Online monitoring of water pollution level based on dissolved oxygen (DO) and biochemical oxygen demand (BOD) using wireless sensor system

W H Sugiharto¹, M I Ghozali¹, S Suryono², H Susanto³, M A Budihardjo⁴

¹Department of Informatics Engineering, Universitas Muria Kudus, Kudus – Indonesia
²Physics Department of Science and Mathematics Faculty, Diponegoro University, Semarang – Indonesia
³Department of Chemical Engineering, Universitas Diponegoro, Semarang, Indonesia
⁴Department of Environmental Engineering, Diponegoro University, Semarang - Indonesia

Corresponding author: wibowo.harrys@umk.ac.id

Abstract. In the case of water pollution, including the sea, rivers, lakes, and reservoirs, usually when measuring the parameter of Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) values exceeds the pollution level. Online and continuous monitoring is essential to monitor water conditions so that if there is pollution, it can be immediate handling. Wireless sensor network technology becomes part of the Internet of Things makes it possible for online data acquisition from several node stations that are spread in monitoring locations. This paper purpose the online BOD dan DO data acquisition continuously builds with combine the wireless sensor system and database replication concept. From implementing a database replication method for online monitoring of water pollution level, database replication continuously ensures consistency and prevents redundant data between node sensor station and server database, and provides reliable information on the www website.

1. Introduction

In the case of water pollution, Dissolved Oxygen (DO) and Biochemical Oxygen Demand usually show values that exceed the pollution level, as in water pollution [1], reservoirs [2], and lakes [3]. DO value in natural waters is an essential parameter in natural environment research [4]. DO concentrations are essential for most aquatic plants and animals to living. DO concentrations are a crucial parameter for characterizing natural water and wastewater and for determining the global state of the environment in general. The decline in dissolved oxygen levels in the world's oceans is increasingly expected to affect the earth's entire ecosystem, including the carbon cycle, climate, etc. [5].

Dissolved Oxygen is an essential need by all living things for respiration, metabolic processes, or substance exchange, which then produces energy for growth and reproduction. Besides, oxygen is also needed for the oxidation of organic and inorganic materials in aerobic processes. The primary source of oxygen in water comes from a diffusion process from free water and the photosynthesis of organisms living in these waters [6]. The minimum DO content is two ppm in normal conditions and is not contaminated by toxic compounds (toxic). This minimum dissolved oxygen content is sufficient to support the life of organisms [7]. Ideally, the dissolved oxygen content should not be less than 1.7 ppm for 8 hours with at least the saturation level of 70%. As it is known that oxygen acts as an oxidizer and a reduction of toxic chemicals into other compounds that are simpler and non-toxic. Besides, oxygen is
also needed by microorganisms for respiration. Organisms individual, such as microorganisms, play a crucial role in breaking down toxic chemical compounds into other compounds that are simpler and less toxic. Because of this critical role, industrial wastewater, and waste before being discharged into the public environment, must first be enriched with oxygen levels [8].

The biological oxygen demand (BOD) parameter is generally widely used to determine the level of wastewater pollution. The determination of BOD is crucial to trace the flow of pollution from upstream to the estuary. The determination of BOD is a procedure that usually involves measuring the amount of oxygen used by the organism as long as the organism decomposes the organic material present in water under conditions that are almost the same as the conditions that exist in nature. During the BOD examination, the examined sample must be free of outside water to prevent contamination of the water's oxygen. The concentration of wastewater/sample must also be at a certain level of pollution, and this is to keep dissolved oxygen always present during the inspection. Dissolved oxygen concentration is necessary to note because the solubility of oxygen in water is limited and only around ± nine ppm at 20 °C. The oxidation reaction during the BOD examination results from biological activity with the speed of the reaction that is very much influenced by the population size and temperature. Hence during the BOD examination, the temperature should be kept constant at 20 °C, the typical temperature in nature [7].

The online data monitoring system has become a significant issue [9][10], especially in water pollution monitoring [11][12]. The application of an online monitoring system can continuously monitor water quality to control water pollution conditions. Traditionally, measuring and detecting water quality is done manually where water samples are taken and sent for test to the laboratory. This process requires a longer time, higher costs, and requires human resources [13]. This paper aims to approach online monitoring water quality using a wireless sensor system and database replication. Database replication method ensures consistency, prevents redundant data between node sensor station and server database, and provides reliable information on the www website [14]. The information can be used as a reference to handling water pollution.

2. Methods

2.1. Internet of things

Internet of Things (IoT) is a concept that has the goal of enhancing the functionality of internet network connectivity that connects networks of machines, equipment, monitoring devices, and other physical objects. With the existence of sensors and actuators on the internet network, it is possible to obtain data and carry out processes independently to perform actions independently [15]. IoT builds a structure in which objects, people are provided with an exclusive identity and the ability to move data through a network without requiring two directions between humans, namely source to destination or human to computer interaction. IoT is a promising technological development. IoT can optimize life with smart sensors and objects that have networks and work together on the internet [16].

The way IoT works is that every object must have an Internet Protocol (IP) address. An IP address is an identity on the network that allows it to be ordered from other objects on the same network. Furthermore, the IP addresses in these objects will be connected to the internet network.

IoT can connect billions or trillions of IP-owned objects over the internet, so there is a critical need for a flexible layered architecture. The collected data is then analyzed to take specific actions based on the services required. IoT sensors can be intelligent sensors, actuators, or sensing devices used [17].

2.2. Wireless sensor system

A wireless sensor system uses a wireless network that is used to communicate between sensors and form a system that is used to monitor environmental, physical parameter parameters. With this network system, interested parties can access systems and data remotely without going into the field [18]. There are two formations in the wireless sensor system network, the first formation is centralized, and the second is a distributed formation [19]. These two formations are shown in Figure 1. In addition to these
formations, wireless sensor networks can also be classified into four categories in handling sensors in the process. monitoring, namely single node – single sensor, single node - multi-sensor [20], multi-node - single sensor [21] and multi-node - multi-sensor [22]. Both the monitoring data are presented in the online form[22] or not[23]. Not all wireless sensor network implementations have database facilities as data storage systems [24]. Some are displaying real-time data, but the data is not stored in a database [25].

Figure 1. Wireless sensor network formation

2.3. Database replication method
It is a process of sharing information to ensure consistency between redundant resources. Data replication performs multiple copies of data, which are called replicas on separate server locations. So data requests that should have been made via network communication to other storage devices are now being answered locally. Data Replication improves performance by reducing latency and increasing throughput. Latency is reduced because users can access replicated data, thus avoiding remote network access, while throughput increases as data are available on multiple computers and can be accessed simultaneously [26]. Database replication is made replicas of a database and synchronizes with the other databases design on the network server [14].

Figure 2. Cascading database concept

2.4. LTE 4G network
LTE technology or Long Term Evolution, better known as 4G-LTE technology to distinguish it from 3G and 3.5G technology. The goal of LTE technology is to increase the capacity and speed of wireless data networks developed at the start of the new millennium. This 4G-LTE wireless interface system is different from 3G and 3.5G networks, so it must be operated on a separate spectrum. In March 2008, the communications sector International Mobile Telecommunications Advanced (IMT-Advanced) set peak speed requirements for 4G services at 100 megabits per second (Mbit / s) for high mobility
communications (such as from trains and cars) and 1 gigabit per second (Gbit/s) for low mobility communication [27].

The term 4G is used broadly to include a wide variety of wireless network access communication systems, not just cell phone systems. 4G is a full packet switching based network that is optimized for data transfer. 4G networks want to provide 100 Mb/s speed while on the move. 4G evolution is a form of a better 3G network. 4G cellular technology is considered to provide high and fast data rates or bandwidth. The following is 1G to 4G network technology along with bandwidth data [28][29][30].

3. Data acquisition design

The research was conducted at Industrial Instrumentation System Research Center (IISRC), Diponegoro University. The system is built using a DO sensor, which is then controlled and acquired by monitoring data and then stored in the master database. The communication system is built using a 4G network. With this design, the position of the base station on the wireless sensor network is completely changed to a cloud computing server, which is in charge of collecting data from node stations and processing the data. Data transmission by node stations is carried out in the Hypertext Transfer Protocol (HTTP) with the HTTP request and HTTP response method. Synchronize data between each node station and cloud computing server using a centralized formation where data transmission is directly sent by the node station independently; this is shown in figure 3 and figure 4.

![Figure 3. Synchronize data acquisition design using HTTP request and response](image)

![Figure 4. Design of centralized formation with 4G communication system](image)
The DO sensor uses Gravity DO Probe with signal converter Gravity Analog Interface (PH2.0-3P). This sensor is calibrated with single-point calibration, which only calibrates the saturated dissolved oxygen at a fixed temperature, suitable for use when the temperature is stable. To determine BOD value, the DO was measured first (DO day 0), while the other samples were incubated for five days at 20 °C, then after five days, the DO (DO day 5) was measured. BOD levels are determined by the formula [1]:

$$BOD = 5 \times [\text{value} \{DO(day\ 0) - DO\ (day\ 5)\}] \text{ppm}$$

(1)

Table 1. Pollution Level of Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) [8]

| Pollution Level | Dissolved Oxygen (DO) (ppm) | Biochemical Oxygen Demand (BOD) |
|-----------------|-----------------------------|---------------------------------|
| Low             | > 5                         | 0-10                            |
| Medium          | 0 - 5                       | 10-20                           |
| High            | 0                           | 25                              |

4. **Online monitoring of water pollution level based on DO and BOD**

Implementation of online DO and BOD data acquisition using database replication method is applied to the cloud computing server using HTTP request and response to send data from the master database on node Station in Figure 5 (on the local database) to the replication database (on server database) it has shown in Figure 6. The microcontroller collects data from the sensor and saves data into a local database as a master database. The cloud computing server read data on the replication database and running Formula (1) shown in Table 2, and present the result on the www website shown in figure 7.

Table 2. Online acquisition pollution level of DO and BOD

| Station | Acquisition Time | DO  | BOD  |
|---------|------------------|-----|------|
| 1       | 3 September 2019 15:00 | 6.98 | 0.27 |
| 2       | 3 September 2019 15:00 | 6.54 | 0.47 |
| 3       | 3 September 2019 15:00 | 6.56 | 1.43 |
| 4       | 3 September 2019 15:00 | 6.52 | 1.32 |
| 5       | 3 September 2019 15:00 | 6.69 | 0.96 |
| 6       | 3 September 2019 15:00 | 6.63 | 0.79 |
5. Conclusion
In this research, the implementation of the database replication method for water online monitoring of water pollution level can repeatedly perform to acquisition data and online synchronize. With the combined concept of replication, database is possible to build multiple data acquisition from multiple node station. And the replication database ensure consistency and prevent redundant data between node sensor station and server database, and provides reliable information on the www website

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References
[1] Prambudy H Supriyatin T and Setiawan F 2019 J. Phys. Conf. Ser. 1360 1
[2] Wahyu Sayekti R Amar Sajali M and Tri Wahyuni I 2020 IOP Conference Series: Earth and Environmental Science
[3] El-Alkhoris Y S A, Abbas M S, Sharaky A M and Fahmy M A 2020 Egypt. J. Aquat. Biol. Fish
[4] Nagy S A et al. 2008 Acta Zool. Acad. Sci. Hungaricae
[5] Näykkki T, Jalukse L, Helm I and Leito I 2013 Water (Switzerland) 5 2 420–442
[6] Salim H 2002 J. Teknol. Lingkung.
[7] Sawyer C N and McCarty P L 1978 Chemistry for Environmental Engineering
[8] Salmin 2005 Oseana 30 3 21–26
[9] Suryono S, Surarso B, Saputra R and Sudalma S 2019 J. Appl. Eng. Sci. 17 1 18–25
[10] Otahalova T, Slanina Z and Vala D 2012 IFAC Proc. 11 PART 1 261–264
[11] Perumal T, Sulaiman M N and Leong C Y 2016 IEEE 4th Global Conference on Consumer Electronics, GCCE 2015
[12] 2018 REALTIME WATER QUALITY MONITORING Int. J. Comput. Commun. Netw.
[13] Das B and Jain P C 2017 *International Conference on Computer, Communications and Electronics, COMPTELIX 2017*

[14] Kemme B Jimenez-Peris R and Patino-Martinez M 2010 *Synth. Lect. Data Manag.* 2 1 1–153

[15] Nugraha A T, Hayati N and Suryanegara M 2018 *International Conference on Signals and Systems, ICSigSys 2018 - Proceedings*

[16] Junaidi A 2016 *J. Ilm. Teknol. Inf.*

[17] Wilianto W and Kurniawan A 2018 *Matrix J. Manaj. Teknol. dan Inform.* 8 2 36

[18] Sugiharto W H, Riadi A A and Ghozali M I 2018 *Web Based Information System of Carbon Monoxide Pollution in E3S Web of Conferences.*

[19] Carlos-Mancilla M, López-Mellado E and Siller M 2016 *J. Sensors 2016*

[20] Chang Y C et al. 2013 *Med. Eng. Phys.* 35 2 263–268

[21] Satya Murty S A V et al. 2012 *Nucl. Eng. Des.* 249 432–437

[22] Jafer E, Ibula C S and Harris J 2013 *Sensors Actuators, A Phys.* 189 276–287

[23] Green O, Nadimi E S, Blanes-Vidal V, Jørgensen R N, Storm I M L D, and Sørensen C G 2009 *Comput. Electron. Agric.* 69 2 149–157

[24] Selvabala V S N and Ganesh A B 2012 *Procedia Eng.* 30 2011 767–773

[25] Liu H, Yin S, Liu L, and Wei S 2011 *Procedia Environ. Sci.* 11, PART B 552–557

[26] Yadav A K, Agarwal A, and Rahmatkar S 2011 *Communications in Computer and Information Science*

[27] Naman Bansal P R 2016 4G *Int. J. Adv. Res. Comput. Sci.* 7 6 97–100

[28] Kumar A, Suman and Renu 2013 *Int. J. Electron. Commun. Eng.*

[29] Khan A H, Qadeer M A, Ansari J A, and Waheed S 2009 *International Conference on Future Computer and Communication, ICFCC 2009*

[30] Kumaravel K 2011 *Int. J. Comput. Sci.*