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Status of livestock water quality and digestive upsets in Babati and Burunge areas, Northern Tanzania

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Abstract

This study investigated the quality of water used by ruminants and pseudo-ruminants in six communities living adjacent to two inland lakes in Manyara region, northern Tanzania. Water sampling included 20 samples from each village (n=120 for 6 villages) followed by laboratory analysis using ISO 5667 standard methods. 480 livestock were examined (n=80 for each village) for digestive upsets. Results for water quality were compared to those of WHO guidelines for livestock drinking water. Physical and chemical parameters for some areas were within acceptable limits except the levels of turbidity (10.88±11.97 NTU, 8.67±11.97 NTU), calcium (550.00±22.19 mg/L, 842.00±70.15 mg/L), chloride (1940±63.90 mg/L, 3380±135.65 mg/L), ammonium (5.94±0.42 mg/L, 6.79±0.58 mg/L), nitrate (113.62±10.64 mg/L, 71.16±12.92 mg/L, and hardness (1372.00±106.96 mg/L, 1280±75.27 mg/L) for Babati and Burunge areas respectively. Total coliform (3500 CFU, 2650 CFU) and *Escherichia coli* (167/100 ml, 192/100 ml) were counted for Babati and Burunge area respectively. Burunge area recorded higher cases of digestive upsets (53.8%) compared to Babati area (46.2%). There were no statistical differences in digestive upsets between the two Babati and Burunge areas (p=0.8246). A correlation analysis revealed a significant linear association between water quality measures and digestive upsets for diarrhoea (p= 0.001694, r > 0.5) and other factors (p= 0.000158, r > 0.5). In order to minimize livestock digestive upsets associated with poor water quality, communities in these areas should avoid excessive use of fertilizers that would increase nitrate levels, as well as prohibit anthropogenic activities taking place close to water sources.

Keywords: Digestive upsets, Escherichia coli, pseudo-ruminants, ruminants, total coliform, and water quality

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1. Introduction

Our livestock cannot exist without water, which contains a large number of minerals and nutrients (Costa, 2021). Surface water (lakes, streams, rivers and ponds), and ground water (bore holes and wells) are major natural sources of water (Higgins *et al.,* 2008). Fresh water is necessary for animal consumption (Thiet *et al.,* 2022). According to OECD (2010), approximately 70% of the world's freshwater outflow is used for agriculture, with a significant portion going toward the production of feed and cattle (Opio *et al.*, 2011: Soltanpour *et al.,* 1999). Livestock sector alone uses 8% of the world's water resources, with the majority of that water going toward intensive, feed-based farming (Thiet *et al.,* 2022).

The physical, chemical, mineral, and biological aspects of the water determine its quality (German *et al*., 2008: Willms *et al*., 2002). Therefore, without the availability of high-quality fresh water in sufficient quantities, livestock health as well as agricultural development cannot be achievable (Higgins *et al.,* 2008; German *et al*., 2008). Water resources are at risk of contamination from garbage disposal due to current population growth (Pfost *et al*., 2001), increased tourism, and industrialization (Matini and Moutou, 2012). The contamination of ground water is increased by the leaching of water into different rock strata (Sunil and Chippa, 2013).

Recent environmental degradation has rendered some surface water sources unfit for livestock consumption because they are frequently contaminated with different organic, inorganic, and microbiological pollutants (Edmond *et al.,* 2019). Water bodies are sensitive to the effects of a wide variety of environmental pollutants from anthropogenic activities, such as agricultural and urban runoff, industrial and municipal facilities, spills, and hazardous waste sites (Ahuja, 2013; Edmond *et al.,* 2019; Sunil and Chippa, 2013). Suspended matter, resulting mainly from deforestation and agricultural activity, has degraded aquatic ecosystems particularly in the tropics and subtropics (Matini and Moutou, 2012; Safari *et al.,* 2012). Elevated concentrations of nitrogen and phosphorus in aquatic systems resulted from the increased application of fertilizers lead to eutrophication (Costa, 2021). The quality of water is now questionable due to ongoing human-related activities close to them and the use of pesticides, insecticides, herbicides, as well as fertilizers that spill during the rainy season (URT, 2013; URT, 2018).

It is essential to regularly assess the quality of the water and to come up with strategies for preserving it (Smith *et al.,* 2008). The drainage basin's altitude, terrain, hydrology, and biology all influence the composition of the groundwater and surface water (Costa, 2021; Donald *et al.,* 2002). Therefore, it is important to evaluate water quality from different sources in order to determine whether they are suitable for livestock drinking in selected villages of Manyara region.

In many cases, the availability, accessibility, and quantity of water for livestock are prioritized; however, the quality of the water in livestock health is often overlooked. In addition, many diseases and stomach upsets are associated with the presence of biotic entities such as viruses, bacteria, fungi, nematodes, and protozoa that are linked to airborne or waterborne diseases in livestock, the position of abiotic factors is underestimated. This calls the need to investigate various causes of poor water quality as well as their effects on livestock in Babati and Burunge areas.

Previous studies conducted on water quality in livestock production and its role in animal health, productivity, and overall welfare have focused on microbial contamination and pathogens (Faries et al., 1998; Moehlenpah et al., 2021; Smith et al., 2008), the assessment of the pH and alkalinity of water sources to determine their suitability for livestock consumption and to prevent digestive issues (Edmond et al., 2019; Wardrop et al., 2018), and the link between poor water quality and the spread of waterborne diseases among livestock, including diarrhea and other gastrointestinal disorders (German et al., 2008; Hooda et al., 2000). Impact of different water sources (well water, surface water, and municipal water) on livestock health and production (Petersen, 2015; Willms et al., 2002), effects of poor water quality on livestock stress levels (Beede, 2012), behavior (Derose et al, 2020), and overall welfare (Giri et al, 2020; Lardner et al., 2005).

Babati and Burunge areas in Manyara region have underground water, lakes, dams, rivers, streams, ponds, and springs for livestock watering. According to the National Census of 2022, the area have 194, 993 cattle, 186, 057 goats, 43, 851 sheep, 7, 923 donkeys, 160, 019 chickens, and 10,182 pigs (URTNC, 2022). The purpose of this study was to assess the suitability of livestock drinking water for livestock watering by evaluating the physicochemical parameters, microbiological characteristics, livestock digestive upsets, and livestock gastric problems. The study evaluates the quality of livestock drinking water and suggests management strategies of water resources.

2. Materials and Methods

2.1 Study area and sampling location

This study was conducted in Babati and Burunge areas located in Manyara region's Babati Town Council and Babati District Council, respectively. Six villages, Babati Majengo, Singe, and Bagara Ziwani adjacent to Lake Babati, a freshwater body, as well as Mwada, Vilima Vitatu, and Sangaiwe adjacent to Lake Burunge, a soda water body were involved in the study (Figure 1).

2.2 Sample determination

Purposive sampling was used to select water sources/points for taking water samples from water sources/points serving livestock in the studied villages. Water sources include springs, shallow wells, rivers, boreholes, and surface water except lake water. The sampling included 20 water samples from each village (n=120 for 6 villages).

Three KIs (1 livestock officer, 1 environmental officer, and 1 worker from the Community Water Committee) and 1 Focus group discussion from each village were purposefully selected to obtain their insights on water quality and livestock digestive upsets cases. Purposive sampling of four groups (cattle, goats, sheep and donkeys) of 20 livestock from each group in each village were examined for digestive upsets in the six villages (n=480 for 6 villages). Sample size from a livestock population were determined using Taro Yamane formula.

$$n = \frac{N}{1 + N(e)2}$$

Where: n = sample size, N = the population of livestock, e = the margin error (0.05). Results on the type of digestive upsets observed and number of livestock affected were recorded in the data recording sheet.

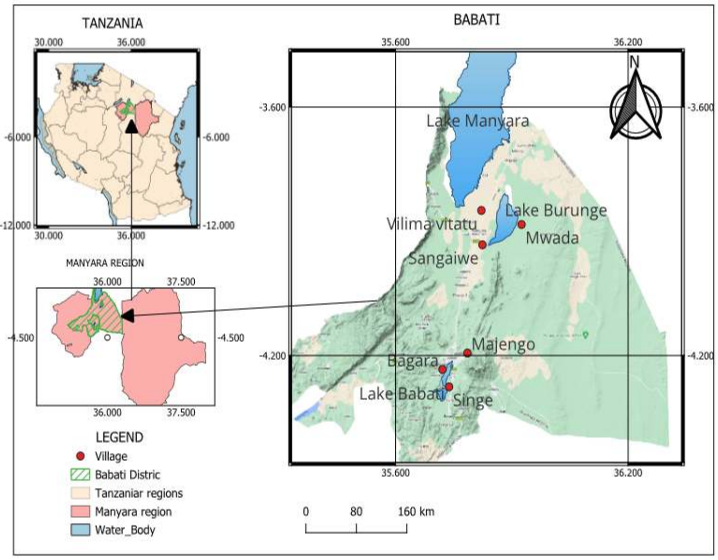

Figure 1: Map of studied villages

2.3 Water sampling

Water samples were collected by dipping a water collecting bottle below the water surface from different sources. The samples were then quickly transferred to a sterilized 1 L container, rinsed with distilled water in the field for immediate in situ testing of physicochemical parameters. Samples for chemical parameters were filled in 1 L standard sterilized bottles, chilled on ice, and stored in a cool box before being transported to the laboratory for chemical analysis. Samples for microbiological tests were collected in sterilized plastic bags underneath each sampling point and transported to the laboratory on ice within 24 hours. All bottles were marked the location, date, sample number, collector name and type of analysis needed. Water bottles containing samples were stored in an iced cooler box at 4^{o}C covered with aluminium foil, which was also sterilized with a methylated spirit to avoid further contamination by microbes during transportation.

2.4 Measurement of physical and chemical parameters

Physical parameters were measured in-situ; temperature, hydrogen ions (pH), and total dissolved solids (TDS) were measured by Multi probe meter, dissolved oxygen (DO) was measured by DO meter and biological oxygen demand (BOD) by BOD meter OxiDirect, turbidity was measured by a nephelometric turbidity meter, conductivity was measured by a Hatch conductivity meter model 44600, and salinity was measured by Salt refractometer 300011 SPER SCIENTIFIC - China as directed by manufacturers. As for chemical parameters, water samples for testing nitrate, nitrite, ammonium, calcium, chloride, fluoride, and magnesium were taken for analysis at the Geological Survey of Tanzania (GST) laboratory located in Dodoma.

2.5 Analysis of microbiological properties

Spread plate method was used for direct count of the viable coliform and *Escherichia coli* colonies in the water sample. Tenfold serial dilutions of the water sample were prepared. A portion of each dilution was poured onto m-FC agar for the growth of coliforms and *Escherichia coli* incubated at 35°C for 24-48 hours. After incubation, the number of colonies on the plates that have the characteristic appearance of coliforms and *Escherichia coli* were counted. Finally, the number of coliforms and *Escherichia coli* colonies per unit volume of the original water sample, and the volume of the samples plated were calculated.

2.6 Evaluation of livestock digestive upsets

Digestive upsets were evaluated in the livestock by clinical observation, where animals were observed for visible signs of digestive upsets, such as changes in behavior, appetite, fecal consistency, and body condition. Physical examination of affected animals, including body temperature, heart rate, respiratory rate, and abdominal palpation, to identify any discomfort or abnormality as well as veterinary consultation by seeking guidance from a livestock officer for a comprehensive diagnosis.

2.7 Data Processing and Statistical Analyses

Results were recorded and stored in an excel format, descriptive statistics were employed to define the essential aspects of the data by providing statistical summaries of livestock cases and other physical and chemical parameters. Results obtained were compared with the WHO standard limits for livestock water quality. Correlation analyses were used to test if there is relationship between livestock gastric problems and water quality.

3. Results

3.1. Physical and Chemical Parameters

The mean, standard error of the mean and WHO acceptable values of each parameter assessed are indicated in table 1 and 2.

Table 1: Physical parameters o/f water in Babati and Burunge areas

Physical parameters	Babati	Burunge	WHO limits
	Mean±SEM	Mean±SEM	
Temperature (^oC)	22.80±2.84	25.28 ±1.50	25-30
Water pH	6.19±0.45	7.50±0.55	5.5-8.5
DO (mg/l)	3.19±0.45	3.50±0.55	< 5
BOD (mg/l)	5.15±0.45	5.50±0.55	< 5
EC(µS/cm)	143.83±73.47	1333.60±165.43	< 2500
TDS(mg/l)	71.33±36.42	145.17±243.10	< 500
Salinity(‰)	20.70±1.06	21.00±0.71	< 25
	F= 0.9333	df = 6.132	p = 0.3705

Source: Field data

Table 2: Chemical composition of water in Babati and Burunge areas

Chemical parameters	Babati	Burunge	WHO limits
	Mean ± SEM	Mean ± SEM	
Calcium	550.00±22.19	842.00±70.15	< 500
Magnesium	0.45±0.02	0.53±0.04	< 30
Fluoride	0.88±0.04	0.64±0.02	< 1.0
Chloride	1940±63.90	3380±135.65	< 1500
Ammonium	5.94±0.42	6.79±0.58	< 1.5
Nitrate	113.62±10.64	71.16±12.92	< 45
Nitrite	4.95±1.35	0.40±0.05	< 33
Total alkalinity	10.83±1.34	11.22±0.79	< 200
Total hardness	1372.00±106.96	1280±75.27	< 600

Source: Field data

Table 3: Microbiological characteristics of water in Babati and Burunge areas

Microbiological properties	Babati	Burunge	WHO limits
Mean coliforms	3500	2650	5000 CFU
SEM	0.45	0.48	
Number tested	60	60	
Mean *E. coli*	167	192	200/100 ml
SEM	0.37	0.38	
Number tested	60	60	

Source: Field data

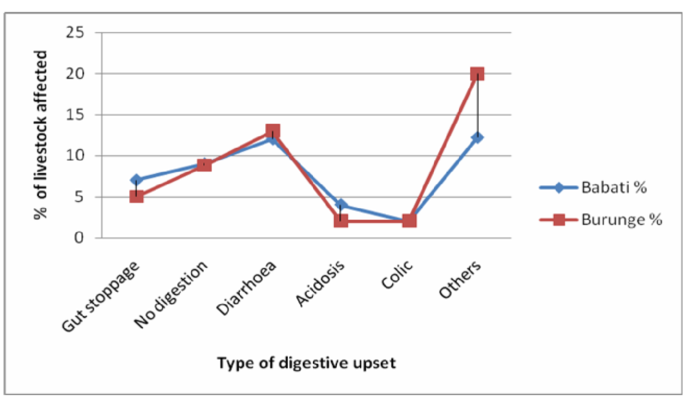

Figure 2: Livestock gastric problem in Babati and Burunge area.
Source: Field data

Table 4: Correlation of water quality parameters and digestive upsets in Babati and Burunge areas

Estimate Coeff	S.E	z value	P-Value
(Intercept)	1.51731	0.98315	1.543	0.122755
Colic	-0.4055	0.6455	-0.628	0.529909
Diarrhoea	1.4271	0.4546	3.139	0.001694 **
Gut stoppage	0.6932	0.5000	1.386	0.165657
No digestion	1.0874	0.4721	2.304	0.021246 *
Others	1.6802	0.4447	3.779	0.000158 ***

Source: Field data

4. Discussions

4.1 Physical parameters

The study results showed that water sources intended for livestock uses were either underground water (water, lakes, dams, wells, boreholes) or surface water (rivers, streams, ponds, and springs). Challenges in the provision of water for livestock were associated with physical inaccessibility and high seasonal variation in the availability of water sources. Poor quality water for livestock drinking was rather a concern for communities in the proximity of settlements and closely adjacent to lakes.

The analyzed physical parameters: temperature, hydrogen ion concentration (pH), TDS, DO, BOD, EC, and salinity, were generally found to be within the WHO standards, except for turbidity, calcium, chloride, ammonium, nitrate, and hardness in Babati and Burunge area (Table 1 and 2). Results in table 1 shows that, there were no statistical differences in physical parameters between Babati and Burunge areas (p= 0.3705).

The differences in temperature between and within areas might have been influenced by the area's climate, and the vegetation surrounding water sources. The pH level of livestock drinking water is a significant marker of its acidity or alkalinity. Numerous minerals and organic substances interact with one another to produce the sample's final pH value. The pH range in the current study was 6.19 to 7.5, which is within the WHO recommended range. The differences in pH levels in the study area may have been influenced by the dissolved bases from the geology in the area, soil characteristics, and runoff or spills of contaminants from anthropogenic activities. These findings are similar to those of Edmond *et al*., (2019) who reported that soil characteristics affect the pH level of a given area.

The DO (Dissolved Oxygen) ranged from 3.19 mg/L to 3.50 mg/L for Babati and Burunge area respectively, which is within the WHO recommended range. The acceptable levels of DO and BOD in livestock drinking water vary depending on the type of livestock and specific water quality guidelines or regulations set by local authorities or agricultural organizations. Different livestock species have varying tolerance levels for dissolved oxygen. However, some general guidelines are followed to ensure safe and healthy drinking water for livestock. To ensure the well-being of livestock and maintain healthy water systems, it is essential to manage and control factors that influence DO and BOD levels. Proper waste management, including appropriate treatment and disposal of livestock waste, prevent excess organic matter from entering water bodies and causing oxygen depletion. Sufficient DO levels are necessary to support the respiratory processes of livestock. If DO levels drop too low, animals may experience stress, suffocation, or even die due to a lack of oxygen. Livestock drinking water in water bodies with low DO may exhibit reduced growth rates, weakened immune systems, and increased susceptibility to diseases. Oxygen levels can also affect the metabolic rates of animals. In waters with lower DO, livestock may become less active and unable to search for food properly, associated with the observed gut stoppage.

The BOD (Biochemical Oxygen Demand) ranged from 5.15 mg/L to 5.50 mg/L for Babati and Burunge area respectively falling within the agreed values. High BOD levels in water indicate high levels of organic pollution, caused by agricultural runoff, including livestock waste. Excessive BOD result to a significant drop in DO levels in the water. As the BOD increases, oxygen levels decrease, potentially creating hypoxic or anoxic conditions. The obtained values pose no effect on water. For most samples electrical conductivity (EC) values were between 143.83 and 1333.60 (S/cm) that were within the acceptable range. The amount of total dissolved matter is directly related to the EC value. The fact that the soils in the Burunge area are rich in alkaline (soda lake), which are potent electrolytes that totally dissolve in a given solution and increase its conductivity, may be the cause of the area's considerably higher average EC.

TDS varied from 71.33 to 145.17 mg/L, according to the WHO, the preferred limit for total dissolved solids in drinking water for livestock is 500 mg/L, while the maximum allowable limit is 1500 mg/L. Water with high residue content is typically less appetizing, causing livestock to react physiologically negatively, and gastrointestinal distress (German *et al.,* 2008). Constipation observed to some livestock is associated with drinking water with a high solids concentration (Higgini *et al.,* 2008).

Turbidity standard value is 25 NTU, in this study ranged from 8.67 to 10.88 NTU, Although turbidity by itself does not necessarily pose a direct threat to the health of livestock, it can reveal the presence of pathogenic microorganisms and serve as a reliable warning sign for dangerous situations in the water body, from the catchment to the point of use. High turbidity suggest for presence of microbiological diseases from E. *coli* contamination (Lander *et al.,* 2005; Smith *et al.,* 2008).

4.2 Chemical composition

There were no statistical differences in chemical composition between Babati and Burunge areas (p=0.6988) (Table 2). WHO regulations allow total hardness less than 600 mg/L. In this study the total hardness ranged from 1280 mg/L to 1372 mg/L, being higher than the permitted upper limit for every sample. The breakdown of alkali earth metal salts from the study area's geological material may be associated with the observed hardness. Calcium and magnesium values in the study region ranged from 550 mg/L to 842 mg/L, according to WHO should not exceed 500 mg/L. All samples had values above the permitted upper limit. According to Thiet *et al*, 2022, Calcium, magnesium, and water hardness are not thought to have an impact on animal water intake or performance.

Salinity ranged from 20.70 mg/L. to 21.00 mg/L, higher than WHO accepted limit of 25 mg/L. Type of species, the salinity level, and the type of salt minerals present affect how well an animal can tolerate salinity (Thiet *et al.,* 2022). According to Costa (2021), animals perform better in environments with low salinity levels than they did in those with higher salinity levels. High chloride levels indicate a risk of salt toxicity (Costa, 2021; Smith *et al.,* 2008). According to Costa, (2021), Excess sodium chloride cause dehydration in ruminants raising rumen osmotic pressure resulting to the decline of the microbial population and metabolic activity, hence animal consume less food linked to the observed digestive upsets in livestock.

The measured average nitrate levels in water ranged from 71.16 to 113.62 mg/L, greater than the maximum permissible limit of 45 mg/L. Nitrate concentrations were substantially greater in the Babati area than in the Burunge area. According to Donald *et al.,* (2002) nitrate from sources other than plant material can be dangerous to livestock. In contrast, water runoffs from feedlot grounds contain a significant level of nitrite and contaminate water supplies, especially during the rainy season. Use of urea fertilizers and ammonium nitrate observed in Babati area due to horticultural farming has been linked to incidents of aquatic poisoning aside from livestock (Higgins *et al.,* 2008; German *et al.,* 2008).

In some of the villages, the average ammonium level, which varied between 5.94 mg/L and 6.79 mg/L, was found to be higher than the WHO standard limit of 1.5 mg/L, whereas in other villages was lower. Ammonia levels beyond a certain threshold in water are frequently signs of fecal contamination (Hooda *et al*., 2000; Lardner *et al*., 2005) contains feces from surrounding cattle or fertilizer contamination. According to Donald *et al.*, (2002), Animals exposed to various ammonium salts in drinking water (between 75 and 360 mg/kg body weight as the ammonium ion) showed physiological tolerance to induced acidosis (Clark, 1998., Hurley, 1999).

4.3 Microbiological characteristics

With the exception of dairy operations, no regulatory restrictions on the amount of bacteria, especially coliform bacteria (Soares *et al*, 2023). The occurrence of bacteria in water 3500 and 2650 CFU for Babati and Burunge areas respectively depend on the rate of contamination and the equilibrium that establishes between bacterial proliferation in that environment and the rate of its elimination. The level of bacterial contamination observed in the livestock drinking water was 167/100 ml and 192/100 ml for Babati and Burunge areas respectively demonstrate that the livestock daily exposure to *Escherichia coli* is considerable. Further study is required to quantify the risks related with microbial contamination of livestock drinking water.

4.4 Livestock digestive upsets

The study examined the occurrence of digestive upsets in livestock across six villages, with a total of 480 animals being examined. The results highlighted various types of digestive upsets observed in the livestock population. These upsets included gut stoppage or a massively full rumen (7, 5%), no digestion (9, 8.8%), diarrhoea (12, 13%), acidosis (4, 2%), colic (2, 2%), and a variety of other conditions (12.2, 20%) in the Babati and Burunge areas respectively. These findings are illustrated in Figure 2.

The results indicated that the Burunge area had a higher number of reported cases of digestive upsets compared to the Babati area. Despite this difference, when statistical analysis was performed, it was found that there were no significant statistical differences in the occurrence of digestive upsets between the two areas. The p-value reported for this comparison was 0.8246, which is higher than the conventional threshold for statistical significance (p= 0.05). Even though the raw numbers of digestive upsets were higher in the Burunge area, the statistical analysis suggests that this difference could have occurred by chance. It's important to note that a p-value of 0.8246 is quite high, indicating that the likelihood of observing these results if there were no actual differences between the two areas is substantial. This study provides valuable insights into the prevalence of digestive upsets in livestock across different areas. While the Burunge area appeared to have a higher incidence of digestive upsets, the lack of statistical significance suggests that factors other than geographical location might be influencing these occurrences.

4.5 Relationship between livestock digestive upsets and physicochemical parameters

Turbidity, calcium, chloride, ammonium, nitrate, and hardness were considered independent variables that influence digestive upsets (gut stoppage, no digestion, diarrhoea, acidosis, colic, and others). These elements were chosen in this analysis because they have shown significant variation and are good representatives of others. The correlation results revealed that the concentrations of these parameters positively influenced digestive upsets, particularly diarrhoea ($p = 0.001694$) and other factors ($p = 0.000158$), significantly correlated ($r > 0.5$). In the present study, it is impossible to draw a conclusion about whether diarrhoea was caused by drinking water of poor quality or by pathogens that obstruct proper food digestion and absorption.

5. Conclusions

The objective of this study was to assess livestock drinking water quality in order to determine the current status at watering point, examine digestive problems, and ascertain the impact of water quality on livestock gastric upsets. Physical and chemical parameters for some areas were within acceptable limits except the levels of turbidity, calcium, chloride, ammonium, nitrate, and hardness. The most polluted water resources are those closest to lakes where there is extensive vegetable cultivation that uses pesticides, herbicides, insecticides, and fertilizers, as well as clothes and car washing businesses, which may have contaminated these livestock watering stations. As for gastric upsets, Burunge area recorded higher cases compared to Babati area. It would be important to incorporate other factors in addition to the water quality indicators utilized in this study in order to acquire accurate information regarding the effects of properties of water on livestock. Water should not be consumed directly by livestock to minimize microbial contamination, necessitating the prohibition of livestock from entering lake buffer zones. Water resources should be monitored on a regular basis to ensure their safety. Local authorities or agricultural extension offices should provide guidelines and recommendations for livestock drinking water quality specific to the region or type of livestock being raised. Farmers and livestock owners should consult these guidelines and, if necessary, conduct water quality testing regularly to ensure health and well-being of their livestock. Further research and investigation might be needed to identify the underlying causes of digestive upsets in these regions and to determine if there are any significant factors contributing to the observed differences.

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References

Ahuja, S. 2013. Monitoring water quality: pollution assessment, analysis, and remediation. *International Journal of Environmental Research and Public Health*. Vol. 15, No. 9.

Beede, D. K. 2012. What will our ruminants drink? *Animal Frontiers*. Vol. 2, No. 2, pp. 36-43, https://doi.org/10.2527/af.2012-0040

Clark, E. A. 1998. Landscape variables affecting livestock impacts on water quality in the humid temperate zone. *Canadian Journal of Plant Science*. Vol. 78, No. 2, pp. 181-190.

Costa, R. G, Freire, R. M. B, de Araújo, G. G. L, Queiroga, R. C. R. D. E, Paiva, G. N, Ribeiro, N. L, Oliveira, R. L, Domínguez, R, Lorenzo, J. M. 2021. Effect of Increased Salt Water Intake on the Production and Composition of Dairy Goat Milk. *Animals (Basel).* Vol. 11, No. 9, pp. 2642.

Derose, K.L, Roche, L.M, Lile, D.F, Eastburn, D.J, Tate, K.W. 2020. Microbial Water Quality Conditions Associated with Livestock Grazing, Recreation, and Rural Residences in Mixed-Use Landscapes. *Sustainability*. Vol. 12*:* 5207. https://doi.org/10.3390/su12125207.

Donald R. M., Benjamin J. A., Stephen, R., and Frank, D. 2002. Livestock Ammonia Management and Particulate-Related Health Benefits. *Environmental Science & Technology.* Vol. 36, No. 6, pp. 1141-1146.

Edmond, A., Lyon, S. W., and Lindborg, R. 2019. Assessment of Water Quality across Irrigation Schemes : A Case Study of Wetland Agriculture Impacts in Kilombero Valley.

Faries, J., Floron, C. J.M, Reagor, J.C. 1998. *Water Quality: Its Relationship to Livestock*. Texas Agricultural Extension Service. 2374.

German, D., Thiex, N., Wright, C. 2008. *Interpretation of Water Analysis for Livestock Suitability*. South Dakota State University. Brookings. SD.

Giri, A., Bharti, V.K., Kalia, S. 2020. A review on water quality and dairy cattle health: a special emphasis on high-altitude region. *Applied Water Science,* Vol. 10: 79. https://doi.org/10.1007/s13201-020-1160-0.

Hooda, P. S., Edwards, A. C., Anderson, H. A., and Miller, A. 2000. A review of water quality concerns in livestock farming areas. *Science of the Total environment*. Vol. 250, No. 1-3, pp. 143-167.

Higgins, S., Agouridis, C., Gumbert, A. 2008. Drinking water quality guidelines for cattle. *Journal of Nutrition,* Vol. 133, No. 5, pp. 1506-1509.

Hurley, T. M., Otto, D., and Holtkamp, J. 1999. Valuation of water quality in livestock regions: An application to rural watersheds in Iowa. *Journal of Agricultural and Applied Economics*. Vol. 31, No. 1, pp. 177-184.

Lardner, H. A., Kirychuk, B. D., Braul, L., Willms, W. D., and Yarotski, J. 2005. The effect of water quality on cattle performance on pasture. *Australian Journal of Agricultural Research*. Vol. 56, No. 1, pp. 97-104.

Matini. L and Moutou J. M. 2012. Seasonal Ground Water quality variation in Brazzaville, Congo. *Research Journal of Chemical Sciences* Vol. 2, No. 1, pp. 7-14.

Moehlenpah, A.N, Ribeiro, L.P.S, Puchala, R, Goetsch, A. L, Beck, P, Pezeshki, A, Gross, M. A, Holder, A. L, Lalman, D. L. 2021. Water and forage intake, diet digestibility, and blood parameters of beef cows and heifers consuming water with varying concentrations of total dissolved salts. *Journal of Animal Science,* Vol. 1, No. 99, Article 10:skab282. doi: 10.1093/jas/skab282. PMID: 34618893; PMCID: PMC8557798.

Opio, C., Gerber, P. & Steinfeld, H. 2011. Livestock and the environment: addressing the consequences of livestock sector growth. *Advances in Animal Biosciences*. Vol. 2, pp. 601–607.

Organisation for Economic Co-operation and Development (OECD) 2010. Sustainable management of water resources in agriculture.

Petersen, M. K. 2015. Sources of variability in livestock water quality over 5 years in the Northern Great Plains, *Journal of Animal Science*, Vol. 93, No. 4, pp. 1792–1801, https://doi.org/10.2527/jas.2014-8028.

Pfost, D. L., Fulhage, C. D., and Casteel, S. W. 2001. Water Quality for Livestock Drinking. Extension Distribution Center, University of Minnesota.

Safari, D., Mulongo, G., Byarugaba, D. and Tumwesigye, W. 2012. Impact of Human Activities on the Quality of Water in Nyaruzinga Wetland of Bushenyi District Uganda. *International Research Journal of Environment Sciences*. Vol. 1, No. 4, pp. 1-6.

Smith, R.P., Paiba, G.A, and, Ellis-Iversen, J. 2008. Turbidity as an Indicator of *Escherichia coli* Presence in Water Troughs on Cattle Farms. *Journal of Dairy Science*. Vol. 91, No. 5: 2082.

Soltanpour, P. N., and Raley, W. L. 1999). *Livestock drinking water quality*. Colorado State University Extension Service.

Soares, A. S, Miranda, C, Coelho, A. C, and Trindade, H. 2023. Occurrence of Coliforms and Enterococcus Species in Drinking Water Samples Obtained from Selected Dairy Cattle Farms in Portugal. *Agriculture* Vol. 13, No. 4, pp. 885. https://doi.org/10.3390/agriculture13040885.

Sunil, K. T. and Chippa, R. C 2013. Analysis of Water Quality of Halena Block in Bharatpur Area. *International Journal of Scientific and Research Publications*. Vol. 3, No. 3, pp. 246 -249.

Thiet, N., Hon, N. V., Ngu, N. T. 2022. Thammacharoen S. Effects of high salinity in drinking water on behaviors, growth, and renal electrolyte excretion in crossbred Boer goats under tropical conditions. *Vet World*. Vol. 15, No. (4):834-840.

United Republic of Tanzania. 2013. United Republic of Tanzania Water Sector Status Report.

United Republic of Tanzania 2018. *Investment and Socio-Economic Profile Manyara Region*. Prime Minister's Office. Regional Administration and Local Government. Regional Commissioner's Office Manyara Region Babati -Tanzania.

Wardrop, N. A, Hill, A. G, Dzodzomenyo, M, Aryeetey, G, Wright, J. A. 2018. Livestock ownership and microbial contamination of drinking-water: Evidence from nationally representative household surveys in Ghana, Nepal and Bangladesh. *International Journal of Hygiene and Environmental Health,* Vol. 221, No. 1, pp. 33-40. doi: 10.1016/j.ijheh.2017.09.014. Epub 2017 Oct 3. PMID: 29031736; PMCID: PMC5739303.

Willms, W. D., Kenzie, O. R., McAllister, T. A., Colwell, D., Veira, D., Wilmshurst, J. F., and Olson, M. E. 2002. Effects of water quality on cattle performance. *Rangeland Ecology and Management/Journal of Range Management Archives* Vol. 55, No. 5, pp. 452-460.

Biographical notes

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