International Journal of Innovative Research and Scientific Studies, 8(2) 2025, pages: 1715-1728

IJIRSS
International Journal of Innovative Research & Scientific Studies

ISSN: 2617-6548

URL: www.ijirss.com

Estimated health impact and economic loss from river water pollution

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Abstract

Water pollution poses significant health risks, particularly in developing countries. This study aims to estimate the health impacts and economic losses associated with pollution in the Pusur River, emphasizing both non-carcinogenic risks and the financial burden on affected communities. The research employs the Environmental Health Risk Analysis (ARKL) method to assess health risks, while economic losses are estimated using the Cost of Illness (COI) approach. Water quality was analyzed at Sudimoro and Cokro village sampling points during both dry and rainy seasons to determine pollutant levels of nitrate, cadmium (Cd), and copper (Cu). Risk evaluation was conducted to measure exposure levels and the associated health risks for children and adults. Laboratory results indicate that nitrate concentrations in both seasons exceed the class 2 river water quality standard (>10 mg/L), whereas Cd and Cu levels remain below the standard (<0.02 mg/L). Children exhibit higher exposure levels than adults, yet the risk assessment shows that the non-carcinogenic risk levels for all pollutants remain within safe limits (Risk Quotient, RQ ≤ 1). Consequently, further risk management interventions were deemed unnecessary. The estimated COI for pollution-related diseases—such as typhoid, diarrhea, skin infections, and leptospirosis—varied across sub-districts: Rp 202,628,333 (community health centers) and Rp 501,654,333 (hospitals) in Tulung; Rp 73,605,833 (community health centers) and Rp 197,183,833 (hospitals) in Polanharjo; Rp 224,480,000 (community health centers) and Rp 607,499,000 (hospitals) in Delanggu; and Rp 156,805,000 (community health centers) and Rp 407,874,000 (hospitals) in Juwiring. The cost discrepancy between community health centers and hospitals averages 62%, indicating that government subsidies cover a significant portion of medical expenses. While pollutant exposure does not exceed hazardous thresholds, water pollution in the Pusur River still contributes to a substantial economic burden on healthcare services. The study highlights the need for continuous water quality monitoring and preventive measures to mitigate potential health risks. The findings provide valuable insights for policymakers in designing effective water pollution control strategies and optimizing healthcare subsidies to alleviate financial burdens on affected populations. Strengthening environmental regulations and improving public awareness of water contamination risks could further enhance community health outcomes.

Keywords: Cost of illness, Environmental economics, Risk analysis, Water pollution, Pusur River.

DOI: 10.53894/ijirss.v8i2.5532
Funding: This study received no specific financial support.
History: Received: 29 January 2025 / **Revised:** 3 March 2025 / **Accepted:** 7 March 2025 / **Published:** 21 March 2025

Competing Interests: The authors declare that they have no competing interests.
Authors' Contributions: All authors contributed equally to the conception and design of the study. All authors have read and agreed to the published version of the manuscript.
Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.
Publisher: Innovative Research Publishing

1. Introduction

River water pollution arises from various sources, which have a significant impact on human health. The main contributors include industrial waste, agricultural runoff, and domestic waste. These pollutants not only degrade water quality but also pose serious health risks to communities that depend on these water sources [1-3]. River water pollution not only impacts human health, such as increasing the prevalence of *waterborne diseases*, but also has implications for large economic losses. Increased public health costs due to treatment, decreased productivity due to disease, as well as losses to the fisheries and tourism sectors are a small part of the economic impacts felt [4].

The Pusur River is within the Pusur River Sub-Watershed (DAS) area, which empties into the Bengawan Solo River. The Pusur River has been used by 12,000 farmers who cultivate crops on an area of approximately 3,000 ha (CIRAD study data, 2009), so the Pusur River greatly contributes to food security in the Klaten district. Apart from that, the Pusur River has also become a new tourist destination, namely tubing tourism, which is visited by many guests from various regions of Indonesia [5]. On the other hand, the many potentials and opportunities for utilizing the Pusur River also have the potential to cause pressure and damage to the river ecosystem, such as the use of agricultural land (plantations and rice fields) upstream and downstream, where the use of pesticides and chemical fertilizers can pollute groundwater and surface water. The Food and Agriculture Organization of the United Nations (FAO) views agriculture as both a cause and a victim of water pollution; agriculture accounts for 70% of total water consumption worldwide and is the largest single contributor of non-point source pollution to surface and groundwater. Agricultural intensification is often accompanied by increases in soil erosion, salinity, and sediment loads in water, as well as by the overuse (or misuse) of agricultural inputs (e.g., fertilizer) to increase productivity. The results of previous research stated that the water quality status of the Pusur River was classified as moderately polluted [6, 7]. Therefore, further research needs to be carried out regarding the health impacts and economic losses of this pollution.

The health risk assessment method is a quantitative analysis method for evaluating substances that are harmful to human health. Water pollution comes into contact with the human body, especially through drinking water and skin, causing damage to human organs and threatening human health [8]. Many studies have been conducted on analyzing health risks due to river pollution, such as Madilonga, et al. [9], who conducted water quality assessments and evaluated human health risks in the Mutangwi River. Fahimah, et al. [10] conducted an assessment of water quality and human health risks due to heavy metal pollution in the Upper Citarum River. In this study, we also carried out a health risk analysis that focused on the pollutant parameters nitrate, Cd, and Cu and used the Environmental Health Risk Analysis (ARKL) method. Apart from that, we also analyzed the economic impact on health resulting from this pollution, which was measured using the cost of disease estimation technique *(Cost of Illness).*

The inaction economic costs of water pollution serve as a tool for assessing the social benefits of pollution reduction. Understanding the healthcare costs of diseases and symptoms associated with exposure to water pollutants will help decision-makers implement new measures to address water pollution and ensure the quality of life for its residents. The costs of inaction act as a basic indicator of the social situation, thereby allowing one to identify potential savings in health services if pollution is reduced and eliminated. This approach is the first step in a future assessment focused on including the costs of inaction in the decision-making process to evaluate the feasibility of new measures to manage pollution and guarantee the quality of life for the population, as well as environmental sustainability.

The objective of this study is to estimate the health impacts and economic losses due to Pusur River water pollution. Using the Environmental Health Risk Analysis (ARKL) method, the study aimed to identify the level of health risks posed by pollutants such as nitrate, cadmium, and copper contained in the river water. It also estimated the economic burden of pollution-related diseases, such as typhoid, diarrhea, skin diseases, and leptospirosis, using the Cost of Illness (COI) approach. The results of this study are expected to provide accurate data for policymakers in designing water pollution mitigation strategies as well as increasing public awareness of the health hazards posed by Pusur River pollution.

2. Methods

2.1. Types of Research

Analysis of the impact of pollution on health is a type of descriptive research using the Environmental Health Risk Analysis (ARKL) method. The research that will be carried out looks at several variables. The independent variable is the concentration of exposure to nitrate, cadmium, and copper, and the dependent variable is the magnitude of the health risk or Risk Quotient (RQ). Exposure to nitrates, cadmium, and copper that enter the body results in possible risks in at-risk populations after exposure to nitrates, cadmium, and copper. Intake or concentration intake is influenced by several risk factors such as body weight, average time period, length of exposure, ingestion rate, frequency of exposure, and duration of exposure. The concentration or number of doses that enter the body is influenced by these risk factors. Risks that may occur are new problems that will arise if there is no good risk management and it is not implemented by the relevant parties. The magnitude of the health risk posed is in the form of a non-carcinogenic risk level (RQ), which projects future health status.

The method for estimating economic losses due to river pollution is the cost of illness analysis. The cost of illness (COI) analysis in this study was calculated by focusing on three dimensions of expenses for various diseases (typhus, diarrhea, leptospirosis, and skin diseases), namely direct costs, indirect costs, and social costs. Direct costs (DC) include the costs of medicines, health checks/doctor visits, outpatient care, and inpatient care. Indirect costs (IC) cover transportation costs. Additionally, loss of job productivity is considered a proxy for social costs (SC) (Ali et al., 2021).

2.2. Time and Location of Research

Pusur River water sampling was carried out in August 2023 for dry season water quality analysis and in January 2024 for rainy season water quality analysis. Distribution of questionnaires was conducted in July 2024. The research location was in the villages of Sudimoro, Cokro, Wangen, Sabrang, Juwiring, and Taji.

2.3. Data Source

The types and sources of data used in this research are primary data and secondary data. Primary data were obtained from taking water samples in the rainy and dry seasons and analyzed at the Physics and Chemistry Environmental Risk Factors Laboratory at the Yogyakarta Center for Environmental Health Engineering and Disease Control, as well as through questionnaires. Secondary data related to waterborne diseases were collected from basic health units/health centers (Typhus, Diarrhea, Leptospirosis, and skin diseases data for 2022 and 2023) and obtained from various sources, such as the results of previous research, literature studies, reports, and documents from various agencies related to the topic being studied.

2.4. Data Collection Techniques

Data collection in research is carried out in the following way:

1. Nitrate, cadmium, and copper concentration data from direct measurements and testing at the Physics and Chemistry Environmental Risk Factors Laboratory at the Yogyakarta Center for Environmental Health Engineering and Disease Control.
2. Individual characteristics data, including age, body weight, ingestion rate, frequency of exposure, and duration of exposure, were obtained from the results of a literature review in the form of default values from the environmental health risk analysis guidelines of the Indonesian Ministry of Health in 2012. These guidelines refer to the Decree of the Minister of Health of the Republic of Indonesia Number 876/Menkes/Sk/Viii/2001 concerning Technical Guidelines for Environmental Health Impact Analysis, as well as the research results of Tokatlı and Islam [11] and EPA [12]. The data obtained is then used to calculate the intake of nitrate, cadmium, and copper that enter the human body through the ingestion route.
3. The sampling method uses a questionnaire with quota sampling (quota sampling) and purposive sampling. Sampling using quota sampling is a technique for determining samples from a population that has certain criteria up to the desired number (quota). The sample size calculation is determined using the Slovin formula (formula 19). Based on the calculation results, the sample size was 100 families.

n = the number of sample respondents taken in the research.
N = total population of water users at the research location; e = 10%.
The distribution of the number of samples/respondents can be seen in Table 1.

$$n = \frac{N}{1+N(and)^2} \tag{1}$$

Table 1.
Number of research sample respondents.

Village	Number of Population (People)	Number of families	Number of Respondents (KK)
Sudimoro	4.234	1.516	25
Cokro	2.035	704	11
cheeks	3.038	1.013	17
Sabrang	3.684	1.228	20
Juwiring	2.052	712	12
Crown	2.772	964	15
Total	17.815	6.137	100

2.5. Data Analysis

2.5.1. Analysis of the Impact of Pollution on Health

Environmental Health Analysis (ARKL) is a method used to estimate the risk of exposure to a toxic agent for human administration. Apart from that, ARKL can also be used to take into account the characteristics of specific targeted toxic agents. There are five components in the implementation of ARKL, namely as follows:

a. Hazard Identification (*Hazard Identification*)

The hazard identification step in this research involves analyzing the presence of nitrate, cadmium, copper, and fecal coliform in the Pusur admin water.

b. Dose-Response Analysis (*Dose-Response Assessment*)

The dose-response analysis activity was carried out by studying the literature on the effects in the form of the body's response caused by exposure to nitrates, aluminum, and copper in the body. The RfD values determined are for nitrate 1.16 mg/kg/day, cadmium 0.0005 mg/kg/day, and copper 0.04 mg/kg/day [13].

c. Exposure Analysis (*Exposure assessment*)

Exposure analysis is carried out by estimating the amount of exposure or intake, which is obtained from the total concentration of nitrate, aluminum, and copper. Calculation of non-carcinogenic intake (Ink) in the ingestion (swallowed) exposure route is done using the following formula 2.

$$Ink = \frac{C \times R \times fE \times Dt}{Wb \times Tavg} \quad (2)$$

Information:

Ink (*Intake*): The total concentration of risk agents (mg) that enters the human body with a certain body weight (kg) every day is expressed in calculation units of mg/kg per day. Additionally, the default value is not applicable.

C (*Concentration*): Concentration of risk agents in river water, with the calculation unit mg/l. Additionally, the default value is not applicable.

R (*Rate*): Consumption rate or the volume of water entering each hour, with units of calculation in liters per day. Additionally, the default values for drinking water are: adults 2 liters per day and children 1 liter per day.

fE (*frequency of exposure*): The duration or number of days of exposure each year, with units of calculation of days per year, as well as the default exposure value of 350 days per year.

Dt (*duration time*): The duration or number of years of exposure, with year calculation units.

As well as value *default* residential lifetime exposure: 30 years.

Wb (*weight of body*): Human body weight/population/population group, with the calculation unit in kg, as well as the default values for Asian/Indonesian adults: 55 kg, children: 15 kg.

Tavg (Ink) (time average): Average time period for non-carcinogenic effects, with units of calculation in days, as well as a default value of 30 years x 365 days/year = 10,950 days.

tE (exposure time): Exposure time. Number of hours exposed each day. As well as value *default* 24 hours

d. Risk Characteristics (*Risk Characteristic*)

Risk characteristics are determined by dividing Intake by the dose or concentration of the risk agent. The risk level for non-carcinogenic effects is expressed in the notation Risk Quotient (RQ). To characterize the risk for non-carcinogenic effects, calculations are performed by comparing/dividing Intake by RfD. The formula for determining RQ is as follows:

$$RQ = I/RfD \quad (3)$$

Information:

Used to calculate RQ on ingested pathway exposure (swallowing) I (*Intake*): *Intake* which has been calculated using formula 2

RfD (*Reference Dose*): Risk agent reference value on ingestion exposure.

Table 2.
RfD Values of Nitrate, Cadmium and Copper

Agent	EPA
Nitrate	1.16 mg/kg/day
Cadmium	0.0005 mg/kg/day
Copper	0.04 mg/kg/day

Source: USEPA (RfD values can also be found on the site www.epa.gov/iris).

Interpretation of non-carcinogenic risk levels. The risk level is expressed in numbers or decimal numbers without units. The risk level is considered safe when Intake ≤ RfD or expressed by RQ ≤ 1. The risk level is deemed unsafe if Intake > RfD or expressed by RQ > 1.

e. Risk Management

Risk management is not included in ARKL steps but rather follow-up actions that must be carried out if the results of

risk characterization show an unsafe or unacceptable risk level. When carrying out risk management, it is necessary to distinguish between risk management strategies and risk management methods. The risk management strategy includes determining safe limits, namely the concentration of the risk agent (C) and/or the amount of consumption (R). After the safe limit is determined, it is then necessary to screen alternatives for the safe limit, which will be used as targets for achievement in risk management. The chosen safe limit is one that is more rational and realistic to achieve.
Risk Agent Concentration (*C*) safe Non-Carcinogenic (Ingestion)

$$C(aman) = \frac{RfD \times Wb \times Tavg}{R \times tE \times fE \times Dt} \quad (4)$$

Total consumption (*R*), Non-Carcinogenic safe consumption rate (Ingestion)

$$R(aman) = \frac{RfDx\ Wb \times Tavg}{C \times tE \times fE \times Dt} \quad (5)$$

The risk management method is the approach that will be used to achieve these safe limits. Risk management methods include several approaches, namely technological approaches, socio-economic approaches, and institutional approaches.

Estimated value of economic losses due to river pollution.

The data analysis method used in this research is descriptive statistical analysis and illness costs (Cost of Illness). Descriptive statistical analysis is used to analyze the impact of pollution that occurs in the Pusur River by describing data collected based on facts in the field. The Cost of Illness method refers to the cost of treatment due to diseases caused by polluted water.

2.5. Descriptive Statistical Analysis:

- Mean (average value) for numeric variables (health care costs, costs of lost work productivity)
- Percentages for categorical variables (level of education, gender, total income, distance from house to river, level of frequency of interaction with river water, use of river water, type of health problems, length of work, length of time off work).

2.6. Cost of Illness

The impact of an activity on the environment, which has an effect on human health, can be measured using the methods of Cost of Illness (COI). The total costs calculated are the expenses incurred to treat the diseases suffered (typhus, diarrhea, leptospirosis, and skin diseases), namely direct costs, indirect costs, and social costs. Direct costs (DC) include drug costs, health examination costs/doctor visits, outpatient costs, and inpatient care. Indirect costs (IC) cover transportation costs. Additionally, the loss of job productivity is considered a proxy for social costs (SC) [14]. The formula used to carry out assessments using this method is:

$$COI = DC + IC + SC = \Sigma COI \quad (6)$$

Where:
COI = Total sick costs/year (Rp) DC = Direct costs/household (Rp) IC = Indirect costs/household (Rp) SC= Social/household costs (Rp)

3. Results and Discussion

3.1. Impact of Pollution on Health

Environmental Health Analysis (ARKL) is a method used to estimate the risk of exposure to a toxic agent on human health. There are five steps in implementing ARKL, namely as follows:

3.1.1. Hazard Identification

The danger in this research is the presence of pollutant parameters: nitrate, cadmium, and copper in the water of the Pusur River. The nitrate, Cd, and Cu content in Pusur River water can be seen in Table 3.

The results of laboratory analysis show that the content of nitrate parameter pollutants at the sample points in Sudimoro and Cokro villages, both dry and rainy season samples, has exceeded class 2 river water quality standards, which means that the presence of this pollutant parameter can cause various serious environmental and health problems. If nitrates enter the body through contaminated water, they can cause various health problems, such as issues with the respiratory and digestive systems. The content of Cd and Cu pollutants in Pusur river water, both dry and rainy season samples, is still below class 2 river water quality standards. The presence of cadmium (Cd) and copper (Cu) in river water can have a significant negative impact on human health, aquatic ecosystems, and the quality of the water itself. These two heavy metals can pollute river water and pose a risk of causing serious damage if their concentrations exceed the limits permitted according to water quality standards.

The results of this study are in line with the findings of Safitri, et al. [15], who found that the waters of the Jenes River have been categorized as heavily polluted, and the values of the parameters taken show that they have exceeded the standard quality standards. Meanwhile, the results of the analysis.

Table 3.
Content of pollutant parameters nitrate, Cd, and Cu in Pusur River water.

Drought Sample (August 2023)			
Village	**Nitrate (mg/L)**	**Cadmium (mg/L)**	**Copper (mg/L)**
Sudimoro	18.3	0.0066	0.006
Cokro	17.51	0.0066	0.006
cheeks	9.21	0.0066	0.006
Sabrang	7.9	0.0066	0.006
Juwiring	8.14	0.0066	0.006
Crown	3.17	0.0066	0.006
Rainy Season Sample (January 2024)			
Sudimoro	13.17	0.0066	0.006
Cokro	13.85	0.0066	0.006
cheeks	9.63	0.0066	0.006
Sabrang	7.39	0.0066	0.006
Juwiring	6.87	0.0066	0.006
Crown	2.68	0.0066	0.006
Class 2 Quality Standards	10	0.01	0.02

The selected text in Word discusses groundwater quality parameters such as temperature, turbidity, Total Dissolved Solids (TDS), pH, and Dissolved Oxygen (DO), which still meet the quality standards set in PERMENKES No. 32 of 2017. Therefore, pollution in the Jenes River does not affect the quality of the surrounding groundwater.

Cadmium Toxicity: Cadmium is a heavy metal that is very toxic to humans and can cause various health problems, even in relatively low concentrations. Chronic exposure to cadmium can result in:

a) Kidney damage: Cadmium is highly toxic to the kidneys, and long-term accumulation can cause acute or chronic kidney damage.
b) Cancer: Cadmium has been classified as a carcinogen, meaning that long-term exposure can increase the risk of cancer, especially lung cancer.
c) Bone disorders: Cadmium can also cause bone disorders, such as Itai-Itai disease, which leads to bone loss and increased susceptibility to fractures.

Poisoning Mechanism: Cadmium can enter the body through contaminated water and settle in body tissues, especially in the kidneys and liver, affecting the function of these organs.

Copper is an essential metal for the human body in small amounts, but if the concentration is too high, it can be toxic. Excessive copper exposure can cause:

a) Digestive disorders: Symptoms such as nausea, vomiting, diarrhea, and stomach ache often occur with exposure to large amounts of copper.
b) Liver and kidney damage: Long-term exposure to copper can cause liver and kidney damage, and in extreme cases, it can lead to acute copper poisoning.
c) Nervous system disorders: High concentrations of copper can also affect the nervous system and cause neurological symptoms such as fatigue, dizziness, and confusion.

Given the potential risks associated with nitrate, cadmium, and copper contamination in river water, immediate and proactive measures are necessary to mitigate their impact on human health and the environment. Strengthening water quality monitoring, enforcing stricter regulations on industrial and agricultural waste disposal, and promoting sustainable water management practices are essential steps toward reducing pollution levels. Additionally, raising public awareness about the dangers of heavy metal exposure and encouraging the use of safer water treatment methods can help minimize health risks. Future research should also focus on long-term ecological assessments and the development of innovative remediation technologies to ensure the sustainability of water resources and safeguard community well-being.

3.1.2. Dose-Response Analysis

Dose-Response Analysis is an approach used to describe the relationship between the dose of a pollutant (for example, nitrate, cadmium, and copper) to which humans are exposed and the response or effect it causes. This Dose-Response analysis is used to assess the level of threat or danger of pollution depending on the concentration of pollutants in the environment and its potential impact on human health.

1) Nitrate (NO_3^-)
a) Low Dose (0–50 mg/L):

Response: At low levels, nitrates in water are generally considered safe for most people. However, in babies younger than 6 months, concentrations greater than 10 mg/L in drinking water can cause a disorder called methemoglobinemia or blue baby syndrome, which reduces the blood's ability to transport oxygen.

b) Intermediate Dosage (50–100 mg/L):

Response: These increased nitrate concentrations may pose a risk to health, especially in infants and people with respiratory disorders. Repeated exposure can cause respiratory problems and disorders of the circulatory system.

c) High Dosage (>100 mg/L):

Response: At higher concentrations, health effects are more pronounced, with serious risks such as nitrate poisoning causing impaired blood oxygenation and risks to the baby. It can also trigger other health problems such as cancer (although this risk is more related to the form of nitrosamines formed in the body after exposure to nitrates).

2) Cadmium (Cd)

a) Low Dose (0–0.01 mg/L):

Response: At low concentrations, cadmium is not harmful, but long-term exposure at these levels can cause accumulation of cadmium in the body, especially in the kidneys and liver.

b) Intermediate Dosage (0.01–0.1 mg/L):

Response: Exposure to these concentrations can begin to have toxic effects on the kidneys and liver, although symptoms may not be immediately apparent. Kidney damage, including a decrease in the kidneys' ability to filter toxins, may occur.

c) High Dosage (>0.1 mg/L):

Response: At high doses, cadmium is very dangerous. Exposure can cause acute poisoning, with symptoms such as vomiting, diarrhea, and acute kidney damage. In the long term, chronic exposure can cause cancer (especially lung cancer) and bone damage (e.g., osteoporosis).

3) Copper (Cu)

a) Low Dose (0–1.3 mg/L):

Response: Copper at this level is considered safe in drinking water. In fact, the human body requires small amounts of copper for metabolism, but it does not cause negative effects.

b) Intermediate Dosage (1.3–5 mg/L):

Response: At higher concentrations, copper may cause mild poisoning symptoms, including nausea, vomiting, and stomach upset. This occurs more often if a person regularly consumes copper-contaminated water.

c) High Dosage (>5 mg/L):

Response: Very high concentrations of copper can cause severe poisoning, leading to damage to organs such as the liver and kidneys, and can reduce nervous system function. Long-term exposure can affect the body's hormonal balance and metabolism.

3.1.3. Exposure Assessment

Exposure analysis is carried out by estimating the amount of exposure or intake, which is obtained from the total concentration of nitrate, cadmium, and copper. The calculation results can be seen in Table 4.

Table 4.
The value of the amount of exposure from the concentration of nitrate, cadmium, and copper in Pusur River water.

Drought Sample (August 2023)									
Village	**C (mg/L) Nitrate**	**Cadmium**	**Copper**	**Intake (mg/kg x hari) Nitrate Mature**	**Children**	**Cadmium Mature**	**Children**	**Copper Mature**	**Children**
Sudimoro	18.3	0.0066	0.006	0.638	1.170	0.00023	0.00042	0.00021	0.00038
Cokro	17.51	0.0066	0.006	0.611	1.119	0.00023	0.00042	0.00021	0.00038
cheeks	9.21	0.0066	0.006	0.321	0.589	0.00023	0.00042	0.00021	0.00038
Sabrang	7.9	0.0066	0.006	0.275	0.505	0.00023	0.00042	0.00021	0.00038
Juwiring	8.14	0.0066	0.006	0.284	0.520	0.00023	0.00042	0.00021	0.00038
Crown	3.17	0.0066	0.006	0.111	0.203	0.00023	0.00042	0.00021	0.00038
Rainy Season Sample (January 2024)									
Sudimoro	13.17	0.0066	0.006	0.459	0.842	0.00023	0.00042	0.00021	0.00038
Cokro	13.85	0.0066	0.006	0.483	0.885	0.00023	0.00042	0.00021	0.00038
cheeks	9.63	0.0066	0.006	0.336	0.616	0.00023	0.00042	0.00021	0.00038
Sabrang	7.39	0.0066	0.006	0.258	0.472	0.00023	0.00042	0.00021	0.00038
Juwiring	6.87	0.0066	0.006	0.240	0.439	0.00023	0.00042	0.00021	0.00038
Crown	2.68	0.0066	0.006	0.093	0.171	0.00023	0.00042	0.00021	0.00038

The number of exposures (Total Exposure) to nitrate (NO_3^-), cadmium (Cd), and copper (Cu) concentrations means assessing how much of these pollutants humans are exposed to over a certain period of time, as well as their impact on health. Exposure can occur through various means, such as inhalation, ingestion, or direct skin contact. In the context of water pollution, exposure is often related to water consumption or direct contact with contaminated water. From the calculation results in Table 4, it can be seen that the amount of exposure to the pollutant parameters nitrate, Cd, and Cu is greater in children compared to adults. This is due to factors such as consuming more per unit of body weight. The results of this study are in accordance with the statements of other researchers who state that children are more susceptible to many environmental contaminants compared to adults due to their higher sensitivity as receptors, higher environmental pollution per unit weight, and developing biological systems that cause significantly increased health risks through drinking water intake and skin contact [16, 17].

These findings emphasize the importance of special protection for vulnerable groups, especially children, in the face of water pollution risks. Prevention efforts should include improving access to clean water sources, implementing stricter water quality standards, and educating the public on how to reduce exposure to harmful pollutants. In addition, regular monitoring of water quality and further research on the long-term impacts of heavy metal contamination should be conducted to develop more effective mitigation strategies. With these measures, it is hoped that health risks due to water pollution can be reduced, so that the quality of life of people who depend on the Pusur River can be better maintained.

3.1.4. Risk Characteristic

Risk characteristics are determined by dividing Intake by the dose or concentration of the risk agent. The risk level for non-carcinogenic effects is expressed in the notation Risk Quotient (RQ). To characterize the risk for non-carcinogenic effects, calculations are performed by comparing/dividing Intake by RfD. The calculation results can be seen in Table 5.

Table 5.
Level of risk of effects of non-carcinogenic nitrate, cadmium and copper pollutants.

Drought Sample (August 2023)												
Village	**Intake (mg/kg x hari) Nitrate**		**Cadmium**	**Copper**		**RQ Nitrate**		**Cadmium**		**Copper**		
	Mature	**Children**	**Mature**	**Children**	**Mature**	**Children**	**Mature**	**Children**	**Mature**	**Children**	**Mature**	**Children**
Sudimoro	0.638	1.170	0.00023	0.00042	0.00021	0.00038	0.550	1.009	0.460	0.844	0.0052	0.0096
Cokro	0.611	1.119	0.00023	0.00042	0.00021	0.00038	0.526	0.965	0.460	0.844	0.0052	0.0096
cheeks	0.321	0.589	0.00023	0.00042	0.00021	0.00038	0.277	0.508	0.460	0.844	0.0052	0.0096
Sabrang	0.275	0.505	0.00023	0.00042	0.00021	0.00038	0.237	0.435	0.460	0.844	0.0052	0.0096
Juwiring	0.284	0.520	0.00023	0.00042	0.00021	0.00038	0.245	0.449	0.460	0.844	0.0052	0.0096
Crown	0.111	0.203	0.00023	0.00042	0.00021	0.00038	0.095	0.175	0.460	0.844	0.0052	0.0096
Rainy Season Sample (January 2024)												
Sudimoro	0.459	0.842	0.00023	0.00042	0.00021	0.00038	0.396	0.726	0.460	0.844	0.0052	0.0096
Cokro	0.483	0.885	0.00023	0.00042	0.00021	0.00038	0.416	0.763	0.460	0.844	0.0052	0.0096
cheeks	0.336	0.616	0.00023	0.00042	0.00021	0.00038	0.289	0.531	0.460	0.844	0.0052	0.0096
Sabrang	0.258	0.472	0.00023	0.00042	0.00021	0.00038	0.222	0.407	0.460	0.844	0.0052	0.0096
Juwiring	0.240	0.439	0.00023	0.00042	0.00021	0.00038	0.207	0.379	0.460	0.844	0.0052	0.0096
Crown	0.093	0.171	0.00023	0.00042	0.00021	0.00038	0.081	0.148	0.460	0.844	0.0052	0.0096

Table 6.
Data on Disease Cases at Research Locations.

Types of	**Tulung**	**District**		**Polanh**	**rjo District**		**Delanggu District**			**Juwiring District**			**Average Disease Cases/year**			
	2021	**2022**	**2023**	**2021**	**2022**	**2023**	**2021**	**2022**	**2023**	**2021**	**2022**	**2023**				
	Year	**Year**	**Year**	**Year**	**Year**	**Year**	**Year**	**Year**	**Year**	**Year**	**Year**	**Year**	**Please**	**Polanharjo**	**Delanggu**	**Juwiring**
1. Typhus	4	35	6	0	0	0	0	0	0	297	254	294	15	0	0	282
2. Diarrhea	265	353	434	267	612	386	1.369	1.928	912	445	296	405	351	422	1.403	382
3. Skin disease	716	724	746	24	28	37	0	0	0	269	202	283	729	30	0	251
4.Leptospirosis	0	1	2	0	2	2	0	0	0	0	10	4	1	1	0	5

Table 7.
Data on drug costs and drug price estimates. Cases of disease due to water pollution.

No.	Types of Disease	Average cases/Year				Type of Medication Given	Estimated Medicine Price (Rp)	Average total drug costs/year (Rp)			
		Please	Polanharjo	Delanggu	Juwiring			Please	Polanharjo	Delanggu	Juwiring
1.	Typhus	15	0	0	282	Ciprofloxacin, paracetamol, antacids, domperidone	15.000-20.000	262.500	0	0	4.929.167
		351	422	1.403	382	Paracetamol, attapulgit, ranitidine, antacids,	15.000-20.000	6.136.667	7.379.167	24.552.500	6.685.000
2.	Diarrhea					domperidone					
		729	30	0	251	Mupirocin (topical), Amoxicillin (oral),	10.000-100.000	40.076.667	1.631.667	0	13.823.333
3.	Skin disease					Loratadine					
		1	1	0	5	Paracetamol, sucralfate, cefixime, lansoprazole,	65.000-70.000	67.500	90.000	0	315.000
4.	Leptospirosis					methylprednisolone					
Total								46.543.333	9.100.833	24.552.500	25.752.500

Note: Average drug costs/year (Rp) is the average result of multiplying the number of cases of each disease by the upper and lower limits of the estimated drug price.

Table 8.
Data on Estimated Costs of Treatment at Community Health Centers.

No.	Types of Disease	Average Please	cases/Year Polanharjo	Delanggu	Juwiring	Outpatient Please	(Rp. 22,500) Polanharjo	Delanggu	Juwiring	Hospitalization Please	(Rp. 120,000) Polanharjo	Delanggu	Juwiring
1	Typhus	15	0	0	282	337.500	0	0	6.337.500	1.800.000	0	0	33.800.000
2	Diarrhea	351	422	1.403	382	7.890.000	9.487.500	31.567.50	8.595.000	42.080.000	50.600.00	168.360.00	45.840.0000
3.Skin disease		729	30	0	251	16.395.00	667.500	0	5.655.000	87.440.000	3.560.000	30.160.000	0
4.Leptospirosis		1	1	0	5	22.500	30.000	0	105.000	120.000	160.000	0	560.000
Total						24.645.00	10.185.00	31.567.50	20.692.50	131.440.00	54.320.00	168.360.00	110.360.000

Source: Secondary data from Community Health Center 2021-2023 and Klaten Regent Regulation Number 34 of 2020

Note: Details of outpatient costs are outpatient administration costs (Rp. 3,500), consultation (Rp. 2,000), health examination (Rp. 7,000), and emergency care (Rp. 10,000). Meanwhile, the details of inpatient treatment are medicine, basic services, room and board (Rp. 120,000).

Table 9.
Data on Estimated Costs of Hospital Treatment

No.	Types of Disease	Average Please	cases/Year Polanharjo	Delanggu	Juwiring	Outpatient (Rp. 140,500) Please	Polanharjo	Delanggu	Juwiring	Hospitalization Please	(Rp. 275,000) Polanharjo	Delanggu	Juwiring
1	Typhus	15	0	0	282	2.107.500	0	0	39.574.167	4.125.000	0	0	77.458.333
2	Diarrhea	351	422	1.403	382	49.268.667	59.244.167	197.121.500	53.671.000	96.433.333	115.958.333	385.825.00	105.050.000
3.Skin		729	30	0	251	102.377.667	4.168.167	0	35.312.333	200.383.333	8.158.333	0	69.116.667
4.Leptospirosis		1	1	0	5	140.500	187.333	0	655.667	275.000	366.667	0	1.283.333
Total						153.894.333	63.599.667	197.121.500	129.213.16	301.216.667	124.483.333	385.825.00	252.908.333

Source: Secondary data from Puskesmas 2021-2023 and health costs rates at Bagas Waras Regional Hospital based on Klaten Regency Regional Regulation No. 15 in 2023
Note: Details of outpatient costs are outpatient administration costs (Rp. 10,000), consultation (Rp. 45,000), health examination (Rp. 47,500), and emergency care (Rp. 38,000). Meanwhile, the details of inpatient treatment are medicine, basic services, room and board (Rp. 275,000).

Table 10.
Total Estimated Cost of Illness (COI).

No.	Types of Disease	(COI) Total cost of illness/yea		r (Rp) at Puske	mas	(COI) Total cost of illness/year		(Rp) at the hosp	ital
		Please	Polanharjo	Delanggu	Juwiring	Please	Polanharjo	Delanggu	Juwiring
1	Typhus	2.400.000	0	0	45.066.667	6.495.000	0	0	121.961.667
2	Diarrhea	56.106.667	67.466.667	224.480.000	61.120.000	151.838.667	182.581.667	607.499.000	165.406.000
3	Skin disease	143.911.667	5.859.167	0	49.638.333	342.837.667	13.958.167	0	118.252.333
4	Leptospirosis	210.000	280.000	0	980.000	483.000	644.000	0	2.254.000
Total		202.628.333	73.605.833	224.480.000	156.805.000	501.654.333	197.183.833	607.499.000	407.874.000

Note: The total cost of illness (COI) is obtained from the sum of drug costs (Table 3) and treatment costs (Tables 4 and 5).

Table 11.
Difference in Total Estimated Cost of Illness (COI) from Community Health Centers and Hospitals.

No. Types of Disease		Difference in (Rp)	COI of Community	Health Centers	and Hospitals	Difference in COI of Community Health Centers and Hospitals (%)			
		Please	Polanharjo	Delanggu	Juwiring	Please Polanharjo Delanggu Juwiring			
1	Typhus	4.095.000	0	0	76.895.000	63	0	0	63
2	Diarrhea	95.732.000	115.115.000	383.019.000	104.286.000	63	63	63	63
3	Skin disease	198.926.000	8.099.000	0	68.614.000	58	58	0	58
4	Leptospirosis	273	364	0	1.274.000	57	57	0	57
Total		299.026.000	123.578.000	383.019.000	251.069.000	60	63	63	62

The risk level is expressed in numbers or decimal numbers without units. The risk level is considered safe if RQ ≤ 1. The risk level is deemed unsafe if RQ > 1. From Table 5, it can be seen that at all sample points in both the dry season and rainy season, the non-carcinogenic risk level for pollutant parameters nitrate, cadmium, and copper is considered safe for adults and children because the average of all RQ values is ≤ 1. Specifically, the RQ value of nitrate in adults ranges from 0.081 to 0.55, and in children, it ranges between 0.148 and 1.009. The RQ value of cadmium in adults is 0.460, and in children, it is 0.844. The RQ value of copper in adults is 0.0052, and in children, it is 0.0096. The risk level for children is greater than for adults because children are more susceptible to health risks due to exposure to pollutants than adults. Factors such as faster metabolism, lower detoxification abilities, and differences in body system responses contribute to children's higher vulnerability [17, 18]. Since the results of calculating the risk level for the presence of nitrate, Cd, and Cu pollutant parameters in Pusur river water are still in the safe category for health, this research did not carry out a risk management analysis.

Although nitrate, cadmium, and copper levels in the Pusur River are still in the safe category, continuous monitoring and preventive measures are still needed to maintain water quality and public health. Children, who are more vulnerable to pollutants, need more protection through strict water management policies, pollution control, and public education. Further research on the long-term impacts and interactions of environmental pollutants is also needed to ensure the sustainability of the Pusur River ecosystem and the well-being of the surrounding communities.

3.2. Sickness costs (Cost of Illness)

The medical costs/sickness costs used are costs borne by the community. Cases of diseases related to water pollution discussed in this research are typhoid, diarrhea, skin diseases, and leptospirosis [19, 20]. The incidence of disease cases for each type of disease in the last three years (2021-2023) at the research location is shown in Table 8, which comes from data from the Community Health Center. The estimated value of the Cost of Illness (COI) is calculated based on direct costs (DC), which include drug costs (Table 9) sourced from Puskesmas data, costs for health examinations/doctor visits, outpatient and inpatient costs sourced from Klaten Regent Regulation Number 34 of 2020 concerning Tariffs for Regional Public Service Agency Technical Implementation Units for Central Public Health Services at Health Services within the Klaten Regency Government (Table 10), and those sourced from data from Bagas Waras Regional Hospital based on Klaten Regency Regional Regulation No. 15 of 2023 (Table 11), as a comparison to find out how much the government subsidy is for treatment costs for cases of this disease. Meanwhile, indirect costs (IC) covering transportation costs and costs of lost work productivity are considered as proxies for social costs (SC), which are not calculated, because from primary data or questionnaire results, only 7% of respondents use Pusur river water to irrigate rice fields and livestock needs, so they feel they have never experienced disease caused by river water pollution.

As for the data on cases of disease caused by water pollution from community health centers in the research location (Table 8) it can be concluded that it is not because the Pusur river water is polluted, it probably comes from poor or unhygienic sanitation of the population, where poor sanitation, unsafe drinking water and poor hygiene practices are the main factors that can be associated with the occurrence of water-borne diseases [19, 21, 22].

The types of diseases most suffered by the community were diarrhea with an average of 1,403 cases in Delanggu subdistrict, 729 cases of skin disease in Tulung subdistrict, 282 cases of typhus in Juwiring subdistrict, and 5 cases of leptospirosis in Juwiring subdistrict (Table 8). Estimated total drug costs are obtained from the average multiplication of the number of each disease case with the upper and lower limits of the estimated drug price which is shown in Table 9. Outpatient costs and inpatient costs in this study are respectively calculated per one drug purchase, one treatment/consultation and inpatient costs per day multiplied by the average number of sufferers in the last three years (2021-2023) (Table 10) treatment at the health center and Table 11 treatment at the hospital), resulting in an estimated value *Cost of Illness* (COI) of the 4 types of diseases caused by water pollution experienced by people living in Tulung sub-district amounting to Rp. 202,628,333, Polanharjo amounted to

Rp. 73,605,833 for Delanggu, Rp. 224,480,000, and Rp. 156,805,000 for Juwiring sub-district (Puskesmas data), along with data from hospitals in Tulung sub-district amounting to Rp. 501,654,333, Polanharjo Rp. 197,183,833, Delanggu Rp. 607,499,000, and Juwiring sub-district Rp. 407,874,000. The difference in the total estimated cost of illness (COI) from community health centers and hospitals is an average of 62%, it can be said that the amount of government subsidy for illness costs is 62% for community health centers in the sub-district.

The findings in this study are in line with research in India from Goyanka [23] shows that water, sanitation, and hygiene (*WASH*)-related diseases pose a significant health and economic burden on the population. These diseases account for 5.7% of all outpatient visits and 6.9% of hospitalizations, with an average treatment cost of ₹703 per outpatient visit and ₹9656 per hospital stay. This financial burden is even greater in rural areas, where 74% of jaundice patients incur medical expenses exceeding their monthly income, while 97% of malaria patients in urban areas face extremely high out-of-pocket expenses for outpatient care. Additionally, each hospitalization due to jaundice in urban areas results in an average income loss of ₹2260, highlighting the broader economic impact of preventable diseases. Multilevel logistic regression analysis also indicates that community-level factors play a crucial role in disease prevalence variation, with an intra-class correlation of 0.28 for outpatient cases and 0.26 for hospitalizations, confirming that environmental conditions and access to WASH facilities significantly influence public health levels.

Another study by Junengsih [24] stated that the estimated economic loss of the community due to industrial liquid waste pollution in three villages, namely Utama, Leuwigajah, and Melong Villages, South Cimahi District, was Rp. 9,896,998,561 per year. This value was obtained by using an approach that considered the cost of replacing clean water, the cost of illness, and loss of income due to illness. The total willingness to accept (WTA) of the community is Rp 5,107,036,092 per year, while the willingness of the community to receive compensation is Rp 105,109/KK/month. However, efforts that have been made by companies or industries in the form of providing clean water facilities to affected communities amount to Rp 63,825/KK/month. The factors that influence people's willingness to accept compensation are education, length of stay, and distance to the river.

These findings highlight the significant economic burden that water pollution-related diseases place on affected communities, reinforcing the urgent need for improved water quality management and sanitation policies. The parallels with studies in India and Cimahi emphasize that inadequate access to clean water and proper sanitation not only leads to increased disease prevalence but also imposes substantial financial strain on households, particularly in rural areas. The discrepancy between estimated illness costs at community health centers and hospitals further underscores the role of government subsidies in mitigating financial hardships. However, the existing support may not be sufficient to fully alleviate the economic impact on affected families. Therefore, strengthening infrastructure, enforcing stricter environmental regulations, and increasing public awareness about waterborne diseases are crucial steps to reduce health risks and economic losses due to water pollution.

4. Conclusion

The findings of this study indicate that pollution in the Pusur River has significant implications for both public health and the local economy. Laboratory analysis revealed that nitrate levels at certain sampling points, particularly in Sudimoro and Cokro villages, exceeded Class 2 river water quality standards, posing potential health risks such as respiratory and digestive issues. Although cadmium (Cd) and copper (Cu) levels remained within permissible limits, their long-term presence still necessitates continuous monitoring due to potential cumulative health effects.

The study also found that diseases related to water pollution, including diarrhea, typhoid, skin infections, and leptospirosis, imposed substantial economic burdens on affected communities. The estimated Cost of Illness (COI) varied across different subdistricts, with higher costs reported in areas with greater disease prevalence. The financial burden was particularly significant for low-income households, further emphasizing the need for improved water quality management. The discrepancy in COI between community health centers and hospitals, averaging 62%, also highlights the role of government subsidies in covering healthcare costs.

In light of these findings, strengthening water management policies, enforcing stricter pollution control measures, and enhancing public awareness about waterborne diseases are crucial steps toward mitigating both health risks and economic losses. Future research should explore long-term exposure effects and develop more effective remediation strategies to ensure the sustainability of the Pusur River ecosystem and the well-being of surrounding communities.

References

[1] A. M. Saad, F. F. A. H. Asari, S. Affandi, and A. Zid, "River pollution: A mini review of causes and effects," *Management*, vol. 7, no. 29, pp. 139-151, 1958. https://doi.org/10.35631/JTHEM.729011

[2] E. Yanti and Y. Aprihatin, "Analysis of River environmental pollution factors," *Jurnal Penelitian Pendidikan IPA*, vol. 10, no. 2, pp. 465-470, 2024. https://doi.org/10.29303/jppipa.v10i2.682

[3] K. Sharma, S. Rajan, and S. K. Nayak, *Water pollution: Primary sources and associated human health hazards with special emphasis on rural areas* (Water resources management for rural development). Elsevier. https://doi.org/10.1016/B978-0-443-18778-0.00014-3, 2024.

[4] U. B. Prajapati, *Socio-economic perspective of river health: A case study of river Ami, Uttar Pradesh, India* (Ecological Significance of River Ecosystems). Elsevier. https://doi.org/10.1016/B978-0-323-85045-2.00022-4, 2022.

[5] M. Afandi, R. Zakaria, A. Wardoyo, and A. Kusumastuti, "Integrative approach in preserving the Pusur Sub-Watershed, Klaten Regency," in *Proceedings of the UMS IX National Geography Seminar: River Restoration Challenges and Sustainable Development Solutions*, 2018, vol. 7, pp. 349–361.

[6] S. R. Sugiyo, R. Rawana, N. S. Nugraha, and A. Prijono, "River health study using biometric methods, case study in the Pusur River, Klaten Regency," *Tropical Forest Journal*, vol. 19, no. 1, pp. 150-155, 2024. https://doi.org/10.36873/jht.v19i1.13037

[7] I. Andesgur, P. Setyono, and E. Gravitiani, "Water quality assessment and evaluation of human health risks in the Pusur River, Klaten Regency, Central Java, Indonesia," in *IOP Conference Series: Earth and Environmental Science*, 2024, vol. 1317, no. 1: IOP Publishing, p. 012024.

[8] F. Xia, X. Niu, L. Qu, R. A. Dahlgren, and M. Zhang, "Integrated source-risk and uncertainty assessment for metals contamination in sediments of an urban river system in eastern China," *Catena*, vol. 203, p. 105277, 2021. https://doi.org/10.1016/j.catena.2021.105277

[9] R. T. Madilonga, J. N. Edokpayi, E. T. Volenzo, O. S. Durowoju, and J. O. Odiyo, "Water quality assessment and evaluation of human health risk in Mutangwi River, Limpopo Province, South Africa," *International Journal of Environmental Research and Public Health*, vol. 18, no. 13, p. 6765, 2021. https://doi.org/10.3390/ijerph18136765

[10] N. Fahimah *et al.*, "The assessment of water quality and human health risk from pollution of chosen heavy metals in the Upstream Citarum River, Indonesia," *Journal of Water and Land Development*, vol. 56, pp. 153–163, 2023. https://doi.org/10.24425/jwld.2023.143756

[11] C. Tokatlı and A. R. M. T. Islam, "Spatial–temporal distributions, probable health risks, and source identification of organic pollutants in surface waters of an extremely hypoxic river basin in Türkiye," *Environmental Monitoring and Assessment*, vol. 195, no. 3, p. 435, 2023. https://doi.org/10.1007/s10661-023- 11042-x

[12] EPA, "Risk assessment guidance for superfund. Human Health Evaluation Manual (Part A)," vol. 1, 1989. https://doi.org/EPA/540/1-89/002

[13] U.S. Environmental Protection Agency (EPA), "Chemical reference dose and slope factor. Office of Environmental Health Hazard Assessment (OEHHA)," Retrieved: https://www.epa.gov/risk/chemical-risk-assessment. [Accessed 2010.

[14] G. Ali, M. K. Bashir, S. Abbas, and M. Murtaza, "Drinking-water efficiency, cost of illness, and peri-urban society: An economic household analysis," *PloS one,* vol. 16, no. 9, p. e0257509, 2021. https://doi.org/10.1371/journal.pone.0257509

[15] F. E. Safitri, A. W. W. Ramadhan, H. Khairunnisa, T. A. Pramitasari, S. Rachmawati, and M. Sholiqin, "Dampak tingkat cemaran Sungai Jenes terhadap kualitas air tanah warga di Kelurahan Joyotakan, Kecamatan Serengan, Surakarta," *Jurnal Ilmu Lingkungan,* vol. 21, no. 2, pp. 318-328, 2023. https://doi.org/10.14710/jil.21.2.318-328

[16] Y. Hu *et al.*, "Risk assessment of antibiotic resistance genes in the drinking water system," *Science of the Total Environment,* vol. 800, p. 149650, 2021. https://doi.org/10.1016/j.scitotenv.2021.149650

[17] A. Ferguson and H. Solo-Gabriele, "Children's exposure to environmental contaminants: an editorial reflection of articles in the IJERPH special issue entitled,"children's exposure to environmental contaminants"," *International Journal of Environmental Research and Public Health,* vol. 13, no. 11, p. 1117, 2016. https://doi.org/10.3390/ijerph13111117

[18] M. Hauptman and A. D. Woolf, "Childhood ingestions of environmental toxins: What are the risks?," *Pediatric Annals,* vol. 46, no. 12, pp. e466-e471, 2017. https://doi.org/10.3928/19382359-20171116-01

[19] W. M. Manetu and A. M. Karanja, "Waterborne disease risk factors and intervention practices: A review," *Open Access Library Journal,* vol. 8, no. 5, pp. 1-11, 2021. https://doi.org/10.4236/oalib.1107401

[20] F. Sugiester, Y. Firmansyah, W. Widiyantoro, M. Fuadi, Y. Afrina, and A. Hardiyanto, "Impact of river pollution in Indonesia on health problems: Literature Review," *Jurnal Riset Kesehatan Poltekkes Depkes Bandung,* vol. 13, no. 1, pp. 120-133, 2021. https://doi.org/10.34011/juriskesbdg.v13i1.1829

[21] Indonesian Ministry of Health, "Indonesian health profile 2021. Pusdatin Kemenkes," Retrieved: https://pusdatin.kemenkes.go.id. [Accessed 2022.

[22] N. F. Salsabila, M. Raharjo, and T. Joko, "River water pollution index and the distribution of waterborne diseases: A systematic study," *Environmental Occupational Health and Safety Journal,* vol. 4, no. 1, pp. 24-34, 2023. https://doi.org/10.24853/eohjs.4.1.24-34

[23] R. Goyanka, "Burden of water, sanitation and hygiene related diseases in India: prevalence, health care cost and effect of community level factors," *Clinical Epidemiology and Global Health,* vol. 12, p. 100887, 2021. https://doi.org/10.1016/j.cegh.2021.100887

[24] J. Junengsih, "Estimation of economic losses to the community due to pollution of the Citarum River (Case: Utama, Melong and Leuwigajah Sub-districts, South Cimahi District, Cimahi City, West Java Province)," Doctoral Dissertation, Bogor Agricultural University (IPB)). 2018.