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Assessment of Effluent Discharges into Waterways from On-Farm Cattle Breeding Operations in Mubi, Adamawa State

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Abstract
The emerging Cattle breeding enterprises in Mubi, Adamawa State, Nigeria, and the unrestricted effluents discharged from the operations into water bodies are observed to be potential health risks to the residents. The runoff from the operations possesses the intrinsic mobility to contaminate the nearby surface waters and groundwater resources through surface infiltration. In this study, the suitability of the water samples from the streams and hand-dug wells across the cattle breeding farms in Mubi was evaluated for various applications using the Canadian Council of Ministers of Environment Water Quality Index (CCME WQI). The results of the CCME WQI show the samples collected from the Jerre, and Gipalma streams and the wells at Gipalma across the nine cattle breeding farms are of poor/marginal ratings which proves that the samples could be unsuitable for irrigation, fisheries, livestock, and human consumption relative to the acceptable standards prescribed by the regulatory bodies. The WQI shows the water quality is almost and frequently threatened/impaired; the conditions are often (marginally, 45-67) or usually (Poor, <45) depart from the acceptable or desirable levels. Among the twenty (20) parameters analysed, the total coliform count was observed to fail the objectives widely. The total coliform detected at the Jere streams ranges from 1.27 x 10^6 to 1.7 x 10^6 Cfu/100 mL. The values recorded at Gipalma streams range from 1.40 x 10^6 to 1.62 x 10^6 Cfu/100 mL and that of the wells in the same locations ranges from 1.06 x 10^6 to 1.08 x 10^6 Cfu/100 mL.

Keywords: Water Quality Index, Cattle breeding, Assessment, Streams, Pollution, Parameters.

INTRODUCTION
Surface water contaminations are reported to be primarily attributed to the runoff of excess biogenic materials from animal wastes and other agricultural-related activities (Malone and Newton, 2020; Gruere *et al.*, 2023). It is also noted that the effects of such direct discharges into streams have the inherent mobility to contaminate not only the surface water but also through surface infiltration transmit contaminants into the groundwater resources (Fan *et al.*, 2020; Pham-Duc *et al.*, 2020). The organic concentrates of the biogenic materials are typically

reported to contain toxic substances that affect benthic water clusters by altering their natural composition and impeding their use for any healthy applications (Fan *et al*., 2020).

Literature studies reveal a direct link between surface water pollution and manure effluents and their effect on public health (Fan *et al*., 2020; Cao *et al*., 2021). Fecal matrix alongside other pathogenic species, excreted in the feces of infected animals, directly or indirectly drop their fingerprints in nearby water bodies (Hoeksma *et al.,* 2021). Szulc and co-workers, (2020) detected various bacterial and fungal genera in cattle breeding premises in central Poland. In the Netherlands, multiple spores of sulfite-reducing clostridia and intestinal enterococci have been found in the input streams receiving effluents from livestock slurry (Hoeksma *et al.,* 2021; Ibekwe *et al.,* 2023). The prevalence of Salmonella spp. was also reported to be relatively high, detected in nearly 41.7% of pig pens and 79.2% of communal drainage areas in samples collected from smallholder pig farms in Ha Nam Province, Vietnam (Pham-Duc *et al.*, 2020) The increase in manure inputs due to the intensification of livestock production raises serious concerns for both human and environmental health, further observed to increase the threat of accumulation in different ecological compartments and released unchanged into the biosystems (Marutescu *et al*., 2022; Patra & Dubey, 2024).

The Nigerian cattle population has been estimated to be 15.3 million milking cows and 13.26 million beef cattle; further reported to be an important economic activity in Adamawa State and particularly Mubi Area. Adamawa State alone accounts for about 2.5 million heads of cattle produced in Nigeria. Mubi in particular has a lot of pasture land, as such it formed an important breeding ground for cattle and hence the formation of one of the largest cattle markets in the state attracting cattle dealers across the continent. However, fifteen percent (15%) of the beef cattle found in Mubi are produced through grass and concentrate fattening at homes and fattening sites (Dzarma, and Hamawa, 2020; Kubkomawa *et al.,* 2019). These activities are on the increase in recent times due to the rising cases of headers-farmers clashes across Nigeria as shown in the aerial drone view in Figure 1. Studies found that the more households engaged in animal breeding, the higher the health risks to local villagers. Globally, there is increasing awareness of the polluting potential of effluents discharged from animal house boundaries in terms of public health concerns. However, these concerns have not been sufficiently reflected in policies, particularly in Mubi, Adamawa State, Nigeria.

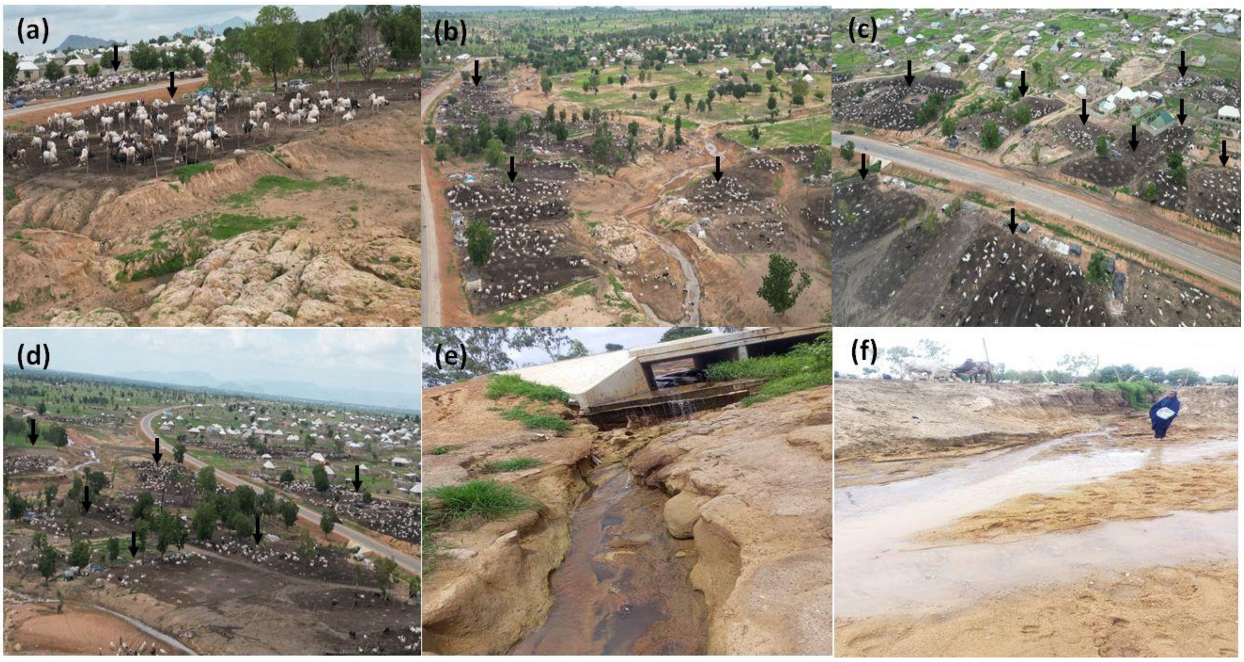

Figure. 1. (a-d) Showing Drone Arial view of Cattle Breeding Farms (e) Runoff into Nearby Streams and (f) Residence Collecting Water from the Streams, in Mubi, Adamawa State, Nigeria.

Though studies conducted in Mubi show some of the water samples are compromised for drinking purposes (Sukamari *et al*., 2020; Amina *et al*., 2020), the authors as reported, however, limit their studies to human consumption only using weighted arithmetic water quality index (WAWQI) model. This model as reported by some authors has no provisions that reflect the overlapping effects of the various water quality parameters and their characteristics for various applications (Gad *et al*., 2023; Panagopoulos *et al*., 2022). And similarly, not able to relate their findings to the sources of the contaminations. As a fallout from these cited works, this present study hereby acquired filed analysis to establish the impact of effluent discharges from the emerging cattle farming operations in Mubi on the surface and groundwater quality using the Canadian Council of Ministers of Environment Water Quality Index (CCME WQI) model. The choice of adopting the CCME WQI tool in the water quality assessments in this study is informed by its flexibility to accommodate different parameters, into a single, dimensionless value in addition to its global acceptability (Panagopoulos *et al*., 2022). The model reflects the overlapping effects of the various water quality parameters as mentioned earlier and their suitability for different applications or uses (Gad *et al*., 2023), based on their acceptable reference standards established for various applications (WHO 1993, 2006, 2008, 2011; NSDWQ, 2007; FEPA/FMEnv, 2003; USEPA, 1999, 2009; FAO, 2011; NAS, 1974; BIS, 1991; CCME, 1987; NESREA, 2011; EEC. 1976). The study explored the development of effluent characteristics of these on-farm cattle farming operations in Mubi as it affects the concentrations of the following general parameters such as pH, temperature, electrical conductivity (EC), total dissolved solids (TDS), and total hardness (TH). The chemical parameters include Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^{+}), Potassium (K^{+}), Bicarbonate (HCO_3^{-}), Carbonate (CO_3^{2-}), Nitrate (NO_3^{-}), Sulphate (SO_4^{2-}), Phosphate (PO_4^{3-}), Chloride (Cl^{-}), and iron (Fe). The biological and microbiological parameters such as the Chemical oxygen demand (COD), biological oxygen demand (BOD, dissolved oxygen (DO), and total coliform (TC) respectively.

METHODOLOGY

Study Area

Mubi senatorial zone is the largest town in Northern Adamawa state, Nigeria, consisting of Mubi North and Mubi South. The people are predominantly farmers with booming cattle farming enterprise as the major business operation (Adebayo, 2004). Geographically located on latitude $10°11'30''N$ to $10°22'30''N$ and longitude $13°13'00''E$ to $13°30'00''E$ as shown in Fig.2. The total land mass was estimated at 506.4 km^2 (Martins and Gadiga, 2015). The temperature reaches its maximum in April (40°C) and minimum between December and January (18°C) with the average values ranging from 26.7°C to 27.8°C. The annual rainfall falls between 998 mm and 1262 mm on average, spanning from April through October. The study areas covered the Jere community at Dazala ward and Gipalma, located at Kolere/Muracha wards of Mubi LGA.

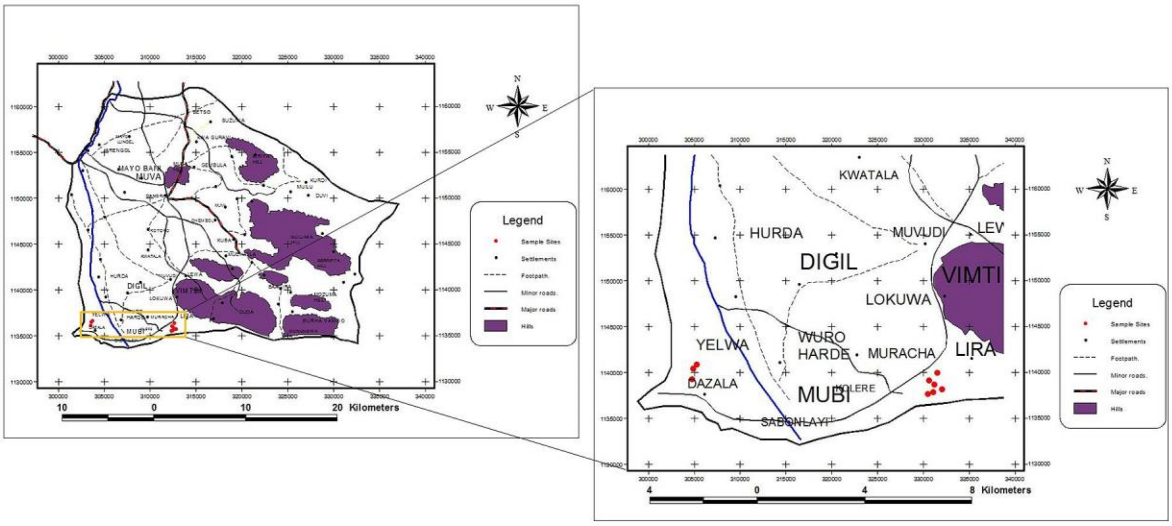

Figure. 2. Map Showing the Geographical Location of Mubi and the Study Areas

Sample collection and parametric analysis:

The summary in Table 1 is the site description of the study areas indicating the nine sampling locations. The water samples were collected for three weeks in replicate (weeks 1, 2, and 3) for each sampling point in sterile plastic bottles. The samples were taken in streams connecting cattle breeding farms in Jere and for both the streams and hand-dug wells at cattle breeding farms from Gipalma. Todd and Mays, (2005) and APHA, (2017) procedures were adopted for the laboratory analyses as described in Bwatanglang *et al*. (2020 and 2021). The pH was measured using an Elico PE 138 pH probe while the titration method with EDTA was used for the determination of total hardness (TH). The TDS and EC were determined using a multipurpose JENWAYportable combined TDS/Conductivity meter. An Atomic Absorption Spectrometer (AAS) (Buck Scientific, VPG 210) was used for the determinations of Fe and Mg, while a Flame Photometer (Systronics 128) was used to analyse Ca, Na, and K ions. The argentometric titration method was utilized for the determination of Cl ions and the acid-base titration used methyl orange as an indicator for the Bicarbonate (HCO_3^-) ions. Sci-04 model of water LaMotte Analyzer was used for the analysis of the anions Nitrate (NO_3^-), Phosphate (PO_4^{3-}), and Sulphate (SO_4^{2-}). The dissolved oxygen (DO), was determined using a DO meter (JENWAY 970). Sealed water was incubated at 20^0C for five days and separately, the water samples were also digested in a sealed vial with potassium dichromate and sulfuric acid at 150^0C for 2 hours. The measure difference of the DO level before and after the incubations and the digestion processes were used for the determination of the biological oxygen demand (BOD) and the Chemical oxygen demand (COD) levels respectively. The membrane filter method (MF) was followed using the most probable number (MPN) techniques and standard plate count methods for the determination of Total coliform (TC) in the water samples. The concentrations obtained for the respective samples analysed for each parameter are then compared for various applications using the standards described in Table 2.

Table 1. Locations, Description, and Coordinates

Sample ID	Sample Area	Site-description	Latitude	Longitude
JF-1	Jere Farm 1	Jere stream. Runoff from the Cattle Farm 1	10.28103	13.22610
JF-2	Jere Farm 2	Jere stream. Runoff from the Cattle Farm 2	10.28607	13.22772
JF-3	Jere Farm 3	Jere stream. Runoff from the Cattle Farm 3	10.28465	13.22648
GF-1	Gipalma Farm 1	Gipalma stream. Runoff from the Cattle Farm 1	10.27814	13.31104
GF-2	Gipalma Farm 2	Gipalma stream. Runoff from the Cattle Farm 2	10.28377	13.30950
GF-3	Gipalma Farm 3	Gipalma stream. Runoff from the Cattle Farm 3	10.27979	13.30846
GW-1	Gipalma Well 1	Well 1 located @ Gipalma Cattle Farms	10.27660	13.30632
GW-2	Gipalma Well 2	Well 2 located @ Gipalma Cattle Farms	10.27715	13.30819
GW-3	Gipalma Well 3	Well 3 located @ Gipalma Cattle Farms	10.28117	13.30678

Table 2. Standards Concentrations Sets by Regulatory Bodies for Various Applications

	Drinking			Fishing			Irrigation					Livestock			
	WHO (2011)	NESREA (2011)	NSDWQ (2007)	WHO (2006)	NESREA (2011)	FEPA (2003)	WHO (2008)	NESREA (2011)	FME/FEPA (2003)	USEPA (2009)	FAO (2011)	BIS (1991)	WHO (1993)	NAS (1974)	CCME (1987)
Temperature (ºC)	Ambient	20-30	Ambient			20-35	26	26	<40			26	26		
Total Hardness (mg/l)	100-500	100-500		200		200	500		200			200	500		
TDS (mg/l)		<1000				500	500-1000		1000			1000	3000	3000	3000
Conductivity (uS/cm)	200-1000		1000	300-1500		20-1500			1000			1000	1600		
pH	6-8.5	7-8.5	6.5-8.5	6.5-7.5	6.5-8.5	6.5-8.5	7.5	6.5-8.5	6-9			8.5	7.5		
COD (mg/l)	10-30	30			30				80			10			
BOD (mg/l)		3		6					30			4			
DO (mg/l)	5		5		6				7.5			4			
Phosphates (mg/l)		3.5				0.01-3.0		3.5	5			0.1	0.1	0.7	
Carbonates (mg/l)			100								0-100	50	500		
Bicarbonate (mg/l)	150-350										600	85	85	1000	
Iron (mg/l)			0.3	<0.15						5	5	2	0.3	0.05	
Calcium (mg/l)	75-100	75-200	200		180			180	150			100	700	100	1000
Potassium (mg/l)	20				50			50				12			
Sodium (mg/l)	200			200					200			300	300	50	1000
Magnesium (mg/l)	30-150	30-150		150				40	50			500	500		<250
Sulphates (mg/l)			100		100			500	500			250	500	50	<500
Nitrates (mg/l)	50	45-50	50	15					20			100	100	100	100-440
Chlorides (mg/l)	250		250	250					250			250	2000		

Water Quality Assessments.

The relationships described in Table 3 are used for the calculations and interpretation of the water quality for irrigation purposes as described in Yohanna *et al.*, (2022).

Table 3: Numerical Indices and Description for the Estimation of Irrigation Water Quality

Index	Formula	Standard Value	Water Quality Status
Sodium Percentage (Na%)	$Na\% = \frac{Na^{+} + K^{+}}{Na^{+} + K^{+} + Ca^{2+} + Mg^{2+}} * 100$	Na% < 20 Na% = 20–40 Na% = 40–60 Na% = 60–80 Na% > 80	Excellent/Safe Good/Safe Permissible/Safe Doubtful/unsafe Unsuitable/unsafe
Magnesium Hazard (MH) %	$MH = \frac{Mg^{2+}}{Ca^{2+} + Mg^{2+}} * 100$	MH < 50% MH > 50%	Suitable Unsuitable
Potential Salinity (PS) (meq L/1)	$PS = Cl^{-} + \frac{1}{2}SO_4^{2-}$	PS < 3.0 PS = 3.0–5.0 PS > 5.	Excellent Good Injurious /Unsuitable
Total Hardness (TH) (meq L/1)	$TH = Ca^{2+} + Mg^{2+}$	0–60 61–120 121–180 >181	Soft Moderate Hard Very Hard
Kelly Ration (KI)	$KR = \frac{Na^{+}}{Ca^{2+} + Mg^{2+}}$	KI < 1 KI > 1	Suitable Unsuitable
Sodium Adsorption Ratio (SAR)	$SAR = \frac{Na^{+}}{\sqrt{\frac{Ca^{2+} + Mg^{2+}}{2}}}$	SAR < 10 SAR = 10–18 SAR = 19–26	Excellent Good Doubtful/Fair Poor
Permeability index (PI) %	$PI = \frac{(Na^{+} + \sqrt{HCO_3^{-}})}{Na^{+} + Ca^{2+} + Mg^{2+}} * 100$	PI > 75% PI = 25–75% PI < 25%	Suitable Moderate Unsuitable
Residual Sodium Carbonate (RSC) (meq L/1)	$RSC = (HCO_3^{-} + CO_3^{2-}) - (Ca^{2+} + Mg^{2+})$	RSC < 1.25 RSC = 1.25–2.50 RSC > 2.50	Good Medium Unsuitable

Further studies were conducted using the CCME Water Quality (WQI) index to assess the suitability of the water for aquatic life, irrigation, livestock, and human drinking purposes. The models assigned for each parameter have specific values or sets of objectives or guidelines that should not be exceeded. The expressions are based on three basic factors (F_1, F_2, and F_3) that are used to derive the single dimensionless number that describes the overall water quality. The F_1 (scope) represents the extent of water quality guideline non-compliance over time, F_2 (frequency) represents the percentage of individual tests that do not meet objectives and the F_3 (amplitude) describes the amount by which failed tests do not meet their objectives. As described in Davies, (2006), the mentioned three factors as shown in equation 1 are computed to give five classes of scores clearly described in Table 4 (CCME. 2005a, CCME. 2005b).

$$CCME - WQI = 100 - \left(\sqrt{\frac{F1^2 + F2^2 + F3^2}{1.732}}\right) \qquad (1)$$

Table 4: The Canadian Water Quality Index (CWQI) Ratings, and Descriptions.

Score ranges	Quality	Description
95–100	Excellent	Water quality at pristine levels suggests the absence of threat or any impairment.
80–94	Good	The water quality suffers only a minor degree of threat or impairment and conditions rarely depart from natural or desirable levels.
65–79	Fair	The water quality is occasionally threatened or impaired and the conditions sometimes depart from natural or desirable levels.
45–64	Marginal	The water quality is frequently threatened or impaired and the conditions often depart from the natural or desirable level.
0–44	Poor	The water quality is almost/always threatened and the conditions usually depart from the natural or desirable levels.

The data were evaluated based on a statistical description using a statistical Package for Social Sciences (SPSS) software (Version 20). The results are expressed as Mean ± SD of three individual experiments. The results are considered significant at $p < 0.05$.

RESULTS AND DISCUSSION

For this study, twenty parameters were considered and presented based on their interaction concerning water qualities for human consumption, fisheries, irrigation, and livestock consumption respectively.

General parameters

The results of the physicochemical parameters for the nine sampling sites are presented in Fig. 3. The potential hydrogen (pH) components in the study were observed to be moving toward alkalinity in the streams receiving effluents discharged from the cattle farms (Fig 3a). The pH readings varied from 6.95-8.90 in Jere (JF-1, JF-2, and JF-3) streams, and 6.31-8.35 in Gipalma (GF-1, GF-2, and GF-3) streams. Values ranging from 7.0-7.80 were recorded in samples from the wells (GW-1, GW-2, and GW-3). The observed values fall within the permissible range of 6.5–8.5 required for most applications (WHO 1993; 2006; 2008; 2011; NESREA, 2011), however, care should be taken when used for aquaculture as fish are reported to have an average blood pH of 7.4 and more sensitive to varying pH (Bhatnagar and Devi, 2013). Abba *et al*., (2016), Alexander, (2008), and Sukamari *et al.,* (2020), reported varied pH values ranging from 6.56 – 8.15 from underground water samples collected from selected wards in Mubi, Nigeria. The pH values observed in this work further suggest that the unrestricted effluent discharged from the cattle breeding farms will favor in the long run the accumulation and formation of insoluble salts in the water and sediments (Ayers and Westcot, 1985). Increasing the pH level by one unit, from 6.5 to 7.5 can increase the concentration of unionized salts such as ammonia by a factor of ten, influencing the solubility and equilibria reactions with other variables, thus altering the water pH (Bhatnagar and Devi, 2013). As shown in the figure, the temperature measured at the points of sample collections was also found to be within the acceptable limits of 20-30^{o}C for drinking purposes (Szulc *et al*., 2020; NSDWQ, 2007; NESREA, 2011), 20-35^{o}C for fishing (FEPA/FMEnv, 2003), <40^{o}C for irrigation and livestock (WHO, 1993; 2008; FEPA/FMEnv, 2003) respectively. Other studies conducted in some locations in Mubi reported temperatures in the ranges of 25 – 28.9^{o}C (Abba *et al*., 2016), 28.28°C, 27.40°C and 28.00°C (Sukamari *et al.,* 2020), and 24.5-25^{o}C, (Alexander *et al.,* 2015). Studies show that a rise in water body temperature increases the eating habits and dissolved oxygen consumption of fish (Bhatnagar and Devi, 2013). Therefore, the unrestricted effluent discharges into the streams are a threat to waterways and thus, not advisable for use for any healthy aquaculture activities.

As shown in Fig 3b, the mean values for TH in the water samples range from 142-291 mg/l in stream samples collected at JF-1, JF-2, JF-3, GF-1, GF-2, and GF-3. The values increase significantly (P>0.05) in samples collected in Wells at Gipalma (GW-1, GW-2, and GW-3) compared to samples from the streams (401.88-403.81mg/l). Except for the limits of 200mg/l set by the WHO, (2006) and FEPA/FME, (2003) for fisheries. These values were observed to all fall within the acceptable ranges of 100-500mg/l set by NESREA, (2011) and WHO, (1993; 2008), for irrigation, livestock, and human consumption respectively. The TH values in this study area are significantly higher than the values reported by Alexander, (2008) and Alexander *et al.,* (2015) in water samples for some locations in Mubi. Traditionally, water is classified as soft (0–75 mg/L), moderately hard (75–150 mg/L), hard (150–300 mg/L), or very hard (> 300 mg/L) (Johnson, 1985). The TH if not checked can serve as an excipient for immobilized ions, reported to have the properties that can antagonize ions depending on the pH of the water bodies (Johnson, 1985). Similarly, TDS was observed to fall in the range of 415-587 mg/l in the stream samples from JF-2, JF-3, GF-1, GF-2, GF-3, and 611 mg/l in samples from JF-1. These values were observed to be significantly higher than the 4.66 – 60.04mg/l reported by Abba et al. (2016), the 17.10-21.640 mg/L reported by Alexander *et al*., (2015), and the 371.15 mg/L and 448.48 mg/L reported by Sukamari *et al.*, (2020) respectively in water samples from selected wards in Mubi. However, in this study, the TDS values are within the acceptable limits of <1000 for human consumption (NESREA, 2011), 500-1000 for irrigation (WHO, 2008; FEPA/FMEnv, 2003), and 3000 set by NSDWQ (2007), WHO, (1993) and CCME, (1987) for livestock consumption respectively. The EC which typically reflects the effects of water-soluble ions was observed to vary from 535-705 µS/cm in the streams (JF-1, JF-2, JF-3, GF-1, GF-2, and GF-3) and significantly higher mean values of 899-902 µS/cm in the well samples from Gipalma (GW-1, GW-2, and GW-3). The values were found to fall within the acceptable limits of 200-1000 µS/cm set for human consumption (WHO, 2011; NSDWQ, 2007), 300-1500 µS/cm set for fisheries (WHO, 1993; FEPA/FMEnv, 2003), 1000 and 1600 µS/cm set for irrigation and livestock consumptions respectively (WHO, 1993; FEPA/FMEnv, 2003). The results were further observed to be significantly higher than the 38.03µS/cm to 128µS/cm reported in some locations in Mubi (Abba *et al*., 2016). Though the EC values observed in this study fall within acceptable limits, the waters from all indications are under threat due to the unrestricted influent discharged. A higher content of dissolved ions in irrigation water can impair soil fertility and hence crop productivity. An EC value <700 µS/cm is considered ideal for irrigation purposes but will introduce severe damage to crops if allowed to exceed 3000 µS/cm (Ayers and Westcot, 1985).

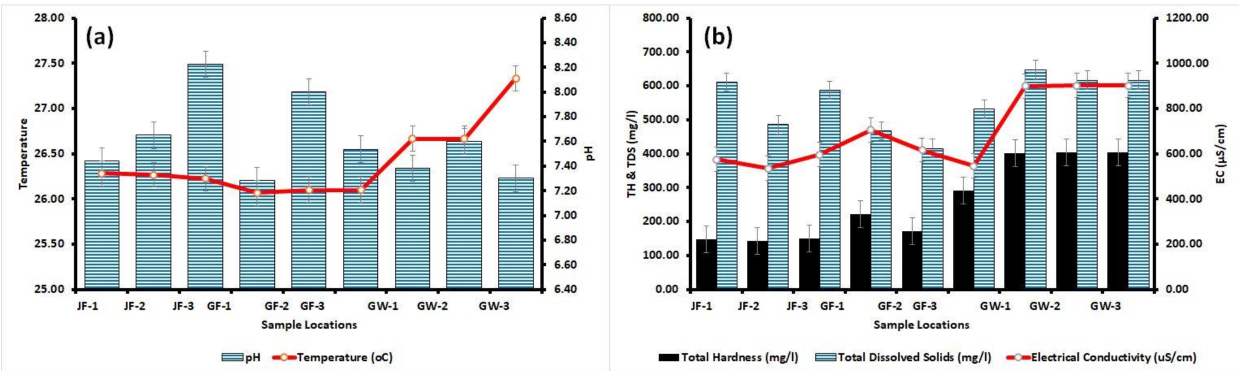

Figure 3: Showing the (a) pH and (b) Temperature levels in the Water Samples Collected from the Study Locations

Anionic Parameters:
Figure 4 shows the concentrations of the anions detected in the water samples. From Fig 4a, the predominant anionic species detected is HCO_3^- ions with mean concentration values ranging 187-285mg/l across the sampling points. The highest mean concentrations are detected in wells (GW-1, GW-2, and GW-3) and streams (GF-1, GF-2, and GF-3) samples from Gipalma. All the values fall within the acceptable levels for human drinking water (150-350 mg/l), irrigation (600 mg/l), and livestock (1000 mg/l) (WHO, 2011; FAO, 2011; NAS,1974). The second most abundant species is carbonate, found in the range of 24.98-37.43 mg/l in the stream samples (JF-1, JF-2, JF-3 and GF-1, GF-2 and GF-3) and from 39.58-44.88mg/l in the well samples (GW-1, GW-2, and GW-3). The values are less than 100mg/l set for human consumption and irrigation (NSDWQ, 2007; FAO, 2011), and 500mg/l set for livestock consumption (WHO, 2011). Mean SO_4^{2-} values in the range of 31.11-45.92mg/l were detected across the sampling points lower than the 100mg/l acceptable limits for human drinking (NSDWQ, 2007), and aquaculture (NESREA, 2011), 500mg/l for irrigation and livestock consumption (WHO, 2011; NESREA, 2011) respectively. The highest NO_3 value of 14.08mg/l were found in a sample from GW-3 and the least at JF-1 (8mg/l) as shown in Fig.4b. These values were found to be below the acceptable limits of 45-50 mg/l set by NESREA, (2011) for human consumption, 15mg/l for fishing (WHO, 2006), 20mg/l for irrigation (FEPA/FMEnv, 2003), and 100 mg/l set by WHO, (1993) for livestock drinking water. The NO_3^- value of 14.08mg/l going by the 15mg/l set by WHO, (1993), suggests that the water samples GW-3 are nearly at risk of NO_3 pollution. Although, not directly harmful to fish, its availability in the water samples will favor the eutrophication of the water body (Dinesh *et al.*, 2017). Similar trends were also observed for nitrate levels found in the ranges of 33.56mg/l to 46.48mg/l by Abba *et al*., (2016) and 11.13 mg/L and 12.95 by Sukamari *et al*., (2020) in selected water samples from hand dug wells in Mubi. The highest Cl^- concentrations were found in GW-1 samples (15.95mg/l) and the lowest concentrations of 8.02 mg/l in samples from JF-1 as shown in Fig 4b. The values were found to be below the acceptable limits of 250 mg/l set for human drinking water, fishing, irrigation, and livestock consumption (WHO, 2006; NSDWQ, 2007; FEPA/FMEnv, 2003; BIS, 1991) and significantly lower than the 83 mg/l-111mg/l reported by Abba *et al.*, (2016), the 10.00 ± 0.04 to 25.00±0.05 mg/l reported by Alexander (2008) and 12-16 mg/L reported by Alexander *et al*., (2015) in water samples from selected Mubi wards. Sukamari *et al*., (2020) also reported mean chloride concentrations of 7.62 mg/L, 12.04 mg/L, and 6.80 mg/L from boreholes, open wells, and River Mudzira respectively in Mubi. The highest PO_4^{3-} levels of 0.90mg/l were found in stream samples from GF-3 and the least in samples from JF-2 (0.45mg/l). As described in Fig 4b, these values fall below the acceptable levels for human consumption (3.5mg/l), fishing (0.01-3mg/l), and irrigation (3.5 mg/l) (FEPA/FMEnv, 2003; NESREA, 2011) but further observed to be higher than the acceptable limits of 0.1-0.7mg/l for livestock consumption in some locations (NAS, 1974; BIS, 1991). Similar low values for phosphate (0.18 mg/L, 0.82 mg/L) were also reported for samples from Barama, Gipalma by Sukamari *et al*., (2020).

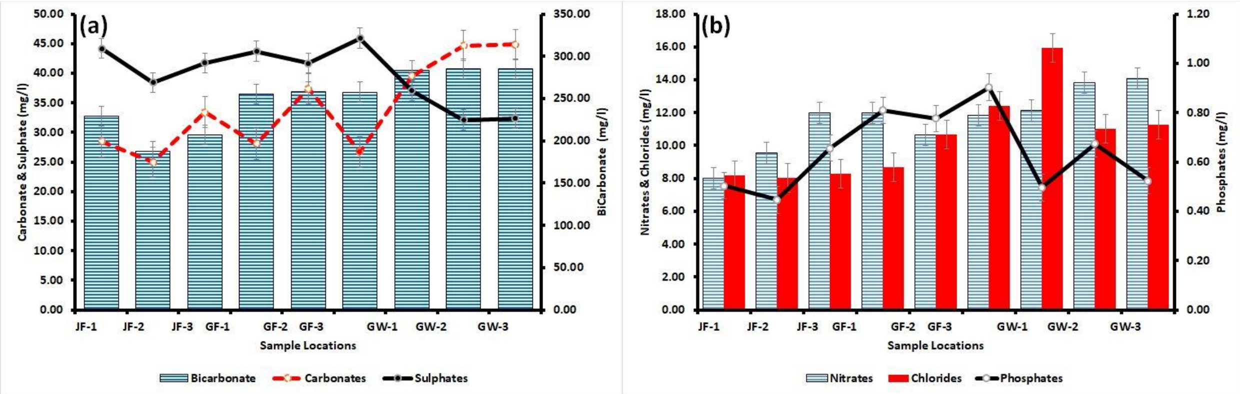

Figure 4: Showing the Concentrations of (a) Bicarbonate, Carbonate, and Sulphate, and (b) Nitrates, Chloride, and Phosphates in the Water Samples Collected from the Study Locations

Cationic Parameters:

Sodium as determined in the study locations was detected to be the most dominating cationic species; as shown in Fig 5a varied from 209.86-346.06 mg/l in the stream samples and from 142.27-150.90mg/l in samples collected from the wells. The values established in the stream samples were observed to be above the recommended 200 mg/l permissible limits prescribed by the WHO, (2011) for human consumption, fisheries (WHO, 2006), and irrigations (FEPA/FMEnv, 2003) but less than the amount recommended for livestock consumption which was put at a maximum of 1000 mg/l by the CCME, (1987). Sodium ion-dominated water increases the level of exchangeable Na^+ in irrigated soils, precipitating Ca^{2+} and Mg^{2+}, deteriorating soil structure, and increasing soil alkalinity. Such an environment impaired crop-nutrient uptake and provoked specific ion toxicity (Singh *et al*., 2018). Thus, the stream water samples from Gipalma (GF-1, GF-2, and GF-3) and Jere (JF-1, JF-2, and JF-3) under continued use for irrigation will degrade the soil structure and impaired crop productivity (Singh *et al*., 2018). The second most abundant cationic species is Ca^{2+}, showing mean concentrations that varied from 77.91-153.89mg/l across the sample sites. The values as shown in Fig 5a fall within the range of 75-200 acceptable for human drinking water quality, and 180mg/l for fishing and irrigation (NESREA, 2011). Similarly less than the values set by WHO, (1993) and CCME, (1987) for livestock consumption. But seemingly higher than the 20.17mg/l to 25.58mg/l reported by Abba *et al*., (2016) and the 9.10±0.05 to 61.50±0.14 reported by Alexander (2008) in water samples from selected Mubi wards.

The lowest mean values of Mg were detected in samples from GW-3 (31.51mg/l) with the highest mean values of 91.65mg/l in samples from GF-3 (Fig 5a). These values were below/within the acceptable limits of 30-150mg/l sets for human consumption (NESREA, 2011), fisheries (WHO, 2006), irrigation (NESREA, 2011), and the 500mg/l set by WHO, (1993) and <250mg/l set by CCME, (1987) for livestock consumptions respectively. However, the concentrations as observed in samples from GF-1, JF-3 and GF-2, GF-3 (51.21, 52.81, 63.27, and 91.65mg/l) when compared with the acceptable standards described in Table 2 suggest the water is not suitable for irrigation having values greater than the recommended limits of 40 mg/l set by NESREA, (2011) and 50mg/l by FEPA/FMEnv, (2003). High contents of Mg^{2+} in water increase the alkaline nature of the soil as well as influence negative effects on the crops (Xu *et al*., 2019). The values observed in this study were higher than the 3.45mg/l to 6.52mg/l reported by Abba and Co (2016) and the 2.92±0.11 to 40.62±0.12 reported by Alexander (2008) in water samples from selected wards in Mubi. The highest mean values for K^+ were found in well samples at GW-3 (16.89 mg/l) and the least in stream at JF-2 (5.72 mg/l) (Fig 5b). Compared to the acceptable limits of 20mg/l set by WHO, (2011) for human consumption, the 50mg/l set by NESREA, (2011) for fisheries and irrigation, and the 12 mg/l set for livestock consumption (BIS, 1991), the samples from these locations are within the acceptable levels. However, water samples from GF-2, GF-3, GW-1, GW-2, and GW-3 having mean values >12mg/l suggest the water is slightly impaired for livestock consumption (BIS, 1991). Exposure to Fe-contaminated water readily induces a reaction with available nitrate, a type of reaction that was implicated in reported Blue baby syndrome (Banerjee *et al.*, 2022). Similarly, Fe despite being a natural capping agent also has the properties to increase sediment phosphorus binding capacity, creating a shift from an algal to a macrophyte-dominated lake (Bakker *et al.*, 2016). Iron interacts and readily oxidizes into insoluble small clumps of iron salts that can settle on fish gills, causing irritation and stress (Buttner *et al.*, 1993). Further reported, when reacted with organic acids in water or sediments can disrupt the crop-nutrient absorption potential (Asano *et al.*, 2007). In this study, as shown in Fig 5b, the mean values for Fe in the range of 3.19-9.34mg/l were detected in the samples taken from the streams. The results appeared to be lower compared to the amounts ranging from 12.39-12.79mg/l detected in the samples taken from the wells. The values in some of the sampling points are found to be above the acceptable limits for human and livestock consumption (0.3mg/l), fishing (0.15mg/l), and irrigation (5mg/l), (WHO, 2006; NSDWQ, 2007; USEPA, 2009). This suggests that the water samples having Fe values higher than the recommended limits are considered unsuitable for the mentioned applications.

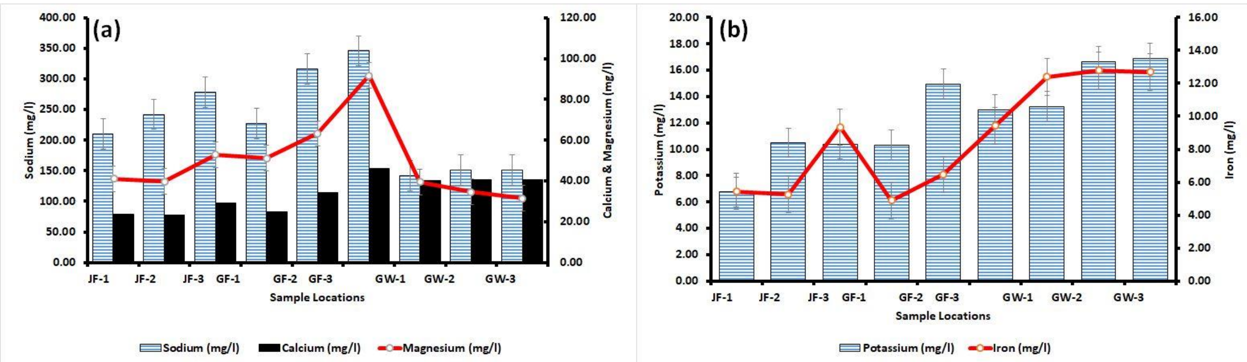

Figure 5: Showing the Concentrations of (a) Sodium, Calcium, and Magnesium, and (b) Potassium, and Iron in the Water Samples Collected from the Study Locations

Biological and Microbiological Parameters:

The aquatic environment depends on the level of DO, COD, and BOD which in addition to other parameters influence the overall health and survival rate of fish. Dissolved oxygen levels>4-5 mg/l are considered ideal levels for a wide range of fish species' survival and could exceed 7 to 8 mg/l in surface water depending on the temperature, salinity, etc. of the water body (Gupta et al., 2017). The possibilities of chronic stress, and loss of appetite, will suffice in fish exposed to water containing DO from 1-3 mg/l. Values <1 mg/l could be lethal to fish and induce gas bubble disease at >14 mg/l (Gupta et al., 2017). In this study, highly depleted DO levels were observed in stream samples from GF-1 (2.98 mg/l) followed by 3.21 mg/l in stream samples from Jere, JF-1 as shown in Fig 6a. The values were found to be below the acceptable level for human consumption (5mg/l), fishing (6mg/l), and irrigation (7.5mg/l) (FEPA/FMEnv, 2003; NESREA, 2011). Similarly lower than the values detected in the open wells samples from Barama/Gipalma (7.89 mg/l) and Lokuwa (7.85 mg/l) respectively (Sukamari *et al.*, 2020). The author also reported mean values of 6.90 mg/L and 6.88 mg/L for samples from Rivers Mudzira and Yedzaram respectively. Thus, it could be concluded that the water from the study areas is unsuitable for any fish farming activities, an indication of the decomposition of organic matter and the presence of microbial communities in the water samples.

Microorganism in water at certain temperatures readily consume oxygen and their rate of respiration rate determined as BOD serves as an indicator in water quality assessment. An increase in the BOD levels suggested less amount of DO available for aquatic organism survival (Gupta et al., 2017). The optimum BOD condition suitable for fish growth and health is between 3.0-6.0 mg/l; values range from 6.0-12.0 mg/l is sublethal and >12.0 mg/l can usually lead to chronic stress and suffocation (Gupta et al., 2017). Thus the BOD levels in this study as shown in the figure suggest highly polluted water bodies (WHO, 2011). The biological decomposition of manure runoff into the waterways from the Cattle farms shots up the BOD levels above the desirable limits of 3 mg/l, depleting also in the process the available dissolved oxygen in the water below the acceptable limits of 5mg/l, thus providing enough substrate for bacterial growth. The highest BOD levels were recorded in stream samples collected from Gipalma (GF-1) with a mean value of 30.18 ± 5.78 mg/l and the least in the Well sample from GF-3 with a mean value of 9.75 ± 1.51 mg/l in Well sample from GF-3. The values were observed to be beyond the drinking water standards of 3 mg/l set by NESREA, (2011), 6mg/l for fishing (WHO, 2006), and within the limits acceptable for irrigation (FEPA/FMEnv, 2003) across the sampling points. The BOD levels determined in the study locations though above the recommended limits for livestock are reported to be unlikely to exhibit any adverse effects, except otherwise overwhelmed by bacteria (Jesse *et al.,* 2022). Furthermore, oxygen readily gets consumed during the decomposition of organic matter in water containing high levels of BOD, thus creating an anaerobic condition in the water body. In the process oxide ions in the water body utilized the O_2 to lower oxidation-reduction potential, which was also reported can impair crop-nutrient absorption potentials (Asano *et al*., 2007). Similarly described in Fig 6a, the COD which is a measure of oxygen equivalent to the organic matter content of the water was observed to be greater than the acceptable limits. The excess entry of effluent discharged from cattle farms induces a high level of organic load thus causing higher levels of BOD and COD. Studies show that the anaerobic digestion of agricultural wastes in water bodies increases the level of COD, (Cazaudehore *et al.*, 2009). In the present study, the value of COD was observed to be in the range of 44.04 ± 19.70-177.18 ± 7.72 mg/l beyond the drinking water standards of 30 mg/l across the sampling points. The COD level detected in the well samples (GW-1, GW-2, and GW-3) were observed to be much lower (44.04-62.68 mg/l) compared to the amounts ranges from 116.65-177.18 mg/l detected in the streams. A COD of 10-30 was set for drinking water quality and agriculture (NESREA, 2011).

The biggest contaminant detected in the study locations is TC, whose concentrations were reported to influence the concomitant rise in the BOD and drop in DO levels accordingly. Surface water as widely reported is inherently susceptible to microbial contamination and predisposed to surface waters receiving unrestricted effluent runoff. The level of TC in this study as shown in Fig 6b was found to be higher in the streams samples compared to the samples taken from the wells. The lowest concentrations were detected in samples from JF-1 (1.01×10^6 cfu/100mL) and the highest in samples from GF-2 (1.62×10^6 cfu/100mL). Making the water unsuitable for human consumption, having failed to meet the standards requirement of 0-10 cfu/100mL (NESREA, 2011) and ≤20 cfu/100mL set by the WHO, (2011) for bathing and human contact. Total Coliform in the range of 138 cfu/100 mL to 185 cfu/100 mL was also reported in water samples from hand-dug wells (Abba et al., 2016), and mesophilic counts of >10^3 cfu/ml in hawked water samples (Sajo, 2001) in some locations in Mubi. The study by Tula *et al.*, (2018) reported a mean HPC in the range of $3.3 \times 10^2 – 4.7 \times 10^4$ cfu/mL for sachet water and $1.1 – 6.0 \times 10^4$ cfu/mL for borehole water obtained from selected communities in Mubi. Total coliform concentrations above the acceptable water quality standards present numerous risks for human consumption and significantly so when the irrigated crops cultivated using the microbe-contaminated water are consumed raw, a situation that could lead to parasitosis or water-related epidemics. Such contaminated water bodies provide a rich nutrient-cultured environment for bacterial growth and proliferation and hence the spread of pathogenic fecal coliforms (Sanders *et al.*, 2013). The results of this study further show the water samples fail to meet the requirement for aquaculture (10000 cfu/100mL), as set by EEC, (1976). A study by Kalika-Singh *et al.,* (2021) reported the presence of bacteria in freshwater tilapia fish, indicating the coliform levels exceeding the acceptable standards. Further suggested that bacteria-infected fish posed some risk to public health on consumption, especially if the fish were cultivated in water containing >10^4 Escherichia coli (Strauss, 1985). Aquatic sediments and biofilms serve as incubation hubs for coliforms and are readily made active with the propensity to proliferate and accumulate in fish meats under appropriate temperatures (Jackson et al., 1998). Strauss, (1985) further reported the possibilities of pathogenic microorganisms accumulating in the digestive tract and intraperitoneal fluid of the fish cultivated in bacteria-infected waters.

The results of this study also show the level of the TC detected in the samples exceeded the desirable limits for livestock drinking water quality set at 5000 cfu/100mL (USEPA, 1999; Carson, 2000). Meeting this prescribed standard is however seen as impractical especially relating to surface water receiving unrestricted effluent. Carson, (2000), subtly puts it that so long as animals are allowed to range freely, proposed limits are unenforceable. Studies reported coliform bacteria as the cause of scours in young calves, chronic or intermittent diarrhoea, and loss of appetite in older cattle (Rodenburg, 1988). Other studies show that infertility and reduced milk production could suffice if livestock are allowed to drink water contaminated with Campylobacter, Listeria, Salmonella, and specific serotypes of E. coli (Tyrrel and Quinton, 2003). Bacteria clogs in the digestive tract of animals can facilitate the conversion of nitrate to nitrite inducing symptoms such as dizziness, difficulties in breathing, blue discoloration of mucous membranes, vomiting, and premature birth (Lardy *et al*., 1998).

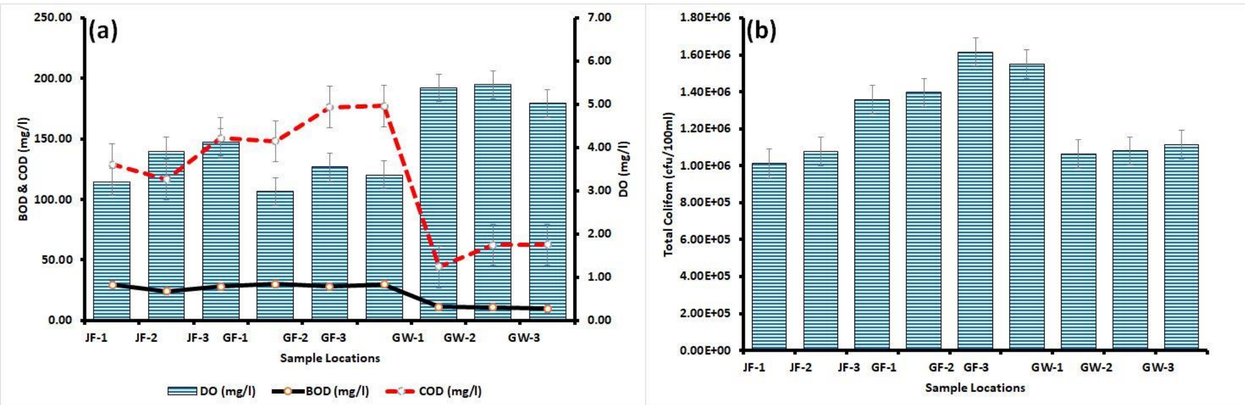

Figure 6: Showing the Concentrations of (a) DO, BOD, and COD, and (b) the Total coliform levels in the Water Samples Collected from the Study Locations

Irrigation-specific Water Quality Assessment

In addition to the booming livestock farming enterprises, Irrigation farming is the second most important activity in the study location. The intricate complexities of irrigation water quality and the much-desired role in ensuring healthy food sufficiency have been a hallmark of discussion in Nigeria; steaming largely from dependence on poorly characterized and virtually unmonitored sources of water (Peter *et al*., 2022). Thus, drawing an understanding of the quality of water used for irrigation in the study location underscores the importance of this study. The results from this study show that the irrigation indices such as sodium percentage (Na%), sodium absorption ratio (SAR), Magnesium Hazard (MH), residual sodium carbonate (RCS), Kelley ratio (KR), potential salinity (P.S), permeability index (PI), chloro-alkaline index I (CAI-1), and chloro-alkaline index II (CAI-2) taken from this study shows emerging trends in salinity. As observed in Fig 7a, the SAR in the ranges of 21-24 is an indication that the stream water samples taken from JF-1, JF-2, JF-3, GF-1, GF-2, and GF-3 are extremely polluted to support healthy irrigation activities, predicting the occurrence of Na hazard in the study area (Schoeller, 1965). A SAR falling in the ranges of 19-26, implies a buildup of sodium ions relative to the proportion of Ca^{2+} and Mg^{2+}, thus limiting the ability of the plants/crops to extract water from the soil due to impaired soil permeability (Gad *et al.,* 2023). However, the SAR values of 11-12 observed in the well samples show the samples from GW-1, GW-2, and GW-3 are of good quality to support irrigation activities. Relative to the percentage of Na as described in Fig 7a, there exists the possibility of the excess Na^+ displacing other ions such as chloride and sulphate ions in the soil (Gad *et al.,* 2023). Thus, the stream samples from JF-1, JF-2, JF-3, GF-1, GF-2 and GF-3 having Na% ≥60 is considered unsuitable for any healthy irrigation activities, as irrigation using water with such Na% values can result in soil degradation. Samples from GW-1, GW-2, and GW-3 could be applied for irrigation purposes having Na% values in the ranges of 47-50%. The impact of excess Na in water can be interpreted also using the CAI-1, and CAI-2 as proposed by Schoeller, (1965) and described in Fig 7b. Chloro-alkaline indices (CAI-I and CAI-II) with negative values indicate that Mg^{2+} and Ca^{2+} are preferentially exchanged for Na^+, and positive where Na^+ are preferentially exchanged for the other ions (Manu *et al.*, 2023). The trend as observed in this study gave negative values for CAI-I and CAI-II respectively across all the sampling points, thus suggest a correlative impact of sodium ion in the irrigation water, which according to the results in Fig 7a is the dominant cation in the water samples. Implies a Na^+-Ca^{2+} exchange, in which Na^+ exchanges with Ca^{2+} in solution, reducing the concentrations of Ca^{2+} in the water. Further implies a reverse ion exchange process, in which Ca^{2+} and Mg^{2+} in the water are being replaced by available Na^+ from surrounding groundwater or aquifer materials (Kelly, 1940).

Susaiappan *et al.* (2021) used the amounts of Na^+ ions measured against Ca^{2+} and Mg^{2+} ions to define an index to predict the impact of Na^+ involvement in irrigation water quality. As shown in Fig 7c, Kelly's index in the present study varied from 0.82 to 0.90 in the well samples, placing the water samples as suitable for irrigation. However, the samples taken from the streams (JF-1, JF-2, JF-3, GF-1, GF-2, and GF-3) show KI values >1. A KR value with an index >1 implies the water contains some level of Na ions, hence unsuitable for irrigation purposes compared to samples from GW-1, GW-2, and GW-3 with KR values of <1. As earlier said, Na ion-dominated water increases the level of exchangeable Na ions in irrigated soils, promoting soil structure deterioration, impairing crop-nutrient uptake, and provoking specific ion toxicity (Gad *et al.,* 2023). The presence of bicarbonate and carbonate, similar to the influence induced by high levels of SAR and Na% can lead to the precipitations of Ca^{2+} and Mg^{2+} in water, the dissolution of organic species in the soil, and facilitate the destruction of the soil's physical structures (Gad *et al.,* 2023). The RSC levels as presented in Fig 7c range from 89-163 mq/l with the highest value detected in samples from GW-3, which suggest that the water samples in the entire study locations are threatened by high levels of carbonate and bicarbonates compared to other cations, hence negate the use of the water for healthy irrigation activities. At higher RSC levels, Ca^{2+} and Mg^{2+} are readily precipitated from the water, increasing the concentrations of Na^+ in the water and soil, thus impairing plant growth and productivity on the continual use of such water bodies for irrigation (Gaagai *et al.*, 2023). Water is classified as unsuitable for irrigation at RSC >2.50, thus the RSC determined in this study having values >2.50 suggests the water bodies are threatened by the continual use of the Na^+-dominated water for irrigation (Gaagai *et al.*, 2023).

Balancing Mg^{2+} concentrations in water directly influences the productivity of agricultural soil. This can be monitored using an index referred to as the magnesium ratio that measures the level of Magnesium hazard (MAH) in irrigation water (Doneen, 1964). As reported in Fig 7d, the lowest magnesium hazard (MH) percentage was found in GW-2 samples (20%) and 37% being the highest was determined in GF-3 samples. Magnesium hazards <50% are considered suitable for irrigation, values >50 will create a structural defect in the soil properties and impaired plant growth with a concomitant increase in soil alkalinity (Doneen, 1964). Potential Salinity (PS) is another index that helps in evaluating the suitability of surface water for irrigation by combining the effects of salinity and sodium content in water, and its potential impact on soil and crops. Soil structure and fertility are impaired under high PSI values due to high salinity and sodium levels in the water. Salt with low solubility usually precipitates and accumulates in soils resulting in the formation of hard water layers, slow emergence of seedlings, and reduced crop yield (Manu *et al.*, 2023). As described in Yonnana *et al.*, (2015), the classifications of irrigation water can be rated as excellent to good (PS < 5), good to injurious (PS = 5–10), and injurious to unsatisfactory (PS > 10). Based on these classifications, the water samples from the study locations as shown in Fig7c having PS values in the range of 27-35 meq/l are injurious to unsatisfactory, thus unsuitable for irrigation purposes. Permeability index (PI), is also an important factor in assessing the risk of soil permeability, found in the ranges of 52-71% across the sampling points. As shown in Fig 7c, the water samples from the study locations could be considered moderately suitable for long-term irrigation purposes (Yonnana *et al.*, 2015). The PI provides information on the soil permeability level which was reported to be influenced by the continued use of irrigation water, used to further express the effects of Ca^{2+}, Mg^{2+}, Na^{+}, Cl^{-} and HCO_3^{-} as described in Yonnana *et al.*, (2015). However, continuous irrigation with water at this moderate level will in the long run increase the level of Ca^{2+}, Mg^{2+}, and CO_3^{2-} contents and hence will create a negative impact on the soil mobility and structural integrity (Yonnana *et al.*, 2015). A PI value >75% suggests the water is highly suitable for irrigation, permissible when the PI values falls in the range of 25-75% and unsuitable at PI<25% (Gad *et al.*, 2023).

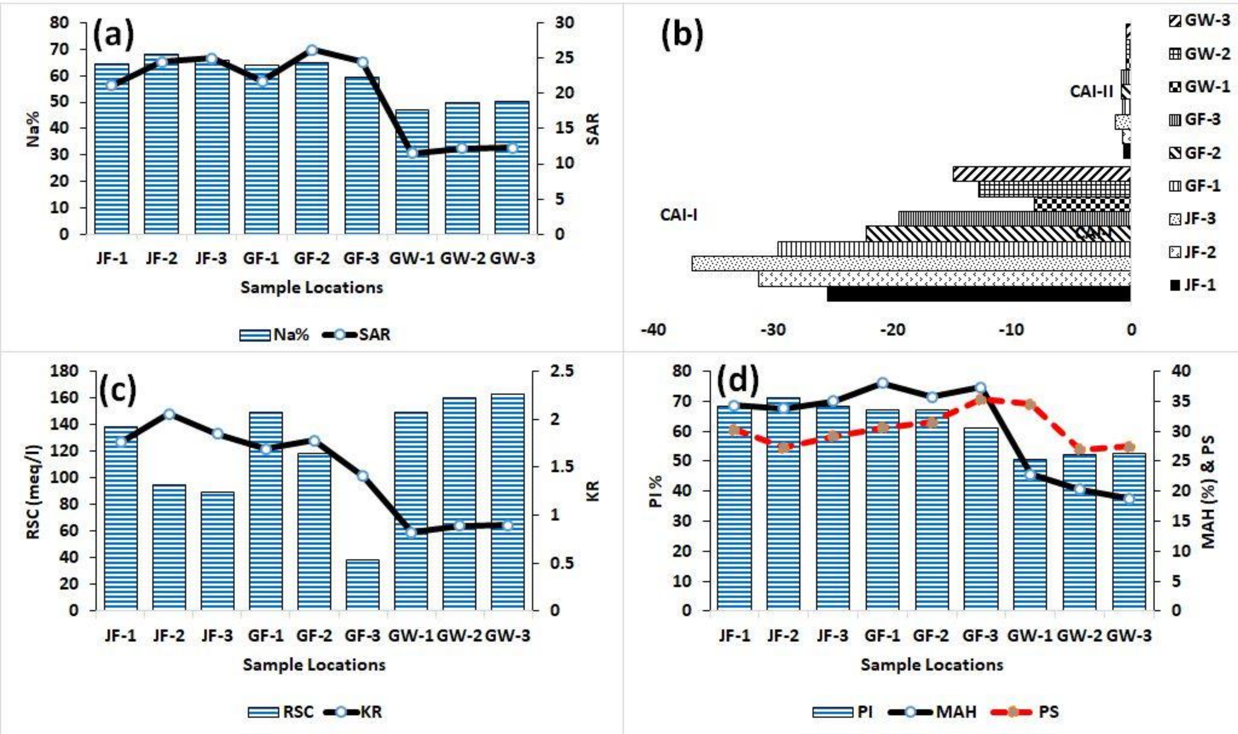

Figure 7: Showing the irrigation Water Quality Index (a) Na% and SAR, (b) CAI-I and CAI-II, (c) RSC and KR, (d) PI, MAH, and PS for the Water Samples Collected from the Study Locations

The CCME Water Quality Index (WQI)

Based on the results of the cation and anion chemistry it will suffice to say that the water samples determined in this study locations are predominantly Na^{+}-Ca^{2+}– Mg^{2+}–HCO_3^{-}– SO_4^{2-}. Therefore to get a comprehensive assessment of the quality of the water from the study locations for various applications, the integration of all the individual parameters discussed above is factored into a model referred to as the Water Quality Index (WQI) to reflect the overlapping effects of the various water quality parameters and their suitability for different applications or uses (Gad *et al.,* 2023; Panagopoulos *et al.*, 2022). The water quality scores based on this model and described in Fig.8 give a rating for human consumption in the range of 35-39, 42-44 for aquaculture, 42-50 for irrigation, and scores in the range of 41-46 for livestock consumptions respectively. The variation of the F1, F2, and F3 values indicates that the number of parameters failing the guidelines (F1) for each purpose of application differs. The results show the COD, BOD, Fe, Na, and TC levels across all the sampling points failed to meet the desired objectives for human drinking water quality (CCME. 2005a; CCME. 2005b; Bhatnagar and Devi, 2013; Abba *et al*., 2016; Alexander, 2008). This suggests that the water quality in the study locations is indeed threatened or impaired; the parameters indicated usually depart from natural or desirable levels. Similar parameters in addition to the DO levels in samples from JF-1, JF-2, JF-3, GF-1, GF-2, and GF-3, the TH and TD levels in samples from GW-1, GW-2, and GW-3, were also observed to threaten or impaired the water bodies to support any healthy fish farming activities. The WQI scores (42-44) for these locations suggest the water to be of poor quality. The irrigation WQI for samples from JF-1, JF-2, GW-1, GW-2, and GW-3, though frequently threatened are rated to be marginally impaired. The COD, BOD, and DO levels were observed to marginally influence the TC levels and hence the suitability of the water for any irrigation activities. Furthermore, the level of Fe, Na, and Mg ions in the samples were also observed to have failed the objectives, given scores that fall in the ranges of 42-50. The water samples from JF-3, GF-1, GF-2, GF-3, GW-2, and GW-3 fail to meet the water quality standards for livestock drinking water, having WQI scores of <44; specifically threatened by Fe, PO_4, K ions, and TC contents in the water bodies. The samples from JF-1, JF-2, and GW-1, having WQI scores slightly >44 are marginally impaired for livestock drinking water. The samples from this location often depart from natural or desirable levels for livestock consumption due to the levels of Fe, K ions, and TC contents in the water bodies. Some studies conducted in Gwakra, Ribadu, and Parya Lakes located at the Upper Benue Valley of Adamawa State using arithmetic weighted scores for the WQI show water from the lakes as unsuitable for human consumption. The study reported a TC count of 2,250 cfu to 2,720 cfu in the lakes and relates the microbial population in the water to the indiscriminate disposal of animal feces around the lakes (Yonnana *et al*., 2015). Similarly, the study conducted in Jimeta-Yola shows the quality of the pipe-bone water supplied by the State water board changes to poor quality before reaching the consumer ends. The analysis showed an increase in bacterial counts in the water samples at the consumer points (Bwatanglang *et al*., 2020). Poor to very poor water qualities were also reported in a related study by Sukamari *et al*., (2020) in the open wells from selected wards in Mubi.

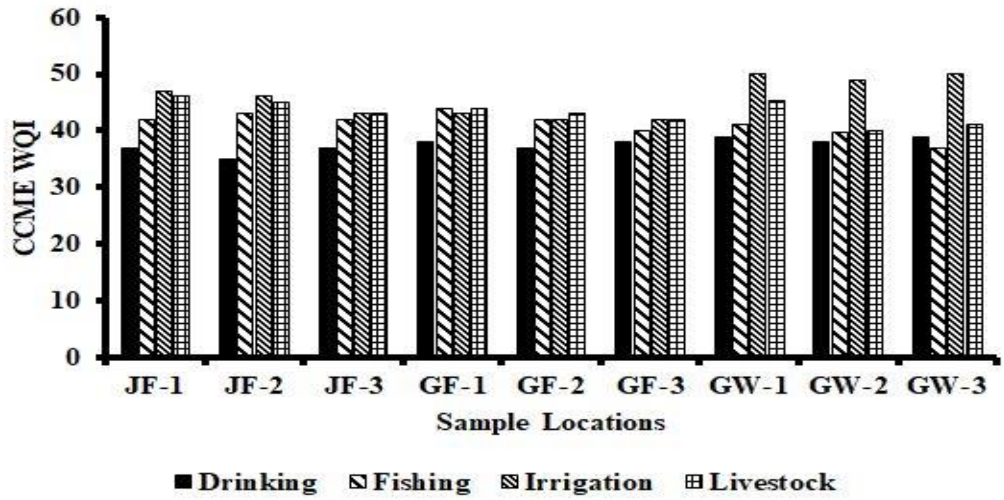

Figure 8: Showing the CCME Water Quality Index (a) Human Drinking Consumption (b) Fishing, (c) Irrigation, (d) Livestock consumption for the Water Samples Collected from the Study Locations

Conclusion

The results from this study established that the emerging cattle breeding operations in Mubi present a potential risk to public health. Signifying the pollution impacts from the unrestricted effluents discharged from the cattle breeding farms into the community's nearby water bodies. The greatest threat as observed from the study is the build-up of coliform bacteria in the water samples, suggesting fecal contamination from the cattle breeding operations. The WQI based on the CCME model shows the water samples failed to meet the objective/guidelines for human consumption, fisheries, irrigations, and livestock consumption. This suggests that the water quality in the study locations is indeed threatened or impaired; the water quality parameters usually and in most cases frequently depart from natural or desirable levels for various applications. The results further suggest a lack of effective pollution and waste control measures as regards manure and related waste management from the cattle breeding operations as the main problem. Thus advocating policy regulations to be initiated by the local environmental enforcement agency on livestock waste management through the establishment of Waste-to-wealth value chain programs. Therefore further study to investigate seasonal variations and their impact on the effluent discharges is recommended. The level of residual antibiotics and determination of bacteria isolates/species is also recommended.

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