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Literature Study on Microorganism-Based Biosensor Applications for Real-Time Water Quality Monitoring

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Abstract: The effect of microbial biosensors and real-time systems on water quality monitoring is a scientific article in the study of literature within the scope of environmental biotechnology. The purpose of this article is to build a hypothesis of the influence between variables that will be used in further research. Research objects were sourced from online libraries, Google Scholar, Mendeley, and other academic online media. The research method is a research library sourced from e-books and open-access e-journals. The results of this article are microbial biosensors have an effect on water quality monitoring, and then real-time systems have an effect on water quality monitoring.

Keywords: Water Quality, Microbial Biosensor, Real-Time System.

INTRODUCTION

Water quality is a crucial factor in maintaining the health of ecosystems and humans. Increased industrial activity and urbanization have caused degradation of water quality in various regions. According to the World Health Organization (2020), around 2 billion people use contaminated water sources. Therefore, effective monitoring methods are needed to identify and address water pollution. One of the emerging approaches is the use of microorganism-based biosensors.

Microorganism-based biosensors offer an innovative solution in detecting water contaminants specifically and sensitively. Microorganisms can react to various chemicals, enabling the detection of various pollutants such as heavy metals and organic compounds. Stafiej and Pyrzynska (2019) stated that microbial biosensors have great potential in environmental monitoring. Another advantage is the ability to provide results in real-time, enabling rapid response to changes in water quality. This is important in efforts to mitigate water pollution.

Real-time water quality monitoring technology enables continuous monitoring of water quality parameters. Integration of biosensors with real-time monitoring systems can improve the efficiency of detection and response to pollution. According to Zhang et al. (2021), this system can provide accurate and timely data. This is very important in water resource

management, especially in areas with high pollution risks. The implementation of this technology can support more effective environmental policies.

The use of biosensors in water quality monitoring also has economic implications. This method can reduce operational costs compared to conventional techniques that require laboratories and experts. In addition, biosensors can be used in the field, allowing direct detection at the water source location. This increases efficiency in decision-making related to water management. However, challenges such as stability and lifetime of biosensors need to be overcome for long-term applications.

In the context of Indonesia, water quality monitoring is becoming increasingly important given the high levels of pollution in various rivers and lakes. Data from the Ministry of Environment and Forestry shows that many water bodies are experiencing declining quality. The implementation of microorganism-based biosensors can be a solution to monitor and manage water quality effectively. This is in line with the government's efforts to achieve the Sustainable Development Goals (SDGs), especially goal 6 on clean water and sanitation. Collaboration between academics, government, and industry is needed to make this happen.

Previous studies have shown the success of using biosensors to detect various water contaminants. For example, E. coli-based biosensors have been used to detect the presence of pathogens in drinking water. In addition, algae-based biosensors can detect toxins produced by harmful algae. However, further research is needed to improve the sensitivity and specificity of biosensors. This is important to ensure the reliability of the data generated.

Biosensor development also requires a multidisciplinary approach, involving biotechnology, electrical engineering, and computer science. Integration with Internet of Things (IoT) technology can improve monitoring and data analysis capabilities. According to Li et al. (2020), the use of IoT in biosensor systems allows for real-time data collection and deeper analysis. This opens up opportunities for the development of more sophisticated and efficient water quality monitoring systems. However, challenges such as data security and system interoperability need to be considered.

Based on this background, this article aims to conduct a literature study on the application of microorganism-based biosensors in real-time water quality monitoring. The main objective is to build a hypothesis on the role of biosensors and real-time monitoring technology.

METHOD

The method of writing a Literature Review article is using the Literature Research (library research) and Systematic Literature Review (SLR) methods, analyzed qualitatively, sourced from the online applications Google Scholar, Mendeley, and other online academic applications. SLR is defined as the process of identifying, assessing, and interpreting all available research evidence with the aim of providing answers to specific research questions (Kitchenham et al., 2009).

In qualitative analysis, literature review must be used consistently with methodological assumptions. One reason for conducting qualitative analysis is that the research is exploratory (Ali & Limakrisna, 2013).

RESULT AND DISCUSSION

Water Quality Monitoring

Water quality monitoring is the process of measuring various physical, chemical, and biological parameters that indicate the condition of the aquatic environment (Li et al., 2020). The main goal is to ensure that water quality meets environmental and health standards. Water quality is very important for various human needs such as drinking water, agriculture, and industry (Wang et al., 2021). Important dimensions observed include dissolved oxygen levels,

pH, temperature, heavy metals, and organic contaminants. Water quality has been the object of many studies, such as by Zhang et al. (2019) who studied heavy metal pollution in industrial rivers, and Kumar & Pal (2022) who developed a water quality monitoring model based on smart technology.

Microorganism Biosensor

Microorganism biosensors are biological detection devices that use microorganisms as sensing elements to detect certain compounds in the environment, especially water (Zhao et al., 2018). Microorganisms such as E. coli, Pseudomonas, or Shewanella have the ability to respond to environmental changes and produce measurable electrical, optical, or chemical signals (Cheng et al., 2021). Important dimensions in microorganism biosensors include the type of microorganism, detection mechanism (enzymatic or respiratory), and sensitivity. Research by Singh et al. (2020) showed that microbial biosensors can detect heavy metals with high sensitivity, while Huang et al. (2019) used Shewanella oneidensis biosensor to detect dissolved oxygen.

Real-Time Monitoring System

Real-time monitoring systems are technological systems that enable the collection and analysis of data in real time or near real time as events occur (Sharma et al., 2021). In the context of water quality, this includes automated sensors and data connectivity such as IoT. This system consists of sensors, data transmission, signal processing, and a user interface that allows continuous monitoring (Nguyen et al., 2020). Important dimensions include accuracy, sensor reliability, data transmission efficiency, and response speed. A study by Park et al. (2022) integrated microbial biosensors with an IoT system for real-time river monitoring, and Zhang et al. (2023) developed a cloud-based and AI-based water quality monitoring system.

Relevant Article Review

Previous relevant studies were used to build theoretical foundations and establish research hypotheses. Several articles examined the relationship between microorganism-based biosensor applications (x1), microorganism characteristics (x2), and the effectiveness of real-time water quality monitoring (y1). These articles revealed that the reliability of biosensors is greatly influenced by the type of microorganisms used and the integration of the technology into the monitoring system. Table 1 below summarizes the results of relevant previous research and shows how these studies correspond and differ with this article.

Table 1: Research Results Relevant

No	Author (Year)	Research Results Previous	Equality With Article This	Difference With Article This	H
1	Wang et al. (2020)	E. coli-based microbial biosensor effectively detects nitrate in wastewater	x1 plays a role in y1	Study focuses on nitrate, not other water parameters	H1
2	Kumar et al. (2021)	Integration of biosensors and IoT accelerates detection of water pollutants	x1 plays a role in y1	Does not discuss the types of microorganisms	H1
3	Zhang et al. (2019)	The ability of microorganisms to detect toxins in wastewater	x2 plays a role in y1	Does not discuss biosensor systems	H2
4	Li et al. (2022)	Autotrophic microorganism biosensors are more stable in extreme environments	x2 plays a role in y1	Focus on extreme environments	H2
5	Suharti et al. (2023)	The combination of local microbes increases the sensitivity of biosensors to heavy metals	x1 and x2 play a role in y1	The study used an experimental approach	H1/H2
6	Aisha & Nugroho (2022)	Real-time microbial biosensor is effective in monitoring polluted river water	x1 and x2 play a role in y1	Focus on rivers, not domestic waste	H1/H2

The Role of Microorganism-Based Biosensors in Water Quality Monitoring In Real Time

Biosensor based on microorganisms combines biological components such as microorganisms that are sensitive to water pollutant parameters and transducers that convert biological responses into measurable signals (Velusamy et al., 2021). Microbial biosensors play an important role in detecting various contaminants such as nitrate, ammonia, heavy metals, and pesticides quickly and accurately (Wang et al., 2020). With high response speed and low cost, these biosensors are suitable for use in real-time water quality monitoring at various scales.

Factors that affect the performance of microorganism-based biosensors include the type of microorganism, electrochemical substrate, biological stability, and technology integration (Zhao et al., 2020). In order to improve real-time water quality monitoring, biosensors need to be developed to be more specific, durable, and easy to calibrate. Biosensors must also be able to work in varying environmental conditions for real applications.

The application of biosensors has shown success in detecting heavy metals in industrial and agricultural wastewater. A study by Kumar et al. (2021) confirmed that biosensors integrated with Internet of Things (IoT) technology provide faster and more efficient monitoring results. This confirms that microorganism-based biosensors play a significant role in water quality monitoring.

Role of Characteristics Microorganisms Regarding Water Quality Monitoring In Real Time

Characteristics of microorganisms used in biosensors includes species type, metabolic ability, sensitivity to pollutants, and biological stability (Zhang et al., 2019). Microorganisms such as *Escherichia coli, Pseudomonas* sp., and *Bacillus subtilis* have been widely studied as active components in biosensors. The character of microorganisms determines the ability of biosensors to detect pollutant compounds. Microbes that have bioluminescent capabilities or produce certain metabolic products are very effective as indicators of water quality (Li et al., 2022). The more appropriate the microorganisms selected, the more accurate the results of real-time water quality monitoring detection obtained.

Factors that influence effectiveness characteristics microorganisms including adaptability to environmental conditions, resistance to toxic compounds, and long-term survival in biosensor systems (Suharti et al., 2023). To improve water quality monitoring, microorganisms with high resistance and fast metabolic responses need to be optimized in biosensor design.

A study by Aisyah and Nugroho (2022) proved that local microorganisms adapted to polluted environments were able to increase the sensitivity of biosensors. This shows that characteristics Microorganisms play a major role in increasing the accuracy and effectiveness of real-time water quality monitoring.

CONCLUSION

Based on objectives, results, and discussion, so can conclude that biosensors based on microorganisms play a role in monitoring real-time water quality through ability to detect pollutant with fast and accurate. Characteristics microorganisms also play a role, where the right microorganisms will increase sensitivity and specificity of biosensors. Article This builds base hypothesis for study furthermore that development of effective biosensors needs to consider synergy between biosensor technology and characteristics microorganisms used.

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