Water consumption and environmental behavior of the residents in Lake Toba water catchment area, North Sumatra, Indonesia

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Abstract. One of seventeen points of Sustainable Development Goals (SDGs) is to provide clean water for at least 80% of the global population in 2025. Rural populations living surrounding Lake Toba water catchment area still utilize the lake water for daily use regardless of the susceptible decreasing water quality. This paper describes anthropogenic aspects affecting the water quality of Lake Toba that is consumed as the drinking water source by surrounding residents. The research used a quantitative approach by interviewing 130 household representatives from 3 regencies around the lake to calculate the water consumption and evaluate the water quality in 2018. In addition, this research also assessed the residents’ behavior in managing household waste and wastewater. The result showed that the average water consumption is 86.93L/person/day. The majority of the respondents barely treat the water and feel satisfied with the water quality based on its color, turbidity, taste, and odor. On the contrary, the respondents have not adequately treated their domestic waste and household wastewater before being released to the lake, contributing to water pollution. Although most respondents are satisfied with the water quality, it is still needed to perform proper water treatment because the water quality of Lake Toba is reported as slightly up to heavily polluted by the Ministry of Environment and Forestry in 2019.

1. Introduction
The water resource is one of the essential resources in the civil life system. However, most of the world’s population do not have access to clean water, so one goal of the Sustainable Development Goals (SDG's) is the provision of facilities and infrastructure of clean water to adequately fulfill the daily needs of at least 80% of the global population in 2025 [1–3]. In the last few decades, developed countries and developing countries have been aware of the importance of efforts to increase the environmental awareness of the population towards water conservation. This concern arises because of inefficient water use [4,5]. Research synthesized the data from 23 countries estimated that water utilization was still much lower than the reality, especially the indirect use of water to produce goods and services [6]. This utilization complements water usage for daily consumption, and the imbalance of water supply and demand leads to water scarcity in certain areas.

Lake, reservoir, spring, and river are some of Indonesia's potential resources for raw water supply. According to the report of Watershed Management Institute (Badan Pengelolaan Daerah Aliran
Sungai-BPDAS) of Asahan Barumun, the central government agency under the authority of the Ministry of Environment and Forestry that has the responsibility to manage the watershed of Asahan Barumun in North Sumatra, at least 80% of the population living at the shore of Lake Toba uses water from Lake Toba to meet the clean water needs. There are three forms of water intake from the lake; firstly, is the direct intake. The households still do this most traditional way. Secondly is communal intake using machinery pump by particular communities. Finally is commercial preservation organized by a local water business unit owned by the local governments, namely Perusahaan Daerah Air Minum (PDAM) [7]. Water processing is barely done in the first two systems. The PDAM has applied the gravimetric method to separate the total suspended solid, followed by the flocculation process using alum (Al$_3$(SO$_4$)$_3$) to separate clean water from sediment. Subsequently, chlorine that functioned as a disinfectant is added to the clean water before being distributed to the consumers [8]. This method increased the water quality, but due to the limited capacity of existing PDAMs in seven regions surrounding Lake Toba, the most popular systems are the first two.

The latest growth of population and economy, such as tourism surrounding Lake Toba, has two main problems related to the available water resources in terms of quantity and quality [9–12]. Lake Toba, which serves various purposes such as tourism, transportation, floating net fishery, and irrigation, also has the primary function of a clean water source for the surrounding population [9,12–18]. Although some previous studies have highlighted the water pollution risk of the lake [19–21], the population takes the risk of its deteriorating quality for fulfilling their daily needs. The problem of the scarcity of available clean water surrounding the Lake is ironic so that there is a famous phrase in Batak Language, and it is expressed as "mauas in Topi ni Tao Toba" that means the people surrounding the lake have to face the thirst problem, while the source of raw water to be processed into drinking water are abundant.

This paper will assess the clean water consumption quantity of the households surrounding Lake Toba, water quality based on the consumer's judgment, and the potential water pollution due to the households' waste and wastewater treatment. This assessment will be analyzed and presented descriptively, associated with the socio-economic characteristics of the water consumers. The result of consumer perception on the water quality also is compared with the quantitative water quality of the Lake Toba conducted by previous research [8,22–25]. This research findings will support clean water management surrounding the lake based on the customer preferences and water quality assessment.

2. Methods
2.1. Data collection
The research was conducted in three regencies located on the Lake Toba Water Catchment Area (LWTCA) in 2018. The study implemented a survey by interviewing 130 respondents from four sub-districts in 3 regencies. They were Onan Runggu and Simanindo Sub-districts in Samosir Regency, Balige Sub-district in Tobasa Regency, and Muara Sub-district in North Tapanuli Regency (Figure 1). The research selected the closest regencies to the lake where the residents have utilized the lake water for their daily consumption. Using accidental sampling as the respondents' selection method, the total respondents consisted of 20 respondents from Silimalombu Village in Onan Runggu Sub-district, 40 respondents from Tuktuk Village in Simanindo Sub-district, 46 respondents from Balige Sub-district, and 24 respondents from Muara Sub-district. To collect the environmental behavior of the households in water use and water conservation, the respondents were interviewed using a structured questionnaire containing socio-economic information, daily water consumption, perception towards water quality, and behavior regarding waste and wastewater treatment.
The consumption of clean water by the population at a specific time and location can be calculated using several methods, i.e., econometrics, artificial neural network (ANN), time series prediction, hybrid method, or micro components methods [26]. The most common technique used for end-users consumption is the micro components method. This approach assesses total water consumption based on the day-to-day utilization components, such as bathing, cooking, washing dishes or clothes, and other personal needs. Thus, the consumption per capita is obtained from the entire utility per person per unit of time [5,26,27]. This research employed this procedure in estimating water consumption per capita.

Water conservation as part of environmental awareness is essential in sustainable water resources management. Previous studies highlighted that environmental consciousness is related to daily living activities [28] and is coherent with norms and values prevailing in specific communities [29]. The values are differentiated by various socio-economic factors such as knowledge and information, attitudes, and behavior [30], and individuals and societies' characters [5]. Since some factors are interrelated, and integrated multidiscipline approach must provide best practices in sustainable water management [30,31].

A review proved that environmental awareness studies contribute to filling the content of environmental cognizance among the pro-environment and non-pro-environment [32]. In summary, the theoretical framework studied in this literature review concluded that individual or social behavior contributes significantly to environmental management, in this case, clean water management. The individual characteristics are encompassed by the values, beliefs, attitudes, knowledge, perceptions, and habits. The behavior of individuals interacting in a group constructs the social balance that emerges the norm, rule, agreement, or consensus belongs to the group.

This study constructs framework analysis based on those conceptual backgrounds. First, it assesses the water consumption per capita using the micro components technique. Then, the result will be compared with previous studies' findings and analyzed with the respondents' socio-economic characteristics. Second, the study elaborates on respondents' valuation towards the water quality based
on their judgment. This result will also be consulted to the latest water quality tested in relevant studies or reports. The last, this recent study evaluates the respondents’ behavior in conserving their clean water resources by presenting the households’ waste and wastewater treatment that potentially affects the pollution status of Lake Toba.

3. Results and discussion

3.1. Water consumption

The water consumption measured in this study is based on micro-components, including utilization for cooking, bathing, washing dishes and clothes, drinking, and other personal needs. The detailing components are made to facilitate the respondents to remember the actual value of the daily water use obtained from the lake. The result revealed that the daily is slightly different, as presented in Table 1. The highest value is in Balige Sub-district, which is 86.9 L/person/day, and the lowest value is in Muara Sub-district, which is 72.2 L/person/day. The consumption in Samosir Regency is 80.2 L/person/day in Simanindo Sub-district and 82.8 L/person/day in Onan Runggu Sub-district.

The difference in the average use of water in each sub-district is likely related to the population’s daily activities. The respondents in Balige Sub-district live in the capital of Tobasa Regency, and their activities are more commercial than the population activities in the other three sub-districts. A regular (once in a week) traditional market in Balige where the traders and consumers from neighboring sub-districts Tobasa and Samosir regencies gathered. This economic activity increases the water consumption of a particular population. Meanwhile, both Onan Runggu and Simanindo Sub-districts in Samosir Regency have located nearby the tourism destination area, and thereby the population consumes more water than they are in the Muara sub-district. This sub-district is primarily inhabited by farmers who need little water for their daily activities.

| No | Sub-districts   | Regency    | Water Consumption (L/person/day) |
|----|----------------|------------|---------------------------------|
| 1  | Onan Runggu    | Samosir    | 82.8                            |
| 2  | Simanindo      | Samosir    | 80.2                            |
| 3  | Balige         | Tobasa     | 86.9                            |
| 4  | Muara          | North Tapanuli | 72.2                      |
|    | Average        |            | 80.5                            |

The average value for water consumption in all sub-districts is 80.5 L/person/day. It is in the range of the national standard of water consumption per capita (SNI 6728.1:2015) in rural areas (60-90 L/person/day). The presence of tourism activity in Samosir Regency or regular Fridays traditional market in Tobasa regency has a slight impact on water consumption in those areas. In general, water consumption in this study is less than the daily consumption of the urban population as found by [5] that amounted to 161.51 L/person/day in Depok, and 215.38 L/person/day in Bogor or the result of another study that amounted to 135.7 L/person/day in Serpong, South Tangerang. The raw water obtained from Lake Toba seems to be still sufficient for supporting the daily needs and thus the health of the inhabitants surrounding the lake. A research stated that the volume of Lake Toba is 256.2 x 10^9 m³ approximately [33]. The challenge is to what extent the water quality follows the drinking water category (class I) in line with the Governor of North Sumatra or national standard [8,13,34,35].

3.2. Socio-economic characteristics of the respondents

This research also elaborated on the socio-economic characteristics of the respondents as part of the societies that inhabited LTWCA. Comprehensive studies have revealed that the water quality is closely related to the population’s anthropogenic activities and some natural factors like climate change or seasonal weather [19,36,37]. The activities that have potential impact on Lake Toba water quality are ranging from domestic activities [20,23], agriculture [8,10], fishery [38,39], tourism [17,40], traditional market [8,41], and transportation [22,24].
Table 2. Socio-economic characteristics of the respondents (n=130).

| No | Category                                      | Value | Total | Percentage |
|----|----------------------------------------------|-------|-------|------------|
| 1  | Sex                                          |       |       |            |
|    | - Men                                        | 37    | 28    |            |
|    | - Women                                      | 93    | 72    |            |
| 2  | Age (years)                                  |       |       |            |
|    | - Minimum                                    | 19    |       |            |
|    | - Average                                    | 45.5  |       |            |
|    | - Maximum                                    | 89    |       |            |
| 3  | Family Size (person)                         |       |       |            |
|    | - Minimum                                    | 1     |       |            |
|    | - Average                                    | 5     |       |            |
|    | - Maximum                                    | 11    |       |            |
| 4  | Length of Living (years)                     |       |       |            |
|    | - Minimum                                    | 1     |       |            |
|    | - Average                                    | 25    |       |            |
|    | - Maximum                                    | 87    |       |            |
| 5  | Settlement distance from the lake (m)         |       |       |            |
|    | - 0-200                                      | 113   | 87    |            |
|    | - 201 – 400                                  | 10    | 7     |            |
|    | - 401 – 600                                  | 2     | 1     |            |
|    | - 601 – 800                                  | 2     | 1     |            |
|    | - >800                                       | 3     | 2     |            |
| 6  | Education                                    |       |       |            |
|    | - Uneducated                                  | 5     | 4     |            |
|    | - Primary School                             | 16    | 12    |            |
|    | - Elementary School                          | 12    | 9     |            |
|    | - Senior High School                         | 84    | 65    |            |
|    | - Higher Education                           | 13    | 10    |            |
| 7  | Livelihood                                   |       |       |            |
|    | - Civil servant                              | 5     | 4     |            |
|    | - Military/Police                            | 2     | 1     |            |
|    | - Self-employment                            | 17    | 13    |            |
|    | - Local trader                               | 40    | 31    |            |
|    | - Farmer                                     | 66    | 51    |            |
| 8  | Monthly Income (IDR)                         |       |       |            |
|    | - 0-2 Million                                | 75    | 58    |            |
|    | - 2.1 – 4 Million                            | 47    | 36    |            |
|    | - 4.1 – 6 Million                            | 6     | 4     |            |
|    | - 6.1 – 8 Million                            | 1     | 1     |            |
|    | - >8 Million                                 | 1     | 1     |            |
|    | - >800                                       | 3     | 2     |            |

The respondents are dominated by women (72%), and the average respondents' age is 45.5 years old. As the respondents represented their households, the number of every family member was counted to measure the water consumption in every family. The result is that the family size is five people on average. According to the duration of living at their recent settlement, the respondents lived for 25 years on average. Most of the respondents (87%) lived close, up to 200 m from the lake. This condition emerges two contrary anthropogenic impacts. On the one hand, the population can utilize Lake Toba as the source of clean water for their daily life. On the other hand, the consequence of the closeness of their settlement to the lake also causing their domestic waste and wastewater to pollute the lake potentially.

According to educational background, the vast majority of the respondents (95%) have been educated, and most (65%) graduated from Senior High School. Although they are living in rural areas, they have a good educational background. Referring to livelihood, most respondents earned their
living as a farmer (51%) and traditional trader (31%). The farmers are spread evenly in all sub-districts, different from the traders in the Balige sub-district.

Another result of this study is that the monthly income of the respondents was below or in the range of the regionals minimum wage. The major part of the respondents (58%) has monthly income amounted up to IDR 2,000,000. This is below the regional minimum wage in Tobasa Regency (IDR 2,668,614/month), Samosir Regency (IDR 2,648,577/month) or North Tapanuli Regency (2,542,836/month). Just 36% of the respondents have a monthly income in the range of all regional minimum wage, and only 6% have a monthly income higher than the regional minimum wage. This financial condition characterizes the residents' choice in the water source system, as most of the respondents prefer to obtain water by themselves rather than get access to available PDAM or communal systems. Both PDAM and communal systems require initial costs for their customers.

3.3. Water quality

Generally, water quality evaluation is conducted using the physical, chemical, and biological parameters [42–45]. The physical parameters used in the Indonesian national standard (Standar Nasional Indonesia or SNI) are color, turbidity, taste, odor, and total dissolved solids (TDS) [46–48]. This study employs four parameters, i.e., color, turbidity, taste, and odor, based on the respondents' judgment. This study did not investigate the chemical and biological parameters but referred to the Lake Toba water quality status resulting from the previous research.

Water quality evaluation is differentiated based on the cyclical drought and rainy seasons on LTWCA. LTWCA has the equatorial type that is affected by two dry seasons and two rainy seasons. The first dry season usually happens during January-March, and the second occurs during June-September. While the first rainy season usually chances during April-May, and the second arises during October-December. The respondents generally evaluate that the water quality is slightly better in the dry seasons than in the rainy seasons (Figure 2). The vast majority of the respondents value the water as clear (91%), bright (89%), tasteless (97%), and odorless (96%). This evaluation value is slightly different in the rainy season. Although most of the respondents evaluate the water quality as the same as in the dry season, there is an increasing portion of respondents' water quality during the rainy seasons. The physical characteristics were valued in more colored (30%), cloudy (37%), tasty (9%), and smelly (12%). The decreasing quality is related to the pollution load of the water brought by the rivers on the water catchment area [8,19,23].

Following this water quality valuation, this research also examined the respondents' satisfaction with Lake Toba water's utilization, based on the accessing time, quality, quantity, continuity, and accessing cost across time and seasons. The respondents' valuation for all parameters can be categorized as good since the majority of the respondents qualify that all aspects are satisfying. Since most respondents live near the lake, they believe that clean water is easy for its accessibility, good quality, availability and sustainability across all seasons, and barely has no accessing cost. There is no restriction or regulation in accessing the water, so the respondents still believe that this resource is also available for their next generation. This satisfaction is also related to the minimum complaints addressed by the respondents to the potential health risk caused by consuming the water. The respondents identify only two primary water-related health disorders. They are skin itching and diarrhea that they believe are related to the lake's water quality. The majority of the respondents (88%) stated that they have no complaint about their health status related to the water quality.
However, the community’s satisfaction (71%) is opposite with recent studies that examined the water quality of Lake Toba based on chemical and biological parameters have been categorized the water as polluted or did not meet the Class I of national raw water standard, which is designated as the clean water source for domestic use (Table 3). The researcher published in national or international journals or proceedings stated that the water quality of Lake Toba water had been deteriorated primarily due to anthropogenic activities. The studies have similar concerns, suggesting that the water should not be directly used for domestic clean water sources without further treatment.

Table 3. Water quality of Lake Toba resulted from previous studies.

| No | Source | Sampling Location | Primary Findings |
|----|--------|-------------------|------------------|
| 1  | Indirawati and Muntaha, 2018 [23] | Simalungun Regency | Water quality does not meet the Class I national standard |
| 2  | Melati and Lukman, 2019 [21] | Samosir, Humbang Hasundutan, Tobasa, Simalungun, and Dairi | Water quality does not meet the Class I national standard due to *E.coli*, coliform and heterotrophic bacteria. |
The water quality of Lake Toba is categorized as lightly to moderately polluted. The phosphorus content of Lake Toba water has exceeded the national standard. Water quality does not meet the criteria for clean water sources and water tourism.

3.4. Respondents behavior in managing waste and wastewater

Previous research in Lake Toba discovered that the population activities were the primary contributor to the degradation of Lake Toba. Intensive human activities surrounding the catchment area of Lake Toba inlet rivers contribute to the high pollution load [19]. It is verified by other research that stated Lake Toba is contaminated by organic material discharged into domestic sewage that finally releases into the lake [21]. Another research mentions that domestic waste is the most significant pollutants on Lake Toba [44], and the waste from floating net fishery in the lake [38]. This research indicated that the contrary condition regarding waste and wastewater treatment occurs on the research site. The same respondents who utilize Lake Toba water as their clean water source treated their domestic waste environmentally friendly. Most of the respondents (80%) already put their domestic waste in a container on their settlement (Figure 4). Furthermore, 84% of them have provided a closed type of waste container ready to be collected to the final waste treatment facility [35]. The environmental awareness of the respondents can be classified as good, which is in line with the educational background of the respondents that is relatively high [32,49].

Another factor found by a researcher in Lake Toba was the wastewater treatment system. The presence of organic matter in the water correlated to untreated wastewater directly discharged to the lake [21]. At certain parts of LTWCA, the government has built the infrastructure for communal wastewater treatment, such as in Ajibata in Tobasa Sub-district, but not effectively utilized by the households due to the lack of environmental awareness [23]. However, this recent study found that 73% of the respondents’ houses have sewer connections, 61% have the opened sewer system, and 22% have the closed sewer system (Figure 5). It seems that the respondents in this study have developed higher environmental awareness.
The challenge is how to maximize the potential environmentally friendly behavior of the population to increase the effectiveness of wastewater treatment. This study found that all research locations do not have a communal wastewater treatment plant, so the wastewater was discharged to the environment without further treatment. The available types are presented in Figure 5 (b), and the most popular types are direct discharge to the ground nearby the houses (23%) and direct discharge to the sewer (that in some cases also end up to the lake) (39%). There was also 6% of the respondents that directly discharged their households’ wastewater to the lake. The lack of wastewater treatment infrastructure is also found in other regencies so that some studies highlighted that the domestic waste and wastewater is the primary contributor to the lake [19–21].

4. Conclusion
This study has discovered that the primary source of clean water utilized by the rural population in LTWCA is lake water. Their valuation is based on the physical performance of the water, and they still believe that the water quality is still in good condition, not posing risks to their health. They also feel satisfied in consuming the water considering the accessing time, quantity, continuity, sustainability, and accessing cost. Nevertheless, as found by previous research, the water quality of Lake Toba has deteriorated nowadays. The community has to be aware of their health risk if they continue to use the lake as the source of clean water for their domestic purpose. If the residents still use the Lake Toba as their source of clean water, they have to implement water filtration to improve water quality. Although the population has better environmental awareness than that found in the previous studies, this research also agrees with those studies that have suggested building a wastewater treatment plant to increase Lake Toba’s water quality.

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