represent of the cumulative analyzed concertation based on detected data at the sensor location k. Then, will find the dynamic change of water pollution based on analyzed concentration C_k^* as implement to the mathematical analysis into the program compare to the C_k^{obs} that the threshold of analysis data to the general analysis data [3].

Measurement of river water parameters by sensor deployed at the monitoring point gives raw data and filtering process done at the node station. The process to identify of source's water pollution location started by initial all the sensor nodes before start doing measurement of all the detection data recorded at the internal memory of the microcontroller unit. All the valid data after the filtering process send to the data center at the backend system to do the next process which is running analysis, by using an advanced system to do analysis using artificial intelligence algorithm for measurement data and data training done at this stage as well. Once data have been analyzed then check the error if more than a threshold then back to analysis for optimization or if less than a threshold then find the source location of water pollution and closed by end of execution. Fig.7 shows a complete flow of the process in the identification of pollution source location.

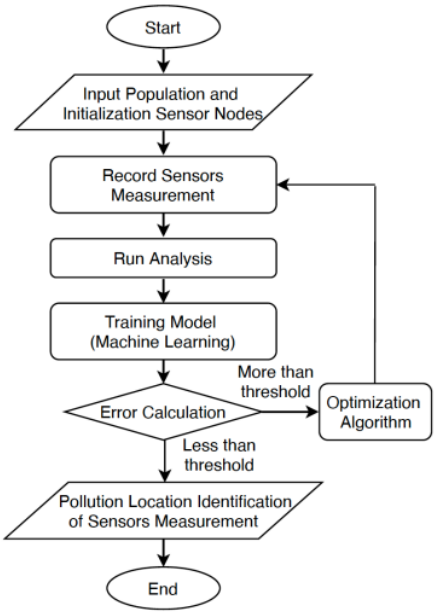
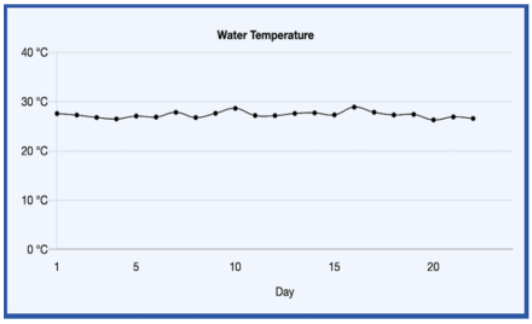


Fig. 7. Flowchart of measurement and optimization method [3]

III. RESULTS AND DISCUSSION

River water data detection and measurement results analyzed at the central processing in the main control unit, then shows the reading results in the graph to check how the behavior of all those data as well as recorded to check the abnormality in the long-time analysis. Fig. 8 shows the graph of measurement results, while fig.8(a) measurement graph of

water temperature, fig.8(b) is measurement results of water pH, while fig.8(c) is a measurement of electrical conductivity (EC) of water and fig.8(d) measurement results of dissolved oxygen (DO) of water. The displaying data range can be adjusted based on daily which 24 hours, weekly, monthly, and yearly scales to check measurement data in detail from the measurement. In addition, any abnormality of data as display and recorded in the system will be triggering an alert for reminding and take attention to something that happens in the monitoring point. The upper and lower limit of unit value in every measurement was calibrated in advance based on standard values of river water properties measured. This calibration has been in preliminary testing the laboratory as initial testing to calibrate all the sensors and to achieve high accuracy data reading, method of calibration by combining several techniques including manual and conventional measurement model.



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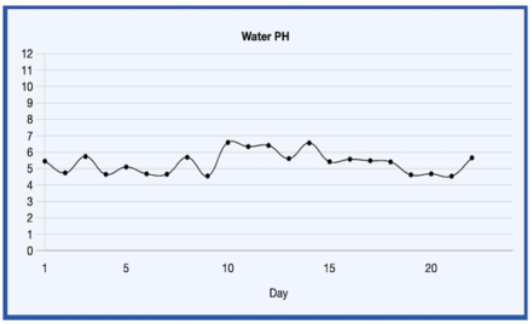

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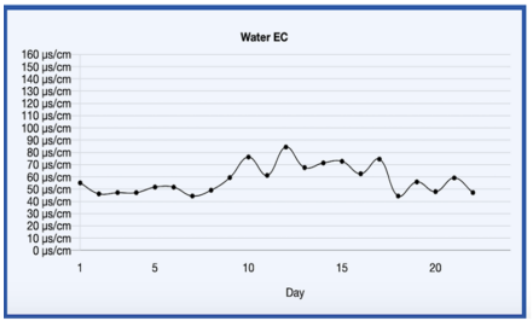

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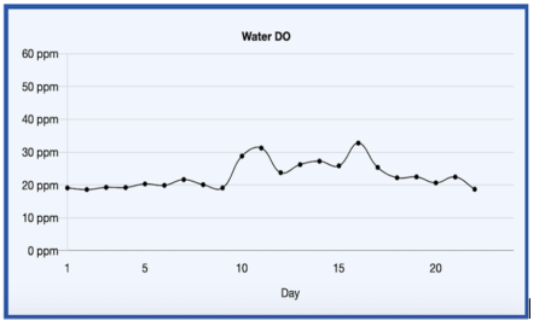

(d)

Fig. 8. Results of water polltuion measurement (a) water temperature (b) water pH (c) electrical conductivity (EC) and (d) water dissolve oxygen (DO)

Measurement and analysis results to find and identify the source of water pollution contamination base on raw data detected by sensors at the monitoring point is different between one sensor node to others, every sensor node has a coverage area, and water parameter reading may be different. The last node at the downstream location may have a high possibility to detect contaminated data compare to the upstream of the river. Figure 9 shows the results of pollution source based on analysis data from the sensor node, especially node number 2 and 4 which are data show high contamination on the all parameters and properties of the detected and recorded data.

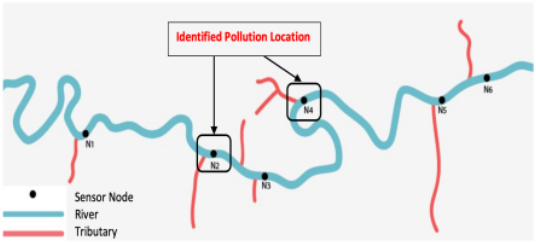

Fig. 9. Results of water pollution source location at the sensor node 2 and 4

According to the data training and detected from sensor node 2 and 4 in the identified measurement of water pollution contamination is not permanent, it's may have some time then water quality recover when to pollution sources is disappear, for example, chemical eject from industrial going into the river then the material follows river flow then neutralized or going into the last miles which end of downstream on the sea. Many other scenarios based on experiment and testing have been done including data analysis and noise data send by the sensor nodes.

IV. Conclusion

A system for detection and monitoring of river water pollution has been developed to get an automatic and intelligent system to find and identify the source location of river water pollution. Six sensor nodes were deployed at the measurement point to collect the live data from the river, the sensors installed refer to the scenario of the river with the tributaries or branches appear from natural. Sensor nodes can detect and send the data to the system which is inside the node for temporary memory and backend system valid data after filtering process to record and shows in the display for

analysis. Data training and analysis with intelligence algorithms have been done to find accurate and correct pollution sources locations. Two source locations detected based on sensor training data which is node number 2 and 4 with record-high water contamination data then conclude with the system and lock the location for further analysis.

ACKNOWLEDGMENT

The authors would like to say thank you very much to the Ministry of Education, Culture, Research, and Technology (KEMENBUDRISTEK) of Indonesia for funding this research project with contract number is 06/Kontrak/LPPM/4-2021 as well as Universitas Islam Riau, Indonesia as well Universiti Teknologi Petronas, Malaysia to support the facilities.

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