International Journal of Science and Research (IJSR)
ISSN: 2319-7064
SJIF (2022): 7.942

Water Quality Assessment in Tagoloan River, Sabangan, Can-ayan, Malaybalay City, Bukidnon

Malyn A. Bete[1], Maria Christine Joy O. Masilang[2], Vannareneal D. Salesa[3]

Science Education Department, Central Mindanao University, Philippines

Abstract: ***This study assessed the water quality of the Tagoloan River in Sabangan, Can-ayan, Malaybalay City, Bukidnon. The research focused on physical geography, physicochemical parameters, and microbial indicators such as temperature, conductivity, salinity, pH, total dissolved oxygen (TDS), nitrate, phosphates, and fecal coliforms. Water samples were collected at various stations, compared to DENR and DOH guidelines, and subjected to laboratory analysis. The results showed that the water temperature and conductivity were within normal ranges. However, the salinity analysis indicated high contamination due to domestic and industrial wastewater, classifying the Tagoloan River as marginal water. pH levels were acceptable, as per DENR standards. TDS measurements were within the guidelines, but nitrates increased compared to historical data. Phosphate concentrations were low, likely influenced by elevated nitrate levels. Moreover, fecal coliforms exceeded the 200 MPN/100 mL limit, rendering the water unsuitable for primary contact recreation. The study contributes valuable information about the Tagoloan River's current water quality, highlighting the need for adaptation and mitigation. Continued research and monitoring are essential for ensuring the river's long-term water quality and sustainability.***

Keywords: water quality, Tagoloan River, microbial indicators, physicochemical parameters, water contamination

1. Introduction

The Philippines is known for its abundant natural resources, including a vast array of water resources such as groundwater, surface water including rivers, lakes, falls, and springs, and an annual rainfall range from 965 mm to 4 064 mm that sustains the communities. However, as a nation rich in water resources, it faces several water-related challenges, such as pollution caused by agricultural runoff, industrial waste, and sewage. According to the Department of Environment and Natural Resources (2015), the demand for water in the Philippines will increase by 38.5% between 2020 and 2030. According to the Philippines News Agency (2019), the Philippines ranked 38th among 48 countries in the national water crisis index. Tagoloan River is the 13th largest river system in the Philippines regarding watershed size. It is one of the primary sources of water for the country, used for irrigation, domestic use, and hydroelectric power generation (Calunsag, 2020). Hence, the Republic Act 9275, known as the Philippine Clean Water Act of 2004, aims to protect, preserve and revive

There has been much observable human activity in the Tagoloan River (Spillway) located at Sitio Sabangan due to its breathtaking view of nature, which recently got people's attention to camp in the area. In addition, the researchers noticed a poultry farm in the upper stream of the river, connecting with the camping site where people carry out recreational activities. The possibility of water contamination exists, which could result in the degradation of water quality and pose a threat to public health. This insight highlights the urgent need for research to address these water-related issues and develop sustainable solutions to ensure the continued availability of this vital resource. Therefore, it is necessary to determine the water quality, evaluate its impacts, and provide measures to mitigate the problems (Martinico, 2014).

Few empirical studies have been conducted on the water quality of the Tagoloan River and its current status. To bridge this gap, this study aims to assess the water quality of the Tagoloan River in Sabangan, Malaybalay City, Bukidnon, by determining its physical geography and examining its physicochemical and microbial parameters. The study's findings will provide a first thorough water quality assessment, which will help the community and the government as a basis for their future development.

Objectives of the Study

This study aimed to assess the water quality of the Tagoloan River in Sabangan, Can-ayan, Malaybalay City, Bukidnon.

Specifically, the researchers aimed to:

a) Determine the physical geography of Tagoloan River Sabangan, Can-ayan, Malaybalay City, Bukidnon.
b) Examine its physicochemical and microbial parameters.

2. Materials and Methods

The research was carried out on the Tagoloan River, which has a length of 106 kilometers and is located in Sabangan, Can-ayan, Malaybalay City, Bukidnon. April 19, 2023, water samples were collected in three (3) different stations.

Entry Protocol

A letter of permission to conduct the study was submitted to the Barangay Officials of Sabangan, Malaybalay City, Bukidnon, as part of the entry protocol (appendix 1).

Location of the Study Area

The research was carried out on the Tagoloan River, which has a length of 106 kilometers and is located in Sabangan, Can-ayan, Malaybalay City, Bukidnon. On April 19, 2023, water samples were collected in three (3) different stations.

Materials used in the study

The materials used in the study include an empty sample container, a Styrofoam box, a marker/pen, a labeling type, a notebook, a cell phone application, a GIS Map, and a Camera for photo documentation.

Establishment of the Study Area

Three (3) sampling stations were established along the river using geographical coordinates, and sampling was done on

April 19, 2023. Station 1 upstream is situated near the poultry farm, which is exposed to the national highway, and residents were found living nearby, exposing the river to some household wastes. Station 2 is the midstream part of the river and is close to the hiking trail. Moreover, abundant vegetation is present in this area. Station 3 is at the main campsite where the hikers stay, and some inhabitants live close to the river, making it exposed to anthropogenic activities. Physical parameters such as surface water temperature, air temperature, altitude (meters AMSL), and Grid Coordinates (longitude and latitude) were directly determined on-site. Water samples for analyses for chemical parameters were collected at three stations. They were placed in fifteen (15) empty plastic containers (labelled with station number, sample name, and replicate number) with five (5) replicate samples per station. Water samples for analyses for microbial parameters were collected at three stations. They were placed in three (3) empty plastic containers (labelled with station number, sample name, and replicate number) with one (1) replicate sample per station. The samples were placed in a styrofoam box with ice and were brought to Bukidnon State University and Central Mindanao University for laboratory analysis.

3. Methods of Collection and Preparation

Phase One: Coding of Samples
The researchers coded test samples to avoid bias and confusion. The sample code PFWS1, where PF is the sampling site, WS is for the water station, and 1 is the station number. Sampling sites are PF (Poultry Farm), VA (Vegetation Area), and CS (Camping Site). Vegetation Area and Camping Site are water stations 2 and 3, respectively.

Phase Two: Preparation of Sampling equipment.
In collecting water samples, the researchers utilized a 1,000 ml Polypropylene sample container. Prior to the collection, the researchers washed the sample container using water for about 3 minutes.

Phase 3: Collection of water samples.
The researchers followed a specific protocol to ensure accurate water sample collection at the sampling sites. Firstly, the 1,000 ml containers were dipped into the river three (3) times before collecting water samples. The researchers then collected water samples one (1) meter beneath the surface water, which was done directly. In total, 18 water samples were collected from all sampling sites. Out of these, five (5) samples were collected from station one (1), five (5) samples from station two (2), and five (5) samples from station three (3), a total of fifteen (15) samples were taken for physical and chemical parameter analysis. Additionally, three (3) water samples were collected from each station for microbial parameter analysis.

Phase 4: Preservation for laboratory analysis
Collected water samples were placed in a styrofoam box with ice packs to minimize the potential for volatilization or biodegradation. The ice packs were placed between each bottle to ensure that temperature was maintained within four degrees Celcius (4°C) while being transported to the Bukidnon State University and Central Mindanao University for analysis. Analysis of Physical and Parameters was conducted by the laboratory technician at Bukidnon State University (BSU), while the analysis of microbial parameters was conducted by Central Mindanao University (CMU), specifically, the Veterinary Medicine Laboratory.

4. Literature Review

Water Quality Assessment
According to the National Marine Sanctuaries, water quality describes the condition of the water, including chemical, physical, and biological characteristics, usually concerning its suitability for a particular purpose, such as drinking or leisure. Water quality can be measured by several factors, such as the concentration of dissolved oxygen, bacteria levels, salinity, or the amount of material suspended in the water (turbidity). In some bodies of water, the concentration of microscopic algae and quantities of pesticides, herbicides, heavy metals, and other contaminants may also be measured to determine water quality. Although scientific measurements define water quality, it is not simple to say "that water is good" or "that water is bad." So, the determination is typically made relative to the purpose of the water.

Aremu et al. (2011) noted that water quality is affected by an increase in anthropogenic activities, and any pollution, either physical or chemical, causes changes to the quality of the receiving water body. According to Messeret (2012), chemical contaminants occur in drinking water worldwide, which could threaten human health. In addition, most sources are located close to valleys where open fields are frequent and flood-washed wastes impact the water's quality. As a result, people are still dependent on unprotected water sources such as rivers, streams, springs, and hand-dug wells. Since these sources are open, they are highly susceptible to flood, bird, animal, and human contamination.

Water pollution can also be described as an undesirable change in the water condition that decreases the water quality. Once the water quality decreases and becomes below acceptable level for a particular use, the water will be classified as polluted. Pollution occurs when pollutants enter the body of water. Pollutants are substances introduced into the water body by human activities or naturally occurring. Prabhakar also stated that the source of water pollution could come from natural runoff, dissolved chemicals in the water that permeates through the soil, as well as from human activities such as agriculture, mining, construction, industry, homes, and businesses. Water pollution caused by human activities can be classified into pollution caused by industry, homes, and businesses. There are many sources where pollutants can enter the body of water. In general, the sources of pollution are divided into two categories known as point sources and non-point sources (Prabhakar, 2015).

The growing socio-economic activities and demands of the increasing population for food and space impact water resources. According to Perez (2016), the dissolved oxygen concentration is a general indicator to assess organic pollution, and a high concentration of dissolved oxygen is a condition favourable for aquatic organisms to thrive in water bodies. Nitrates and phosphates are essential for growing bacteria, algae, and other microorganisms in the water; however, excessive amounts increase algae blooms. Hence, it

would impair the ecosystem's health if left neglected. Nevertheless, anthropogenic disturbances like domestic wastewater and drains from farms pose threats to water quality that could result in pollution and damage to river ecosystems.

Water Quality Issues and Mitigation in Developing Countries

The Philippines is a developing country undergoing rapid urbanization and industrialization. Out of more than one hundred million Filipinos, nine million rely on unsafe water supplies. A study by WEPA (2017) says that the situation is particularly alarming in Metro Manila, where water bodies are heavily polluted. Water quality measurements conducted by monitoring stations at various locations along the rivers have indicated that most of them are biologically dead. The term "biologically dead" refers to the absence mainly of dissolved oxygen (DO) in a water body. A waterbody is considered biologically dead when it has a zero DO level (meaning it has undergone complete "eutrophication"). The government of Metro Manila adopted measures to improve water quality in the city's water bodies, among them building new sewage treatment facilities, expanding sewerage infrastructure, and relocating informal settlers along the riverbanks. Recently, the government started using economic instruments such as pollution fines and environmental taxes.

Water's physical and chemical characteristics can change depending on temperature, which also affects several other factors. A temperature rise consequently increases conductivity, claims Fondriest Environmental, Inc. (2014). Every one-degree Celcius (1°C) increase in temperature increases conductivity by about 2–3%. In addition, as warm water dissolves several minerals and salts more readily than cold water, many salts are soluble at high temperatures. According to Atlas Scientific (2021), conductivity rises with temperature and salinity, which has a detrimental influence on water quality because higher conductivities mean more pollutants, such as total dissolved solids. Increasing conductivity indicates that the relative condition or health of the water body and its accompanying biota has likely declined as a result of a discharge or some other cause of the disturbance. Generally, human disturbance tends to increase the number of dissolved solids entering the water, which increases conductivity.

Measuring the salinity of the water is vital as aquatic organisms, livestock, and crops thrive at different salinity levels. Freshwater has a salinity value of less than 0.5 ppt, which can be used for drinking and all types of irrigation. Marginal and many freshwater organisms cannot live in salinity levels above one ppt. Water with a salinity between 0.5 and 1 ppt is typically referred to as marginal water because it is marginal for many uses by humans and animals. Marginal water denotes water resources that have quality issues, such as domestic and industrial effluent, which contains a large number of contaminants (Cornelissen, 2021)

Water Quality Assessment in the Philippines

According to Escatron (2022), water quality affects the life and health of the ecosystems. Hence, it is crucial to understand the water quality parameters for environmental monitoring and habitat determination. One of the most sensitive to changes in water quality is the dissolved oxygen; the lower the DO concentration, the lower the quality of the water. Moreover, temperature affects water quality and environmental parameters because it stabilizes the maximum dissolved oxygen concentration in the water, the frequency of chemical and biological reactions, and human activity. All physicochemical parameters except for the pH of the Surigao River in Surigao City met the DAO series of 2016-08 water quality standards. Due to the heterogeneous environment, water discharges, and human activities, the Surigao River has a low pH, which affects river creatures; hence, pH is an essential indicator of water quality and pollution levels.

Most of the physicochemical parameters of the Dapitan River, such as temperature, pH level, nitrate, and dissolved oxygen, were within the normal limits set by the DENR standard. According to Calunsag (2020), with a mean pH of 6.34, Dapitan River's water is in good to excellent condition for supporting the aquatic ecosystem; however, the water is not advisable for human consumption given its classification set by the DENR- EMB. If organic pollution from domestic wastewater, agricultural and urban runoff, dumped garbage, and other solid wastes continue, further deterioration of rivers will happen in the future.

The study by Wiederhold (2021) aimed to determine the selected water physicochemical characteristics of the river, such as electrical conductivity, temperature, pH, and calcium content. It was revealed that the electrical conductivity and calcium content of the Batiano River in Iloilo exceed their limit except for pH values and temperature. The study concluded that the Batiano River is near the sea, making the river saline and having a high calcium content that threatens the life of freshwater aquatic organisms. It was also attributed to the irresponsible management of wastes being thrown in the river as the river is a recipient of many pollutants that deteriorate water quality.

5. Results and Discussion

Table 1 (a): Physical Parameter and Geography Relative to Weather Pattern, Altitude and Grid Coordinates of Tagoloan River (Spillway) Sabangan, Can-ayan, Malaybalay, Bukidnon

Station	Time	Weather	Altitude (meter AMSL)	Grid Coordinates (Longitude, Latitude)
1	3:11 P.M	Scattered Clouds	650	8º19’23.26” N 125º14’82.23” E
2	2:13 P.M	Partly Sunny	652	8º12’13.9” N 125º09’01.5” E
3	1:40 P.M	Sunny	646	8º12’20.6” N 125º08’52.0” E

*AMSL: Above Mean Sea Level

Table 1a shows the physical parameters and geography relative to the weather patterns, altitude, and Tagoloan River (Spillway), Sabangan, Can-ayan, Malaybalay, Bukidnon grid coordinates. In comparison to the other sites, Station 2 is more elevated than other stations, followed by Station 1 and Station 3, respectively. Minimal differences in elevation were there. Station 1 was farther east of the equator, while Station 3 was farther north of the equator. Furthermore, the above table shows that the weather conditions at the different stations

during the sampling period ranged from sunny to partly sunny to scattered clouds. The weather conditions show a favourable time to collect water samples from the Tagoloan River (Spillway).

Table 1 (b): Physical Parameter Relative to Temperature, Conductivity, and Salinity of Tagoloan River (Spillway) Sabangan, Can-ayan, Malaybalay, Bukidnon

Station	Temperature (ºC)		Conductivity (µS/cm)	Salinity (ppt)
	Air	Water		
1	24	23.64	1500	0.008
2	24	23.18	1080	0.006
3	27	23.5	1340	0.007

Table 1b depicts the physical parameters relative to temperature, conductivity, and salinity of Tagoloan River (Spillway), Sabangan, Can-ayan, Malaybalay, Bukidnon. The above table depicts the water's temperature, conductivity, and salinity, revealing a consistent pattern. Station 1 has the highest water temperature (23.64 ºC), followed by Station 3 (23.50 ºC) and Station 2 (23.18 ºC), respectively, which are within the normal range (18.33 ºC- 23.88 ºC). In addition, the conductivity of the three stations is within the freshwater stream normal range (100 µS/cm- 2000 µS/cm); however, the salinity levels of Tagoloan River (Spillway) range from 0.6-0.8, which is considered to be marginal water. According to Cornelissen, 2021, marginal water denotes that the river contains many contaminants.

Much like water temperature, Station 1 has the highest conductivity and salinity, followed by Station 3 and Station 2, respectively. The high conductivity and salinity of Station 1 could be attributed to the presence of a poultry farm near the site. This notion is consistent with Cornelissen (2021) since human activity increases the tendency to have water quality issues. Atlas Scientific (2021) and Fondriest Environmental, Inc. (2014) assert that an increase in temperature causes an increase in conductivity and salinity. As the quantity of dissolved materials entering the water increases the conductivity and salinity levels, the health of the river and its biota might worsen. However, the water temperature varies naturally as rivers undergo daily temperature changes due to many factors, such as weather conditions, groundwater inflow, evaporation rate, and turbidity. Moreover, the Department of Health (DOH) in the Philippine National Standards for Drinking Water of 2017 (PNSDW) did not set a maximum water temperature in the Philippines, as it is not considered the primary or secondary parameter for drinking water.

Table 2: Chemical Parameters of Tagoloan River (Spillway) Sabangan, Can-ayan, Malaybalay City, Bukidnon

Station	pH	TDS (ppm)	Phosphate (mg/L)	Nitrate (mg/L)	mV Potential (J/C)
1	7.93	0.06	0.2	1.21	-45.1
2	8.01	0.07	0.23	0.92	-49.36
3	8.19	0.06	0.26	1.03	-57.72

Table 2 presents the chemical parameters of the Tagoloan River in Sabangan, Can-ayan, Bukidnon. The pH level in all three (3) stations indicates a good water quality ranging from 7.93-8.19, which, according to DENR, belongs to class AA with a value between 6.15 and 8.19. This could suggest that it is safe for biotic species to take shelter (Robertson, 2004) as well as influence the river to be greenish and cloudy in color. Another contributing factor could be the amount of Total Dissolved Solid (TDS) in the water. The total dissolved solids from each station ranged from 0.06 to 0.07, which could contribute to the number of contaminants in the water. However, the total dissolved solid is less than the amount set by the Environmental Protection Agency (EPA), indicating that it is still an acceptable value for biotic species to interact. Acceptable pH level and Total Dissolved Solid (TDS) does not necessarily mean the water is drinkable and good.

Moreover, the nitrate levels observed in the research ranged from 0.92 to 1.21 mg/L, which falls within the Class C classification according to the guidelines set by the Department of Environment and Natural Resources (DENR), as it exceeds the threshold value of 0.5 mg/L. This indicates a significant presence of nitrate, a type of contaminant, in the river. This finding is consistent with a study conducted by Aram et al. (2019), which established a direct proportional relationship between nitrate and fecal coliform. Elevated nitrate concentrations can imply increased fecal coliform, posing a potential risk to public health. Moreover, Saalidong et al. (2019) asserted that phosphate is inversely proportional to nitrate. Phosphate level ranges from 0.20 - 0.26 mg/L compared to the Nitrate level; this could be the case for both parameters. This further highlights the potential threat that the nitrate level in the Tagoloan River poses to the community.

Lastly, the river exhibits an mV potential ranging from -45.10 to 57.72, indicating its ability to act as an oxidizing and reducing agent. The mV potential, called Oxidation-Reduction Potential (ORP), provides insights into how water interacts with contaminants. A higher ORP suggests a more potent defense mechanism against contaminants, potentially improving water quality. However, the Tagoloan River shows a low mV potential, suggesting contamination by substances that can compromise water quality and pose a risk to its integrity.

Table 3: Microbial Parameters of Tagoloan River, Sabangan, Can-ayan, Malaybalay City, Bukidnon

Station	Total Coliform (MPN/100mL)	Thermotolerant Coliform (MPN/100mL)	Standard Plate Count (CFU/100mL)
1	2,400	2,400	510
2	2,400	2,400	455
3	2,400	2,400	358

Table 3 shows the Total Coliform (MPN/100 mL), Thermotolerant Coliform (MPN/100mL), and Standard Plate Count (CFU/100mL), respectively. The same levels of coliforms (2,400 MNP/100 mL) were found in all three stations. The high levels of coliforms determined in all stations could be due to the incidence of both anthropogenic activities and animal waste in the water. Jithesh and Radhakrishnan (2015) also reported a similar result in the water of the Chaliyar River, Kerala, India.

The presence of coliforms that exceeds the standard level of Coliforms (DENR-EMB limit: 200 MPN/100mL) renders it to be unfit for primary contact recreation such as swimming and bathing, though it can be used for other purposes. Exceeding the standard limit for coliform count is an alarming scenario since the presence of coliform bacteria indicates that

disease-causing organisms could be in the water system. Consequently, this could affect public health and water quality. According to Messeret (2012), chemical contaminants occur in drinking water throughout the world, which could threaten human health. So, to protect the water in the Tagoloan River, it is highly recommended that the local government unit should provide policies for the management of human-caused sources of high microbial load to make the microbial level considered safe for human health.

All three stations generally had the same Total Coliform and Thermotolerant Coliform counts. All of these sites are situated near anthropogenic activities. Sewage from poultry farms impacts the present microbial contaminants in the water. The result of the Standard Plate Count, which in station 1 has the higher heterotrophic plate count, indicates a general decrease in water quality in the Tagoloan River, Sabangan, Malaybalay City, Bukidnon. The high standard plate count obtained in the present study may be an indication that water sources are fecally contaminated (Osuinde & Enuezie, 1999). However, the microbial load varies according to the weather and the location of the stations, which indicates human contribution to the contaminants. Furthermore, the detection of a high load of microbiological contamination in the Tagoloan River, Sabangan Malaybalay City, Bukidnon, where the coliform bacteria thrive, must be given a high concern due to a strong indication of sewage and animal waste.

6. Conclusion

Based on the findings, the water temperature and conductivity of the Tagoloan River are within the normal range. However, the analysis of the salinity shows an alarming status of the river; it was found that the water in the Tagoloan River is marginal water, which indicates that the water is highly contaminated due to domestic and industrial wastewater.

In addition, it was found that the pH levels at all monitoring stations met the quality standards established by DENR in 2018. The analysis of total dissolved solids (TDS) did not reveal any concerning results, which did not align with the guidelines set by the EPA. The assessment of parameters such as nitrates, phosphate, and mV potential indicated negative findings. While the nitrate levels were average, they were notably higher compared to previous years. On the other hand, phosphate levels were low, possibly influenced by the increased nitrate content in the water. The mV potential was also low, suggesting weakened defense mechanisms against contaminants like nitrate, phosphate, and fecal coliform.

Regarding the microbial parameters in Tagoloan River Can-ayan, Malaybalay City, Bukidnon revealed that water samples exceeded the standard level of Coliforms (DENR-EMB limit: 200 MPN/100mL). The increasing fecal coliform contamination in the three stations that exceed the national limit makes the water unsuitable for human consumption and other domestic and recreational purposes. The use of this water may pose a danger to human health.

The findings present compelling evidence, highlighting the urgency for local government units (LGUs) and locals in the area to implement mitigation measures in maintaining acceptable water quality. These include actions to reduce nitrate and fecal coliform levels in the river. The outcomes are particularly crucial considering the increasing popularity of the river as a recreational destination for families, hikers, and travellers.

7. Recommendation

Based on the results of the study, the following recommendation was made:

a) For future researchers, a long-term monitoring of water quality is suggested for accuracy and precision.
b) For the Government, Increase public awareness about the importance of water quality and the potential impacts of contaminants.

Acknowledgement
The researchers express their heartfelt gratitude to everyone who contributed to the success of this study. Special thanks go to the Bukidnon State University Science Laboratory for their exceptional support. We also extend our appreciation to Andrea G. Azuelo for her invaluable guidance and insights. We are grateful to our families for their unwavering moral support. Lastly, we thank the Department of Science and Technology (DOST) for providing the necessary financial assistance.

References

[1] Aram, S. A., Saalidong, B. M., & Osei Lartey, P. (2021). Comparative assessment of the relationship between coliform bacteria and water geochemistry in surface and groundwater systems. PLOS ONE, 16(9), e0257715. https://doi.org/10.1371/journal.pone.0257715
[2] Aremu, M. O., Akinloye, D. I., Oluremi, B. B., & Suleiman, A. S. (2011). Physicochemical characteristics of a stream, well, and borehole water source in Eggon, Nasarawa State, Nigeria. Journal of Chemical Society of Nigeria, 36(1), 131-136.
[3] Calunsag, K. L. (2020). Water quality assessment of Dapitan River in Dapitan City, Philippines. Published Thesis, 1-17.
[4] Cornelissen, P., van der Zee, S. E. A. T. M., & Leijnse, A. (2021). Framework for the integrated sustainability assessment of irrigation with marginal water. Water, 13(9), 1168. https://doi.org/10.3390/w13091168
[5] Escatron, M. J. (2022). Water quality assessment of Surigao River, Surigao City, Philippines. Journal of Entomology and Zoology Studies, 10(1), 1-10.
[6] Jha, D. K., Devi, M. P., Vidyalakshmi, R., Brindha, B., Vinithkumar, N. V., & Kirubagaran, R. (2015). Water quality assessment using water quality index and geographical information system methods in the coastal waters of Andaman Sea, India. Marine Pollution Bulletin, 100(1), 555-561. https://doi.org/10.1016/j.marpolbul.2015.09.036
[7] Jithesh, M., & Radhakrishnan, M. V. (2015). Seasonal variation in the microbial population of Chaliyar River water Kerala, India. International Journal of Water Research, 5(2), 64-69.
[8] Martinico-Perez, M. F. (2016). Evaluation of Water Quality Index of Major Rivers in Palawan, Philippines

using Physico-Chemical Parameters and Water Quality Index. Philippine Statistics Authority.

[9] Messeret, B. (2012). Assessment of drinking water quality and determinants of household potable water consumption in Simada district, Ethiopia. Unpublished doctoral dissertation.

[10] Naik, R. R., & Phadke, M. R. (2022, September). High levels of nitrate in well waters of Saipem Ward, Candolim, Goa. In M. A. Rahman, A. A. M. Nizami, & P. K. Varma (Eds.), Environmental Concerns and Remediation: Proceedings of F-EIR Conference 2021 (pp. 237-247). Cham: Springer International Publishing. https://doi.org/10.1007/978-3-030-95991-4_18

[11] Osuinde, M. I., & Eneuzie, N. R. (1999). Bacteriological analysis of groundwater. Nigeria Journal of Microbiology, 13(1), 47-54.

[12] Prabhakar, S. (2015). Study of water quality in Hindon River using pollution index and environmetrics, India. Desalination and Water Treatment, 57(24), 11120-11133. https://doi.org/10.1080/19443994.2015.1098570

[13] Ramakrishna, C. R., Sadashivaiah, C., & Ranganna, G. (2009). Assessment of water quality index for the groundwater in Tumkur Taluk, Karnataka State, India. E-Journal of Chemistry, 6(2), 523-530. https://doi.org/10.1155/2009/757424

[14] Teves, C. (2019). Experts advocate water demand management. Philippines News Agency. Retrieved from https://www.pna.gov.ph/articles/1065244

[15] Tyagi, S., Sharma, B., Singh, P., & Dobhal, R. (2013). Water quality assessment in terms of water quality index. American Journal of Water Resources, 1(3), 34-38. https://doi.org/10.12691/ajwr-1-3-3

[16] Uddin, M. G., Nash, S., & Olbert, A. I. (2021). A review of water quality index models and their use for assessing surface water quality. Ecological Indicators, 122, 107218. https://doi.org/10.1016/j.ecolind.2020.107218

[17] Water Environment Partnership in Asia (WEPA). (2017). Retrieved from http://wepa-db.net/3rd/en/index.html

[18] Wiederhold, B. N. (2021). Selected water physico-chemical characteristics of Iloilo Batiano River, Philippines: A baseline study. International Journal of Environmental Science and Development, 12(9), 261-266. https://doi.org/10.18178/ijesd.2021.12.9.1352