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MINERALS CONTENT OF WATER SOURCES FOR LIVESTOCK PRODUCTION IN ETHIOPIA

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ABSTRACT: Minerals are essential nutrients for sustainable livestock production and productivity. Water is a source of minerals to livestock production beside feed minerals. Presence of some minerals in water at higher levels will be toxic to animals and will affect animal health and productivity. So, it is essential to know the mineral content of water sources for livestock consumption in the country. This paper is based on a review of literature that was conducted on the mineral content and quality of water sources mainly for human consumption and other purposes in Ethiopia. Based on the literature values of the mineral content of the water sources and recommended values of minerals in livestock drinking water, the water sources were assessed for their suitability for livestock production. The review showed the presence of variation in the mineral content of the water sources in Ethiopia. In addition, there is variation in the mineral content of the water sources between the dry and the wet season. The total dissolved solids (TDS), Calcium, magnesium, chromium and zinc content of the water sources in Ethiopia is within acceptable levels for livestock consumption. But the sodium, chloride, copper, fluoride, iron, lead and manganese content of some of the water sources (river, well and lake) in the country is beyond the maximum recommended level. This demands implementation of mitigation mechanisms to reduce the mineral contents of water sources; otherwise, it will result in deleterious effects on the health and productivity of animals. Generally, there is a lack of adequate research on the mineral content of water sources for livestock production in the country. So, there is a need to conduct more research on the water sources being consumed by livestock in the country in the future.

Keywords: Ethiopia, Livestock production, Minerals, Season, Toxic elements, Water sources.

INTRODUCTION

Minerals are one of the essential nutrients for livestock production. Minerals are inorganic substances that are required for the maintenance of certain physicochemical processes that are essential to life (Soetan et al., 2010; McDonald et al., 2011). The major elements are required in higher amounts while the trace elements are required in smaller amounts by the animal body. There are certain trace elements in the animal body and plants with no known functions yet (McDonald et al., 2011). Minerals are important for health, reproduction and productivity of livestock. At optimum levels minerals enhance the health, reproduction and productivity of animals. If some minerals are supplied in excess amounts to livestock, they will adversely affect the health, reproduction and productivity of animals. Similarly, if animals are deficient in essential minerals (below the minimum threshold level); their feed intake, growth and development will be affected (Wu, 2018). Feeds and forages are the main sources of minerals for livestock production in the world (Suttle, 2010; Arthington and Ranches, 2021).

Water is not a major source of minerals for livestock production (Suttle, 2010). The minerals contained in water have a valuable contribution to animal nutrition (Chesworth, 1992; Saha and Pathak, 2021). Generally, water usually contains several minerals in it. According to Pagot (1993), water may contain ions of calcium, magnesium, sodium, chlorine and iron in it. These minerals are essential minerals for livestock production (Pagot, 1993). The mineral content of water sources varies depending on the source of water (Petersen et al., 2015).

The quality of drinking water for livestock affects the health and productivity of animals (Umar et al., 2014; Giri et al., 2020). Water can be contaminated by bacteria and algae. Contaminated water will affect the health of animals' especially young ruminant animals (Chesworth, 1992). Drinking water can be one source of livestock contamination with viruses, bacteria and parasites (Pagot, 1993). It is known that drinking water supplies several minerals for livestock.

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Some minerals (trace elements) are needed in smaller amounts by livestock. If these minerals and substances are supplied in excess to livestock the health as well as the productivity of the animals will be affected. For example, water containing above 2 g per litre sodium carbonate causes diarrhoea in cattle (Pagot, 1993). Drinking water that contains 4 g per litre sodium sulphate causes the same effect on livestock as water that contains high levels of sodium carbonate. It is reported that consumption of saline drinking water affects the health and productivity of livestock. According to Dryden (2008), livestock consuming high salinity drinking water near their limit of tolerance show reduced growth (or decline in body weight), occasional diarrhoea and general weakness. To alleviate the adverse effects of the high mineral content of water on livestock production knowledge on the mineral content of the available water sources is crucial. Currently, there is no adequate research on the mineral content of water sources for livestock consumption in Ethiopia. There are several studies in Ethiopia on the mineral content and quality of water sources for human consumption and other purposes. So, the objective of this paper is to review the available literature on the mineral content of different water sources and to assess their suitability for livestock production in Ethiopia.

Recommended levels of minerals in drinking water for livestock

Minerals are required by livestock for their normal metabolism. Minerals in livestock nutrition are divided into three groups based on their requirement by animals (Dryden, 2008). Major minerals are required in large quantity and the requirement of animals per day is expressed in g/kg or per cent. Trace minerals are required by animals in small quantities and the requirement of animals is expressed in mg/day or microgram per day. Minerals that are required in the diet less than 50 microgram per kg are known as ultra-trace minerals (Dryden, 2008). Sodium, K, Ca, Mg, P, S and Cl are major minerals. Generally, minerals are essential for livestock nutrition. However, if some minerals (trace minerals) are supplied to animals in higher amounts they will be toxic, affect production and health of animals. The recommended daily requirement of minerals in water for livestock production is given in Table 1.

The recommended maximum level of minerals and other constituents in water for livestock production is given in Table 2. If livestock drinking water contains minerals and other constituents beyond the maximum recommended level it will have adverse effects on their health and productivity.

Higher levels of minerals in water have variable effects in different livestock species (NRC, 1974) (Table 3). Short-term consumption of high level of minerals in water have less effects than log-term consumption. Different livestock species may react differently to high levels of minerals in water. In addition, the effect may vary between young and mature animals. In some cases, intake of high levels of minerals may not show measurable effects on growth, production and reproduction. But they may cause sub-cellular damage and increase the susceptibility of the animals to diseases and parasitic infection. In other cases, some minerals may not be toxic to livestock but they may accumulate in meat, milk and egg and may be harmful to humans that consume these animal products (NRC, 1974).

Mineral content of water sources in Ethiopia

Several studies have been conducted in Ethiopia to assess the quality and mineral content of different water sources. The studies that were conducted on water quality and mineral content of the different water sources in Ethiopia are given in table 4. Generally, the water sources in Ethiopia contain calcium, chloride, chromium, cobalt, fluoride, iron, lead, magnesium, nickel, potassium and sodium (Table 5).

Total dissolved solids (TDS) content

Saline water is water that contains dissolved soil minerals, trace minerals and other substances (Dryden, 2008). Almost all the water sources in Ethiopia contain less than the maximum recommended level of total dissolved solids (TDS) (Tables 2 and 5). The TDS content of different water sources in Ethiopia ranges from 32.5 to 3017.10 mg/l TDS (Table 5). The TDS level in Ethiopian water sources is lower than the NRC (1989) maximum recommended level as cited by Dryden (2008) for livestock production (Tables 2 and 5). But this level is higher than CCME (1987) recommendations as cited by Dryden (2008) (Tables 2 and 5). Generally, almost all the water sources in Ethiopia have less than the maximum recommended level of TDS in them based on NRC (1989) as cited by Dryden (2008) and ANZECC (2000) recommendations (Tables 2 and 5).

The total dissolved solids (TDS) level in water has variable effects on livestock species. High levels of TDS in water causes livestock poisoning or animals stop drinking this water and leads to loss of production (Drechsel et al., 2023). Tolerance of livestock species to saline water is given in table 6. Tolerance of animals to saline water depends on physiological state of the animal, type of feed eaten and the ability of the animal to concentrate its urine (Dryden, 2008). Generally, young animals are less tolerant than mature animals to saline water.

Table 1 - Recommended daily requirement of mineral elements in drinking water for different livestock species

Animal species	Water intake (liters)	Requirement daily (g)											
		Calcium	Cobalt	Copper	Iodine	Iron	Magnesium	Manganese	Phosphorus	Potassium	Selenium	Sulfur	Zinc
Beef cattle (450 kg)													
Nursing cow	60	28	0.74	79	1.7	0.99	14	49	22	90	0.74	10	0.15
Finishing steer	60	21	0.71	75	1.6	0.94	9	47	21	70	0.71	9	0.14
Dairy cattle (450 kg)													
Lactating cow	90	76	1.4	160	5.1	2.0	14	100	58	99	2.0	20	0.86
Growing heifer	60	15	0.7	80	1.6	1.0	9	50	16	70	1.0	10	0.43
Maintenance cow	60	12	0.5	51	1.6	0.64	9	32	12	45	0.6	6	0.27
Sheep													
Lactating ewe (64 kg)	6	7	0.18	13	1.0	-	1.5	-	5	-	0.1	3	0.25
Fattening lamb (45 kg)	4	3	0.13	9	0.8	-	1.1	-	3	-	0.1	2	0.18
Swine													
Growing (30 kg)	6	10	-	15	-	0.20	1.0	50	9	8	0.25	-	0.13
Fattening (60 – 100 kg)	8	17	-	20	-	0.26	1.0	66	14	9	0.33	-	0.17
Lactating sows (200 – 250 kg)	14	33	-	33	-	0.44	2.2	110	22	14	0.55	-	0.28
Horses (450 kg)													
Medium work	40	14	0.39	78	0.5	0.39	13	-	14	30	-	10	-
Lactating	50	30	0.40	78	-	0.39	15	-	24	35	-	10	-
Poultry													
Chicken (8 wk old)	0.2	1.0	-	14	0.035	0.008	0.05	6	0.7	-	0.01	-	0.005
Laying hen (60% production	0.2	3.4	-	-	0.037	-	-	-	0.8	-	-	-	-
Turkey (8 wk old)	0.2	1.2	-	9	-	0.006	0.05	6	0.8	-	0.02	-	0.007

*Source: NRC (1974)

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Table 2 - Recommended maximum levels of minerals and other constituents in drinking water for animals

Constituent / mineral	Unit	Recommendations			
		ANZECC (2000)	NRC (1974)	CCME (1987)	NRC (1989)
TDS	mg/l	3000 - 13000		3000	6500
pH	-	6.5 – 8.5**			
Nitrate N	mg/l	30.0	99.5	22.5	100.0
Calcium	mg/l	1000		1000	
Chromium	mg/l	1.0	1.0	1.0	1.0
Cobalt	mg/l	1.0	1.0	1.0	1.0
Copper	mg/l	0.5	0.5	0.5 – 5.0	0.5
Fluoride	mg/l	2.0	2.0	2.0	2.0
Lead	mg/l	0.1	0.1	0.1	0.1
Manganese	mg/l	0.01*			
Magnesium	mg/l	600.0			
Nickel	mg/l	1.0	1.0	1.0	1.0
Chloride	mg/l	1.0*			
Iron	mg/l	0.05*			
Phosphate	mg/l	-			
Potassium	mg/l	-			
Sodium	mg/l	50*			
Sulphate	mg/l			1000	
Zinc	mg/l	20.0	25.0	25.0	25.0

#Source: Dryden (2008); * Çapar et al. (2020); **NRC (2005), recommended range.

Table 3 - Effect of high levels of some mineral elements in drinking water in different livestock species

Mineral element	Level in drinking water	Livestock species	Effect on health and production
Copper	625 mg/L	Turkeys	Decreased feed and water intake; fatal
Fluoride	100 mg/L	Calves	Decreased feed intake, growth and Ca absorption, bone decalcified
	11.8 mg/L	Cattle	Mottled teeth
	20 mg/L	sheep	Decreased health; severe teeth mottling
Lead	100 mg/L	Calf	Died after 4 mo of drinking $Pb(NO3)_2$
Manganese	500 mg/L	Cattle	Reduced liver Fe but no toxicity
Iron	17 mg/L	Cattle	In pasture irrigation water; scouring; decreased milk production and body weight
Sulphate	100 mg/L	Cattle	Lost weight; decreased water intake by 35%; feed intake by 30%; and creatinine excretion by 12%
Zinc	2320 mg/L	Hens	Decreased water consumption; egg production stopped after 3 days; body weight decreased

*Source: NRC (1974)

Table 4 - Water quality studies considered in this review paper and type of water sources studied by the authors in Ethiopia

Type of water source	Statistics used in this study	Reference
Tap water	Mean	Amogne et al. (2015)
Well water	Mean	Rango et al. (2012)
Well water	Mean	Berhanu et al. (2021)
Well and spring water	Mean	Abegaz et al. (2021)
Tap water	Mean	Meride and Ayenew (2016)
Spring water	Mean	Reda (2015)
Well water	Mean	Gebresilasie et al. (2021)
Well water	Maximum	Beyene et al. (2019)
Well and spring water	Mean	Lewoyehu (2021)
Well and tap water	Mean	Garoma et al. (2018)
Well water	Mean	Alemu et al. (2017)
River, stream and well water	Mean	Berhe (2020)
River water	Mean	Eliku and Leta (2018)
Lake water	Mean	Dinka (2017)
Tap, well and spring water	Mean	Yasin et al. (2015)
Well and spring water	Mean	Shigut et al. (2017)
Spring, tap and well water	Median	Alemu et al. (2015)
River and Lake water	Mean	Shishaye and Asfaw (2020)
Lake water	Mean	Worako (2015)
Lake water	Mean/ Maximum	Goshu et al. (2017)

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Table 5 - Mean, minimum and maximum mineral and other constituents' content of the water sources reviewed in this review paper

Mineral	N	Mean	Minimum	Maximum
Total dissolved solids (TDS)	30	478.46	32.5	3017.10
pH	35	7.41	6.22	9.56
Calcium	24	50.06	2.52	142.0
Chloride	22	95.52	0.01	929.50
Chromium	4	0.39	0.03	0.75
Cobalt	1	1.09	-	-
Copper	13	0.51	0.01	1.20
Fluoride	19	2.85	0	15.08
Iron	23	0.72	0.03	2.77
Lead	8	0.25	0	0.81
Magnesium	23	15.61	1.35	70.43
Manganese	10	0.33	0.02	0.92
Nickel	3	0.41	0.05	1.08
Nitrate	27	11.36	1.05	45.73
Phosphate	27	0.79	0	9.10
Potassium	17	24.55	0.43	163.0
Sodium	21	271.0	6.36	2584.50
Sulphate	25	98.71	0.33	988.50
Zinc	9	0.59	0.08	1.55

N = Number of studies

Table 6 - Tolerance of livestock species to total dissolved solids (TDS) in drinking water (mg/L)

Livestock species	A: No adverse effects on animals expected	B: Animals may initially exhibit reluctance to drink or there may be some scouring, but stock should adapt without loss of production	C: Loss of production and decline in animal condition and health would be expected. Livestock may tolerate these levels for short periods if introduced gradually
Beef cattle (mature, on dry pasture)	0 – 4000	4000 – 5000	5000 – 10000
Beef cattle (feedlots)	0 – 4000	-	> 4000
Dairy cattle (mature, dry)	0 – 2400	2400 – 4000	4000 – 7000
Dairy cattle (milking)	-	-	3500
Sheep (mature, on dry pasture)	0 – 4000	4000 – 10000	10 000 – 13000[a]
Sheep (mature, dry, feedlots)	0 – 4000	-	> 7000[b]
Sheep (mature, dry confinement feeding)	0 – 4000	-	> 7000[c]
Sheep (weaners, lactating and pregnant on pasture)	0 – 4000	-	6600
Sheep (lambs, intensive feeding)	0 – 4000	-	> 4000
Horses	0 – 4000	4000 – 6000	6000 – 7000
Poultry	0 – 2 000	2000 – 3000	3000 – 4000
Pigs	0 – 4000	4000 – 6000	6000 – 8000

[a] Sheep on lush green feed may tolerate up to 13 000 mg/L TDS without loss of condition or production; [b] Intensive feeding for growth; [c] Confinement feeding for maintenance. *Source: Drechsel et al. (2023).

Macro mineral content of water sources

Calcium content

Calcium is one of the essential minerals for livestock production. It is required in larger amounts and it is crucial for bone and teeth development (McDonald et al., 2011). About 99% of the calcium in the animal body is found in the skeleton and teeth (McDonald et al., 2011). Water is one of the sources of calcium for livestock. Most of the water sources in Ethiopia contain calcium and the calcium content of the water sources in Ethiopia is less than the maximum recommended level of calcium for livestock (Table 2 and 5). Based on several studies in Ethiopia the calcium content of the water sources in Ethiopia ranges from 2.52 to 142.0 mg/l (Table 5). Calcium content of water determines its hardness or softness together with other minerals. Based on calcium content of water sources, the Ethiopian water sources are suitable for livestock production.

Chloride content

Chloride is an essential mineral for livestock production. Almost all of the water sources in Ethiopia contain chloride in them. Chlorine occurs in the gastric secretion and it is required for hydrochloric acid production in the stomach (McDonald et al., 2011). The chloride content of the water sources in Ethiopia ranges from 0.01 to 929.50 mg/l (Table 5). Most of the water sources in Ethiopia contain higher levels of chloride beyond the maximum recommended level (Table 2 and 5). According to Reda (2015), the spring water sources in Arbaminch area in Ethiopia contain higher levels of chloride (260 mg/l and above). This value is higher than the maximum permissible level of chloride for livestock drinking water (Table 2).

Magnesium content

Magnesium is essential for livestock production. Magnesium is important for enzymes in carbohydrate and lipid metabolism (McDonald et al., 2011). The magnesium content of water sources in Ethiopia ranges from 1.35 to 70.43 mg/l (Table 5). The maximum recommended level of magnesium in drinking water for livestock production is 600.0 mg/l (Table 2). All of the water sources tested in the country contain less magnesium than the maximum recommended level of magnesium in drinking water that is used for livestock production.

Potassium content

Potassium is essential for livestock production. It is important in acid-base balance, nerve and muscle excitation (McDonald et al., 2011). The potassium content of water sources in Ethiopia ranges from 0.43 to 163.0 mg/l (Table 5). Hora natural mineral water contains the highest level of potassium (163 mg/l) in it (Alemu et al., 2017). According to Berhanu et al. (2021), Arba Minch University main campus water wells contain high levels of potassium and nitrate in them. Higher levels of potassium (26.9 and 31.8 ppm) in livestock drinking water are also reported in the central highlands of Ethiopia (Mesfin et al., 2015). According to Wu (2018), excessive potassium intake in animals results in reduced feed intake and impaired growth, fatigue and muscle weakness, hypomagnesemia and even death.

Sodium content

Sodium is an essential mineral for livestock production. It is important in acid-base balance in the animal body (McDonald et al., 2011). The sodium content of the water sources in Ethiopia ranges from 6.36 to 2584.50 mg/l (Table 5). Some of the water sources have high levels of sodium beyond the maximum recommended level for livestock production (Table 2 and 5). The sodium content of Lake Basaka in 2015 as reported by Dinka (2017) is the highest (2587 mg/l) in Ethiopia.

Micro mineral and other constituents of water sources

Chromium content

In Ethiopia, Chromium is reported in four water sources (Amogne et al., 2015; Alemu et al. 2017; Eliku and Leta, 2018). Chromium supplements increase dry matter intake and milk yield in dairy cows (McDonald et al., 2011). According to Wu (2018), chromium regulates the metabolism of glucose and lipids in animals. In addition, it is involved in the synthesis of fatty acids and cholesterol in the liver. The chromium content of water sources in Ethiopia ranges from 0.03 and 0.75 mg/l (Table 5). Based on Dryden (2008), the chromium content of the water sources in Ethiopia is less than the maximum recommended level of chromium for livestock production. So, the water sources are safe for livestock production.

Cobalt content

Cobalt is required by micro-organism in the rumen of ruminant animals to synthesize Vitamin B12 (McDonald et al., 2011). From the literature reviewed one source of water was analysed for cobalt content in Ethiopia. The cobalt content of Hora natural mineral water is 1.09 mg/l (Alemu et al., 2017). This value is greater than the recommended maximum level of cobalt in drinking water used for livestock production (Table 5). The recommended maximum level of cobalt in livestock drinking water is 1.0 mg/l (Table 2). Higher levels of cobalt in livestock drinking water sources may have an effect on the health and productivity of animals. According to Wu (2018), excess cobalt in animals results in reduced feed intake, growth restriction, dermatitis, cardiomyopathy and goiter.

Copper

Copper is one of the essential minerals for livestock production. Copper is essential for the activity of several enzymes (Amine oxidase, Ascorbate oxidase, Tyrosine oxidase) (Wu, 2018). In addition, it is also required for the normal red blood cell formation (Pond et al., 2005). According to Pond et al. (2005), sheep and calves are more susceptible to copper toxicity than other species. On average, the copper content of Ethiopian water sources is 0.51 mg/l (Table 5). The copper content of the water sources (spring, river, well and lake) in the country ranges from 0.01 to 1.20 mg/l. The copper content of some of the water sources in Ethiopia is beyond the maximum recommended level for livestock production (Table 2 and 5). Especially cattle and sheep in rural areas of the country will be exposed to this toxicity in the country.

Fluorine content

Higher levels of fluorine are toxic for ruminant animals (McDonald et al., 2011). The fluoride content of the water sources in Ethiopia ranges from 0.0 to 15.08 mg/l (Table 5). Some of the water sources in the country contain higher

levels of fluoride beyond the maximum recommended level in drinking water for livestock (Table 2 and 5). The groundwater sources in Jimma Zone have higher levels of fluoride in them and defluorination of the water is recommended to use the water for drinking purposes (Beyene et al., 2019). According to Dryden (2008), the recommended maximum level of fluoride in drinking water for livestock is 2.0 mg/l (Table 2). Higher levels of fluoride in drinking water of humans affects the dental as well as the skeletal system. According to Rango et al. (2012), the water sources in the main Ethiopian Rift valley area in Ethiopia have higher levels of fluoride and there are signs of dental fluorosis on humans living in that area. According to the same source, based on preliminary data, milk intake reduces the adverse effects of high levels of fluoride intake (i.e. dental fluorosis). Based on this study milk intake reduces the severity of dental fluorosis in the study area. According to Wu (2018), chronic exposure to high levels of fluoride in the diet leads to dental fluorosis and osteoporosis in bones in dairy cows.

Iron content

Iron is important for haemoglobin formation and enzymes function in the electron transport chain (McDonald et al., 2011). Most of the water sources in Ethiopia contain iron. The iron content of the Ethiopian water sources ranges from 0.03 to 2.77 mg/l (Table 5). Some of the water sources in the country have higher levels of iron in them (Table 2 and 5). According to Eliku and Leta (2018), Awash River water contains higher levels of iron (2.2 mg/l) in it. This value is beyond the maximum recommended level of iron for livestock production (Table 2). To reduce the iron and heavy metals content of Awash River water establishment of a buffer zone is recommended in order to control entry of soil and agricultural nutrients into Awash River in Ethiopia. According to Gebreselassie et al. (2021), hand-dug well water samples in Kafta Humera District contain higher levels of iron. The iron content of the water sources in this area is beyond the maximum recommended level for use for livestock consumption (Table 2). To reduce the iron content of the hand-dug well waters for human consumption the adoption of water treatment technologies is recommended by the authors in this area. According to Berhe et al. (2020), the water sources in Kombolcha area also have higher levels of iron (0.54 mg/l) beyond the maximum recommended level for livestock production (Table 2). Higher levels of iron (0.33 to 89.95 ppm) in livestock drinking water is also reported in the central highlands of Ethiopia (Mesfin et al., 2015).

Lead content

Higher lead content of water affects the health of humans and animals. According to Wu (2018), excess lead intake inactivates several enzymes that are involved in energy metabolism, protein synthesis, DNA synthesis and repair, immunity and it enhances the production of reactive oxygen species. The lead content of the water sources in Ethiopia ranges from 0 to 0.81 mg/l (Table 5). The recommended maximum level of lead in drinking water for animals is 0.1 mg/l (Table 2). Hora natural mineral water and Awash River water contain higher levels of lead above the maximum recommended level in drinking water for livestock. According to Azimi et al. (2017), there are several methods to reduce heavy metals from water and wastewater sources. These include membrane filtration, ion-exchange, adsorption, chemical precipitation, nanotechnology treatments, electrochemical and advanced oxidation processes. Utilization of the best method based on cost and effectiveness on removal of heavy metals is recommended (Chowdhury et al., 2016).

Manganese

The water sources (spring, river, well and lake) in the country contain manganese in different levels (Table 5). The mean manganese content of the water sources in Ethiopian is 0.33 mg/l (Table 5). The manganese content of the water sources in the country ranges from 0.02 to 0.92 mg/l. Manganese is essential in the animal body and it is activator of many enzymes (McDonald et al., 2011). The manganese content of the water sources is higher than the value reported by Çapar et al. (2020), so safety measures have to be taken by the livestock producers to avert the toxicity. Higher levels of manganese (0.83 to 20.76 ppm) are also reported in livestock drinking water in the central highlands of Ethiopia (Mesfin et al., 2015). According to McDonald et al. (2011), growing pigs are less tolerant to manganese toxicity.

Nickel Content

Three studies report the nickel content of water sources in Ethiopia. The nickel content of the water sources in Ethiopia ranges from 0.05 to 1.08 mg/l (Table 5). The nickel content of Hora natural mineral water and Awash River water is 1.1 and 0.05 mg/l, respectively. Hora natural mineral water contains higher levels of nickel (1.1 mg/l) in it which is higher than the maximum recommended level of nickel in drinking water that is used for livestock production (Table 2). According to Azimi et al. (2017), there are several methods to reduce heavy metals from water and wastewater sources (membrane filtration, ion-exchange, adsorption, chemical precipitation, nanotechnology treatments, electrochemical and advanced oxidation processes). To reduce the high nickel content of the water sources, utilization of the best method based on cost and effectiveness on removal is recommended (Chowdhury et al., 2016). According to Alemu et al. (2017), Hora natural mineral water is used for human and livestock drinking purposes in the study area. It is believed that Hora natural mineral water is still used as natural medicine to cure people and livestock with various health problems (Alemu et al., 2017).

Zinc

Zinc is essential for livestock production. Zinc is a constituent of several enzymes and it is involved in enzyme activation and immune function (Pond et al., 2005). On average, the water sources in Ethiopia contain 0.59 mg/l zinc. The

zinc content of the water sources in the country ranges from 0.08 to 1.55 mg/l (Table 5). The zinc content of the Ethiopian water sources is within the acceptable range that is recommended for livestock production (Tables 2 and 5).

Nitrate

On average, the nitrate content of the water sources in Ethiopia is 11.36 mg/l (Table 5). The nitrate content ranges from 1.05 to 45.73 mg/l. The nitrate content of the water sources in the country is within acceptable range that is recommended for livestock production (Tables 2 and 5). According to Pond et al. (2005), nitrate concentrations in water as high as 1320 mg/l may be tolerated by livestock.

Phosphate

Water sources in Ethiopia contain phosphate. On average, the phosphate content of the water sources in the country is 0.63 mg/l (Table 5). The phosphate content of the water sources ranges from 0 to 4.60 mg/l. Generally, there is no maximum recommended level of phosphate in water that is used for livestock production.

Sulphate

Several water sources in Ethiopia contain sulphate. On average, the sulphate content of the water sources in Ethiopia is 101.07 mg/l (Table 5). The sulphate content ranges from 0.33 to 988.50 mg/l. This value is less than the maximum recommended level for livestock drinking water (Table 2). According to Pond et al. (2005), sulphates are more detrimental to animals than carbonates and chlorides.

Variation in mineral content of water sources in the country

There is variation in mineral and other constituents' content of the water sources in the country. According to Khatri and Tyagi (2015), ground and surface water quality is affected by both natural processes and anthropogenic influences. Natural processes include weathering of rocks, evapotranspiration, depositions due to wind, leaching from soil, run-off due to hydrological factors and biological processes in the aquatic environment. Anthropogenic factors include impacts due to agriculture, use of fertilizers, manures and pesticides, animal husbandry activities, inefficient irrigation practices, deforestation of woods and other activities. The TDS content of lake water is higher than other water sources (Table 7). In addition, the chloride, fluoride, phosphate, potassium, sodium and sulphate content of lake water is higher than other water sources. Other studies also reveal that there is variation in mineral content among the water sources (Fasae and Omolaja, 2014; Petersen et al., 2015).

Table 7 - Mean mineral and other constituents content variation among the water sources in Ethiopia

Variable	N	Tap water	N	River water	N	Spring or stream water	N	Well water	N	Lake water	N	Total mean
TDS	4	259.61	3	444.89	6	413.10	14	418.93	3	1212.42	30	478.46
pH	5	7.51	5	7.30	7	7.11	14	7.19	4	8.73	35	7.41
Calcium	3	29.97	3	75.18	5	70.27	9	55.23	4	9.37	24	50.06
Chloride	4	7.71	3	22.74	4	81.09	8	38.33	3	457.14	22	95.52
Copper	-	-	4	0.75	2	0.64	6	0.40	1	0.02	13	0.51
Fluoride	1	0.98	3	0.58	4	0.87	9	2.55	2	12.49	19	2.85
Iron	1	0.07	5	1.29	4	0.47	10	0.58	3	0.82	23	0.72
Magnesium	3	10.15	3	9.45	5	16.95	8	20.42	4	13.06	23	15.61
Nitrate	4	13.69	3	5.53	6	11.11	13	12.71	3	2.99	29	10.77
Phosphate	4	0.48	3	0.19	6	0.29	11	0.41	3	4.27	27	0.80
Potassium	2	13.07	3	4.67	3	1.80	6	32.01	3	59.92	17	24.55
Sodium	3	21.54	3	51.28	4	42.53	7	170.94	4	1026.48	21	271.0
Sulphate	2	1.17	3	76.77	5	76.89	12	41.01	3	452.82	25	98.71

N = Number of studies

Seasonal variation in mineral and other constituent content of water sources

There is seasonal variation in the mineral and other constituent content of water sources in the country. The TDS content of the water sources is higher in the dry season than in the wet season (Table 8). Generally, the chloride, nitrate, sodium and sulphate content of the water sources is higher in the dry season than in the wet season. On the other hand, the copper, fluoride, magnesium and potassium content of the water sources is higher in the wet season than the dry season (Table 8). According to Petersen et al. (2015), there is seasonal variation in the mineral content of water sources in the Northern Great Plains in USA. According to these authors the sodium and TDS content of stock water was higher

during the dry season. A study in Ethiopia shows that the heavy metals content of Awash River water varies between the dry and wet seasons (Eliku and Leta, 2018).

Table 8 - Seasonal variation in mineral content of the water sources in Ethiopia

Variable	N	Mean in dry season	Mean in wet season	N	Total mean
TDS	3	638.15	469.83	6	553.99
pH	4	7.68	7.19	8	7.43
Calcium	3	100.85	97.50	6	99.18
Chloride	3	27.89	9.57	6	18.73
Copper	4	0.56	0.78	8	0.67
Fluoride	3	0.004	0.006	6	0.005
Iron	4	1.10	1.0	8	1.05
Magnesium	3	6.57	9.21	6	7.89
Nitrate	3	13.27	4.96	6	9.11
Phosphate	3	0.006	0.004	6	.005
Potassium	3	0.91	0.97	6	0.94
Sodium	3	52.74	0.97	6	0.94
Sulphate	3	116.51	20.45	6	105.70

N= number of studies

CONCLUSION

The water sources in Ethiopia usually contain calcium, chloride, chromium, cobalt, fluoride, iron, lead, magnesium, nickel, potassium and sodium. There is variation in mineral content and other constituents of the different water sources in Ethiopia. The mineral content of the water sources also varies with season. The calcium, chromium, magnesium, zinc and total dissolved solids (TDS) content of the water sources in Ethiopia is within acceptable levels of these minerals and substances for livestock consumption. Some water sources in Ethiopia contain sodium, chloride, copper, fluoride, iron, lead and manganese beyond the maximum recommended level. This might affect livestock production and productivity unless safety measures are taken. Higher levels of minerals in drinking water may have adverse effects on livestock production. So, to make these water sources to have acceptable levels of these minerals, implementation of mechanisms (i.e. adsorption and chemical precipitation) that reduce the mineral content of these waters is recommended. Generally, as the current knowledge on the mineral content of the different water sources in Ethiopia for livestock consumption is inadequate further research is needed in this area in the country in the future to improve the mineral nutrition, productivity and health of livestock in the country.

DECLARATIONS

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Data availability
The datasets collected from research papers and/or analysed during the current study are available from the corresponding author on reasonable request.

Authors' contribution
Both authors reviewed the paper and contributed in writing this review paper equally.

Competing interests
The authors declare that they have no competing of interests.

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