Research Article

Assessment of Water Quality Parameters for Aquaculture uses: The Case of Guder River, Main Tributaries of Blue Nile, Ethiopia

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Abstract | The goal of this study was to evaluate the Guder River's water quality parameters for aquaculture purposes. In this study, parts of Guder river were divided into three streams (upper, middle, and down). From each stream, five sites were chosen. During the dry and rainy seasons, water samples were collected at a depth of 10 to 15 cm in plastic bottles from each site of three streams for laboratory study. Water quality parameters such as CO_2, Chloride, and alkalinity were instantly assessed using the titration method, while water turbidity, temperature, water pH, and dissolved oxygen were measured directly on site. A simple test kit was used to evaluate nitrite and ammonia levels. The result revealed a high level of alkalinity (66.3±39. 1mg. L^{-1}) at downstream and lowest concentration (58±40mg.L^{-1}) was found in the middle stream. The upper stream has a high CO_2 concentration (14±3.6mg.L^{-1}) while the middle stream has a low CO_2 concentration (9.4±0.77mg.L^{-1}). The maximum chloride content (28.7±2.6 mg. L^{-1}) was found at downstream, whereas the lowest (22.7±4.1mg.L^{-1}) was found in the upper stream. The pH of the water was measured to be between 5.89 and 7.33, with a temperature of 23.4 to 26.2°C. Nitrite and ammonia concentrations were 0.01 to 0.04mg.L^{-1} and 0.03 to 0.05mg.L^{-1}respectively. The results revealed that the site had a significant impact on the concentration of free carbon dioxide ($P<0.05$). However, no significant changes in alkalinity and chloride were found in any of the streams ($P>0.05$). Generally, even though the concentrations of the analyzed parameters vary among streams and river basins, they are generally within the range of fish production.

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Introduction

Water pollution has a negative impact on both human and aquatic organisms, therefore water quality is a major concern around the world (Tortajada and Biswas, 2018; Edokpayi *et al.*, 2020). Aquaculture is a net consumer of water and necessitates a large quantity and high quality supply. In fish production, irrigation, and drinking water, water quality is critical (Daniel and Elliot, 2021). Anthropogenic activities (agriculture, mining, and factory discharge) and natural processes (interaction between animals, plants, and the environment) usually have an impact on surface water quality (Barletta *et al.*, 2019; Daniel and Elliot, 2021). The most decisive element in fish production is a lack of sufficient water quantity, poor water quality, and pond volume (Xianyu *et al*., 2020). A discharge of industrial effluents and sewage has influenced the physiological activities of aquaculture organisms (Nazari–Sharabian *et al*., 2019; Dabi, 2020). Aquaculture relies primarily on surface and groundwater for its water supply. However, not all surface and groundwater are suitable for aquaculture. The study of water's chemical, physical, and biological qualities is critical for aquaculture organism raising (Gupta, 2006; Warish *et al*., 2017). In aquaculture production, an imbalance of water quality factors can harm organisms' health and lower the quality of products for sale (Rameshkumar *et al*., 2019). Abiotic parameters that need to be tested in aquaculture production include alkalinity, water pH, ammonia, dissolved oxygen (DO), temperature, hardness, and nitrite (Menegotto *et al*., 2019; Rau *et al*., 2019). A discharge of industrial effluents and sewage has influenced the physiological activities of aquaculture organisms (Nazari–Sharabian *et al*., 2019; Dabi, 2020). However, salinity, chlorides, and carbon dioxide may be evaluated dependent on the aquaculture system (Jacome *et al*., 2018). When it comes to water quality parameters, there is a lot of variety among fish species (Boyd, 1998). Waste from aquaculture farms can degrade the quality of the aquatic water ecosystem on its own. The fertilizer intake from aquaculture effluent may cause the aquatic environment's water quality to deteriorate (Falconer *et al*., 2018).

The Guder river is one of the Blue Nile's left-hand tributaries in Ethiopia. Taranta and Dabissa are two well-known tributaries of the Guder River. It has a drainage area of approximately 7,011 km2. As a result, it is critical to examine the water quality and ensure that it can support the fish. As a result, the purpose of this article is to evaluate the current water quality of the Guder River, which is one of the tributaries of the Blue Nile, for aquaculture purposes. The majority of low-income countries do not treat wastewater before releasing it into bodies of water (Edokpayi *et al*., 2020). The majority of our country's water resources have not been evaluated in connection to aquaculture output. Furthermore, Ethiopia lacks a clear limit for harmful compounds such as ammonia and heavy metals produced by agricultural farms and industry to rivers, which may have an impact on the health of aquatic animals Pesticides, fungicides, herbicides, and fertilizers used by farmers to boost productivity are also pollutant sources for aquatic creatures because they disrupt the equilibrium of water quality parameters. The goal of this study was to determine the important water quality characteristics for aquaculture in the Guder River, one of the Blue Nile's main tributaries in Ethiopia.

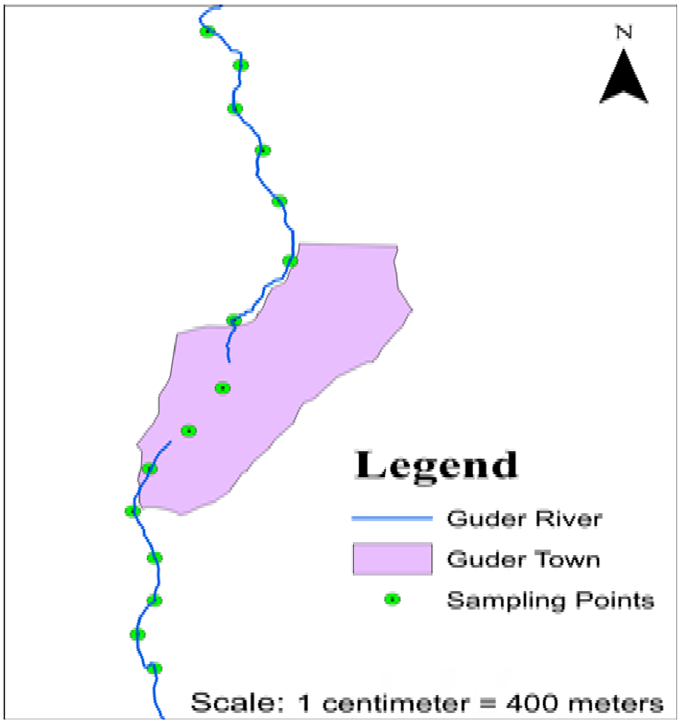

Figure 1: *Map of Guder River indicate where sampling sites are located*.

Materials and Method

Sample size and sampling techniques

This research took place over the period of a year, from December 2018 to August 2019. The Guder River was chosen for this investigation, and its river basin was divided into three streams. Based on pollutant load, the river basins above the town were designated as upper stream (southern portion), middle stream (region of the river within Guder town), and downstream (northern part) (Figure 1). The water was sampled six times between 9:00 and 12:00 a.m. in both dry and rainy seasons (December, January, and February) (June, July, and August). Ninety (90) water samples were collected in transparent plastic from five points at a distance of 0.8 km each stream in both seasons from a depth of 10-15 cm. The locations within the streams were chosen based on their geography, natural and man-made pollution sources, and other factors. In the laboratory of Ambo University, the sampled water was immediately analyzed using fundamental methods according to American Public Health Association (APHA) standard methods,

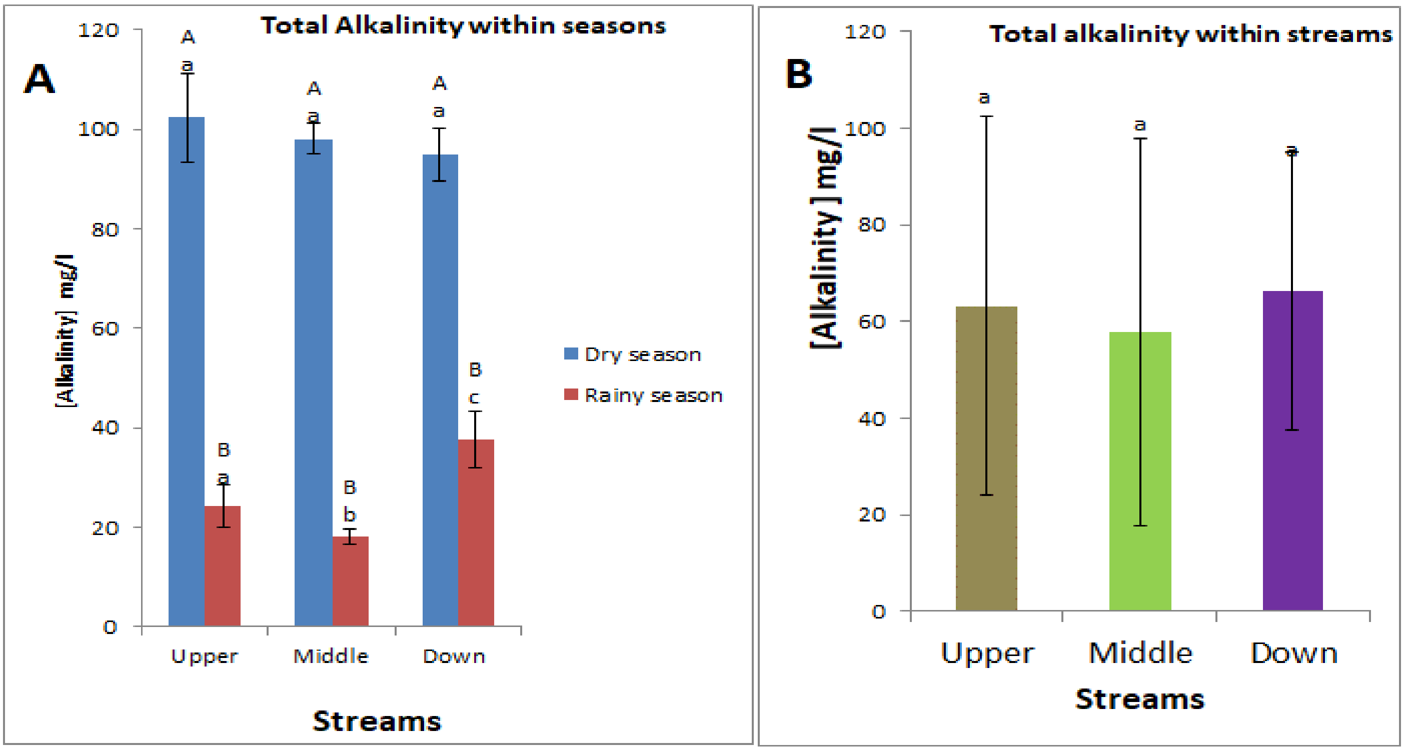

Figure 2: *The concentration of alkalinity in the Guder river basins in dry and rainy seasons (A) and concentration of alkalinity along Guder river basins in the whole year round (B). Values are (means ± S.E, n=5), different small letters (a, b, c) denote significant differences between different streams along the river basins. Capital letters (A, B, C) denote significant differences between dry and rainy seasons.*

such as the titration method (APHA, 2000), for water quality parameters such as CO_2, Chloride, and alkalinity, while water turbidity, temperature, water pH, and dissolved oxygen were measured onsite. Using an interpretive simple ammonia test kit and a nitrite test kit, the nitrogen component concentrations of ammonia and nitrite were determined.

Determination of water quality analysis: Total alkalinity in mg. L^{-1} = T*N*50*1000/S, Free carbon dioxide in mg. L^{-1}= T*N*22*1000/S and Chlorides in mg. L^{-1} =T*N*35.5*1000/S

Where;
T: Volume of titrant in ml (T=Tf-Ti); Ti: Initial volume of titrant in the burette before; Tf: Final volume of titrant in the burette after; N: Normality of titrant; S: Volume of water sample used in ml.

Ammonia and Nitrite: Was measured by using interprets easy ammonia/nitrite test kit.

Onsite measurements for physical parameters: *dissolved oxygen* (Hand Held Dissolved oxygen meter (AZ 8403), water pH by (pH meter (HI 8314), turbidity by (Portable turbidity meter (BANTE TB100), temperature by (laboratory thermometer).

Data Analysis
The data were presented by using descriptive statistics such as mean, standard error of means, and p-value. For statistical data analyses, one-way ANOVA was run to test the significant difference among different values. All analyses were performed using the software program SPSS version 25. $P \leq 0.05$ was used.

Results and Discussion

Alkalinity
The concentrations of alkalinity at the several sites in this study were variable. During the dry seasons, alkalinity levels were moderate in all streams. This could be related to the fact that during dry seasons, waste materials from households and institutions are discharged because they cannot be diluted as they can during rainy seasons. During dry seasons, however, the concentration of alkalinity differed among the three streams (Figure 2A). This fluctuation could be due to the number of rocks (limestone, such as calcium carbonate) in the river and the terrain around it. During dry seasons, there was less waste material discharge to the river at the upper stream, but there was a continuous flow of waste materials to the river at the middle stream in both dry and rainy seasons. From upper to lower, the average alkalinity ranges

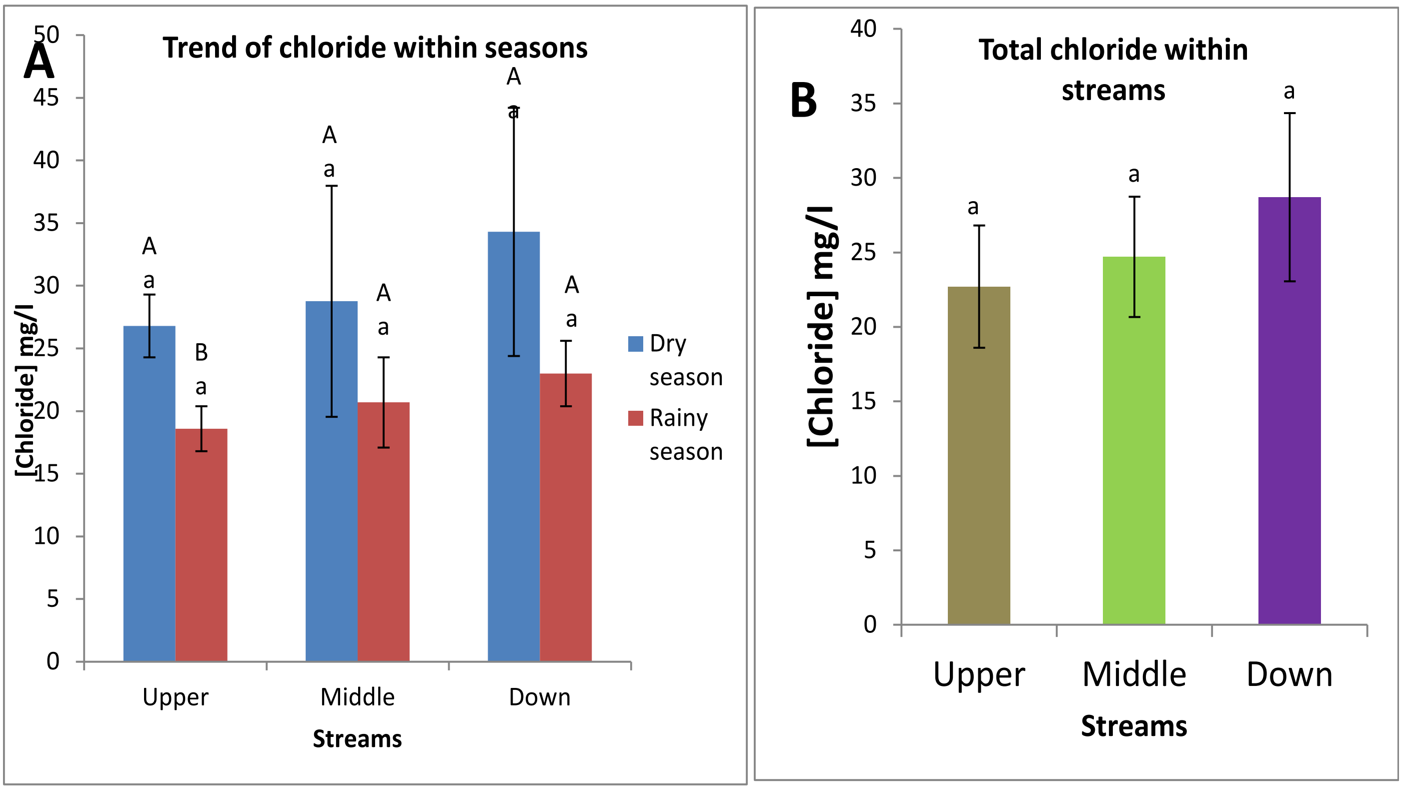

Figure 3: *Concentration of chlorides in the Guder river basins in dry and rainy seasons (A) and concentration of chlorides along Guder river basins in the whole year round (B). Values are (means ± S.E, n=5), different small letters (a, b, c) denote significant differences between different streams along the river basins. Capital letters (A, B, C) denote significant differences between dry and rainy seasons.*

from 58 to 66.7mg.L^{-1}. This amount of alkalinity is classified as moderate (25 to 75 mg.L^{-1}) in terms of fish production potential, while concentrations less than 20mg.L^{-1} cause water pH to fluctuate, causing damage to the nitrifying bacterial community (Hugh, 2020). This high level of alkalinity in the water could be attributable to a lack of carbonate sources in the Guder River. The concentration of alkalinity changed not because of different places along the river (Figure 2B), but because of seasonal variation, particularly during dry seasons when the volume of the water bank was lowered to a minimal level between December and January, according to this study.

Chlorides

Chloride is the most critical ion in maintaining osmotic balance in aquaculture species (Stone *et al*., 2013) and is utilized to balance acid and base (Powers, 1999). During the rainy and dry seasons, there is no discernible difference in the streams along the river basins (Figure 3A and B). This could signal that there are no further chloride sources available in the environment. The most common reason for adding chloride to water is to control microbes. There are no such municipal wastes from the town of Guder, nor agricultural activity by nearby farms. In dry conditions, the chloride level of sewage effluent can increase the chloride content of receiving water by up to 70mg.L^{-1} (Malcolm *et al*., 2017). The greatest level of chloride in our investigation was 35mg. L^{-1} is a normal component of fish production.

Free carbon dioxide

When comparing the middle stream to the upper and lower streams in the current study, there were significant variances (Figure 4B). This is because there is a significant likelihood of nutrient accumulation in the middle stream, which promotes aquatic plant growth. Photosynthesis occurs as a result of the strong growth of aquatic plants, resulting in a low CO_2 content in the water. On the other hand, the high CO_2 concentrations observed at the upper and downstream are due to a lower chance of nutrient accumulation in the water, which resulted in less aquatic plant availability, less photosynthesis, and available CO_2 that was not accumulated in the water did not react with water to convert to glucose and oxygen. This finding is consistent with the findings of (William *et al*., 1992; Santhosh and Singh, 2007), who found that most fish can take 20mg.L^{-1} CO_2 without adverse consequences (*e.g*. catfish). During the wet season (June to July), the carbon dioxide concentrations in the streams were more diverse (Figure 4A). This could be due to the intensity of sunshine during the rainy season or to the

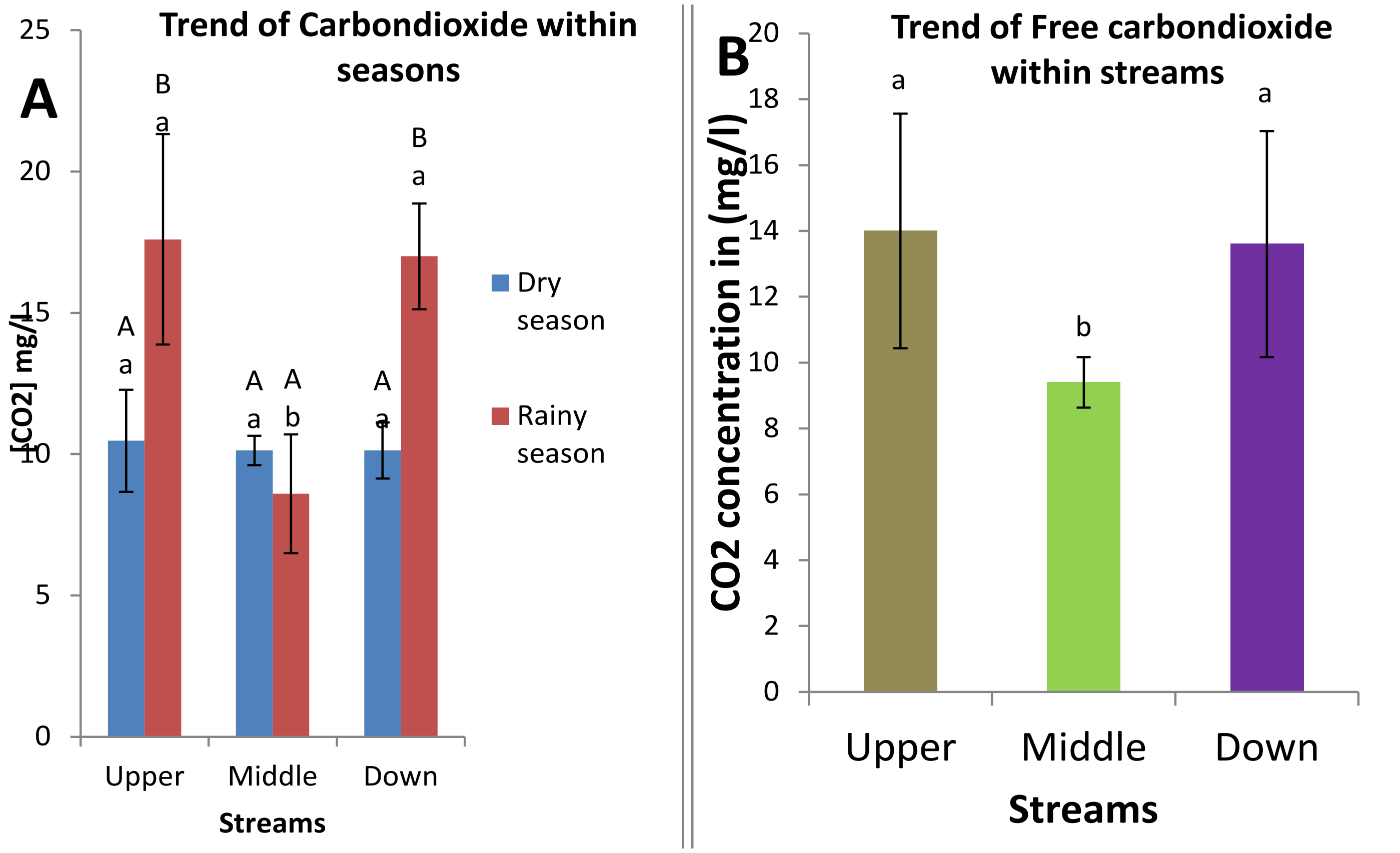

Figure 4: *Concentration of Carbon dioxide in the Guder river basins in dry and rainy seasons (A) and concentration of Carbon dioxide along Guder river basins in the whole year round (B). Values are (means ± S.E, n=5), different small letters (a, b, c) denote significant differences between different streams along the river basins. Capital letters (A, B, C) denote significant differences between dry and rainy seasons.*

turbidity of water caused by agricultural runoff water containing suspended solids, which prevents CO_2 from reacting with water to form glucose and oxygen, which is necessary for life.

Dissolved oxygen (DO)

The lower stream had the lowest average DO value (6.2mg.L^{-1} Table1) throughout the year, which could be owing to increased organic matter accumulation from the nearby farm, which invited more decomposers to absorb oxygen. The 12mg.L^{-1} DO record at the middle stream could be attributed to the water temperature in the area dropping. This observation is consistent with earlier findings, as the concentration of DO decreases with decreasing temperature (Pedapoli and Ramudu, 2014). The density of cultural organisms and temperature can have an impact on DO concentration (Xianyu *et al*., 2020). The DO content in the current study for fish production is within the range of previously reported findings by (Bhatnagar and Singh, 2010) who found DO concentration in the water should be greater than 5mg.L^{-1}.

Nitrite

The concentration of nitrite in the upper stream in this study is substantially higher than in other areas of the river, which can be linked to various agricultural activities in the area. High levels of nitrite affect aquatic organisms by converting haemoglobin to methemoglobin in the blood, causing browning of the blood and gills, obstructing respiration, and causing damage to the liver, kidney, spleen, and nervous system (Stone and Thomforde, 2004). The lowest concentration of nitrite (0.01mg.L^{-1}) was found downstream, whereas the highest concentration (0.04mg.L^{-1}) was found in the upper stream. The oxidation of ammonia to nitrite, especially in the presence of dissolved oxygen, is clearly responsible for the rise in nitrate As a result, the current study's findings are well below the OATA's 2008 recommendation, which states that the maximum nitrite concentration level is 0.125mg.L^{-1} in sea water and 0.2mg.L^{-1} in freshwater.

Ammonia

In current study, the dramatic increase in ammonia content seen at the upper stream (Sites 1&2) was attributed to the direct impact of agricultural operations inflow from several tributaries of the Guder River. As a result of the ammonification process, organic matter is transformed to ammonia at high temperatures.

Table 1: *The measured water quality parameters value in the study area.*

Streams	The concentration of water quality parameters in both seasons								
	Alkalinity (mg. L^{-1})	DO (mg. L^{-1})	CO_2 (mg. L^{-1})	Chlorides (mg. L^{-1})	Ammonia (mg. L^{-1})	Nitrite (mg. L^{-1})	Temperature (℃)	pH	Turbidity (NTU)
Upper	63.3	6.2	14	22.7	0.05	0.04	24.6	5.89	178
Middle	58	12	9.4	24.4	0.01	0.02	23.4	6.9	250
Down	66.3	8	13.6	28.4	0.03	0.01	26.2	7.33	317
Average	62.53	8.73	12.33	25.16	0.03	0.02	24.73	6.71	248.33
Range	58-66.3	6.2-12	9.4-14	22.7-28.4	0.01-0.05	0.01-0.04	23.4-26.2	5.89-7.33	178-317

As a result, the highest levels of ammonia (0.05mg.L^{-1}) were found during wet seasons. The river's downstream and intermediate reaches showed minor changes. The maximum ammonia boundary for aquaculture species, according to Santhosh and Singh (2007) and Bhatnagar (2004), is 0.1mg.L^{-1}. However, there is dispute over what the maximum ammonia level in the water should be. According to (Pilly, 1990), the highest saves level of ammonia allowed in fish farming is around 0.02mg.L^{-1} (at pH 7.0). As a result, regardless of the findings of various writers, my conclusion falls within the range of previously published bounds of less than the maximum limit.

Temperature

At different seasons (23.4 to 26.2 °C Table 1), the temperature varies from site to site along the studied river basins. The recommended temperature range for fish rearing is 30 to 35°C (Delince, 1992). Our findings matched those of (Santhosh and Singh, 2007), who said that the best water temperature for carp species culture is between 24 and 30 degrees Celsius. This means that, above all, the Guder River's water temperature is better for carp culture than for other fish species.

Water pH

The pH of water is affected by factors such as alkalinity, hardness, and carbon dioxide (Warish *et al.*, 2017). The pH of Guder river water ranged from 5.89 to 7.33 (Table 1), depending on the location and season. The pH range for freshwater fish is believed to be between 6.5 and 8.5. (Boyd, 1998; Warish *et al.*, 2017). As a result, a pH value lower than the optimum value was recorded in the current study at the upper stream of the Guder River, which could result in delayed growth and an imbalance in the ability to osmoregulate salts. In water with a pH of 4.0 to 6.5 and 9.0 to 11.0, fish can get stressed (Ekubo and Abowei, 2011; Anita and Devi, 2019). Because of the high concentration of free carbon dioxide observed as a result of possible liberation of hydrogen sulfide, methane gases, and organic debris, the lowest pH values were generally recorded in the upper part of the river. However, the high pH value found (7.33) at downstream of the river may be attributable to variations in physicochemical conditions, as previously suggested by other scientists (Pedapoli and Ramudu 2014).

Turbidity

Turbidity is the cloudiness of water and one of the most important water quality indicators since it affects light transmission to the depths of the water (Daniel and Elliot, 2021). Because light cannot easily reach the limnetic and benthic zones of water bodies, turbidity can kill aquatic creatures. According to Bhatnagar *et al.* (2004) and Anita and Devi (2019) if the water turbidity is a dark brown color, it is hazardous to fish and shrimp culture since sunlight cannot easily penetrate the water depth to perform photosynthesis. Suspended solids or plankton can cause it. In my investigation, the lowest turbidity (178NTU) was found in the upper stream (Table 1), which could be attributed to the lower stream having a lower likelihood of encountering a lot of suspended materials. On the other hand, downstream had the highest (317NTU) turbidity, which could be due to high waste materials emitted from Guder campus and Guder town.

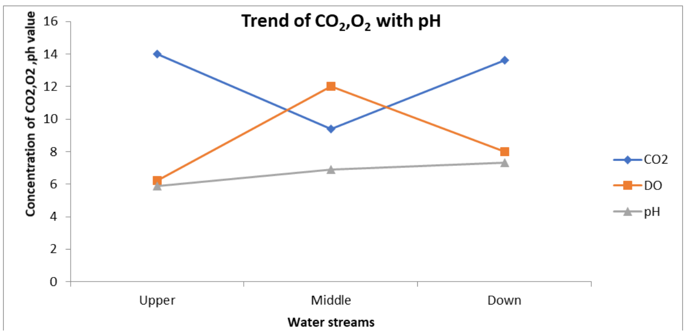

Figure 5: *The trend of Guder river water pH versus concentration of DO and CO_2.*

Water pH versus free CO_2 and DO

The interplay between CO_2 and pH has an impact on the water quality in fish ponds (Lawson, 1995). The pH of the water was raised from the upper streams to the lower streams in the current investigation. This means that there is a strong likelihood of wastewater from Guder town being added to the river in the middle and downstream, increasing the organic matter in the water or changing the basic features of the water. When pH levels rise above the recommended range, it can have a variety of detrimental impacts on fish, including slowed growth and even death (Robertson, 2004). The middle stream had the highest concentration of DO, while the concentration of carbon dioxide in each stream was inversely proportional to the concentration of DO (Figure 5). When there is enough sunlight for photosynthesis, the inverse connection between DO and CO_2 indicates that DO is accessible. Carbon dioxide levels in the environment are often higher at night because more respiration is predicted. The maximal concentration of DO in the middle stream in this study indicates that there is adequate sunshine to perform photosynthesis from CO_2 and water. In reality, nutrient accumulation is better in the middle stream, causing phytoplankton development to produce a high concentration of carbon dioxide. The values recorded for DO were still within the permissible range for aquatic survival, given that DO value below 5mg.L^{-1} impairs the growth and reproduction of fish, furthermore making them more susceptible to disease and becomes deleterious below 2mg.L^{-1} (Mulongaibalu *et al*., 2014).

Conclusions and Recommendations

The study gave information on the Guder River's water quality and potential for aquaculture. Due to the imbalance of the water ecosystem, which is disrupted by agricultural operations and the discharge of wastewater from Guder town into the river, water quality varies significantly across sources at different locations. This research shows that when there is a high concentration of carbon dioxide, there is a lower concentration of dissolved oxygen, and when there is a high pH value, there is a large accumulation of ammonia. Water turbidity was found to be high during rainy seasons as a result of anthropogenic activities (agricultural operations such as pesticide, herbicide, and fertilizer) and waste discharge from Guder town, according to this study. The concentrations of carbon dioxide, alkalinity, dissolved oxygen, temperature, turbidity, nitrate, ammonia, chloride, and water pH measured from Guder River, on the other hand, are indicative of the culture of most freshwater fish species such as catfish (*Siluriformes*), common carp (*Cyprinus carpio*), perch (*Perca*), salmon (*Salmo salar*), trout (*Oncorhynchus mykiss* (*Oreochromis niloticus*). The Guder River is suitable for freshwater fish production, according to this study.

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Novelty Statement

Even though there are related works in other parts of the world, in the study area there is no similar work previously conducted neither by me nor by others researchers.

Conflict of interest

The author declares that there is no conflict of interest regarding the publication of this article.

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