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Determination of Water Quality in Dairy Cattle Enterprises: A Case of Niğde Province

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A B S T R A C T

In dairy farms, water is crucial for the health, productivity, and welfare of animals. Water is a fundamental component in all biological processes, and insufficient water intake can negatively impact milk production, reproductive health, and overall animal welfare. The water requirement for dairy cattle depends on various factors such as age, weight, milk yield, environmental temperature, and nutritional status. An adult dairy cow can consume approximately 80-150 liters of water per day. This requirement increases in high-yielding cows. Adequate water intake directly affects milk production, as approximately 87% of milk is composed of water. The quality of water is as crucial as its quantity. This study investigates the quality of drinking water in dairy farms within Niğde Province, Turkey, focusing on its implications for livestock health and productivity. Water samples were collected from 11 livestock enterprises, encompassing water tanks and troughs, and analyzed for electrical conductivity (EC), pH, nitrate (NO_3), nitrite (NO_2), and phosphate phosphorus (PO_4) concentrations. Results showed EC values averaging 0.803 dSm^{-1}, within acceptable standards for livestock, although high concentrations in certain tanks raised concerns regarding mineral content and potential health impacts. The pH ranged from 7.27 to 8.20, remaining suitable for all livestock classes. NO_3 concentrations averaged 21.834 mgL^{-1}, with no samples below the 10 mgL^{-1} threshold, highlighting risks from prolonged exposure. In contrast, NO_2 concentrations averaged 0.251 mgL^{-1}, remaining within safe limits. PO_4 concentrations were minimal, averaging 0.056 mgL^{-1}, and posed no significant risks. The findings underscore the importance of periodic water quality monitoring in livestock farms to mitigate risks of contamination and ensure optimal health and productivity. These findings highlight the necessity for customized water management techniques to fit particular farm settings and advance our understanding of the complex effects of water quality on livestock performance.

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Introduction

Water is an essential nutrient for the vital functions of living beings. For this reason, we must always ensure that clean and continuous water is available to animals on the farm. However, sometimes caretaker errors, differences in the animal's needs in climate conditions (winter and summer), differences in feeding, physiological differences in the animal, the nutrient content of the feed, and the level of minerals in the feed can cause the animal's water needs to increase or reduce. In such cases, insufficient or poor quality water given to dairy cattle can limit milk production, limit the animal's growth, and cause health problems. For this reason, always having enough clean water in front of the animal supports normal rumen function, high feed intake, digestion, and nutrient absorption. Water also maintains blood volume, meets tissue needs, and makes up approximately 87% of the milk secreted by the cow (Paul & Kim, 2017).

The need for a steady supply of high-quality water is sometimes overlooked by managers of animal production systems, who instead focus on changing feed to improve performance (Beede, 2012).

Water's pH indicates how acidic or alkaline it is, and it greatly affects both microbial activity and water palatability. A livestock's feed intake and general health may be impacted by gastrointestinal problems brought on by too acidic or alkaline water. Extreme pH levels can also have an impact on the toxicity and solubility of other dissolved materials, including minerals and metals, which can further alter the quality of water. Generally, the ideal pH range for animal water is between 6.5 and 8.5; any variations could have negative health implications.

However, water is necessary for many vital processes in the animal body, including the delivery of nutrients and hormones, the removal of waste products, the control of osmotic blood pressure, and the regulation of secretions such as milk, saliva, and body temperature (Yoshihara et al., 2016). In livestock production, it's just as crucial to guarantee that ruminant animals always have access to enough water as it is to have feed on hand (Utley et al., 1970). There are three ways to receive water: drinking water, feed water, and metabolic water (produced during the breakdown of nutrients). Most livestock production systems do not measure the latter two types of water (Romanzini et al., 2024).

When assessing the suitability of water for livestock, various criteria must be considered, with local conditions and the availability of alternative sources playing significant roles (FAO, 1994). Water sources such as small, shallow wells and streams are more prone to contamination and poor water quality compared to larger wells or running streams. Groundwater, in particular, is often more chemically imbalanced than surface water. Seasonal changes also influence water quality; during hot and dry periods, factors such as extreme evaporation from stock watering ponds or tanks can lead to higher salt concentrations, increased water consumption due to heat, and elevated water temperatures. These conditions can render marginally suitable water sources unusable. The age and condition of animals further affect their vulnerability, with young, frail, and lactating animals being particularly susceptible. Additionally, the composition of feed plays a critical role; dry pastures and protein-rich supplementary feeds, which have lower moisture content and higher salt levels, can harm livestock and reduce their salt tolerance. Some feed additives are specifically controlled by adding salt to slow down consumption. Lastly, different animal species have varying abilities to tolerate salt levels in their water, necessitating tailored water quality management for each species (FAO, 1994).

Regardless of the size of the operation, livestock farming requires a constant availability of clean, safe water to support animal development, reproduction and milk production. Water quality and agricultural ecosystems interact in a dynamic and complex manner. Farms often use groundwater sources such as wells or surface water such as rivers and lakes to provide drinking water for their livestock. Because of their close proximity to these water sources, farms are vulnerable to contamination from agricultural runoff, which can include pathogens from manure as well as pollutants such as phosphates, nitrates and pesticides. The health of animals can be seriously compromised by contamination of drinking water, leading to illness, reduced weight gain and, in severe situations, even death. Livestock water quality is directly impacted by farming activities. Water quality problems can be caused by improper water management, fertilizer and pesticide contamination, and inadequate water supplies. According to farm management guidelines, the water supply must be protected from pollutants and checked regularly to ensure excellent quality. Additionally, it is important to integrate water management with other agricultural techniques, including crop management and soil health (USEPA, 2005, USEPA, 2015).

The quality of drinking water varies significantly depending on the source and environmental conditions, leading to variations in water quality parameters. These include electrical conductivity (EC), pH, nitrate (NO_3), nitrite (NO_2), and phosphate (PO_4), which all play critical roles in determining water suitability for animal consumption (NRC, 2001). The amount of dissolved minerals including calcium, magnesium, and salt is directly correlated with EC, a measurement of water salinity. Especially when exposed for an extended period of time, animals may get dehydrated or consume less feed as a result of high EC values that decrease water palatability (McDowell, 2003). To avoid possible health hazards for cattle, it is crucial to identify water sources with high dissolved salts (FAO, 1985). Nitrogen and Phosphorus are the two nutrients that are most important for animal production. While other forms of nitrogen (mostly NO_2) are thought to be potentially extremely toxic and disease-causing, high amounts of nitrogen in drinking water in the NO_3 form induce methemoglobinemia, or "blue baby disease." Because it eutrophicates surface water bodies, phosphorus in the PO_4 form is of concern (Hubbard et al., 2004).

Different types of livestock have different water needs. Factors that influence water intake include the animal's size, diet, production level (e.g., milk production in dairy cows), environmental conditions, and water quality. Clean, fresh water should always be available on the farm, with particular attention during times of heat stress or high physical activity. Monitoring water intake can serve as an early indicator of health problems, as reduced water consumption often precedes illness. The water requirements of different livestock species, taking into account factors such as environmental conditions, age and physiological condition, are shown in Table 1 and 2.

Table 1. Daily total water intake of cattle and cows

Animal Type and Daily Total Water Intake (DTWI)			(lt/animal)			References
Cattle DTWI	360 kg	408 kg	500 kg	544 kg	816 kg	Parker & Brown, 2003
	15-22	25-37	23-33	28-66	33-78	Cemek et al., 2011
Temperatures	4.4^{o}C	10^{o}C	26^{o}C	32.2^{o}C		NRC,1974, Olkowski, 2009
Growing Cattle 182-364 kg DTWI	15.1-23	16.3-25.7	25.4-40.1	36-56.8		
Finishing Cattle 273-454 kg DTWI	22.7-32.9	24.6-35.6	37.9-54.9	54.1-78		
Wintering Pregnant Cows 409-500 kg DTWI	25.4-28.7	27.3-24.6	-	-		
Lactating Cows 409 kg DTWI	43.1	47.7	67.8	81		
Lactating Cows 600 kg	15 kg milk yield daily 10^{o}C	59				
	15 kg milk yield daily 32^{o}C	89				
	30 kg milk yield daily 10^{o}C	92				
	30 kg milk yield daily 32^{o}C	146				
	45 kg milk yield daily 10^{o}C	124				
	45 kg milk yield daily 32^{o}C	203				
Temperature	Beef Cows 500 kg	Beef Cows 590 kg	Beef Cows 680 kg			Spencer et al., 2016
4^{o}C	31-48	35-55	39-58			
18^{o}C	41-58	45-65	48-71			
32^{o}C	51-68	54-75	58-81			

Table 2. Water consumption of other livestock and poultry animals

Animal Type	Situation	Water consumption (lt/animal)	References
Mature Bulls 636-727 kg	4.4ºC 10ºC 26ºC 32.2ºC	30.3-32.9 32.6-35.6 50.7-54.9 71.9-78	NRC,1974; Olkowski, 2009
Calf	1 month 4 month	5-8 11-13	Parker & Brown, 2003; Cemek et al., 2011
Calf 227 kg (6 kg DMI)	5ºC 16ºC 27ºC 32ºC	16 20 28 40	Winchester & Morris, 1956; Henning et al., 2000; Higgins & Carmen, 2008
Calf 340 kg (8 kg DMI)	5ºC 16ºC 27ºC 32ºC	23 29 39 55	
Heifer	5 months 18-24 months	14-17 28-36	Parker & Brown, 2003 Cemek et al., 2011
Dry Cow	Jersey Guernsey	49-59 52-61	
Dry Cow 500 kg	5ºC 16ºC 27ºC 32ºC	28 35 47 67	Winchester & Morris, 1956 Henning et al., 2000; Higgins & Carmen, 2008
Lactating Cow 500 kg	5ºC 16ºC 27ºC 32ºC	31 38 51 73	
Rams Sheep Ewe Lambs Goats (Per a body kg) Meat goats		7.6 7.6 11.3 0.4-5.7 1.43-3.5 0.7	Parker & Brown, 2003 Cemek et al., 2011
		lt/bird/week	
Broilers 1-8 week Broilers 1-8 week White Leghorn Hens 1-20 week		0.10-0.48 0.22-2 0.2-1.6	Parker & Brown, 2003 Cemek et al., 2011; NRC,1994; Olkowski, 2009
Chicken 1-18 week with white eggs or brown eggs Brown Egg Laying Hens 1-20 week		0.20-1.30 0.2-1.5	

Cows consuming dry feed like hay require more water to support digestion, as dry feeds increase the demand for fluid intake compared to fresh forages. Environmental factors such as temperature and humidity significantly impact livestock water consumption. In hot weather, animals lose more water, so this leads to increasing their daily water requirements. Conversely, in cold climates, water intake may decrease, but it is critical to the health of livestock that they continue to have access to clean, unfrozen water. Several rules and conditions should be considered to guarantee the purity of the water given to animals. Some of the most important indicators of drinking water quality parameters are heavy metals, nitrates, nitrites, dissolved salts, pH, total dissolved solids (TDS), and microbial contamination. It is very important for livestock to have a safe source of water. If the water quality is below standards, health problems can occur in the animals, or their feed intake can decrease. Mineral or organic contaminants in water lead to a reduction in productivity and can lead to various diseases. When assessing the quality of water to be used for animal husbandry, consideration should be given to whether animal productivity declines, whether the water has disease-spreading properties, and whether the animal product affects human health in a manner that is potentially harmful to human health (Cemek et al., 2011). Although water quality for livestock animals varies widely, it will cause harmful effects if there are high levels of some substances in it. Poultry is known to be the most sensitive group to water among farm animals. Although providing animals with poor-quality water does not cause widespread specific production problems in animals, it can cause low productivity and possible problems. Selected water quality criteria for farm animals are given in Table 3.

The novelty of this study lies in its comprehensive approach to analyzing these parameters across multiple livestock enterprises. By evaluating a range of water sources, including water troughs and storage tanks, the study provides a detailed understanding of how these parameters interact and influence the overall quality of drinking water. By providing useful insights for enhancing water safety and animal welfare on farms, the findings add to the expanding body of information on the significance of routine water quality monitoring and management. Contaminated or dirty water can lead to the spread of diseases and reduce water intake by animals. It is necessary to regularly test and clean water sources. High mineral and microbial contamination levels can cause digestive disorders and metabolic diseases.

Table 3. Recommended livestock drinking water quality guide

	Limits	Explanations	References
Water Salinity (EC)	<1000 mg/l <1.5 dS/m	Excellent for all classes of livestock and poultry	FAO, 1985 Guyer, 1996, FAO, 2002, NAS, 1972 NAS, 1974
	1000-3000 mg/l 1.5-5 dS/m	Satisfactory for all classes of livestock. May cause temporary mild diarrhea in livestock not used to it. If the water reaches the upper limits, poultry may experience watery droppings.	
	3000-5000 mg/l 5-8 dS/m	Sufficient for farm animals, but may be rejected by animals that are not used to it. If sulfate salts predominate, the animals may experience temporary diarrhea. Poor water for poultry, often resulting in watery droppings, increased mortality, and reduced growth, particularly in turkeys.	
	5000-7000 mg/l 8-11 dS/m	All farm animals, with the exception of lactating or pregnant animals, may use this water. Animals may refuse it until they get used to it, and it can have a laxative effect. It is not suitable for chickens.	
	7000-10000 mg/l 11-16 dS/m	Significant risk to sheep, horses, and pregnant or lactating cows, as well as to the young of these animals. It can be used on older horses or ruminants. Unsuitable for pigs and most likely poultry.	
	> 10000 mg/l > 16 dS/m	This water is insufficient for all livestock and poultry categories.	
pH	6.5-8.5	Only EPA info available; no cow studies have been done. Low pH (<6) causes corrosiveness and gives water a metallic taste. High pH gives the water a slippery feel, soda taste, and leaf deposits.	NRC,2001
NO_3	0-44 45-132 133-220 221-659 660-799 >800	Generally considered safe Sure – if other sources (Such feed etc) are lower in N2. Harmful- if used for an extended length of time Risky- potential death risks Not safe- high risk of death Not safe- high risk of death-Should not be used	Freedman & Fleming, 2003
NO_3-N	<10 mg/l	Livestock guidelines	NRC, 2001
	0-10 10--19 20-39 40-99 100-199 >200	Generally considered safe Sure – if other sources (Such feed etc) are lower in N_2. Harmful- if used for an extended length of time Risky- potential death risks Not safe- high risk of death Not safe- high risk of death-Should not be used	Freedman & Fleming, 2003
	10 22.7 20 100 23	Livestock guidelines Upper level Upper level Risky- Maximum upper level Livestock guidelines	USEPA, 2003 Shaw et al., 2006 USEPA, 2003 Socha et al., 2002* Shaw et al.,2006 NAS, 1974; Shaw et al., 2006 CCME, 2005
NO_2-N	10 mg/l	Livestock guidelines	NAS, 1972
Nitrate + Nitrite (NO_3-N + No_2-N)	100	Livestock guidelines	NAS, 1972 CCME, 2005
Phosphorus (PO_4)	0.7 ppm	Upper level and also maximum upper level	USEPA, 2003 Shaw et al., 2006

* Socha et al., (2002) reported that these guidelines are acomposite of several sources; (NRC, 1974; NRC, 1980; Bergsrud & Linn, 1990; Puis, 1994; Hutcheson, 1996;).

For the aforementioned reasons, this article aims to discuss the importance of water for dairy cattle, the effects of water quality and quantity, and the issues to be considered in water supply. In this context, drinking water samples were taken from dairy cattle enterprises in Niğde province and analyzed, and the results were compared with the relevant standards to determine the current situation and aimed to contribute to similar research, relevant stakeholders and farm owners by emphasizing the importance of the subject.

Materials and Methods

Materials

Drinking water samples taken from dairy farms were used as material in the study. Livestock enterprises from which animal drinking water samples were taken are established in Niğde province and its districts (Table4). Animal drinking water samples were randomly selected sampling from 11 livestock farms, from points likely to be affected by pollution.

Table 4. Identifiers information of enterprises

N	Code	Location	NDC	Race	NS
1	E1 (E1K[a]-E1Y[b])	Niğde/Kayı	100	Holstein crossbred	1* 2**
2	E2 (E2K[a]-E2Y[b])	Niğde/Bor	35	Holstein crossbred	1* 2**
3	E3 (E3K[a]-E3Y[b])	Niğde/Edikli	120	Holstein crossbred, Montofon crossbred, Simmental crossbred	1* 2**
4	E4 (E4K[a]-E4Y[b])	Niğde/Edikli	90	Holstein crossbred, Montofon crossbred, Simmental crossbred	1* 2**
5	E5 (E5K[a]-E5Y[b])	Niğde/Edikli	20	Holstein crossbred, Montofon crossbred, Simmental crossbred	1* 2**
6	E6 (E6K[a]-E6Y[b])	Niğde/Kayı	90	Holstein crossbred	1* 2**
7	E7 (E7K[a]-E7Y[b])	Niğde/Edikli	60	Holstein crossbred	1* 2**
8	E8 (E8K[a]-E8Y[b])	Niğde/Badak	50	Holstein crossbred	2* 2**
9	E9 (E9K[a]-E9Y[b])	Niğde/Ovacık	200	Holstein crossbred, Simmental crossbred	1* 2**
10	E10 (E10K[a]-E10Y[b])	Niğde/Edikli	45	Holstein crossbred, Montofon crossbred, Simmental crossbred	1* 2**
11	E11 (E11K[a]-E11Y[b])	Niğde/Ovacık	15	Holstein crossbred, Montofon crossbred, Simmental crossbred	1* 2**

N: Number; NDC: Number of Dairy Cattle; NS: Number of Samples; a Water samples were taken from water storage tank,*From water storage tank b Water samples were taken from troughs ** From different points of troughs

The main criteria when taking animal drinking water samples was the volunteering of the enterprises owner. Since enterprises owners did not want detailed information to describe their farms, location information and other detailed information about the enterprises were not provided. Therefor only enterprises information that can identify the type of enterprises and animal water systems are included. Identifiers ınformation of enterprises are given in Table 4. In addition, all enterprises are integrated, closed systems. The barn types in the enterprises were recorded as semi-open. Enterprises use city mains water as a drinking water source, but due to water distribution in farm, all of them have water tanks. In enterprises, animal drinking water is first stored in water tanks and then delivered to troughs. It can be said that there is no routine in farms' drinking water distribution practices. When the animal's drinking water runs out in the troughs, drinking water is transferred from the tank to the troughs.

Methods

While the collection of animal drinking water samples, strict adherence to standard drinking water sample collection rules was ensured. During the water collection process, the selection of enterprises from which water samples were taken was determined based on transportation conditions and the voluntary participation of the operators. Some operators did not permit access to their enterprises or the collection of water samples. Consequently, the number of enterprises that could be reached and sampled was determined according to this limitation. For each enterprise, three different drinking water samples were collected: one from the tank and two from different points of the troughs. The samples were coded based on their collection locations. Samples taken from the water tank were labeled with the code "E-K," while those taken from the troughs were coded "E-Y." In the case of enterprise no. 8, two separate samples were collected from the drinking water tank due to its large size.

Pre-sterilized laboratory analysis bottles were used to collect the drinking water samples. Once collected, the samples were transported on the same day to the Çukurova University, Agricultural Structures and Irrigation Department Laboratory via a cold chain system using a refrigerated vehicle. Upon arrival, the samples were logged in the laboratory registration sheet. The water samples were then filtered using blue band filter paper and transferred to plastic bottles that had been cleaned with a chromic acid solution. These bottles were labeled according to proper technical procedures. Depending on the availability of time and labor, the water samples were either analyzed immediately or stored in a refrigerator at +4°C until the analysis was performed.

In the animal drinking water samples obtained;

Electrical Conductivity (EC) analyzes were completed with an EC meter and pH analyzes were completed with a pH meter (Electrometric Method). Nitrite (NO_2) analyzes (SM 4500-NO_2- B / Spectrometric Method) and Nitrate (NO_3) analyzes (SM 4500-NO_3- B / Spectrometric Method) in waters; It was performed on a Shimadzu brand spectrophotometer device according to Standard Methods, 2017. In the phosphate phosphorus (PO_4) analysis, the SM 4500-P-E Ascorbic Acid Method was applied using the same spectrophotometer. MERCK brand chemicals were used in the analyses.

Results and Discussion

The results obtained from the analyses carried out on animal drinking water samples taken from enterprises are given in this section with tables and graphs.

EC and pH Concentrations in Animal Drinking Water Samples

EC concentrations of samples taken from animal drinking water are given in Figure 1. Among the EC values obtained as a result of the analyses, the highest values were recorded in the animal drinking water tanks of enterprise no. 8, with 4 dSm^{-1} and 3.88 dSm^{-1}, respectively. The lowest value, 0.20 dSm^{-1}, was measured in the animal drinking water tank of enterprise no. 4. The average of all EC analyzes performed is 0.803 dSm^{-1}. While the average of measurements taken only from water tanks was 0.98 dSm^{-1}, the average of samples taken only from troughs was 0.70 dSm^{-1}.

The EC analysis results of animal drinking water samples obtained from enterprises were found to be compatible with the standards. For the wellbeing and production of animals, drinking water's EC is an essential factor. The concentration of dissolved salts and minerals in the water is correlated with the water's EC. Elevated concentrations of salts, as indicated by high EC levels, can cause dehydration, digestive problems, and decreased feed intake in animals. On the other hand, low EC values usually indicate high-quality water with minimal dissolved contaminants. Animals receive water that supports optimal health and performance when EC levels in drinking water are regularly monitored, reducing potential health issues and increasing overall productivity.

The pH level appears to influence various factors such as palatability, efficacy of chlorination, corrosive characteristics, and numerous additional attributes of drinking water (Hersom & Crawford, 2008). A slight degree of alkalinity is considered more acceptable than acidity in herbivorous species. A pH value lower than 5.5 induces acidosis, which presents a potential risk for weight reduction and diminished production. Deviations from these specified pH ranges may result in decreased water and feed consumption, alterations in digestive processes, diarrhea, and suboptimal feed conversion ratios (Looper, 2012).

The results of the pH analysis are given in Figure 2. As seen from Figure 2, pH values are within the desirable range (Table 3) since the highest value is 8.20 and the lowest value is 7.20. According to the guidelines given in Table 3, these waters can be used safely for all classes of livestock and poultry in terms of pH. High water pH is the result of many interacting chemical and biological processes. Animals may experience burning or irritation in their eyes, oral cavity irritation, and thirst refusal if pH levels are higher than acceptable levels. Dairy cows that drink water with a pH higher than 9.0 may experience health issues linked to mild or chronic alkalosis. Water pH extremes have the potential to dissolve things from ditches, pipes, and other materials. Some of these may be harmful or give the water a disagreeable flavor; in particular, high-pH materials can give off a metallic taste that cattle seem to dislike. The negative effects of animals consuming extremely basic or alkaline water are not well documented.

NO_3, NO_2 and PO_4 Concentrations in Animal Drinking Water Samples

Both nitrate and nitrite have the potential to cause toxicity in animal populations, with nitrite exhibiting significantly higher toxicity compared to nitrate. Manifestations of acute poisoning include increased urine output, cyanosis, and restlessness, which may result in vomiting, seizures, and mortality. There may be some confusion regarding the limit values for nitrate and nitrite, as the concentrations are sometimes presented in relation to their respective nitrogen components (N), in particular as nitrate-N and nitrite-N. While both nitrate and nitrite can be toxic to animals, nitrite is 10 to 15 times more lethal than nitrate (Case, 1963).

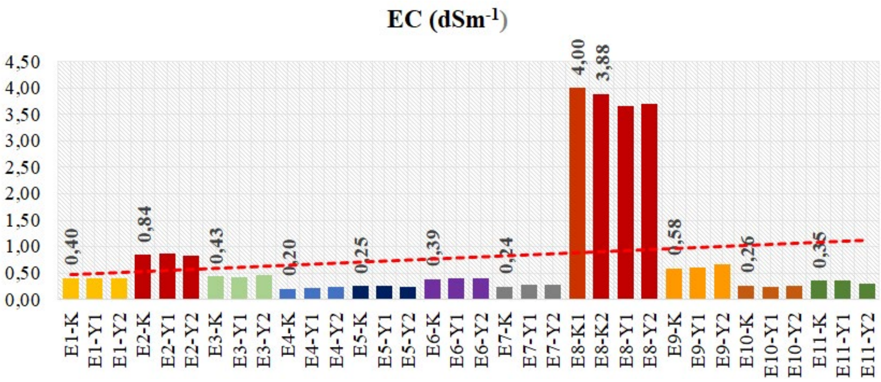

Figure 1. EC concentrations in animal drinking water samples

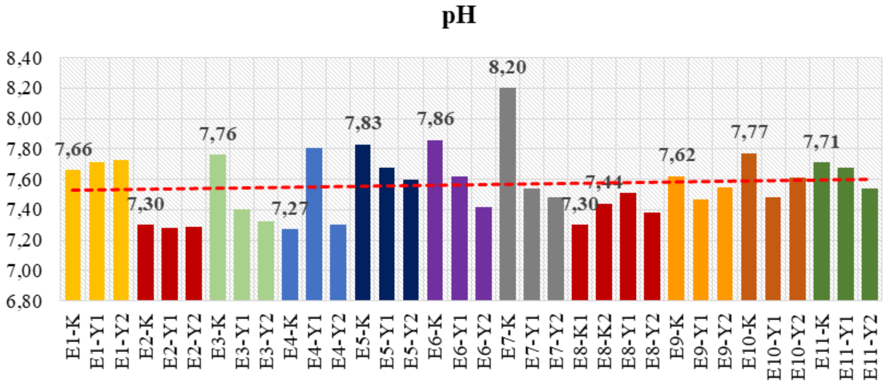

Figure 2. pH concentrations in animal drinking water samples

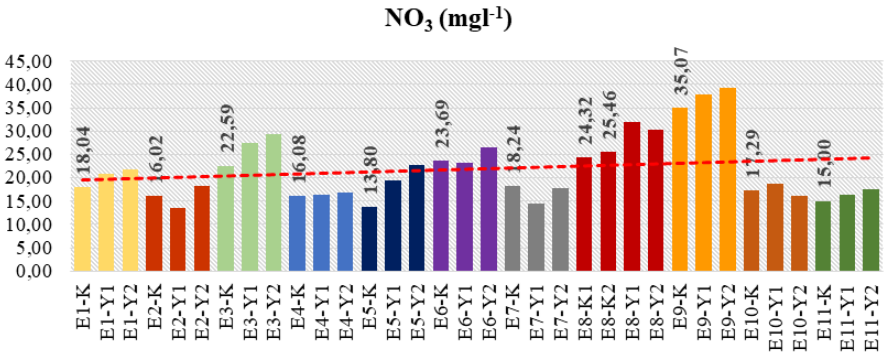

Figure 3. NO_3 concentrations in animal drinking water samples

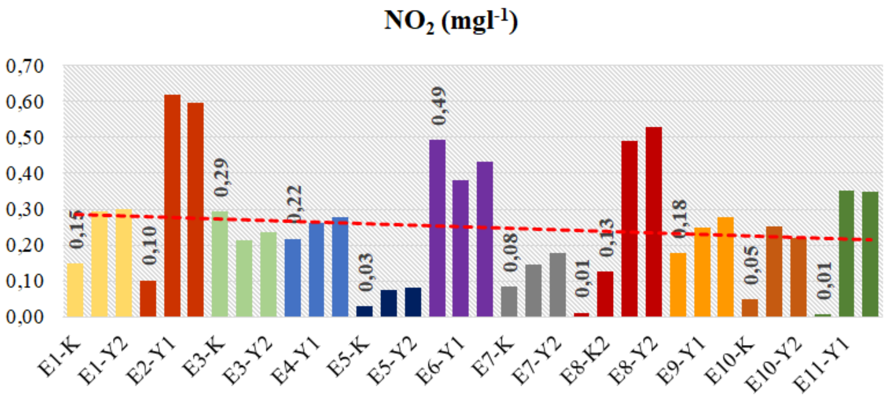

Figure 4. NO_2 concentrations in animal drinking water samples

The results of the NO_3 analysis are given in Figure 3. As seen from Figure 3, NO_3 values are not within the desirable range (Table 3). Because the results are mostly in the ranges which are described as harmful if used for an extended length of time. According to the obtained NO_3 concentrations, the lowest value was calculated as 13.606 mgl^{-1}, the highest value was 39.313 $mgl^{-1}$and the average was 21.834 mgl^{-1}. None of the samples have NO_3 concentrations lower than 10 mgl^{-1}. In all results, 52.95% of the samples contain 13-19.5 mgl^{-1} NO_3, 32.35% of the samples contain 20-30 mgl^{-1} NO_3, and 14.70% of the samples contain 31-39.2 mgl^{-1} NO_3. Even if these results are within the recommended limit values, water samples in livestock enterprises should be analyzed periodically against concentration risks accumulating over time.

The results of the NO_2 analysis are given in Figure 4. As seen from Figure 4, NO_2 values are within the desirable range according to the literature given in Table 3. When the obtained NO_2 concentrations were examined, the highest value was found to be 0.618 mgl^{-1}, the lowest value was 0.008 mgl^{-1}, and the average was 0.251 mgl^{-1}.

NO_3 are infrequently found in potable water and exhibit lower toxicity; conversely, NO_2 are significantly toxic and carcinogenic in nature, with nitrogenous fertilizers and livestock farming potentially increasing their concentration (Schütz, 2012, Wright, 2007). In the context of ruminants, nitrates are assimilated via the oral route into the rumen, where they undergo conversion into NO_2. The NO_2 are then assimilated into the circulatory system, thereby impairing the oxygen transport capacity of erythrocytes (RBCs), leading to fatal outcomes primarily due to asphyxiation resulting from inadequate oxygenation (Hersom & Crawford, 2008; Schütz, 2012; Wright, 2007; Hubbard et al., 2004).

The results of the PO_4 analysis are given in Figure 5. As a result of the study, the highest value among the phosphorus concentrations in the waters obtained was calculated as 0.131 mgl^{-1}, the lowest value as 0.017 mgl^{-1}, and the average value as 0.056 mgl^{-1}. When the obtained data are compared with the literature values (Table 3), it can be said that the results are below the desired limits.

The proposed limits for humans and/or cattle correspond to the upper acceptable limits for most chemicals. However, it should be noted that the values listed as the highest acceptable values may vary. Nitrate and sulfate, two TDS elements, also have different desirable upper limits. As seen in Table 3. The U.S. Environmental Protection Agency (EPA) sets the safe limit for cattle at 22.7 ppm, but the National Academy of Sciences lists 100 ppm as the safe limit for nitrate nitrogen. The desired upper limits for livestock may vary depending on a number of factors, including the age of the cattle, the amount of water they consume per unit of body weight (lactating cows drink more water than growing animals), and whether or not they are cattle adapted to the water and the amount of nitrates that the livestock feed contributes (Socha et al., 2002).

Williams et al. (2002) reported a 23% increase in weight gain among heifers provided with access to cleaner water, in contrast to those obtaining water directly from a pond. Williams et al., (1994), indicated a 20% reduction in weight among 18-month-old steers consuming water from dugouts during the summer over a duration of 71 days (Umar et al., 2014).

Temperature exerts a significant influence on the assessment of water quality for livestock animals, which in turn impacts their hydration, nutritional intake, respiratory rates, various physiological functions, milk production, weight gain, and overall performance (Wilks et al., 1990; Brod et al., 1982).

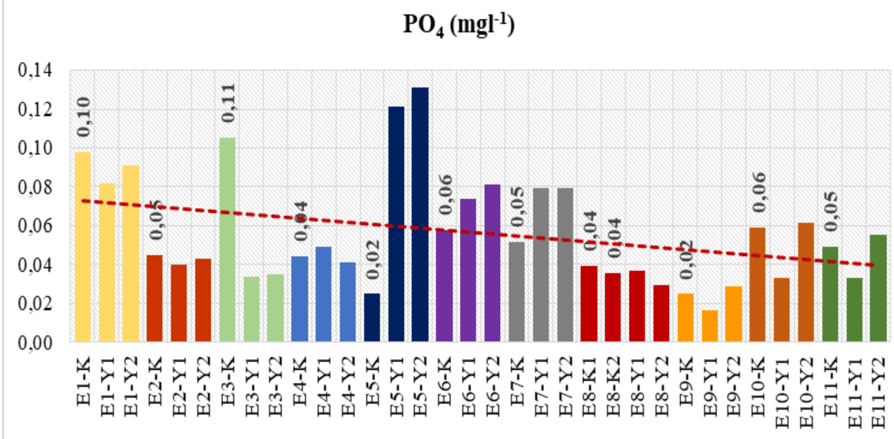

Figure 5. PO_4 concentrations in animal drinking water samples

Table 5. Descriptive statistics

	EC (dSm^{-1})	pH	NO_3 (mgl^{-1})	NO_2 (mgl^{-1})	PO_4 (mgl^{-1})
Mean	0.803	7.56	21.834	0.251	0.056
Standard Error	0.194	0.04	1.187	0.028	0.005
Median	0.398	7.55	19.024	0.241	0.047
Mode	0.403	7.30	none	0.294	0.025
Standard Deviation	1.129	0.21	6.921	0.164	0.029
Sample Variance	1.274	0.04	47.895	0.027	0.001
Kurtosis	4.139	0.95	0.376	-0.258	0.396
Skewness	2.380	0.69	1.059	0.568	1.027
Range	3.800	0.93	25.707	0.610	0.115
Minimum	0.200	7.27	13.606	0.008	0.017
Maximum	4.000	8.20	39.313	0.618	0.131
Count	34.000	34.00	34.000	34.000	34.000

EC: Electrical conductivity, NO_3: Nitrate, NO_2: Nitrite, PO_4: Phosphate Phosphorus

The influence of temperature on quality occurs through alterations in palatability and acceptability by the animals or by perturbing the microflora within the gastrointestinal tract. Typically, livestock exhibit a preference for cool water, particularly under elevated thermal conditions (Arias & Mader, 2011). Besides, the quality of drinking water for animals varies depending on where the water is supplied. In the summer months, water contained in shallow ponds and small troughs experiences elevated temperatures, which can impede an animal's ability to satisfy its hydration needs, thereby leading to a reduction in feed consumption, ultimately resulting in diminished production and growth rates. Conversely, deeper aquatic systems such as tanks, ponds, and groundwater stored in larger troughs typically do not reach temperatures sufficient to influence consumption behaviors. Similarly, animals have been observed to prefer consuming warmed water during winter periods when ambient temperatures approach the freezing point (Umar et al., 2014).

Livestock productivity is impacted when upper contamination limits are exceeded, yet there is disagreement over how this affects animal performance. The precise reason for the influence on livestock output is unknown until more investigation is conducted. In certain circumstances, high concentrations may not directly affect production but instead make water less palatable. As a result, less water is used, which lowers performance without endangering animals due to toxicity issues. In other instances, high concentrations might cause toxicity issues, especially with regard to bacteria and trace elements, which can impair function and, in the case of prolonged exposure, result in death (Schlink et al., 2010).

Descriptive statistics for the analysis performed on animal drinking water samples are given in Table 5.

Conclusion

This study investigated the quality of drinking water in livestock enterprises, analyzing key parameters such as EC, pH, NO_3, NO_2, and PO_4 concentrations. The results revealed that while the EC values were generally within acceptable ranges, with a mean of 0.803 dSm^{-1}, the highest EC levels observed in some water samples (up to 4.0 dSm^{-1}) highlight the need for regular monitoring to ensure water quality does not negatively impact animal health. Most of the samples, particularly from water troughs, exhibited lower EC values, which indicate relatively high-quality water with minimal dissolved salts and minerals. These findings suggest that, in general, the water quality regarding salinity is within acceptable limits for livestock consumption, supporting animal hydration and overall health. Elevated EC values observed in some water tanks (up to 4.00 dSm^{-1}) may, however, warrant further investigation, especially for those animals that are not accustomed to such levels of dissolved minerals. Prolonged exposure to high salinity levels could lead to dehydration, reduced feed intake, and digestive issues, particularly in sensitive livestock groups. Therefore, regular monitoring of EC levels, particularly in water storage tanks, is recommended.

The pH levels, ranging from 7.27 to 8.20, were also within the safe zone, indicating that the water in the studied enterprises is unlikely to cause issues related to palatability or digestion and indicating that the water pH was within the desirable range for livestock health. Water with a pH within this range is generally acceptable for both ruminants and non-ruminants, as it supports palatability and prevents issues such as eye irritation or oral discomfort that can occur with more alkaline or acidic water. Given the variation in pH observed across different enterprises, it is crucial to monitor pH levels periodically to ensure they remain within safe limits for all livestock, especially during periods of water system adjustments or when using new water sources. However, NO_3 concentrations exceeded the desirable limits in many samples, with an average concentration of 21.83 mgL^{-1}. Nitrate concentrations in the water samples showed significant variability, with values ranging from 13.61 to 39.31 mgL^{-1} and a mean concentration of 21.83 mgL^{-1}. These concentrations, although generally within the recommended safety limits, are concerning because prolonged exposure to nitrate levels above 20 mgL^{-1} can cause toxicity, particularly in young or pregnant animals, and lead to health issues like methemoglobinemia. Given that 32.35% of the samples exceeded the 20-30 mgL^{-1} range, it is advisable to monitor nitrate concentrations closely and implement mitigation strategies (such as dilution or treatment) if nitrate levels approach harmful thresholds. Regular testing of water sources is essential to mitigate long-term risks associated with elevated nitrate concentrations.

Nitrite levels, on the other hand, were found to be within the desirable range, with concentrations ranging from 0.008 mgL^{-1} to 0.618 mgL^{-1} and an average of 0.251 mgL^{-1} .Nitrite is considerably more toxic than nitrate and can cause severe health issues in animals, particularly when consumed over extended periods. The low nitrite concentrations observed in this study suggest that the water quality in terms of nitrite contamination is largely safe for livestock, but continued vigilance is necessary to prevent any potential accumulation over time, particularly in water sources impacted by agricultural runoff or livestock waste. PO_4 levels, although low, remain an important consideration for long-term water quality management. PO_4 concentrations were relatively low, ranging from 0.017 mgL^{-1} to 0.131 mgL^{-1}, with a mean of 0.056 mgL^{-1}. These values are well below the upper acceptable limits, suggesting that PO_4 contamination in the drinking water is not a significant concern. However, elevated phosphate levels, if detected in future assessments, could indicate pollution from agricultural runoff, which may require treatment to prevent eutrophication in nearby water bodies.

Birds, animal feces, animal carcasses, runoff from exposed paddocks, extensive livestock operations, and sewage waste can contaminate livestock enterprises' water. Low productivity, illness, or animal mortality may arise from this. Local authorities should take necessary precautions to prevent consumption of these water bodies by livestock. A vital component of farm production and livestock health is the quality of the drinking water quality. Animals exposed to contaminated water may experience severe health issues that affect their general performance, growth rates, and reproduction ability. Farms may safeguard both animal health and financial sustainability by implementing sustainable water management techniques, monitoring water sources often, and addressing contamination threats. Farm owners should put in place routine testing procedures to keep an eye on the quality of the water and take appropriate measures when needed.

Maintaining the health and production of livestock depends on providing them with clean drinking water. Livestock farmers may increase the productivity and sustainability of their operations by providing for the unique requirements of various livestock species and by comprehending the intricate relationships between farm management techniques and water quality. Maintaining water quality and making sure cattle are healthy requires routine inspections, appropriate waste disposal, and the application of best practices.

Numerous elements, such as species, nutrition, temperature, and physiological state, affect how much water cattle consume. In order to meet the needs of each species, livestock farm managers must make sure that their animals have access to clean, sufficient water supplies. Maintaining the health, productivity, and well-being of livestock requires routine monitoring of the quality and quantity of water, especially during times of heightened demand like lactation, hot weather, or growth. Farmers may ensure animal welfare and farm efficiency by optimizing management procedures by knowing the unique water consumption requirements of their animals.

In conclusion, the majority of the water samples from the examined businesses meet acceptable water quality criteria; nevertheless, special attention should be paid to the nitrate concentrations, especially in water sources that are used for lengthy periods of time. Regularly checking for EC, pH, and other contaminants and putting remedial measures like water treatment or source diversification into place will assist guarantee the best possible water quality for the productivity and health of cattle. Animal welfare can be preserved and possible production losses brought on by low water quality can be reduced by following these procedures. Overall, the findings of this study emphasize the need for continuous monitoring of drinking water quality in livestock enterprises, particularly concerning nitrate and nitrite levels. Ensuring optimal water quality not only supports animal health but also enhances productivity. This results contributes to the growing understanding of the relationship between water quality and livestock performance, highlighting the importance of maintaining safe drinking water standards in agricultural settings to promote animal welfare and farm productivity.

Declarations

Ethical Approval Certificate is not required.

Author Contribution Statement

MEC: Investigation, conceptualization, formal analysis, writing the original draft, review and editing

MB: Data collection, investigation, conceptualization, review and editing

All authors have read and agreed to the published version of the manuscript.

Conflict of Interest

The authors declare no conflict of interest.

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