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LITERATURE STUDY OF *ESCHERICHIA COLI* RESISTANCE TO STREPTOMYCIN AND GENTAMICIN IN WATERSHED AREAS

Studi Literatur Resistansi *Escherichia coli* terhadap Antibiotik Streptomisin dan Gentamisin di Sekitar Daerah Aliran Sungai

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Abstract

Water is an essential requirement for life, as approximately 70% of living organisms' bodies are composed of water. River basins are an important source of water; however, they are highly vulnerable to contamination originating from the direct discharge of human feces into water bodies, leakage from septic tanks, and animal feces from livestock enclosures located near river basins. This literature study aims to review various studies on the resistance of *Escherichia coli* (*E. coli*) to the antibiotics streptomycin and gentamicin reported in various river basins. The method used was a literature review of relevant national and international scientific journals, with secondary data collection in the form of the percentage of *E. coli* and its resistance to these two antibiotics. The results of the review indicate that the percentage of *E. coli* in river basins varies between 0–100%, with most locations showing high levels of contamination. Resistance to streptomycin tends to be higher than to gentamicin, with the highest values reaching 93% for streptomycin and 100% for gentamicin in several locations. These findings suggest that fecal contamination contributes to the dissemination of antibiotic-resistant bacteria in aquatic environments. It can therefore be concluded that elevated levels of fecal pollution in watersheds not only degrade water quality but also potentially enhance the spread of antibiotic-resistant bacteria. Accordingly, the implementation of prudent antibiotic use, alongside effective watershed pollution control strategies, is strongly recommended to preserve water quality and mitigate the risk of antibiotic resistance.

Keywords: Antibiotic resistance, *E. coli*, fecal contamination, gentamicin, river basins, streptomycin

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Abstrak

Daerah Aliran Sungai (DAS) merupakan salah satu sumber air yang penting bagi kehidupan, namun rentan terhadap pencemaran yang berasal dari pembuangan feses manusia secara langsung ke badan air, kebocoran *septic tank*, serta feses ternak dari kandang yang berada di sekitar DAS. Studi literatur ini bertujuan untuk meninjau berbagai penelitian mengenai resistansi *Escherichia coli* (*E. coli*) terhadap antibiotik streptomisin dan gentamisin yang dilaporkan pada berbagai DAS. Metode yang digunakan adalah studi literatur dari jurnal ilmiah nasional dan internasional yang relevan, dengan pengumpulan data sekunder berupa persentase *E. coli* dan resistansinya terhadap kedua antibiotik tersebut. Hasil kajian menunjukkan bahwa persentase *E. coli* di DAS bervariasi antara 0–100%, dengan mayoritas lokasi menunjukkan tingkat kontaminasi yang tinggi, sedangkan resistansi terhadap streptomisin cenderung lebih tinggi dibandingkan gentamisin, dengan nilai tertinggi mencapai 93% untuk streptomisin dan 100% untuk gentamisin pada beberapa lokasi. Temuan ini menunjukkan bahwa pencemaran feses berperan dalam penyebaran bakteri resistan antibiotik di lingkungan perairan. Berdasarkan temuan tersebut dapat disimpulkan bahwa pencemaran feses yang tinggi di DAS tidak hanya menurunkan kualitas air, tetapi juga berpotensi meningkatkan penyebaran bakteri resistan antibiotik. Oleh karena itu, disarankan perlunya pengelolaan penggunaan antibiotik secara bijaksana serta upaya pengendalian pencemaran DAS untuk menjaga kualitas air dan meminimalkan risiko resistansi antibiotik.

Kata kunci: *E. coli*, Daerah Aliran Sungai, gentamisin, kontaminasi feses, resistansi antibiotik, streptomisin.

INTRODUCTION

Water is an essential requirement for life because nearly 70% of the bodies of living organisms consist of water (Apriliana *et al*., 2014). The availability of clean water is very important, not only for consumption but also for various daily activities such as cooking, bathing, and washing, as well as for agricultural and livestock activities, including as a source of drinking water for livestock, cleaning animal enclosures, and sanitizing livestock equipment (Iskandar *et al*., 2024). Watersheds (DAS), as one of the sources of water, play an important role in supporting various human activities but are highly vulnerable to pollution originating from the direct discharge of human feces into water bodies, septic tank leakage, and livestock feces from animal enclosures located around watersheds (Sitorus *et al*., 2024). This condition makes water quality in watersheds a highly strategic aspect of efforts to maintain the sustainability of aquatic ecosystems and public health, particularly concerning the presence of bacteria such as *Escherichia coli* (*E. coli*), which are frequently found in polluted waters (Khan, 2020).

The presence of *E. coli* in aquatic environments plays a very important role because it serves as a major indicator of fecal contamination and is associated with potential health risks to both humans and animals (Khan, 2020). The problem becomes increasingly complex when environmental *E. coli* isolates exhibit resistance to antibiotics due to uncontrolled antibiotic use in the healthcare and livestock sectors (Tama & Hilmi, 2022). Antimicrobial resistance (*antimicrobial resistance*/AMR) has become one of the serious global health threats. AMR was reported to directly cause approximately 1.27 million deaths and contribute to 4.95 million deaths worldwide in 2019 (Collaborators, 2022). In addition to increasing mortality, AMR also causes treatment failure of infections, prolongs hospital stays, increases healthcare costs, and reduces societal productivity (Cosgrove, 2006). One group of antibiotics widely used in the treatment of bacterial infections is aminoglycosides, such as streptomycin and gentamicin. Both antibiotics work by inhibiting bacterial protein synthesis through binding to the 30S ribosomal subunit, thereby interfering with the translation process. Streptomycin and

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gentamicin were selected in this study because they are still used in human and veterinary medicine to treat Gram-negative bacterial infections, including *Escherichia coli* (Krause *et al.*, 2016). In addition, resistance to aminoglycoside antibiotics has been widely reported in bacteria originating from the environment and has the potential to spread through mobile genetic elements, such as plasmids, transposons, and integrons. Therefore, the emergence of streptomycin- and gentamicin-resistant *E. coli* isolates in watershed environments is an important concern because they have the potential to serve as reservoirs and media for the dissemination of antibiotic resistance genes that may threaten human, animal, and environmental health.

Based on these problems, this article aims to conduct a literature review of *E. coli* resistance to the antibiotics streptomycin and gentamicin reported in various studies across different watersheds. This review is expected to provide a comprehensive overview of the patterns and levels of antibiotic resistance in aquatic environments and serve as a basis for consideration in efforts to control water pollution and promote more prudent antibiotic use.

RESEARCH METHODS

Ethical Clearance for Experimental Animals

This study did not require ethical clearance because it did not use live animals as subjects for treatment/intervention. The study was conducted using a literature review method based on various journal sources and scientific articles related to the presence and resistance of *E. coli* to the antibiotics streptomycin and gentamicin reported in watershed environments.

Research Objects

The research objects in this literature review were scientific articles discussing the presence of *E. coli* and its resistance to the antibiotics streptomycin and gentamicin in water samples originating from areas surrounding watersheds, including rivers, wells, and springs. Articles were obtained through searches in *Google Scholar*, *ScienceDirect*, and *PubMed* using the keywords "*E. coli*", "*streptomycin resistance*", "*gentamicin resistance*", and "*watershed*". The literature used consisted of publications from 2016–2025. The articles used were original research studies reporting the presence of *E. coli* and/or resistance data to streptomycin and gentamicin in water samples. A total of 8 articles were used to assess the presence of *E. coli*, while 5 articles were used to assess resistance to streptomycin and/or gentamicin. The data collected included the study location, number of samples, number of *E. coli* isolates, and percentage of resistance to the antibiotics studied.

Research Design

This study was a descriptive observational study using a literature review approach. The researchers did not conduct direct trials or experiments but instead based the study on the collection and analysis of secondary data from various existing scientific publications. The researchers reviewed, synthesized, and compared previous findings regarding the presence and percentage of *E. coli* resistance to the antibiotics streptomycin and gentamicin in watershed aquatic environments.

Research Variables

The independent variables in this study were the types of antibiotics, namely streptomycin and gentamicin, as well as the watershed locations reported in each literature source. The dependent variable was the percentage of *E. coli* resistance to the antibiotics streptomycin and gentamicin reported in various previous studies.

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Data Collection Method

Data were collected through a systematic literature search of relevant national and international scientific journals concerning *E. coli* resistance in areas surrounding watersheds. Articles were selected based on topic relevance and the availability of resistance testing data for the antibiotics streptomycin and gentamicin. The data collected included the type of water source, number of water samples, number of isolates in which *E. coli* was detected, and the percentage of resistance to the antibiotics streptomycin and gentamicin.

Data Analysis

Data from various literature sources were analyzed descriptively and qualitatively. Information such as watershed location, number of water samples, number of *E. coli* isolates, and percentage of antibiotic resistance (streptomycin and gentamicin) was systematically organized and compared. The data were presented in tabular form to facilitate interpretation. Since this was a literature review study, no statistical tests were performed.

RESULTS AND DISCUSSION

Results

Escherichia coli in Watersheds

Based on the literature study presented in Table 1, the percentage of *E. coli*-positive samples varied among locations. The highest percentage of 100% was found at several locations, including the Cimanuk River (Syamsudin *et al*., 2024) and the Citarum River (Kusumah *et al*., 2025), whereas the lowest percentage of 73.3% was reported in the Musi Watershed, Palembang City (Sunarti *et al*., 2022).

Resistance Patterns of *Escherichia coli* to Streptomycin and Gentamicin Antibiotics

Based on Table 2, the percentage of *E. coli* resistance to the antibiotics streptomycin and gentamicin varied among study locations. In general, the resistance rate to streptomycin tended to be higher than that to gentamicin, as reported in the Ameca River, Western Mexico (Díaz-Zaragoza *et al.,* 2025). This condition indicates differences in the response of *E. coli* to different types of aminoglycoside antibiotics in watershed environments. Table 2 also shows the highest resistance to streptomycin, reaching 93%, reported in several rivers in Sarawak, Malaysia (Lihan *et al*., 2021), followed by the Ameca River, Western Mexico, at 89.6% (Díaz-Zaragoza *et al*., 2025), and the Code River, Sleman, at 73.3% (Suswati *et al*., 2024). Several locations did not report resistance data for streptomycin (Syamsudin *et al.,* 2024; Tarigan *et al*., 2019).

Resistance to gentamicin showed the highest result in the Sekanak River, Palembang, at 100% (Tarigan *et al*., 2019), whereas the lowest value (0%) was found in the Cimanuk River, Garut, West Java (Syamsudin *et al*., 2024). The Ameca River, Western Mexico, showed gentamicin resistance of 48.1% (Díaz-Zaragoza *et al*., 2025). Overall, Table 2 illustrates that *E. coli* in various watersheds has different levels of resistance, with a tendency toward higher resistance to streptomycin than to gentamicin.

Discussion

The high percentage of *E. coli* at most locations in Table 1 indicates that many watershed waters have experienced substantial fecal contamination. *Escherichia coli* is a bacterium that indicates fecal contamination in water because it originates from the gastrointestinal tract of humans and warm-blooded animals and can be found in water exposed to the direct discharge of human feces into water bodies, septic tank leakage, and livestock feces from animal enclosures located around watersheds (WHO, 2004). Percentages reaching 100% at several

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locations, such as the Cimanuk River (Syamsudin *et al*., 2024), Citarum River (Kusumah *et al*., 2025), Poopoh Village (Ratumbanua *et al*., 2021), Sukasari Village (Suryani, 2023), five villages within the working area of UPTD Puskesmas Suatang Baru (Rachman, 2025), and wells around the former Punggolaka landfill (Pratiwi *et al*., 2022), indicate high levels of contamination. This is consistent with other studies reporting that rivers located in areas with high human activity tend to have higher levels of *E. coli* contamination due to the discharge of domestic wastewater, livestock feces from animal enclosures around watersheds, and inadequate sanitation (Díaz-Zaragoza *et al*., 2025).

The high proportion of *E. coli*-positive samples at most locations in Table 1 indicates fecal contamination originating from the water sources studied. Variations in the percentage of *E. coli*-positive samples among locations may be influenced by sanitation conditions, the presence and distance of pollution sources, the density of human activities, and environmental conditions surrounding the water sources. *E. coli* is an indicator bacterium of contamination originating from the gastrointestinal tract of humans and warm-blooded animals (WHO, 2004). *E. coli* contamination in water sources may occur through the entry of human and animal feces, domestic wastewater discharge, septic tank leakage, and discharge from livestock areas into water sources (WHO, 2004; Díaz-Zaragoza et al., 2025). The proximity of water sources to septic tanks, livestock enclosures, settlements, and human activities may increase the likelihood of *E. coli* entering water sources (WHO, 2004). Conversely, good sanitation conditions and adequate waste management can reduce the entry of *E. coli* into water sources (WHO, 2004). In addition to sanitation factors, rainfall and surface runoff conditions may influence the presence of *E. coli* because fecal-containing materials from the surrounding environment can be carried toward water sources (Díaz-Zaragoza et al., 2025).

The proportion of *E. coli*-positive samples in the Bedadung River (98.3%) (Suswati *et al*., 2024), Citarum Watershed (94.1%) (Zainun *et al.*, 2016), and Musi Watershed (73.3%) (Sunarti *et al*., 2022) may be associated with factors such as water discharge, the natural dilution capacity of rivers, flow patterns, and the intensity of human activities along the river. This is consistent with the findings of Daramusseng (2020), who reported that the Karang Mumus River in Samarinda experienced *E. coli* contamination with the highest concentration reaching 2400 CFU/100 ml, particularly in areas where domestic wastewater was directly discharged into the river. In addition, Ibrahim *et al*. (2026) reported that rivers in areas with high population density and intensive livestock activities had higher levels of *E. coli* contamination compared with less densely populated areas. This condition is attributed to increased discharge of domestic wastewater, agricultural waste containing animal feces, and poor environmental sanitation.

Conversely, the absence of *E. coli* (0%) in Skyline, Entrop Subdistrict, Jayapura, was attributed to the distance from pollution sources, particularly septic tanks, which were relatively far from the water sampling points. This is in accordance with the Indonesian National Standard (SNI) 03-2916-2012 on specifications for dug wells as clean water sources, which requires wells to be located at a minimum distance of 10 meters from pollution sources such as septic tanks, waste disposal sites, livestock enclosures, and wastewater drainage channels (SPAL).

E. coli is a bacterium that naturally inhabits the gastrointestinal tract of humans and animals; therefore, its presence in aquatic environments is not natural but originates from waste contamination (Khan, 2020). This bacterium can reach water sources through seepage through the soil, which occurs gradually and is influenced by time, distance, and soil physical conditions (WHO, 2004). The farther the distance between the pollution source and the water source, the lower the likelihood that the bacteria will survive and migrate until reaching the water source. Therefore, a distance of ≥10 meters plays an important role in reducing the risk

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of contamination. This condition is consistent with the study by Nissa & Pujiastuti (2024), which showed that wells located far from waste sources had a lower risk of *E. coli* contamination compared with wells located close to septic tanks or wastewater drainage channels.

In relation to these findings, the high presence of *E. coli* at most locations also has implications for antibiotic resistance, as shown in Table 2. Variations in *E. coli* resistance to streptomycin and gentamicin across different watersheds indicate that fecal contamination not only affects water quality but may also serve as a source of dissemination of antibiotic-resistant bacteria. Streptomycin and gentamicin are aminoglycoside antibiotics that are still used to treat Gram-negative bacterial infections, including *E. coli*, so increased resistance to these two antibiotics may reduce treatment effectiveness. The dissemination of antibiotic resistance in watersheds may occur through the mechanism of *horizontal gene transfer* (HGT), namely the transfer of resistance genes between bacteria through conjugation, transformation, and transduction. These mechanisms allow resistance genes carried by plasmids, transposons, and integrons to be transferred to other bacteria, causing previously susceptible bacteria to become resistant. A study by Díaz-Zaragoza *et al*. (2025) showed that resistance to streptomycin and gentamicin was higher during the rainy season than during the dry season, which was suspected to be associated with increased rainwater flow carrying bacteria and genetic material containing resistance genes into rivers. Lihan *et al*. (2021) reported that resistance to streptomycin reached 93% among *E. coli* isolates from rivers in Sarawak, Malaysia, which was suspected to be associated with the entry of agricultural and livestock waste as sources of antibiotic-resistant bacteria.

CONCLUSION AND SUGGESTIONS

Conclusion

The percentage of *E. coli* in areas surrounding watersheds varied considerably, ranging from 0% to 100%, with the highest contamination occurring in rivers exposed to domestic wastewater discharge, septic tank leakage, and livestock feces from animal enclosures around watersheds. In addition, *E. coli* resistance to the antibiotic streptomycin tended to be higher than that to gentamicin. This indicates a risk of dissemination of antibiotic-resistant bacteria in environments surrounding watersheds. The main factors influencing the presence and resistance of *E. coli* are the distance between pollution sources and water bodies, sanitation quality, and uncontrolled antibiotic use. These findings emphasize the importance of proper waste management and prudent antibiotic use to maintain water quality and prevent the dissemination of resistant bacteria in rivers.

Suggestions

Improved management of domestic waste and livestock activities is needed, particularly regarding the disposal of human and animal feces, as well as prudent antibiotic use, accompanied by the implementation of integrated water management strategies to reduce the risk of *E. coli* contamination and antibiotic resistance in rivers.

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Tables

Table 1. Studies related to *Escherichia coli* in Watersheds from 2016–2025

Location	Year of Study	Sample Type	Number of Samples	Positive *E. coli*	Prevalence (%)	Identification Method	Reference
Bedadung River, Jember Regency	2022	River water	60	59	98.3	Culture on selective media and bacterial identification	(Suswati *et al*., 2024)
Cimanuk River, Garut Regency, West Java	2024	River water	4	4	100	Isolation on TSB, Blood Agar, and MacConkey Agar, followed by identification using BD Phoenix M50	(Syamsudin *et al*., 2024)
Citarum Watershed	2016	River water	17	16	94.1	MPN (*Most Probable Number*), LEMB agar, and IMViC biochemical tests	(Zainun *et al*., 2016)
Musi Watershed, Palembang City	2022	River water	15	11	73.3	MPN and molecular identification of the 16S rRNA gene	(Sunarti *et al*., 2022)
Citarum River, West Java	2025	River water	14	14	100	Agar Method and β-D-Glucuronidase Detection (MPR Method)	(Kusumah *et al*., 2025)
Poopoh Village, Minahasa Regency	2021	Dug well water	30	30	100	Laboratory examination of *E. coli*	(Ratumbanua *et al*., 2021)
Sukasari Village, Hamlet I,	2023	Dug well water	4	4	100	MPN (*Most Probable Number*)	(Suryani, 2023)

RT 2, Seluma Regency, Bengkulu							
Five villages in the working area of UPTD Puskesmas Suatang Baru, Paser Regency, East Kalimantan	2025	Dug well water	30	30	100	Membrane Filter (Membrane Filtration)	(Rachman, 2025)
Around the former Punggolaka Waste Disposal Site, Kendari City	2022	Dug well water	5	5	100	Laboratory examination of *E. coli*	(Pratiwi *et al*., 2022)

Table 2. Data on *E. coli* resistance to streptomycin and gentamicin antibiotics

Location	Gentamicin	Streptomycin	Reference
Code River, Sleman	–	73.3%	(Suswati *et al*., 2024)
Cimauk River, Garut, West Java	0%	–	(Syamsudin *et al*., 2024)
Sekanak River, Palembang	100%	–	(Tarigan *et al*., 2019)
Ameca River, western Mexico	48.1%	89.6%	(Díaz-Zaragoza *et al*., 2025)
Sarawak River, Northwest Borneo	–	93%	(Lihan *et al*., 2021)