Water quality assessment of Pattunuang River, Bantimurung Bulusaraung National Park for tourism

I A Putri* and F Ansari†

1 Environment and Forestry Research and Development Institute of Makassar, Jalan Perintis Kemerdekaan Km 16, Makassar, South Sulawesi, 90243, Indonesia

*E-mail: indra.arsulipp@gmail.com

Abstract. Pattunuang asue Nature Tourism Object is a primary destination at Bantimurung Bulusaraung National Park. Visitors of Pattunuang asue used the Pattunuang river to conduct their activities, such as swimming, bathing, river tubing, and also used the river water for drinking and cooking. However, using river water for these activities needs to fulfill standard water quality for tourism activities and drinking water. Therefore, this study aims to determine the quality of the Pattunuang river water. Data of physical parameters and conditions of river water were conducted using the survey method. We also collected water samples using the purposive sampling method. Furthermore, these samples were analyzed at the laboratory to measure other physical data such as total suspended solids (TSS) and total dispended solids (TDS), chemical, and microbiology. Data were analyzed following water quality parameters, compared to several regulations regarding water quality standards for tourism and drinking water. The results showed that the Pattunuang river water fulfills most of the standard of physical quality for tourism and drinking water, except TDS. However, some chemical parameters exceeded the threshold for tourism and drinking water. Microbiology parameters meet the standard requirements for several regulations but did not meet the requirements for water that can be drunk directly. Furthermore, this study discussed how to overcome this problem.

1. Introduction

River provides water that has an essential role in human life, and it has been utilized to support their life, for instance, drinking water [1,2], bathing [3], laundry [4], toilet facilities or public defecation [5], fishery [6], livestock watering [7], agriculture [8], and industry [9].

Rivers also have an essential role in tourism. Many rivers have become famous destinations and attract tourists to visit. For example, the Yangtze River [10], the Mekong River [11], the Colorado River and the Mississippi River [12], the Nile River [13], the Amazone River [14], and the Ganga River [15].

Pattunuang river is one of the rivers that has become a tourism destination [16]. This river has a beautiful panorama and magnetizes visitors. This river divides Pattunuang asue Natural Tourism Object...
Pattunuang river is located in the karst ecosystem area, so it has unique geology and geomorphology not found in another ecosystem. This river is bordered by tower karst, which flows on the surface and divides the karst landscape, creating an enchanting sight. The beautiful panorama within the presence of flowing water makes this location becomes a favorite area for nature tourism. Many visitors visit the Pattunuang river all year round.

The Pattunuang river has clear water. Some of the water comes from several springs that originate from karst on the banks of the Pattunuang river. The existence of several springs makes some part of the Pattunuang river flow throughout the year[16]. This river also has a shady natural atmosphere due to a secondary forest and a diversity of fauna.

The Pattunuang river is a place for visitors to carry out various activities, including tourism activities related to water. Visitors used the water of the Pattunuang river as drinking water, cooking, and bathing [17]. In addition, visitors use the river for swimming. Visitors also enjoyed this river for river tubing when the water increased in the rainy season. These various activities showed that visitors' dependence on Pattunuang river water is relatively high. Visitors use water for activities related to their external bodies, but the river water will enter their bodies. Thus, it can be said that river water quality can affect visitors' health, comfort, and safety. These three factors are critical to consider in the management of river tourism [18]. Therefore, it is crucial to examine the water quality and condition of the Pattunuang river to secure the health and ensure the comfort and safety of visitors. Besides that, this information will be beneficial to support sustainable river tourism management.

2. Method

2.1. Study site

This study was conducted at Pattunuang asue Natural Tourism Object (Pattunuang NTO), Bantimurung Bulusaraung National Park (Babul NP). Administratively, Pattunuang NTO is located in Samangki Village, Simbang subdistrict, and Maros District (Figure 1).

Samples of water were taken at Pattunuang river in September 2015, at the peak of the dry season and some parts of the river were dry. The river water starts from around 2500 meters from the old entrance gate. The community called these parts of the Pattunuang river (1) Jonjongan, (2) Bisseang labboro, and (3) Mata air. These parts of the Pattunuang river flow continually because of several springs, which come out from the karst. The springs still flow water throughout the year, even during a dry season, and bring on these areas become a favorite place for visitors to carry out their activities. Two samples of water were taken purposively at these river parts.
2.2. Materials
The river water, reagent, bottles for sample (water sampler bottle 600 ml, winkler bottles 100 ml, and dark glass bottles 100 ml), aluminum foil, drop pipette, cool box, ice packs, label, thermometer, camera, and GPS.

2.3. Procedure
2.3.1. Measuring feasibility of water river for tourism. Feasibility of Pattunuang river water for tourism followed [19] Government Regulation Number 22/2021 (GR 22/2021) concerning Implementation of Environmental Protection and Management - Attachment VI Point I Class II, [20] Health Ministry Regulation Number 32/2017 (HMR 32/2017) about water quality standard for public bath except for microbiology parameter and [21] South Sulawesi Governor Regulation Number 69/2010 (SSGR 69/2010) about quality standards and criteria for environmental damage. Parameters were measured (1) Physical parameters such as temperature, ultraviolet index, and clear water; (2) Biology (microbiological) parameters such as concentration of coliform bacteria; (3) Chemical parameters such as pH dan dissolved oxygen (DO); this study also measured (4) some parameter such as the existence of vector and animal bring disease, observed cleanliness of river, and source of pollutant from household, industry, and oil pollutant.
2.3.2. Measuring feasibility of water river for drinking water. Feasibility of Pattunuang river water usage for drinking water refers to GR 22/2021 [19], Health Ministry Regulation Number 492/2010 (HMR 492/2010) about drinking water quality requirements [22], and SSGR 69/2010 [21]. According to these regulations, this study used vital parameters to determine the water quality of the Pattunuang river. Parameters were physical, chemical, and biology. Physical parameters include temperature, ultraviolet index, smell, taste, clarity, total suspended solids (TSS), and total dispensed solids (TDS). Chemical parameters such as pH, dissolved oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), and total phosphorus. In addition, we measured levels of several substances that can be dissolved in river water, such as Ammonia (NH$_3$), Nitrate (NO$_3$), Nitrite (NO$_2$), Sulfate (SO$_4$), S in the form of H$_2$S, free chlorine, Chloride (Cl), Arsen (As), Cobalt (Co), Barium (Ba), Boron (B), Selenium (Se), Cadmium (Cd), Chrom (VI) Cr$^{6+}$, Cuprum (Cu), Plumbum (Pb), Zinc (Zn), Mangan (Mn), Fluoride, Mercury, and Cyanide. Furthermore, we measured microbiology parameters such as fecal coliform and total coliform to determine water quality as drinking water.

2.3.3. Sampling. The sampling method used purposive sampling at the river parts, which is on preliminary observations known as a location for visitors to conduct their activities and estimated to have an impact from visitors’ activities. Water temperature was measured by dipping the thermometer into the water for 2-3 minutes [23]. Measurement of the ultraviolet index refers to Dobbinsin, Niven, Buller, Allen, Gies and Warne [24], and it is carried out using a digital solar power meter or solar light meter. Measurements were taken at noon by placing the tool towards the sun and recording the index value listed. The level of water clarity was observed directly because the water discharge of the Pattunuang river had decreased hence that the riverbed was still clearly visible without using any tools.

The water sampling method follows SNI 06-2412-1991 [25], SNI 03-7016-2004 [26], SNI 6989.57.2008 [27], and procedures of water sampling in the Laboratory of Productivity and Water Quality, Faculty of Marine and Fisheries Sciences, Hasanuddin University [28]. Samples of water used clean and sterilized sample bottles. The water sample was taken by firstly flushed the bottle sample three times using river water before it dipped into the river to fill the bottle with water. For metal inspection, the sample bottle was filled until ¾, and Sulfuric acid (H$_2$SO$_4$) was added to preserve the water. For nitrogen (nitrate, nitrite, and ammonia) inspection, we added toluol (toluene) to the sample of water to preserve it. The bottles are labeled and stored in a cool box with ice to prevent chemical changes. Water samples were analyzed at the Laboratory of Productivity and Water Quality, Faculty of Marine and Fisheries Sciences, Hasanuddin University.

2.3.4. Data analysis. Data from measuring various parameters to determine the feasibility of water quality for tourism and drinking water were then tabulated. Water quality data were analyzed descriptively by comparing the data with water quality standards based on various regulations mentioned in procedure chapters 2.3.1 to 2.3.2.

3. Results and discussion

3.1. Results

3.1.1. Physical parameter of water quality of Pattunuang River. Results of water quality of Pattunuang river based on physical examination show in Table 1.
Table 1. The water physical examination result of the Pattunuang River.

| No. | Parameters | Unit | Water quality standards for tourism | Water quality standards for drinking water | Result of examination |
|-----|------------|------|-------------------------------------|------------------------------------------|-----------------------|
|     |            |      | GR 22/2021 | HMR 32/2017 | SSGR 69/2010 | GR 22/2021 | HMR 492/2010 | SSGR 69/2010 |            |
| 1   | Temperature | °C   | Deviation 3 | 15 - 35 | Deviation 3 | Deviation 3 | Deviation 3 | Deviation 3 | 27.2 |
| 2   | Ultraviolet index | 4 hours around the middle of the day | Deviation 3 | ≤ 3 | Deviation 3 | Deviation 3 | Deviation 3 | Deviation 3 | 1 |
| 3   | Smell | organoleptic | No smell | No smell | No smell |
| 4   | Taste | organoleptic | No taste | No taste | No taste |
| 5   | Clarity | m | Clarity enough |
| 6   | Total Suspended Solids (TSS) | mg/l | 50 | 50 | 40 | 50 | 5 |
| 7   | Total Dissolved Solids (TDS) | mg/l | 1000 | 1000 | 1000 | 500 | 800 | 1616 |

Table 1. shows that the temperature, ultraviolet index, smell, taste, clarity, and TSS of Pattunuang river water were below the thresholds of regulations. Only one physical parameter, the total dispersed solid (TDS) value which exceeded the threshold for use as drinking water. However, the latest regulations, HMR 32/2017 [20] did not require the TDS value as the feasibility parameter of using water for tourism (swimming and public bathing).

3.1.2. Chemical parameter of water quality of Pattunuang River. Results of water quality of Pattunuang river based on chemical parameter examination shows in Table 2.

Table 2. The water chemical examination result of the Pattunuang River.

| No. | Parameter | unit | Water quality standards for tourism | Water quality standards for drinking water | Result of examination |
|-----|-----------|------|-------------------------------------|------------------------------------------|-----------------------|
|     |           |      | GR 22/2021 | HMR 32/2017 | SSGR 69/2010 | GR 22/2021 | HMR 492/2010 | SSGR 69/2010 |            |
| 1   | pH        | o°C  | 6 - 9 | 6 - 8.5 | 6 - 9 | 6 - 8.5 | 27.2 |
| 2   | Dissolved Oxygen (DO) | mg/l | 3 | ≥ 4 | ≥ 6 | 2 | 1.45 |
| 3   | Biochemical Oxygen Demand (BOD) | mg/l | 3 | 3 | 2 | 2 | 1.45 |
| 4   | Chemical Oxygen Demand (COD) | mg/l | 25 | 25 | 10 | 10 | 7 |
| 5   | Total Phosphorus (T-P) | mg/l | 0.2 | 0.2 | 0.2 | 0 | ND |
| 6   | Ammonia (NH₃) | mg/l | 0.2 | 0.1 | 1.5 | 0.5 | 0.001 |
| 7   | Nitrate (NO₃) | mg/l | 10 | 10 | 50 | 10 | 0.63 |
| 8   | Nitrite (NO₂) | mg/l | 0.06 | 0.06 | 0.06 | 0.06 | 0.023 |
| 9   | Sulfate (SO₄) | mg/l | 300 | 300 | 250 | 400 | 12.81 |
| 10  | Sulfur as H₂S | mg/l | 0.002 | 0.002 | 0.002 | 0.002 | 0.002 |
| 11  | Free Chlorine | mg/l | 0.03 | 0.03 | Chlorine | 0.03 | 7 |
| 12  | Chloride (Cl⁻) | mg/l | 300 | 300 | 600 | 600 | 47.95 |
| 13  | Arsen (As) | mg/l | 0.05 | 0.05 | 0.05 | 0.05 | ND |
| 14  | Cobalt (Co) | mg/l | 0.2 | 0.2 | 0.2 | 0.2 | ND |
| No. | Parameter               | unit | Water quality standards for tourism | Water quality standards for drinking water | Result of examination |
|-----|------------------------|------|-------------------------------------|------------------------------------------|-----------------------|
|     |                        |      | GR 22/2021                         | HMR 492/2010                             | SSGR 69/2010          |
|     |                        |      | Class II                           | Class II                                 | Class I               |
| 15  | Barium (Ba)            | mg/l | (─)                                | 1.0                                      | 0.7                   | 1                     | < 0.5                  |
| 16  | Boron (B)              | mg/l | 1.0                                | (─)                                      | 1.0                   | 0.5                   | 1                     | ND                     |
| 17  | Selenium (Se)          | mg/l | 0.05                               | 0.05                                     | 0.01                  | 0.01                  | 0.01                  | 0.0125                 |
| 18  | Cadmium (Cd)           | mg/l | 0.01                               | 0.01                                     | 0.01                  | 0.003                 | 0.01                  | 0.0125                 |
| 19  | Chromium hexavalent (VI) Cr<sup>6+</sup> | mg/l | 0.05                               | 0.05                                     | 0.05                  | Total Chromium       | 0.05                  | 0.1                   |
| 20  | Cuprum (Cu)            | mg/l | 0.02                               | 0.02                                     | 0.02                  | 2                     | 0.02                  | 0.0095                 |
| 21  | Plumbum (Pb)           | mg/l | 0.03                               | 0.03                                     | 0.03                  | 0.01                  | 0.03                  | 0.296                  |
| 22  | Manganese (Mn)         | mg/l | (─)                                | (─)                                      | 0.1                   | 0.4                   | 0.1                   | ND                     |
| 23  | Mercury (Hg)           | mg/l | 0.002                              | 0.002                                    | 0.001                 | 0.001                 | 0.001                 | ND                     |
| 24  | Zinc (Zn)              | mg/l | 0.05                               | 0.05                                     | 0.05                  | 3                     | 0.05                  | ND                     |
| 25  | Cyanide (CN)           | mg/l | 0.02                               | 0.02                                     | 0.02                  | 0.07                  | 0.02                  | < 0.01                 |
| 26  | Flouride               | mg/l | 1.5                                | 1.5                                      | 1                     | 1.5                   | 0.5                   | 0.345                  |

Remarks
(─): Did not require
ND: Not Detected

According to GR 22/2021 [19], the result showed that some parameters exceeded the threshold of drinking water class II, which is used for water tourism, such as Sulfur in the form of H2S, free chlorine, Chromium hexavalent (Cr (VI) or Cr<sup>6+</sup>), Cadmium (Cd), and Plumbum (Pb). These parameters also exceeded the threshold for drinking water based on GR 22/2021 [19] and SSGR 69/2010 [21] requirements.

3.1.3. Microbiology parameter of water quality of Pattunuang River. Results of water quality of Pattunuang river based on microbiology parameter examination are shown in Table 3.

Table 3. The water microbiology examination result of the Pattunuang River.

| No. | Parameter          | unit     | Water quality standards for tourism | Water quality standards for drinking water | Result of examination |
|-----|--------------------|----------|-------------------------------------|------------------------------------------|-----------------------|
|     |                    |          | GR 22/2021                         | HMR 492/2010                             | SSGR 69/2010          |
|     |                    |          | Class II                           | Class II                                 | Class I               |
| 1   | Total Coliform     | Colony/100 ml | 5000 | 5000 | 1000 | 0 | 1000 | 335 |
| 2   | Fecal Coliform     | Colony/100 ml | 1000 | 1000 | 100 | 0 | 100 | 0 |

Table 3. shows that microbiology parameter examination results were appropriate within Government regulation. However, these results exceeded the threshold for drinking water according to HMR 492/2010 [22].

3.1.4. Environmental condition of Pattunuang River water. Observation on vector and animal-bring diseases such as larvae of mosquitoes and flies showed that the Pattunuang river was clean enough from mosquito larvae. We also did not find flies around the river and riverbank. Pattunuang river was clean, free from faeces and oil pollutants. However, this condition did not indicate that Pattunuang asue NTO was free from the trash. We found that there was trash scattered in several places along the riverbanks of the Pattunuang river. The results of observations on the environmental conditions of the Pattunuang river are shown in Table 4 below.
Table 4. The environmental condition of the Pattunuang River.

| No. | Parameters                                      | Type of condition and substance | Observation method       | Observation result |
|-----|------------------------------------------------|-------------------------------|--------------------------|--------------------|
| 1   | Locations did not become breeding places of vector and animal-bring disease | Larvae mosquito, flies         | Survey/direct observation | Not found          |
| 2   | The surrounding environment is clean and organized | Cleanness of the river         | Survey/direct observation | Clean              |
| 3   | Free from pollutants from household and industrial activities | The existence of settlement and industry | Survey/direct observation | Free               |
| 4   | Free from oil pollutant that causes discoloration and odor | Oil pollutant                  | Survey/direct observation | Not found          |

3.2. Discussion

3.2.1. Water quality of the Pattunuang River based on physical parameters. The water of the Pattunuang river was feasible for tourism based on physical parameters. The results showed that physical examination values were below of regulations threshold for tourism and drinking water usage. However, the water of the Pattunuang river has a high TDS value. The TDS value exceeded the threshold for drinking water usage. TDS is a solid that has a smaller size than suspended solids [29] or has a diameter of $< 10^{-3} \text{µm}$ [30], and it is dissolved in water. TDS consists of inorganic minerals and organic matter [31]. TDS also contains a variety of inorganic salts [32]. Generally, TDS is stated as the concentration of dissolved ions [33]. No health effects have been explicitly associated with high TDS concentrations [34,35].

The high TDS value of river water was assumed as a result of an accumulation of ions, mineral, or micro-organic matter in the stagnant water because the research was conducted at the peak of the dry season, while the water discharge decreased and the river water flow slowly. According to Han, Li and Tan [36], TDS value fluctuated following season, and water contains higher ions and TDS in the dry season than in the rainy season. The dry season causes water discharge decreasing, leading water to flow slowly and stagnant in some places. Consequently, various inorganic, organic materials and ions that should be drifting along with water flow stagnate in places where the water exchange flows slowly. This condition is in line with Qian, Peng, Zhao, Ma, He and Lu [37] statement that TDS value increased in areas where the water moves slowly or stagnant.

The TDS value determines water feasibility as drinking water because increasing the concentration of TDS can reduce the aesthetics of the water. The higher TDS value occurs because algae and microalgae grew at the locations with low water transmitting ability or stagnant water, and visitors' activities made the turbulent water stir up muddiness. These factors changed the color of the Pattunuang river water. However, watercolor changes did not discourage visitors from using river water as drinking and cooking water. Instead, they adapted by choosing to use water that looks clear and clean at the river parts that had not been disturbed by visitors' activities.

Devesa and Dietrich [38] reported that TDS influenced the taste of water. However, organoleptic observation showed that taste of Pattunuang water was not change. Visitors did not complain about the taste of water, and they still used it for drinking and cooking.

3.2.2. Water quality of the Pattunuang River based on chemical parameters. Some values of chemical parameters exceeded the threshold feasibility for tourism and drinking water usage, such as Sulfur in the form of $\text{H}_2\text{S}$, free chlorine, Chromium hexavalent (Cr VI), Cadmium (Cd), and Lead or Plumbum (Pb).

3.2.2.1. Sulfur in the form of $\text{H}_2\text{S}$. The concentration of Sulfur in the form of hydrogen sulfide ($\text{H}_2\text{S}$) in Pattunuang river water slightly exceeded the threshold based on GR 22/2021 [19] and SSGR 69/2010 [21]. Rubright, Pearce and Peterson [39] stated that the existence of hydrogen sulfide ($\text{H}_2\text{S}$) could be...
detected from a smell like rotten eggs. However, that smell was not found at Pattunuang river water. WHO [40] and Madabhushi [41] stated that humans could detect the smell of $\text{H}_2\text{S}$ at 0.05 mg/liter. Therefore, the undetected smell of $\text{H}_2\text{S}$ in the water of Pattunuang river because the concentration of $\text{H}_2\text{S}$ is only around 0.0025 ppm.

$\text{H}_2\text{S}$ in the water was sometimes assumed due to fecal contamination [42,43]. However, based on laboratory examination, the water of the Pattunuang river did not contain fecal bacteria. WHO [40] and Madabhushi [41] stated that $\text{H}_2\text{S}$ could present naturally in groundwater because of the rock dissolving process or the presence of sulfur-reducing bacteria that convert sulfates into $\text{H}_2\text{S}$. Therefore, we assumed that concentration $\text{S}$ in the form of $\text{H}_2\text{S}$ due to mineral rock dissolve or the presence of another coliform bacteria that can produce $\text{H}_2\text{S}$.

### 3.2.2.2. Free chlorine.

GR 22/2021 [19] and SSGR 69/2010 [21] stated that the threshold for free chlorine is 0.03 mg/L. However, HMR 492/2010 [22] did not list free chlorine as one of the requirements, but listed chlorine (as a disinfectant) as an additional parameter, with a concentration threshold, is 5 mg/L.

Chlorine is an element of the halogen family, but it is never found uncombined in nature. Instead, chlorine is fabricated through chemical processes in the industry [44]. Thus, the existence of chlorine in nature was assumed from human activities. For example, visitors' used calcium hypochlorite to purified the river water for drinking and cooking.

Chlorine is an unstable compound in water and will decrease over time, distance from the source [45], turbidity [46], pH, and water temperature [35,45]. Free chlorine is the amount of chlorine existing in water as dissolved gas ($\text{Cl}_2$), hypochlorous acid (HOCl), and hypochlorite ion (OCl\textsuperscript{−}) that is not combined with ammonia or other compounds in water [45].

However, there is dissent regarding the negative impact of high chlorine and free chlorine on human health. Rook [47], Morris, Audet, Angelillo, Chalmers and Mosteller [48] and Zheng, He and He [49] mentioned that free chlorine is a chemical substance adverse to human health, but Australian NHMRC [34] stated that there are insufficient data to determine the concentration at which chlorination by-product might cause an increased risk to human health. However, Muegge [50] stated that humans have a high tolerance to chlorinated water. Similarly, Cantor [51] stated that heavily chlorinated water is not correlated with cancer risk. Australian NHMRC [52] even reported that soldiers who consumed water containing more than 32 mg/L chlorine for months did not experience any side effects.

### 3.2.2.3. Chromium hexavalent.

HMR 492/2010 [22] stated that the concentration total chromium threshold for drinking is 0.05 mg/L, while GR 22/2021 [19] and SSGR 69/2010 [21] mentioned that the concentration Cr(VI) threshold for drinking water and tourism is 0.05 mg/L. This study showed that the concentration of Cr(VI) dissolved in the water of Pattunuang river exceeded the regulations threshold.

Chromium is an element that occurs naturally in rocks, soil, and groundwater [53]. Cr is found in the form of Cr (III) and Cr (VI) in natural water [54]. The presence of Chromium in water can occur naturally or due to human activities [53]. There is a big difference between Cr (III) and Cr (VI). Fantoni, Brozzo, Canepa, Marini and Zuccolini [55] stated that Cr (III) is almost immobile and has low toxicity. Cr (III) compounds have an essential role in biological processes, such as being an essential element for human and animal nutrition [53], as well as in the process of glucose metabolism [56]. Conversely, Cr (VI) or also known as Chromium hexavalent, is mobile and has high toxicity [55], carcinogenic and mutagenic [57–59].

The high concentration of Cr(VI) is caused by anthropogenic pollution [60], such as industrial waste [61]. Given that the Pattunuang river area is free from industrial activities, it is assumed that Cr (VI) in river water occurs naturally due to erosion and weathering or dissolving of karst. The presence of Cr (VI) naturally in carbonate rocks of the karst ecosystem was proposed by Fantoni, Brozzo, Canepa, Marini,
and Zuccolini [55], who stated that limestone contains Cr up to 11 mg/kg. Sulistiawaty, Arsyad and Tiwow [62] also identified the occurrence of Chromium in the karst Maros-Pangkep. Apart from karst rocks, Cr (VI) is also found in groundwater, as stated by Barnes and Langmuir [63], who found total Cr thresholds in groundwater associated with carbonate rocks. Thus, it is assumed that Cr (VI) in the Pattunuang river results from the dissolution of karst rock. It is transmitted by rain and enters the Pattunuang river through surface flows and an underground water system.

Another factor that is presumed to cause Cr (VI) to surpass the threshold is the presence of chlorine in the water of the Pattunuang river, which also exceeded the threshold. The relationship between chlorine and the formation of Cr (VI) was proposed by Saputro, Yoshimura, Takehara and Matsuoka [64] and Chebeir and Liu [65], who stated that chlorine causes rapid oxidation of Cr (III) to Cr (VI).

Cr (VI) has a very high level of toxicity [15]. Ingested of Cr (VI) is 100 times more toxic than Cr (III) [66]. Therefore, Cr (VI) is classified as a significant groundwater pollutant. The high toxicity of Cr (VI) causes visitors should be careful in using river water for drinking and cooking.

3.2.2.4. Cadmium and Plumbum. Cadmium (Cd) and Plumbum or lead (Pb) are toxic metals that can contaminate water. Both elements can be distributed and released into the water naturally or due to human activities [67]. Naturally, these elements dissolved into the water through the weathering process of rocks. However, large quantities of Cadmium and Lead are generally caused by anthropogenic pollution, such as pesticides and phosphate fertilizer [68–70]. Lead and Cadmium are known to be the main components of pesticides. In addition, Sukarjo, Hidayah and Zulaechah [71] stated that organic and inorganic fertilizers also contain Cadmium and Lead.

Based on observations, the majority of people living around the karst Maros-Pangkep work as farmers. Therefore, pesticides and fertilizers usage by farmers were suspected of causing Cadmium and Lead to exceeding the threshold in the Pattunuang river water. In this case, heavy metals, Cadmium, and Lead from pesticides and fertilizers are supposed to enter the Pattunuang river through underground rivers and pollute the river.

3.2.3. Water quality of the Pattunuang River based on microbiology parameters. Faeces contamination in water is a severe problem that can cause disease. Therefore, it is crucial to examine the presence of total coliform and fecal coliform bacteria in the destination where visitors use surface water directly for drinking and cooking. These two forms of microbiological examination have been widely used globally to measure water health hazards [72]. The test result showed that the Pattunuang river water quality meets the requirements in terms of microbiological parameters based on GR 22/2021 [19] and SSGR 69/2010 [21]. However, HMR 492/2010 [22] required microbiology parameter for total and fecal coliform is zero, so the water of Pattunuang river was not passed the standard for drinking water. In this case, according to the HMR 492/2010 [22], drinking water is water that goes through processing or without a processing process that meets health requirements and can be drunk directly.

River water did not contain fecal coliform bacteria and contained low total coliform [16]. The absence of fecal coliforms in river water can be caused by the positive behavior of visitors who did not throw faeces into the river water [17]. The presence of total coliforms in water is usual and does not automatically indicate fecal contamination. The total coliforms can be caused by environmental water conditions that allow the growth of other types of coliform bacteria, for example, due to the presence of organic matter derived from weathering plants or soil in the water [73,74]. However, the presence of total coliform bacteria in Pattunuang river water can be easily overcome. WHO [75] stated that total coliform bacteria would die through the heating process. Thus, visitors who use the river water contain total coliform bacteria can kill these bacteria by boiling the water before drinking.
3.2.4. *Water quality of the Pattunuang River based on environmental parameters.* The environmental conditions at the Pattunuang river and the Pattunuang NTO greatly support tourism activities because this area is far from industries. In addition, this area is also not disturbed by community activities because it is quite far from residential areas. This situation generates tranquillity and comfort for visitors. This condition made this destination free from sources of industrial and household pollution and oil contamination.

3.3. *Management implication*

Several parameters of the water quality of the Pattunuang river exceeded the threshold, both for water tourism and drinking water. Therefore, the management needs to pay attention to managing tourism, especially to overcome some problems such as chemical compounds and heavy metals whose concentrations exceed the regulations threshold, thus potentially risking visitors’ health. Given that these hazardous chemical elements probably occur from visitors and community activities, the management needs to anticipate and prevent the increasing level of these elements.

Furthermore, management needs to inform visitors about the presence of chemical compounds and heavy metals in river water and explain the destructive effects, such as cancer and DNA mutation, that may arise cause consuming it. Management also needs to encourage visitors to bring their drinking and cooking water. It is better if the manager prohibits river water from drinking and cooking for a while until the content of harmful chemical elements can be neutralized or reduced to a safe level. This prohibition needs to be carried out by the manager to prevent the emergence of silent victims because the victims will only feel the negative impact after several years.

Moreover, the Pattunuang asue manager needs to monitor directly, patrol, and educate visitors regularly. A warning should be given when they encounter chemical usage that can increase chemical compounds and heavy metals levels. The manager should explain the impact of pollution that can arise from using these materials. In addition, the manager can install warning boards and banners and distribute brochures containing an invitation to reduce and minimize the usage of chemicals that can pollute the destination's environment.

On the other hand, managers should also concern with the communities’ activities, especially agricultural activities, around the tourism area. Although pesticides and fertilizers were used far from the destination, managers also need to concern about this situation. The uniqueness of the karst ecosystem allows transmission of hazardous substances from agricultural locations that might be considered far enough, contributing to carcinogenic chemical compounds and heavy metals in river water. To overcome this problem, managers can elucidate and introduce the uniqueness and vulnerability of the karst ecosystem and its response to chemical pollution. Besides that, the manager can collaborate with stakeholders to educate the community, especially farmers, about the negative impact of pesticides and fertilizers on the karst ecosystem and karstic water system.

Furthermore, managers should monitor the quality of river water regularly. This information can help the manager to ensure the health of visitors. This information is also helpful for the manager to manage the Pattunuang river according to the factual conditions of the river. Managing the Pattunuang river tourism base on scientific data in actual conditions can increase the management capacity of the Pattunuang asue Natural Tourism Object.
4. Conclusion and recommendation

4.1. Conclusion
The concentration of several carcinogenic chemical compounds and heavy metals (Sulphur in the form of \(H_2S\), Chlorine, Chromium hexavalent, Cadmium, and Plumbum) in the water of Pattunuang river exceeded the threshold and can threaten visitors’ health. Therefore, managers need to anticipate ensuring visitors’ health and restoring the river's environmental condition.

4.2. Recommendation
The manager of Pattunuang needs to monitor visitors’ activities and elucidate information to visitors and the community about the negative impacts of the presence of polluting compounds and heavy metals in the Pattunuang river water. They are also necessary to provide information on factors that can emerge hazardous chemical compounds and heavy metals. Moreover, the manager needs to start preventive procedures to maintain the quality of the river. The manager also needs to alert the visitors in case of their destruction activities to maintain the environmental quality of the Pattunuang river.

It is noteworthy to study further the presence of various hazardous chemicals in the Pattunuang river and other karst rivers along the karst Maros Pangkep to enhance management properly.

Acknowledgments
Thanks to reviewers, the Environment and Forestry Research and Development Institute of Makassar, and Bantimurung Bulusaraung National Park Officer.

References
[1] Joshi D M, Kumar A and Agrawal N 2009 *Rasayan J. Chem.* **2** 195–203
[2] Demeter K, Derx J, Komma J, Parajka J, Schijven J, Sommer R, Cervero-Aragó S, Lindner G, Zoufal-Hruza C M and Linke R 2021 *Sci. Total Environ.* **768** 144278
[3] Noviana S, Arisanty D and Normalani E 2018 *JPG (Jurnal Pendidik. Geogr.* **5**
[4] Gordon A K 2011 *Assessing the effect of a laundry detergent ingredient (LAS) on organisms of a rural South African river* (Rhodes University)
[5] Londong A S, Santoso N E and Mokoginta J 2013 *J. Kesehat. Lingkung.* **3** 326
[6] Chowdhury M S N, Hossain M S, Das N G and Barua P 2011 *J. Coast. Conserv.* **15** 163–80
[7] Mekuyie M 2014 *J. Nat. Sci. Res.* **4** 47–56
[8] Alemu M M and Desta F Y 2017 *Int. J. Water Resour. Environ. Eng.* **9** 127–32
[9] Bahrami A R, Rahimi E and Ghasemian Safaei H 2013 *Sci. World J.* **2013** 5
[10] Zhu Y, Zhu Q and Zhu Z 2014 *Asia Pacific J. Tour. Res.* **19** 932–49
[11] Laws E and Semone P 2009 *River tourism* ed B Prideaux and M Cooper (CAB International) pp 55–74
[12] Timothy D J 2009 *River tourism* ed B Prideaux and M Cooper (CAB International) pp 41–54
[13] Cooper M, Prideaux B and Cooper M 2009 *River tourism* ed B Prideaux and M Cooper (CAB International) pp 74–94
[14] Prideaux B and Lohmann G 2009 *River tourism* ed B Prideaux and M Cooper (CAB International) pp 147–64
[15] Panta M P 2014 *Our National River Ganga* ed R Sanghi (Springer) pp 341–54
[16] Putri I A and Ansari F 2021 *J. Landsc. Ecol.* **14**
[17] Putri I A 2020 *Lambung Mangkurat Univ. Press*
[18] Nakagami K, Nwe K M, Prideaux B and Cooper M 2009 *River tourism* vol 217, ed B Prideaux and M Cooper (CAB International)
[19] Government of Indonesia 2021
[20] Health Ministry of Indonesia 2017 ed H M of Indonesia
[21] Governor of South Sulawesi 2010
[22] Health Ministry of Indonesia 2010
[23] Stevens H H, Ficke J F and Smoot G F 1978 Techniques of Water Resources Investigations of the United States Geological Survey Chapter D1: Water temperature-influential factors, field measurement, and data presentation-Book 1 Collection of Water Data by Direct Measurement (Washington: US Government Printing Office)
[24] Dobbinson S, Niven P, Buller D, Allen M, Gies P and Warne C 2016 Photochem. Photobiol. 92 208–14
[25] Badan Standardisasi Nasional 1991
[26] Badan Standardisasi Nasional 2004
[27] Badan Standardisasi Nasional 2008
[28] Laboratory of Productivity and Water Quality 63
[29] Day B A and Nightingale H I 1984 Groundwater 22 80–5
[30] Mukhtasor 2007 pencemaran pesisir dan laut (Jakarta: PT. Pradnya Paramita)
[31] Miranda J and Krishnakumar G 2015 Environ. Monit. Assess. 187 1–25
[32] Thirumalini S and Joseph K 2009 Malaysian J. Sci. 28 55–61
[33] Rusyidi A F 2017 IOP Conf. Series: Earth and Environmental Science vol 118
[34] Australian NHMRC 2011 ed N R M M C National Health and Medical Research Council Commonwealth of Australia
[35] WHO and Organization W H 2008 Guidelines for Drinking-water Quality 3rd Ed Incorporating the First and Second Addenda Volume 1 Recommendations (Geneva: World Health Organization)
[36] Han G, Li F and Tan Q 2014 Hydrol. Sci. J. 59 1063–73
[37] Qian J, Peng Y, Zhao W, Ma L, He X and Lu Y 2018 Hydrogeol. J. 28 1721–9
[38] Devesa R and Dietrich A M 2018 Desalination 439 147–54
[39] Rubright S L M, Pearce L L and Peterson J 2017 Nitric Oxide December December 0 1–13
[40] WHO 1996 Hydrogen Sulfide in Drinking-Water. Background Document for Development WHO Guidelines for Drinking-water Quality. Health Criteria and Other Supporting vol 2 (Geneva: World Health Organization)
[41] Madabhushi B S 2000 Tap Spring
[42] Thomas J and Matwewe F 2013
[43] Saha A 2015 Glob. Water Sustain. Program-Florida Int. Univ.
[44] Desiderio D and Nibbering N M M 2010 White’s Handbook of Chlorination and Alternatives Disinfectants 5th ed (Canada: John Wiley and Sons, Inc)
[45] Health Canada 2009 ed F-P-T C on D Water
[46] LeChevallier M W, Evans T M and Seidler R J 1981 Appl. Environ. Microbiol. 42 159–67
[47] Rook J J 1976 Journal-American Water Work. Assoc. 68 168–72
[48] Morris R D, Audet A M, Angelillo I F, Chalmers T C and Mosteller F 1992 Am. J. Public Health 82 955–63
[49] Zheng M, He C and He Q 2015 Ecotoxicology 24 2151–2155
[50] Muegge O 1956 J. Am. Water Works Assoc. 48 1507–9
[51] Cantor K P 1982 Environ. Health Perspect. 46 187–95
[52] Australian NHMRC 2004 ed G of A National Health Medical Research Council
[53] Kaprara E, Kazakis N, Simeonidis K, Coles S, Zouboulis A, Samaras P and Mitrakas M 2015 J. Hazard. Mater. 281 2–11
[54] Selomulya C, Meeyo V and Amal R 1999 J. Chem. Technol. Biotecnol. 74 111–22
[55] Fantoni D, Brozzo G, Canepa F, Marini L, Ottonello. G and Zuccolini M V 2002 Environ. Geol.
42 871–82

[56] Drincic A, Zuliani T, Scancar J and Milacic R 2018 Sci. Total Environ. 637–638, 1
[57] Cohen M D, Kargacin B, Klein C B and Costa M 1993 Crit. Rev. Toxicol. 23 255–281
[58] Costa M and Klein C B 2006 Crit. Rev. Toxicol. 36 155–163
[59] Ding M and Shi X 2002 234/235 293–300
[60] Brilly M, Jamnik B and Drobne D 2003 Mater. Geoenvironment 50 71–4
[61] Banchlor A, Pandey M, Chakraborty M and Pandey P K 2020 J. Heal. Pollut. 10 1–19
[62] Sulistiawaty, Arsyad M and Tiwow V A 2014 Simp. Fis. Nas. (SFN XXVII) 219–317
[63] Barnes H L and Langmuir D 1978 Geochemical prospecting handbook for metals and associated elements
[64] Saputro S, Yoshimura K, Takehara K and Matsuoka S 2011 Anal. Sci. 27 649
[65] Chebeir M and Liu H 2016 Environ. Sci. Technol 50 701–10
[66] Kazakis N, Kantiranis N, Voudouris K S, Mitrakas M, Kaprara E and Favlon A 2015 Sci. Total Environ. 614 224–38
[67] Kubier A, Wilkin R T and Pichler T 2019 Appl. Geochemistry 108 104388
[68] Dopico E, Linde A R and Garcia-Vazquez E 2009 Hum. Ecol. 37 235–40
[69] Bandara J M R S, Wijewardena H V P, Bandara Y M A Y, Jayasooriya R G P T and Rajapaksha H 2010 Environ. Geochem. Health 33 439–53
[70] Sarong M A, Jihan C, Muchlisin Z A, Fadli N and Sugianto S 2015 Aquac. Aquarium, Conserv. Legis. 8 1–6
[71] Sukarjo, Hidayah A and Zulaechah I 2018 Seminar Nasional Pendidikan Biologi dan Saintek III pp 205–11
[72] Thomas R V and Mueller J A 1987 Harper Collins 57 679–88
[73] Bartram J and Pedley S 1996
[74] Seo. M, Lee H and Kim Y 2019 Water 11
[75] WHO 2017