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Chemical Composition of Drilled Wells Water for Ruminants

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Abstract

This study aimed to evaluate the chemical composition of water wells and to discuss the results in relation to nutritional requirements and tolerance limits of domestic ruminants. Ten samples of water wells (three replicates) from Brazilian semi-arid were collected and analyzed for their macro and trace minerals levels. A variation was found in the mineral composition of the waters and the macro minerals presenting highest levels were Cl, Mg, Ca and Na, while the predominant trace minerals were Fe and Mn. The concentration of the examined minerals can provide a small contribution to the animal as in the case of P or supply a considerable amount as Cl. The levels of total dissolved solids found in the majority of the samples can be tolerable for ruminants. In some of the samples the presence of Pb, Cd and Cr was found in concentrations higher than the upper recommended limit for ruminants.

Keywords: heavy metals, trace minerals, water source

1. Introduction

Water is a vital nutrient for all human beings and is considered a scarce resource in several regions in the world. In arid and semi-arid regions, animal production present great social and economic importance, where water availability constitutes one of the greatest challenges (Araújo et al., 2010).

Apart from water volumes, Beede (2012) points out that qualitative water parameters are important for the livestock production systems. Valtorta et al. (2008), Arjomandfar et al. (2010) and Visscher et al. (2013) report that ruminants can tolerate and accept water showing considerable salts concentration.

In addition, Brum and Sousa (1985) indicate that water can be an important source of mineral for ruminants. Minerals are important to grazing and feedlot animals as cattle, sheep and goats, and their deficiency may cause nutritional (Herdt & Hoff, 2011), reproductive (Mendonça Junior et al., 2011) and productive disorders (Tokarnia et al., 1999).

At the NRC (2001), it was also pointed out how important it is to observe the presence of minerals potentially toxic in the water such as Pb and Cd in order to avoid the supply to the animals. Cadmium and Pb are elements considered toxic to animals, which may accumulate in the body (Pareja-Carrera et al., 2014).

In the Brazilian semi-arid, subsurface waters can be an important source for the herds, especially from tube wells, but the physical-chemical composition of total dissolved solids (TDS), macro and trace minerals is scarce. On the other hand, it is important to understand the potential of water to be offered to animals and to propose measures to watering ruminants.

The objective was to examine the mineral composition of well water in the Brazilian semi-arid and to discuss the results based on the nutritional requirements and tolerance levels of ruminants.

2. Materials and Methods

This study lasted from March 2011 to March 2012. Water samples were collected from drilled wells in the Brazilian semi-arid in the municipalities of Jaguarari, Santa Brígida and Pintadas, in Bahia State; Lagoa Grande and Petrolina, in Pernambuco State; and Tauá, in Ceará State, Brazil. We collected ten samples of drilled wells water, with three replicates.

The mineral composition of all samples was determined at the Soil Laboratory of Embrapa Semiárido. The concentrations of potassium (K), phosphorus (P), calcium (Ca), magnesium (Mg), sulfur (S), copper (Cu), iron (Fe), manganese (Mn), zinc (Zn), sodium (Na), chlorine (Cl), nickel (Ni), lead (Pb), cadmium (Cd) and chromium (Cr) were determined according to the methodologies described by Nogueira et al. (2005). The concentrations of the minerals present in the water were obtained as mg/L.

Sodium and potassium levels were determined by flame photometry, whereas the concentrations of Ca and Mg were analyzed by titration, by determining the Ca contents, and subsequently the Ca + Mg contents, and the Mg concentration was defined as the difference. Chlorine and sulfur levels were determined indirectly, first by obtaining the concentrations of chlorines and sulfates and subsequently, by considering the atomic molecular weight, the concentrations of S and Cl were determined.

Phosphorus was determined using a molecular spectrophotometer while the determination of Cu, Fe, Mn, Zn, Ni, Pb, Cd and Cr was performed on an atomic absorption spectrophotometer (model Analyst 100, Perkin Elmer®). The data were presented as descriptive statistics (means and standard deviations).

3. Results and Discussion

The average macro mineral found in greater concentrations were Cl, Mg, Ca and Na with 1.010, 270, 240 and 230 mg/L, respectively. Chlorine was also the element with highest variation: from 430 to 2.580 g/L. The average of S was 100 mg/L, whereas K was 10 mg/L. Phosphorus content was found at very low concentration, at the order of 80 mg/L (Table 1).

The sum of macro and trace minerals, on average, was 1.940 mg/L (1.94 g/L) ranging from 750 to 4.660 mg/L. According to Brazilian legislation lesser than 0.5 g/L (500 mg/L) of total dissolved solids (TDS), in the water, is considered fresh, between 0.5 g/L to 30 g/L are classified as brackish and with more than 30 g/L are saline (CONAMA, 2005). Oliveira and Maia (1998) examined the physical and chemical composition of waters from different aquifers in the state of Rio Grande do Norte, (496 samples from water wells, 129 samples from subsurface waters) and observed 0.8 to 4.0 dS/m of electrical conductivity, equivalent to 510 to 2.560 mg/L of TDS, with 1.0 dS/m = 640 mg/L.

Nine of the ten samples found in the current study showed TDS levels that were within the limits proposed by Beede (2012), which are 3.000 mg/L, in order to avoid problems to the animals. Kattnig et al. (1992), Bahman et al. (1993), Valtorta et al. (2008), and Arjomandfar et al. (2010) examined the productive response of bovines receiving water containing high TDS levels, over 1.400 mg/L and observed no negative effect on productive response. Valtorta et al. (2008) observed an increase in water intake with 10.000 mg/L of TDS, which was also observed by Visscher et al. (2013) when studying the tolerance of bulls receiving saline water with 100, 5.000 or 10.000 mg/L of a NaC1 and KCl mixture.

According to McGregor (2004) bovines can also tolerate waters containing 2.300 to 11.000 mg/L of TDS, however, the author points out the necessity of adapting animals to saline water as an important factor to improve their tolerance. Abou Hussein et al. (1994) examined increased salinity up to 17.000 mg/L of TDS of total water intake of goats and sheep. Increased salt content from 9.500 to 17.000 mg/L of TDS reduced feed intake of both sheep and goats. Water intake with 9.500 mg/L of TDS reduced the feed intake of sheep but not of goats.

Table 1. Macro mineral concentration (mg/L) of the water from drilled wells in the Brazilian semi-arid

Sample	P	K	Ca	Mg	S	Na	Cl	TDS
1	30	10	210	80	80	120	430	960
2	-*	10	200	180	160	220	740	1,510
3	-*	20	220	540	200	180	1,430	2,590
4	250	20	160	290	40	220	1,060	2,040
5	10	20	510	660	120	760	2,580	4,660
6	40	10	180	130	110	260	740	1,470
7	140	20	450	140	70	140	670	1,630
8	-*	20	170	200	100	160	770	1,420
9	90	20	190	420	60	130	1,360	2,270
10	60	10	110	80	80	60	350	750
Mean	80	10	240	270	100	230	1,010	1,930
SD	80	10	130	200	50	200	650	1,110
Guidelines[a]	0.70	20	200	100	-[1]	300	-[1]	3,000
Guidelines[b]	-[1]	-[1]	> 500	> 125	-[1]	> 20	-[1]	> 3,000

Note. P* = phosphorus (mg/L); K = potassium; Ca = calcium; Mg = magnesium; S = sulfur; Na = sodium; Cl = chlorine; SD = standard deviation; TDS = total dissolved solids (macro and trace mineral sum); [a,b] Beede (2012) ([a]: concentrations above which problems likely could occur in livestock; [b]: possible cattle problems); [1]: non presented; * = non detected.

According to NRC (2001), TDS concentrations below 1.000 mg/L are considered safe in the bovine drinking water. Concentrations from 1.000 mg/L to 2.999 mg/L are generally considered safe, but may cause diarrhea in animals that are not adapted to these hydric sources. Water containing 4.600 mg/L of TDS may be rejected by the animals without previous experience, cause diarrhea or reduce productivity compared to the waters with lower TDS. Waters with 5.000 to 6.999 mg/L of TDS should be avoided by pregnant or lactating animals while waters with more than 7.000 mg/L should not be offered to cows (NRC, 2001).

Domestic ruminants have been used and accepted saline waters with considerable TDS levels (Valtorta et al., 2008; Arjomandfar et al., 2010), but there are differences among the species as to their tolerance. Masters et al. (2007) reported the order in which animals are tolerant to salinity as camels > sheep > goats > cattle. In studies conducted in the Brazilian semi-arid with cows and goats that ingest waters with 650 to 8.960 mg/L, it was also observed that ruminants accepted and tolerated waters of up to 8.960 mg/L of TDS (Albuquerque, 2012; Alves, 2012; Costa, 2012).

Costa (2012) did not find differences in productive performance of sheep, nor in intake and digestibility of DM and nutrients (neutral detergent fiber, crude protein, total carbohydrates and total digestible nutrients) when they were exposed to waters with 5.760 mg/L of TDS, superior to their found in the water of drilled wells in the current study.

Tolerance to saline water is also related to the different physiological stages of the animal (Squires, 1993; NRC, 2001), as well as the type of salt or the mineral, and not only the TDS (Squires, 1993; Valtorta et al., 2008). All the examined waters in the present study presented high Cl levels, considering the potential water intake of a lamb weighting 20 and showing 100 g/day of weight gain. The sodium supply through the brackish waters is also elevated compared to the daily requirements of this animal. Beede (2012) does not indicate maximum tolerable levels of Cl in the drinking water, but suggests 300 mg/L of chlorides (an ionic form of Cl). The average Cl levels in the water of drilled wells (1.010 mg/L) ranged from 350 to 2.580 mg/L.

In the case of Na, Beede (2012) suggests 300 mg/L as the maximum level which is higher than the average obtained in nine out of ten water samples. Only one of the samples showed more than 300 mg/L of sodium. For young ruminants (veal calves), Beede (2012) suggests significantly lower Na levels (20 mg/L) because this category can be less tolerant to sodium.

Sodium chloride is considered the main component of TDS, apart from other salts or elements that also contribute to TDS (NRC, 2001). In animal nutrition, sodium and chlorine are considered jointly and, on average, sodium levels found were high, representing 82.80% of mineral requirements of a lamb weighting 20 kg. Chlorine also showed high concentration, with a potential contribution to the animal that exceeds the daily requirements, especially when considering the waters with larger concentrations.

The excess of NaCl in the water can reduce feed intake and increase intake of water (Peirce, 1957; Wilson & Dudzinski, 1973). Increase in milk production (Solomon et al., 1995) and greater efficiency in milk production (Guadalupe et al., 2015) were observed in lactating cows receiving water desalinated compared to saline water. However, saline water has been used in domestic ruminants without health damage reports (Kii & Dryden, 2005; Valtorta et al., 2008; Visscher et al., 2013). According to Peirce (1957), Wilson (1975) and Squires (1993), 1.0 to 1.2% of NaCl in the water (10 to 12 g/1.000 g of the solution) does not cause health damages to the animals.

According to NRC (2005), it is described NaCl toxicity from intake of 4.0% of DM, corresponding to 25.20g/day for an animal eating 630 g/day of DM. Considering a daily water intake of 1.44 L and the average concentration observed in the current study, the NaCl intake through water would be 1.79 g/day, which are below the toxic level.

Considering each analyzed element and considering a growing ovine with 20 kg of body weight, showing 100 g/day of weight gain and presenting macro minerals requirements of (g/day) 1.50 P; 2.90 K; 2.30 Ca; 0.60 Mg; 1.10 S; 0.40 Na and 0.30 Cl (NRC, 2007) and an estimated water intake of 1.44 L/day (NRC, 2007), the daily supply based on the average levels of the analyzed water of drilled wells would be < 0.01%, < 1.0%; 15.03%; 64.80%; 13.00%; 81.80% and > 100.00%, respectively. Phosphorus and K showed a low potential of being supplied by water while Cl, Na and Mg presented a considerable potential to be supplied by water.

Brum and Sousa (1985) examined the mineral composition of drinking water for bovines and found low contribution, below 1% of the daily requirements of cows for Ca; P; Mg; Cu; Co and Zn. On the other hand, the contribution of K and Fe was 9.27% and 16.64%, respectively. In the case of Na, the contribution of saline water, considering a daily intake of 26 L/day would meet 209.73% of Na requirements, which may affect mineral mix intake.

Phosphorus causes environmental worries because, in water, in the form of PO_4, can promote eutrophication (Hubbard et al., 2004). Sinclair and Atkins (2015) identified an excess of phosphorus in the diet as one of the main mineral contaminants on dairy farms. Castillo et al. (2013) verified that high mineral concentration in the water may increase the supply to the animals and consequently in the waste, and according to these authors when the objective is to reduce mineral excretions in waste, it is important to consider the water supply.

Supplementing P through water is one of the strategies to supply this element to ruminants (Karn, 2001), especially when soluble phosphorous are used. The supply of minerals to animals is done through intake of feed, water and soils. According to Duarte et al. (2011) in Brazil, the deficiency of P is the most important among the minerals, resulting in reproductive disorders and reduction in the productive performance. In addition, Prasad et al. (2015) reported that P deficiency can promote bone disorders and weakness in the animals.

Calcium, magnesium, sulphur, sodium and chlorine may be supplied considerably through water wells. In the case of Ca, two of the analyzed water showed 450 and 510 mg/L, which could supply 28.17% and 31.93% of the daily requirements for an ovine of 20 kg with a weight. Considering a diet insufficient to provide mineral to animals, the intake of water can be favorable to complement the supply of minerals. However, when the diet is sufficient to provide minerals as reported by Tebaldi et al. (2000), the excessive supply of a particular element may cause antagonistic or toxic effects.

Beede (2012) proposed 200 mg/L of Ca as the upper limit in the drinking water for livestock farming. Five of the ten water samples showed Ca concentration below 200 mg/L while only one exceeded 500 mg/L. The maximum level of Ca in the diet is 1.50% of DM (NRC, 2005). Considering a lamb with an intake of 630 g DM/day, the daily Ca intake would be 9.45 g/day. The estimated water intake in the current study was 1.44 L/day, so the lamb could receive 0.35 g/day of Ca, which leaves a considerable amount of Ca to be supplied through the diet. Calcium is the main structural component of bones and teeth and its deficiency can cause rickets in young animals, osteomalacia in adults and milk fever in lactating animals. On the other hand, according to McDowell (1989), the excess can cause hypercalcemia or calcification of body tissues.

The highest concentration of Ca compared to the P promoted high Ca:P ratio in the drinking water. According to NRC (2007) the ideal Ca:P is described in the order of 2:1. In the analyzed water samples was 3:1 on average and one sample showed 51:1 of Ca:P. The imbalances in Ca:P can affect mineral absorption.

High levels of Mg were observed in the water of drilled wells. The water samples with greater Mg concentration (420; 540 and 660 mg/L) has potential to provide the requirements of a lamb and those with lower Mg levels (80 mg/L) showed considerable potential to contribute to the animal.

The Australian Water Resources Council (AWRC) (1969) and Ayers and Westcott (1994) suggested 250 to 500 mg/L, depending on the category and physiological state of the animal, as the maximum limits for the concentration of Mg in drinking water for ruminants. The average Mg level (270 mg/L) is higher the limits for lactating animals (250 mg/L). Two water samples showed Mg higher than 500 mg/L, which are above the recommendation. Beede (2012) suggested 100 and < 125 mg/L of Mg in the water as the maximum limit to be allowed for livestock farming and for bovines, respectively. Therefore, only two samples (80 mg/L) would be safe to the animals.

The negative effects of high levels of Mg are the possible restriction in feed intake and diarrhea (NRC, 2001). Fasae and Omolaha (2014) examined Mg levels in the drinking water for ruminants, verified that concentration of this mineral was slightly above the recommended (30 mg/L) and reported possible aesthetic problems. According to NRC (2001), water samples containing 0-60 mg/L of Ca and Mg are considered light, from 61 to 120 mg/L are considered moderately hard, with 121 to 180 mg/L hard and containing more than 180 mg/L very hard, but, on the other hand, hardness of water up to 290 mg/L was not associated with ruminant disorders.

High concentrations of Mg can also affect the absorption of other minerals such as P, as well as an excess of P and K can affect the absorption and metabolism of Mg (NRC, 2001). Magnesium levels above 0.60% of DM in the diet are considered as the maximum level of the daily intake, which may promote intoxication and cause urolithiasis, lethargy, diarrhea, reduction in feed intake and reduce the productive performance (NRC, 2007).

In the case of K, the percentage of the nutritional requirements potentially supplied by water would be low, lower than 1.0% for a growing sheep. Potassium levels varied from 10 to 20 mg/L in the water samples. All the water samples are within the maximum limits suggested by Beede (2012) for use in livestock farming. Potassium deficiency can promote reduction in growth, production and in feed intake (Puls, 1994).

Potassium is also important in the peripartum of lactating animals, especially those showing elevated milk production. In this phase, the animals are more susceptible to metabolic and nutritional disorders such as hypocalcemia and retained placenta (Greghi et al., 2014). A method to reduce hypocalcemia is to supply anionic diets promoting a negative cation-anion balance (Wilkens et al., 2012), which is calculated by the sum of K^+ and Na^+ subtracting the sum of Cl^- and S^{2-} in order to increase Ca absorption.

The potential contribution of water is considerable for S, in order to 26.08% in the sample with the highest concentration (200 mg/L). Beede (2012) does not give any recommendations for maximum limits of S, but suggested 300 mg/L of sulfate (SO_4) for use in livestock farming. Wright (2007) reported 1.000 g/L as a safe sulfate level but above 4.000 mg/L it can be potentially toxic. In all water samples S levels were below 200 mg/L, suggesting low concentration of SO_4, below 300 mg/L, which does not restrict the water intake.

High sulfate concentration may reduce water intake (Beede, 2006). According to Lardner et al. (2013) animals did not choose treated waters and preferred non-treated waters from wells with TDS < 3,000 mg/L and SO_4 < 2,000 mg/L. Sulfate levels of over 2.000 mg/L in the drinking water negatively influenced the animals' intake.

Beke and Hironaka (1991) reported the occurrence of poliencephalomalacia in Hereford calves receiving saline water with predominance of Na and S, suggesting that the elevated intake of S as the causative agent. In the diet, the maximum tolerable S level is 0.30% of DM (NRC, 2005) when the animals are fed with concentrated ingredients.

In the case of trace minerals, Fe showed the highest concentration in the analyzed water samples with 1.36 mg/L, with a large variation, followed by Mn, Pb, Ni, Zn, Cr and Cu, which averaged 0.27, 0.10, 0.08, 0.07, 0.04 and 0.04 mg/L. (Table 2). The potential contribution of water for a lamb with a body weight of 20 kg for Fe, Mn, Cu and Zn would be low, on average, 6.12%, 3.24%, 1.86% and 0.78%, respectively. The water sample with 0.23 mg/L of Cu has a potential to contribute to 10.68% of the daily requirements of a growing sheep.

The AWRC (1969), Ayers and Westcott (1994) and Beede (2012) suggest 0.50 mg/L as the maximum limit of Cu in drinking water for ruminants. The concentrations of Cu in all the water samples were below 0.50 mg/L. In nine of the ten analyzed samples, the concentrations of Cu did not exceed 0.03 mg/L, but in one of them, the concentration of Cu was 0.23 mg/L.

Copper is important to the animal as part of the enzymatic systems and its deficiency can cause anemia. The maximum tolerable level of Cu for a lamb is 15 mg/kg of DM when diets with normal concentrations of Mo (1 to 2 mg/kg of DM) and S (0.15% to 0.25%) are offered. Goats may have greater tolerance than sheep, while for cattle 40 mg/kg of DM is used as the maximum tolerable level. The minerals Cu, Mo, S and Fe should be considered jointly for the animal because the availability of Cu is reduced in the presence of the other three elements (NRC, 2005). According to Mohammed et al. (2014) Cu and P are the main limiting minerals for grazing ruminants in

Asia, Africa and Latin America and copper deficiency can cause growth reduction, bone disorders, diarrhea and infertility. The relationship between trace minerals is important to the absorption of minerals and according to Marques et al. (2013), increased levels of Fe, Mn and Zn limit absorption of Cu.

The water sample with greater Fe may contribute on the level of 50.40%, in the matter of the daily requirements of lamb with a body weight of 20 kg. Iron is the most abundant trace mineral of the body and constituent of hemoglobin. In addition, elevated intake of Fe can promote Cu deficiency in sheep and goats, with the maximum tolerable level of 500 mg/kg of DM (NRC, 2005). In other words, the observed levels in the water are well below the concentrations of Fe considered toxic. In Brazil, Fe has not been identified as a deficient mineral for ruminants, due to the production system based and tropical pastures (Peixoto et al., 2005; Malafaia et al., 2014).

Beede (2006) reported that Fe levels over 0.30 mg/L can reduce water feed intake by the animals and may also promote the proliferation of microorganisms, contributing to mud formation and affect the flux of water in tubing. The predominant form of Fe in the water is important for mineral nutrition because the ferrous form (Fe^{2+}) is soluble in water compared to the ferric form (Fe^{3+}), which is present in the food. The highly soluble iron can interfere in the absorption of Cu and Zn. In the current study, the presented values corresponded to total Fe. Four of the ten water samples showed Fe levels above 0.30 mg/L. One water sample showed 11.20 mg/L of Fe, much higher than the maximum suggested which may cause rejection of water. Al-Khaze'leh et al. (2015) examined water quality for goats in Jordan and also found high levels of Fe.

Genther and Beede (2013) examined the water intake, preference and behavior of dairy cows receiving water with different concentrations, valences and sources of Fe, supplying 0, 4 and 8 mg/L in the form of ferrous lactate. These authors observed that cows spent less time ingesting water with 8 mg/L of Fe in comparison to the other waters. They also observed that the cows' preference was not affected by the sources of P nor by the valences.

Table 2. Trace mineral concentration (mg/L) of the water from drilled wells in the Brazilian semi-arid

Sample	Cu	Fe	Mn	Zn	Ni	Cd	Pb	Cr
1	0.01	0.14	0.04	0.08	0.09	0.01	0.01	0.03
2	0.03	0.92	0.01	0.06	0.08	0.01	0.03	0.06
3	0.23	0.19	0.06	0.25	0.10	0.00	0.22	0.05
4	0.01	11.2	2.18	0.07	0.15	0.00	0.10	0.05
5	0.01	0.11	0.10	0.06	0.16	0.00	0.24	0.06
6	0.01	0.06	0.18	0.06	0.11	0.01	0.09	0.03
7	0.02	0.05	0.03	0.03	0.11	0.00	0.09	0.04
8	0.01	0.06	0.02	0.04	0.05	0.00	0.11	0.04
9	0.02	0.42	0.03	0.02	0.00	0.06	0.01	0.00
10	0.01	0.44	0.04	0.02	0.00	0.08	0.00	0.04
Mean	0.04	1.36	0.27	0.07	0.08	0.02	0.10	0.04
SD	0.07	3.48	0.67	0.07	0.05	0.03	0.08	0.02
Guidelines[a]	0.50	0.40	0.50	25.00	1.00	0.05	0.10	1.00
Guidelines[b]	> 0.60 to 1.00	> 0.30	> 0.05	> 25.00	-[1]	> 0.05	> 0.10	-[1]

Note. Mo* = molybdenum; Co* = cobalt; Cu = copper; Fe = iron; Mn = manganese; Zn = zinc; Ni = nickel; Cd = Cadmium; Pb = Lead; Cr = chromium; SD = standard deviation; [a,b]Beede (2012) ([a]: concentrations above which problems likely could occur in livestock; [b]: possible cattle problems); [1]: non presented.

Water samples with high levels of Mn may contribute on the level of 26.16%, when it comes to of the daily requirements for a growing sheep. According to Zhang et al. (2014), Mn is an essential trace element related to the organic matrix, a cofactor for important enzymes and is also involved in the amino acid metabolism. According to NRC (2007), Mn is described as being slightly toxic to ruminants even at high levels, but can promote antagonism between Mn and Fe. According to NRC (2005), the maximum tolerable level of Mn is 2.000 mg/kg of DM.

In drinking water for ruminants, Ayers and Westcott (1994), Runyan and Bader (1994) and Beede (2012) suggest that 0.05 mg/L of Mn is the maximum limit for domestic animals. Four water samples presented Mn concentrations above this recommendation. According to Beede (2012), concentrations above 0.05 mg/L of Mn affect water intake. Pérez-Carrera et al. (2007) found that 12.50% and 92% of water samples from water table and deep wells, respectively in dairy production systems in Argentina, showed Mn levels above 0.05 mg/L.

The Zn concentrations observed in all water samples were low in relation to the daily requirements of lambs. The water sample containing the highest concentration would supply 2.77% of the daily requirement of a lamb with a body weight of 20 kg. Zinc is involved in the composition of many enzymes that participate in various metabolic pathways and its deficiency can cause reproductive and skeletal disorders, skin and wool anomalies and anorexia (NRC, 2007). Ruminants can tolerate higher levels of Zn than non-ruminants. For sheep, the maximum tolerable level is 300 mg/kg of DM (NRC, 2005). Ten water samples showed Zn levels below 25 mg/L, suggested as the maximum tolerable (Beede, 2012). Smith (1980) examined the addition of zinc sulfate to drinking water for bovines (0.25, 0.50 and 1.0 g/L of Zn) and found a reduction in water intake by 8.0%, 35.0% and 54%, respectively, compared to the animals receiving water without the addition of Zn.

The average levels of Ni, Cd and Cr were below the maximum level suggested by Beede (2012), in the order of 1.00, 0.05 and 1.00 mg/L, respectively, while the concentration of Pb was at the suggested level (0.10 mg/L). Nickel and Pb showed higher average levels (Table 2). Chromium and nickel are elements required by the animals. Chromium is associated with stress responses, glucose metabolism and immune response, while nickel is required by the microorganisms of the rumen (NRC, 2007).

In all analyzed water samples the presence of Ni and Cr was found in concentrations below 1.00 mg/L. Cadmium levels above 0.05 mg/L and Pb above 0.10 mg/L were observed in two and three water samples, respectively. The average concentration of Cd also was below the limits of 0.05 mg/L established by the AWRC (1969) and by Ayers and Westcott (1994).

The NRC (2001) is more restrictive to these elements (heavy metals) and for Ni, Cd, Pb and Cr the suggested upper limits are: 0.25 mg/L, 0.005 mg/L, 0.105 mg/L and 0.10 mg/L, respectively. Cadmium and Pb averages observed in the water exceeded the recommended limits. Five of the ten water samples showed concentrations below the suggested levels for Cd and three for Pb.

Cadmium and Pb are elements considered toxic to the animals, accumulating in the body. Cadmium can cause renal damages (NRC, 2001) and Pb may promote hematologic, reproductive, immune, vascular and renal damages (Pareja-Carrera et al., 2014). They are also antagonists of others minerals. Cadmium interferes in the absorption and metabolism of Zn and Cu, while Pb affects the absorption and function of Zn (NRC, 2001) and the metabolism of Ca (Pareja-Carrera et al., 2014). In addition, Ca, P, Fe and Zn can reduce the absorption of Pb (NRC, 2001).

Valente-Campos et al. (2014) found a great variation in the upper permitted limits of minerals in the water for domestic animals in different countries. Cadmium, for instance, ranged from 0.005 mg/L to 0.14 mg/L. In Brazil, the presented limits varied from 0.01 to 0.05 mg/L. The multiple recommendations of maximum limit for macro and trace minerals makes difficult the understanding of physical-chemical parameters of the water for animals.

The analyzed water presented levels of TDS and other macro minerals that, in accordance with the presented information are not restricted for domestic ruminants as sheep, goats and cattle. However, its use may be dependent of several factors as animal species and physiological stage. In general, water samples presented heterogeneity in mineral composition with different potential contribution to the animal, but minerals levels can be considered in the animal nutrition, avoiding for example antagonistic effects.

The dilution of drinking water with fresh water or rainwater can contribute to use of saline water. The reduction of evaporation rates of water in the reservoirs is also an important strategy to prevent the increase of mineral in the water. Shirley (1985) reports that the bioavailability of minerals in water is similar to those observed in food. However, the mineral bioavailability in each type of water sample is an important information in order to verify the real potential to supply minerals for domestic ruminants.

Trace minerals were found to be more potentially restrictive in the water samples, especially Cd and Pb, while Fe and Mn were found at levels that can promote a rejection or a reduction in water intake by the animal or interfere in the absorption and metabolism of other mineral. Determination of mineral levels in the water is fundamental to promote a safe use of this natural resource. The spatial and temporal variation in the electric conductivity of subterranean waters in the Brazilian semi-arid region (Andrade et al., 2012) and the physical-chemical characterization of water should be more frequent. Additional research is required to establish the limits of the mineral in the drinking water of domestic ruminants.

4. Conclusions

Well waters showed a variation in mineral levels with a predominance of Cl, Mg, Ca and Na as macro minerals and Fe and Mn as trace minerals. The waters showed low levels of P and consequently presented low contribution potential in this mineral, but showed an elevated potential to supply chlorine. Total dissolved solids (TDS) levels in the majority of the samples are within the acceptable range, apart from having the presence of potentially toxic elements such as Cr, Cd and Pb in concentrations above the recommended.

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