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Assessment of Livestock Drinking Water Quality: A Case Study in a Special Environmental Protection Area

***Gökşen Çapar[1], Çiğdem Coşkun Dilcan[1], Şebnem Arslan[2]**

*[1] Ankara University, Water Management Institute, ANKARA
[2] Ankara University, Faculty of Engineering, Department of Geological Engineering, ANKARA

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Abstract: The livestock drinking water quality was evaluated for Gölbaşı Special Environmental Protection Area (SEPA) of Ankara city, which is subject to severe water quality and quantity problems as a result of urbanization and agricultural activities. Samples collected from 32 groundwater resources were analyzed and their conformity with international livestock drinking water quality standards was assessed. At least half of the samples were acceptable for parameters such as sulfate, sodium, chloride and boron. On the other hand, 34% of the samples were considered unsafe due to high nitrate levels. These results show that groundwater resources in Golbasi SEPA are adversely affected by agricultural practices. This study recalls the urgent need for a national regulation on livestock drinking water quality in Turkey.

Hayvancılıkta Kullanılan İçme Sularının Kalite Değerlendirmesi: Bir Özel Çevre Koruma Bölgesi Örnek Çalışması

Anahtar Kelimeler

Tarım,
Gölbaşı,
Hayvancılık,
Nitrat,
Su kalitesi

Öz: Kentleşme ve tarımsal faaliyetlerden etkilenen Ankara'nın Gölbaşı Özel Çevre Koruma Bölgesi'nde, hayvancılıkta kullanılan yer altı sularının kalitesi değerlendirilmiştir. 32 adet su kaynağından alınan örnekler analiz edilmiş ve uluslararası hayvancılık içme suyu kalitesi standartlarına uygunluğu değerlendirilmiştir. Örneklerin en az yarısı sülfat, sodyum, klorür ve bor gibi parametreler açısından uygun bulunmuştur. Öte yandan, örneklerin %34'ü, yüksek nitrat seviyeleri nedeniyle güvenilir bulunmamıştır. Bulgular, Gölbaşı bölgesindeki su kaynaklarının tarımsal faaliyetlerden olumsuz etkilendiğini göstermektedir. Bu çalışma, Türkiye'de hayvancılıkta kullanılan içme suyu kalitesine ilişkin bir yönetmeliğe ihtiyaç duyulduğunu göstermektedir.

1. Introduction

Livestock production is a big industry in modern agriculture, extending to downstream industry such as milk processors, upstream industry such as feed producers and relevant services such as veterinarians [1]. Having a global value as high as almost 900 billion dollars [2] on one hand, livestock production is one of the most significant causes of most serious environmental problems, with a share of 18% greenhouse gas emissions, on the other hand [3]. Along with problems such as deforestration, land degradation, climate change and air pollution, water shortage, quality and pollution are the water related issues of livestock industry, and the focus of this study.

Turkey is one of the leading countries in the field of agriculture with a growing food and agriculture industry, which corresponds to 9% of the overall gross value-added (GVA) and 25% of the employment levels in the country [4]. The share of livestock production in agriculture is about 35% in Turkey and 44% in European Union (EU) [5]. The number of cattle and sheep are given as 14.899.000 and 32.186.000, respectively [6]. Agriculture is the highest water consuming sector in Turkey, with a ratio of more than 70% of the total available water

Water Management Institute, Ankara University, Ankara
*Corresponding author, email: gcapar@ankara.edu.tr

potential. Therefore, existence of water with adequate quality and quantity is very important for sustainable crop production and livestock production.

Turkey, having a semi-arid climate, is under the risk of becoming a water-poor country by 2030 due to population increase and expected adverse impacts of climate change.

As a candidate country to the EU, Turkey has to adopt the environmental policy of EU and transpose the related legislation such as the Water Framework Directive (WFD) (2000/EC/60). The WFD promotes integrated management of water resources to reduce problems associated with excessive water abstraction, pollution, floods and droughts [7]. Turkey has to use her water resources wisely to minimize water stress in the future. The average precipitation is 643 mm per year in the country; however some regions suffer from water scarcity due to lower precipitation levels. Golbasi district, located at a distance of 20 km south of Ankara city, is one of these regions. It gets an average of 400 mm precipitation per year and has a terrestrial climate. The weather is cold and rainy in winters, whereas it is hot and arid in summers. These conditions result in water scarcity in the region. Ankara city has only a number of wetlands, two of which are in Golbasi district. These natural wetlands are named as Mogan and Eymir Lakes and these lakes are widely used for recreational purposes. Most of the creeks feeding Mogan and Eymir Lakes dry in summer.

Contamination of water resources occur naturally with elements such as boron in the region and pollution due to anthropogenic activities such as livestock production is common. Indeed, the share of Ankara in Turkey's livestock production is only 4% (cattle, sheep, goat and poultry) [8]. However, the region is of high importance since Golbasi is one of the fifteen special environmental protection areas (SEPA) of Turkey. Unfortunately, it has been under pressure resulting from urbanization and agricultural activities since 1990s. These activities adversely affect the quality of surface waters and groundwaters, and there is an urgent need to assess the quality of water resources used for livestock production in Golbasi district.

Water quality is very important for livestock production since it can affect both the health of the livestock and its total water consumption [9]. Besides various environmental factors, the animal's age, physiological condition and diet influence livestock water consumption. The water consumption might reduce if the odor and taste is objectionable and this might, in turn, reduce livestock feed intake and eventually affect weight gain [10]. Therefore, livestock water quality should be known in order to maintain productivity. Evaluation of water quality requirements for livestock drinking water is complicated due to the interactions of the previously mentioned factors and the recommendations should be used with expert judgment [11].

The water quality for livestock can be evaluated by several parameters including electrical conductivity (EC) and nitrate concentrations. According to some studies cattle select water based on flavor, sulfate [12], [13] and organic solid contents [14]. National Academy of Sciences (NAS) [11] and [15], emphasized that water salinity, measured by EC, should be less than 5000 μScm-1 in order to prevent physiological disturbance (Table 1). Salinity up to 8000 μScm^{-1} may be satisfactory for livestock; however this water may be refused by animals because of its taste or even if accepted, might cause diarrhea [15]. Sodium, calcium, magnesium, chloride, sulfate and bicarbonate are the ions which are not very toxic by themselves, yet concentrations should be monitored, since they might cause an increase in salinity. Sulfate salts are more harmful than chloride salts or carbonate salts since they are more likely to cause health problems [10]. For example, sulfate content higher than 2500 mgl^{-1} might cause diarrhea in livestock and might also cause reduction in copper availability in ruminants [16]. Moreover, Weeth and Hunter [17] reported reduced feed intake and weight loss in cattle when concentrations of 3493 ppm SO_4 were applied to the drinking water of animals. [9] recommended maximum sulfate levels of less than 1000 mgl^{-1} for adult livestock and less than 500 mgl^{-1} for calves.

Although sodium itself poses little risk to livestock, its involvement with sulfate might be risky. It has been reported by [18] that water with 10000 mgl^{-1} sodium sulfate (Na_2SO_4) caused severe reduction in water intake, diarrhea and weight loss in beef heifers compared with heifers provided water containing 4000 mgl^{-1} sodium sulfate. Water with 800 mgl^{-1} sodium can cause diarrhea and a drop in milk production in dairy cows [10].

Nitrate comes from nitrogen, which is a plant nutrient supplied by inorganic fertilizer and animal manure. Nitrate can contaminate groundwaters and persist there for long times, accumulating to high levels as more nitrogen is applied to the land surface every year [11]. High concentrations of nitrates in drinking water of livestock might be poisonous, however its intake from all sources should be considered while evaluating the threat solely from drinking water. For livestock waters, nitrates tend to accumulate as nitrites in the rumen when they are present in excessive levels. Nitrites absorbed into the bloodstream interfere with respiration since they first interfere with hemoglobin. Acute nitrate poisoning can cause labored breathing and rapid pulse. Chronic nitrate poisoning signs include reduced weight gain, decreased appetite and lower milk production [19].

Table 1. Guide to using saline waters for livestock [11] [15]

EC (µScm^{-1})	Comments
Less than 1500	These waters have a relatively low level of salinity and should present no serious burden.
1500 – 4999	These waters should be satisfactory however might cause temporary and mild diarrhea in livestock unaccustomed to them. They should not affect their health or performance.
5000 – 7999	These waters should be satisfactory however might cause temporary diarrhea or be refused by animals not accustomed to them.
8000 – 10999	These waters can be used with reasonable safety however should be avoided using for pregnant or lactating animals.
11000 – 15999	Considerable risk may exist in using for pregnant or lactating livestock or for the young species. In general, use should be avoided although older livestock may subsist on them under certain conditions.
More than 16000	These highly saline waters can not be recommended for use under any conditions because the risks are so great.

According to the guidelines, NO_3-N concentrations of 0-10 mgl^{-1} are safe for livestock, 10-20 mgl^{-1} of NO_3-N would still be safe if used with diet low in nitrates. On the other hand, 20-40 mgl^{-1} of NO_3-N could be potentially harmful if continuosly consumed, and 40-100 mgl^{-1} of NO_3-N is actually toxic to cattles. These levels may eventually affect production and fertility. Concentrations of NO_3-N higher than 100 mgl^{-1} are not recommended for use and unsafe for livestock consumption [9], [10], [11], [20] and [21]

For human consumption, special care must be given to nitrate. Ingestion of nitrate in drinking water by infants can cause low oxygen levels in the blood, which is a potentially fatal condition. For this reason, the U.S. Environmental Protection Agency (EPA) has established a drinking water standard of 10 mgl^{-1} nitrate as nitrogen [22]. The corresponding limit in Turkish drinking water standards is 25 mgl^{-1} [23].

Besides the aforementioned substances, there are other toxic elements and ions which should be monitored in livestock drinking water. These elements might occur either naturally or as a result of anthropogenic activities. The maximum allowable concentration limits [11] for such elements like arsenic, lead and mercury should not be exceeded in livestock water (Table 2).

Golbasi SEPA is located very close to Ankara, the capital city of Turkey, where livestock production and agriculture are still practiced. There are a total of 6.471 cattle, 11.241 sheep and 210.000 poultry in Golbasi SEPA. The annual water requirement of the livestock in the region is estimated to be 118.096 m^3 for cattle, 61.544 m^3 for sheep and 22.995 m^3 for poultry, making a total of 202.635 m^3 per year. This amount of water is obtained mostly from groundwater via dug wells, drilled wells, fountains (public taps at certain points of the villages), springs, etc. Irrigated agriculture is performed in 34 da of the study area, where a total of 30.458 da is used in whole Golbasi for agriculture. These figures show that area of irrigated agriculture accounts for less than 1% of the total agriculture area. However groundwaters are still polluted as a result of fertilizer application, which in turn are used for livestock production and even for human consumption in some cases. The uncontrolled use of these waters for long term may adversely affect the health of animals.

In Turkey, there is still no legislation in force to control the livestock drinking water quality. Farmers are either unaware or they do not pay attention to the quality of water they use, so there is a need to figure out the existing situation. To this end, the aim of this study is to determine the quality of water resources used for livestock production in Golbasi SEPA and to assess the suitability of these waters as livestock drinking water. Water quality of samples were evaluated in terms of parameters such as EC, pH, boron, nitrate, calcium, sodium, chloride, sulfate, and some heavy metals.

Table 2. Livestock water quality guidelines for selected parameters

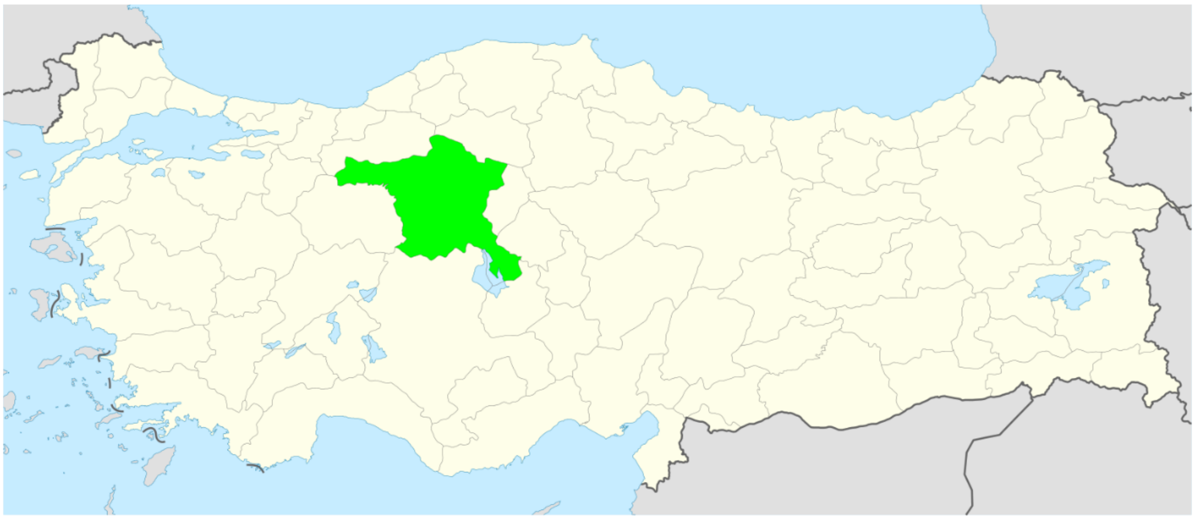
Substance	Safe upper limits (mgl^{-1})	
	NAS (1974) [11]	Others ([9] [10] [20] [21] [24])
Less than 1500	0.2	
Arsenic	0.01	
Cadmium	100	
Calcium	100	
Chloride	1	
Chromium	1	
Cobalt	0.2	

Copper	No limit		
Iron	0.05		
Lead	0.05		
Manganese	0.01		
Mercury	25		
Zinc	0.2		
Nitrate (NO3-N)	100	0 - 10	Safe for all.
		10 - 20	Safe with low nitrate feeds for livestock and cattle. Safe for poultry.
		20 - 40	Harmful for livestock and cattle with long periods of exposure.
		40 - 100	Risk of death for cattle.
		100 - 200	Not reliable, high risk of death.
		> 200	Can not be used.
Sodium	50	< 50	No risk for livestock and cattle. Low risk for poultry.
		50 - 100	Diuretic effects for poultry. Affects performance with high sulfates and chlorides in the water for poultry. Detrimental to broiler gains.
		100 – 800	Health risk for livestock when high sulfates are present in the water. Diarrhea and drop in milk production for cattle.
Sulfate	50	< 50	Safe for all.
		< 250	Safe, may have laxative effect for cattle, may reduce performance for poultry.
		< 1500	No harmful effect for cattle, may reduce performance for poultry.
		1500 - 2500	No harmful effect for cattle, may reduce copper availability in ruminants, temporary diarrhea, may reduce performance for poultry.
		2500 -3500	Very laxative, substantial reduction in copper availability for cattle, not recommended for poultry.

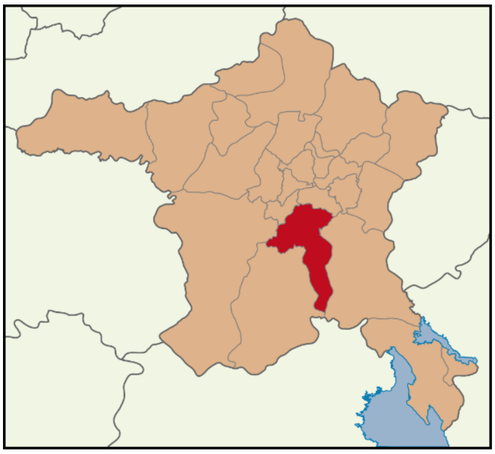
2. Material and Method

2.1. Sampling

The map of the study area is shown in Figure 1. In Golbasi SEPA, 7 villages (Ballikpinar-BP, Gokcehoyuk-GH, Hacihasan-HH, Karaoglan-KO, Ogulbey-OB, Yaglipinar-YP, Yurtbeyi-YB) were visited during the irrigation season (May-June) in 2012. The population and area of Golbasi SEPA are 40803 and 274 km^2. These figures are almost one-third of the population and area of the whole Golbasi district that is 115924 and 738 km^2, respectively. In Golbasi SEPA, the water resources used for livestock production were identified with the help of Golbasi Governorate District Directorate of Food, Agriculture and Livestock. A total of 32 samples were collected from several resources such as wells, lagoons and fountains. Samples were collected in 1 l polyethylene bottles and immediately sent to the laboratory for analysis. In most villages, the class of livestock was cattle and sheep. Poultry was the class of livestock only in one village, namely Ogulbey (a private company), the total number of poultry was much higher than cattle and sheep (Table 3).



(a)



(b)

Figure 1. Map of (a) Turkey showing Ankara city (b) Golbasi SEPA with a population of 40803 and area of 274 km^2 [1]

2.2. Water Quality Analyses

Samples were analyzed for EC, pH, boron, nitrate, calcium, magnesium, sodium, chloride, sulfate, and heavy metals such as arsenic, cadmium, mercury, chromium, copper, iron, manganese, lead and zinc. Analyses were carried out at the Irrigation Water Quality Analysis Laboratory of Soil Fertilizer and Water Resources Central Research Institute Turkish Republic of Ministry of Agriculture and Forestry.

EC was measured with a Jenway model electrical conductivity meter with temperature correction according to method TS 9748 EN 27888. Sodium was measured by a flame photometer. The color of the flame was measured at a wavelength of 589 nm following the procedures of the method TS 4530/T1. Calcium was measured by titration with EDTA according to method TS 8196. Boron was measured by the Karmin method using a spectrophotometer following the method TS 3661. Chloride was measured by Mohr method via titration with silver nitrate (method TS 4164 ISO 9227). Sulfate was measured according to barium chloride turbidimetric method. Heavy metals were analyzed by a Varian model ICP instrument.

Table 3. Characteristics of the study area in terms of water resource and the class of livestock

Village	Sample	Water resource	Livestock	
			Class	Number
Ballikpinar	BP-1	Fountain	Sheep	150
	BP-2	Dug well (12 m depth)	Cattle	10
Gokcehoyuk	GH-1	Fountain 1	Sheep	350
	GH-2	Fountain 2	Sheep	350
Hacihasan	HH-1	Dug well (10 m depth)	Cattle	100
	HH-2	Drilling well (80 m)	Cattle	650
Karaoglan	KO-1	Drilling well (110 m)	-	
	KO-2	Fountain	Sheep	60
	KO-3	Drilling well (130 m)	Cattle and sheep	120
	KO-4	Drilling well (125 m)	Cattle and sheep	100
	KO-5	Fountain	Sheep	120
	KO-6	Drilling well (110 m)	Cattle	25
	KO-7	Drilling well	Cattle	80
	KO-8	Drilling well	Cattle	80
	KO-9	Lagoon	Cattle	2500
Ogulbey	OB-1	Drilling well (125 m)	Cattle	125
	OB-2	Drilling well (45 m)	-	
	OB-3	Drilling well (170 m)	-	
	OB-4	Old network	-	
	OB-5	Drilling well (110 m)	-	
	OB-6	Drilling well (120 m)	-	
	OB-7	Fountain	Sheep	300
	OB-8	Drilling well (75 m)	Poultry	210000
Yaglipinar	YP-1	Drilling well (72 m)	Sheep	800
	YP-2	Old network	Sheep	400
	YP-3	Creek	Sheep	400
	YP-4	Fountain 1	Sheep	200
	YP-5	Fountain 2	Sheep	400
Yurtbeyi	YB-1	Drilling well (50 m)	Cattle	100
	YB-2	Fountain 1	Cattle	600
	YB-3	Old network	Sheep	1000
	YB-4	Fountain 2	Sheep	1000

3. Results

The results of the water quality analyses are presented in Figures 2-10 and Table 3. As seen from Figure 2, EC values are within the desirable range (Table 1) since the highest value is 3850 µS cm^{-1}. EC contents of 28 samples are less than 1500 µS cm^{-1}, which corresponds to 88% of all samples. According to the guidelines given in Table 1, these waters can be used safely for all classes of livestock and poultry. The remaining four samples have EC contents between 1500-5000 µS cm^{-1}, which means salinity is not a significant problem for these waters (Table 1). Samples BP-2, OB-2, OB-6 and YP-3 should be used with attention since these waters might cause temporary and mild diarrhea in livestock, especially in those unaccustomed to them. For OB-8, which is used to feed chicken, EC is slightly less than 1500 µS cm^{-1}, so it is acceptable.

The pH values vary between 7.1 and 8.4 (Figure 3), and they are suitable for livestock water. There are only few studies linking water pH with livestock health or performance issues and pH should fall between 5.0 and 9.0 [9], [25].

Nitrate concentrations are depicted in Figure 4. As seen, NO_3-N concentrations in water samples from the study area range between 2-205 mgl^{-1}. Half of the samples have NO_3-N concentrations lower than 10 mgl^{-1} and these samples are safe for consumption for all classes of livestock. Only 16% of the samples contain l0-20 mgl^{-1} NO_3-N, which can be considered as safe for all classes with low nitrate feeds and a balanced diet. Similarly, 19% of samples (BP-1, GH-2, OB-1, OB-5, YP-1, YB-2) contain 20-40 mgl^{-1} NO_3-N, which can be harmful for livestock and cattle if consumed for long periods. Although the ratio of samples having NO_3-N concentrations between 40-100 mgl^{-1} is as low as 6% (HH-1, OB-7), it is quite dangerous as it indicates risk of death. Similarly, about 9% of samples have NO_3-N concentrations higher than 100 mgl^{-1}, which are totally unsafe for livestock consumption. These samples were collected from Ballikpinar (BP-2) and Ogulbey villages (OB-2, OB-6). The government local authorities should take the necessary precautions to avoid consumption of these waters by the livestock and the villagers.

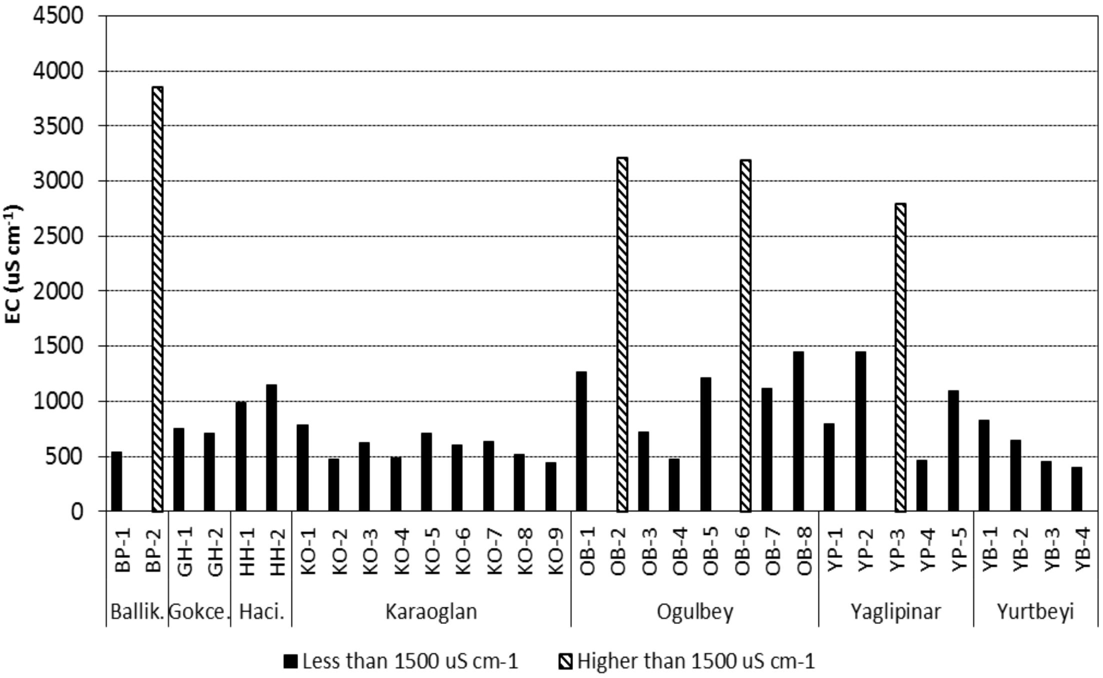


Figure 2. EC contents of samples

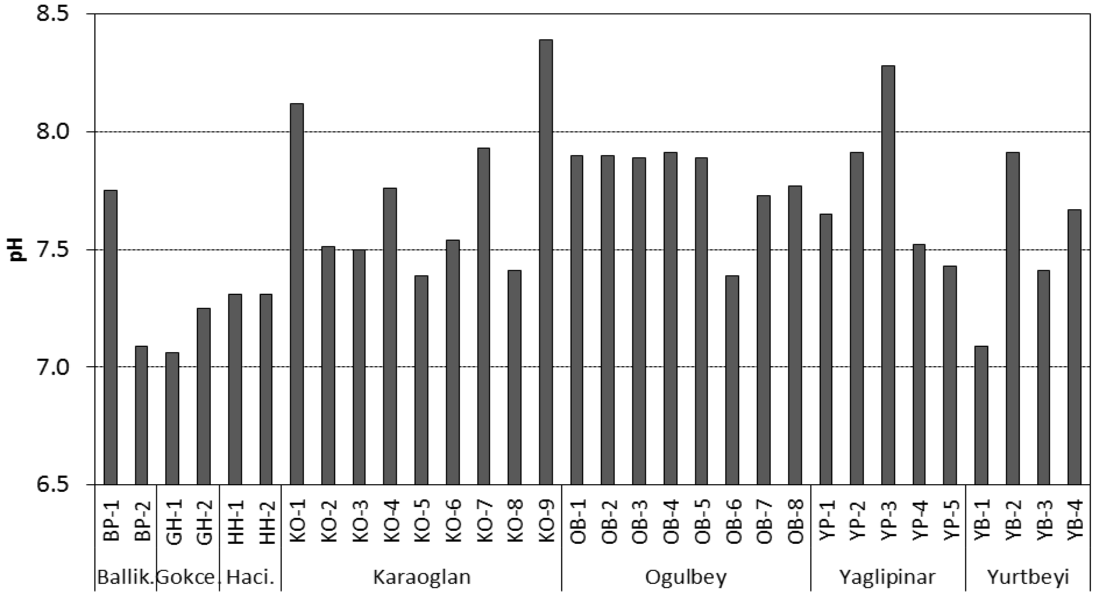


Figure 3. pH values of the samples

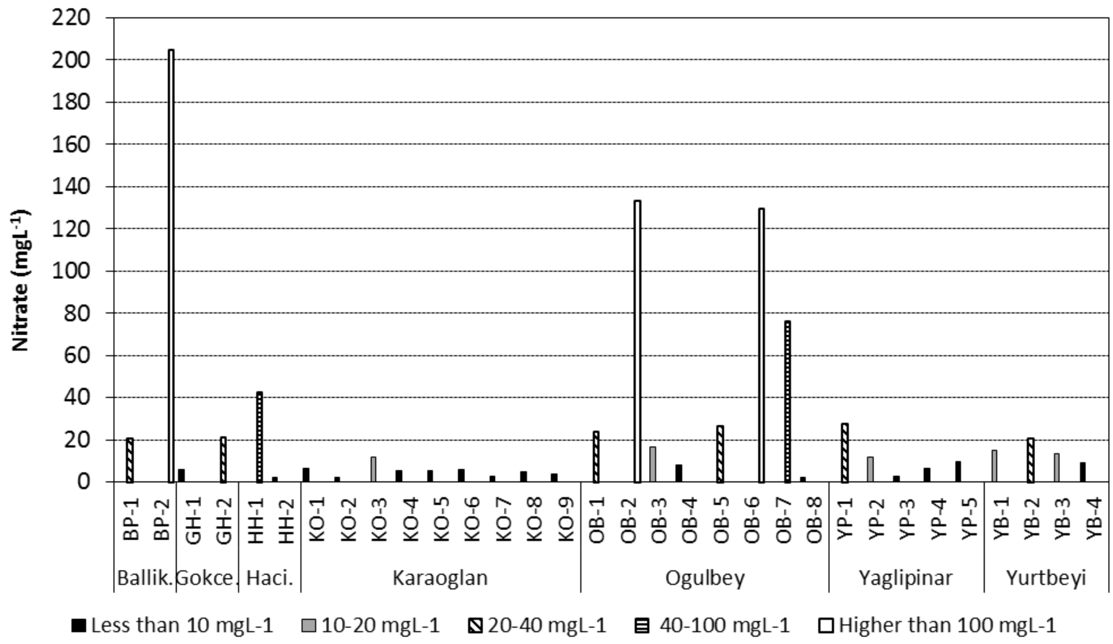


Figure 4. Nitrate concentrations of the samples

The distribution of nitrate concentrations in the study area is also depicted in Figure 5, which shows that Karaoglan village had the best water quality in terms of nitrate levels. These figures clearly show how diffused pollution can adversely affect the water resources. Nitrate concentrations resulting from agricultural activities (plant production) carried out in a relatively small area, i.e., 30.5 km^2, plus the livestock production activities performed mostly by the villagers in scattered locations indicate that the whole water resources of Golbasi SEPA (a total area of 274 km2) were polluted to some extent. A study conducted in Slovenia has shown that in regions with high intensity of livestock production, the net nitrogen balance surplus is much higher as compared to mineral fertilizer input [26]. So, nitrate pollution is a serious problem, and should be handled urgently.

As Turkey is a candidate country to the EU, there are several obligations we need to comply such as the WFD [7] and the Nitrate Directive [27]. The national regulation about nitrate control (Regulation no 29779) aims to avoid or reduce the nitrate pollution due to agriculture, and requires preparation of a code of good agricultural practice (COGAP), which should be used by the farmers voluntarily. Determination of nitrate sensitive zones is also required, which needs to be followed by the preparation of action programmes. These programmes should enable the control of fertilizer application areas. According to Nitrates Directive, surface waters and groundwaters containing or that could contain nitrate concentrations above 50 mgl^{-1} are identified as water polluted or water at risk of pollution. Hence, our results show that nitrate levels in four samples, namely BP-2, OB-2, OB-6 and OB-7 exceed 50 mgl^{-1}, and therefore they should be identified as polluted waters. Furthermore, the areas of land which drain into these waters may be identified as nitrate vulnerable zones. As these results rely on limited sampling period, there is a need to perform long term monitoring. In this regard, there is a long way to go in Golbasi district of Ankara in order to fully comply with the Nitrate Directive and other relevant legislation.

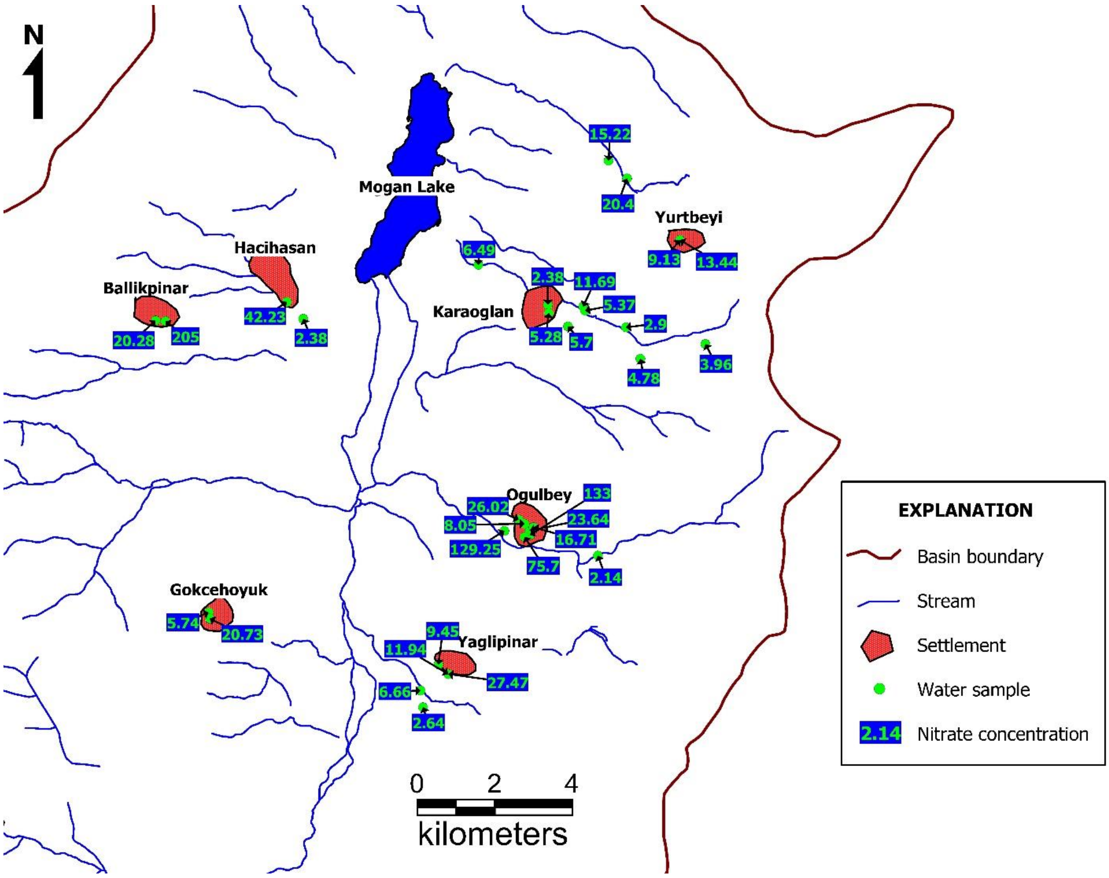


Figure 5. Distribution of nitrate in the study area

Boron (B) is an element known to be essential for plants for a long time [28]. It was thought to be an element not required by animals however there have been recent studies putting forward the importance of B supplementation in animal feeding systems[29], [30]. Besides, it was revealed that B eases fluoride toxicity in buffalo calves [31] and B supplementation prevents metabolic disorders during pregnancy in dairy cattle [32]. There is no evidence that it accumulates in livestock, however there are some studies reporting accidential ingestion resulting in death and intake of boron by fertilizer resulting in poisoned livestock [33]. Puls et al. [34] also reported that there were toxic signs in livestock which were started in 30 days after consuming 150-300 mgl^{-1} of B in drinking water.

According to the literature [11], the upper limit of boron in livestock waters is 5 mgl^{-1} (Table 2). If this concentration is exceeded, then the total boron content of the livestock diets should be investigated. According to Figure 6, 26 samples (81%) had boron concentrations less than 0.5 mgl^{-1}. The boron concentrations of three samples (BP-1, KO-7, OB-1) were close to 1 mgl-1, and the highest concentrations were observed in two samples, i.e., BP-2 and KO-1, with 1.9-2.0 mgl^{-1} of boron. These are lower than the suggested upper limit, therefore all of the samples from the study area can be considered suitable for livestock. These figures do not necessarily mean than there is no boron problem in the region. As Turkey lands are rich in boron, it is quite probable to have high boron concentrations in water resources. The reason for having acceptable boron concentrations in the study area is most likely the fact that sampling was performed mostly in existing water wells, which are thought to be drilled to the depth of safe boron limits.

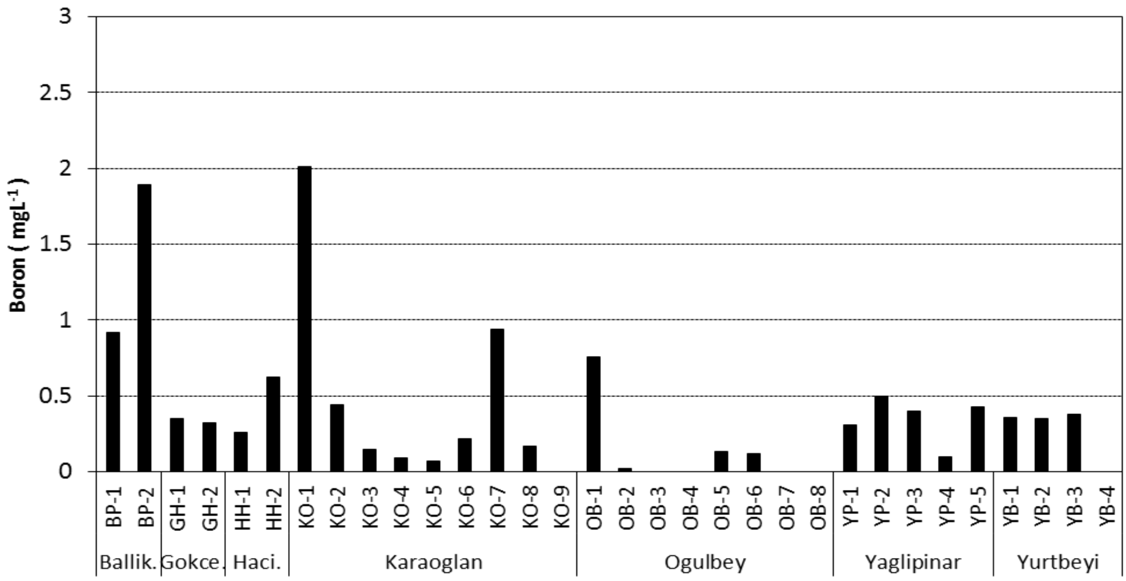


Figure 6. Boron concentrations of the samples

Regarding sulfate concentrations, it is clear from Figure 7 that 50% of samples had sulfate concentrations less than 50 mgl^{-1}, which is the safe level for cattle and poultry (Table 2). Sulfate concentrations of 10 samples were between 50-250 mgl^{-1}. These waters may have laxative effect for cattle, and they may reduce the performance of poultry. It can be stated that all samples are in general suitable for cattle since the highest sulfate concentration was 850 mgl^{-1}, which is below the limit of 1500 mgl^{-1} (Figure 7, Table 2). However, sulfate levels at 150 mgl^{-1} may potentially cause a drop in water consumption for livestock due to taste. As poultry production was performed by a company in Ogulbey, special attention should be given to the sulfate concentration of the sample OB-8. As seen from Figure 7, this value is as high as 131 mgl^{-1}, which may reduce the performance of chicken. The highest sulfate levels (680-850 mgl-1) were observed in four samples, namely BP-2, OB-2, OB-6 and YP-3.

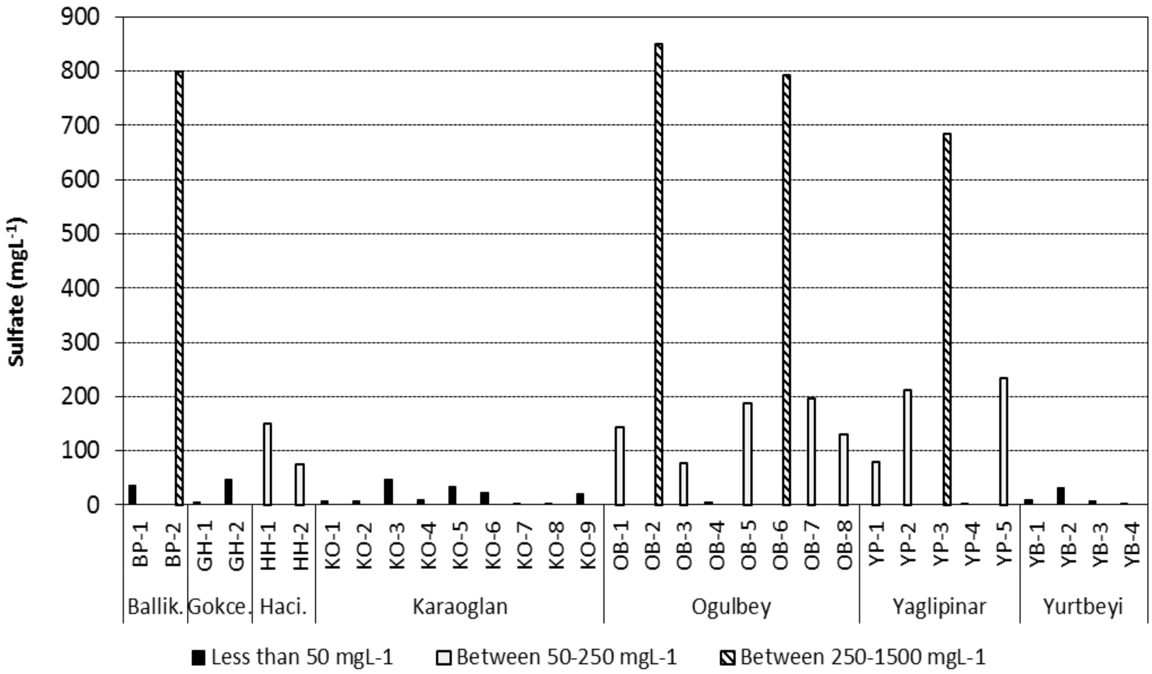


Figure 7. Sulfate concentrations of the samples

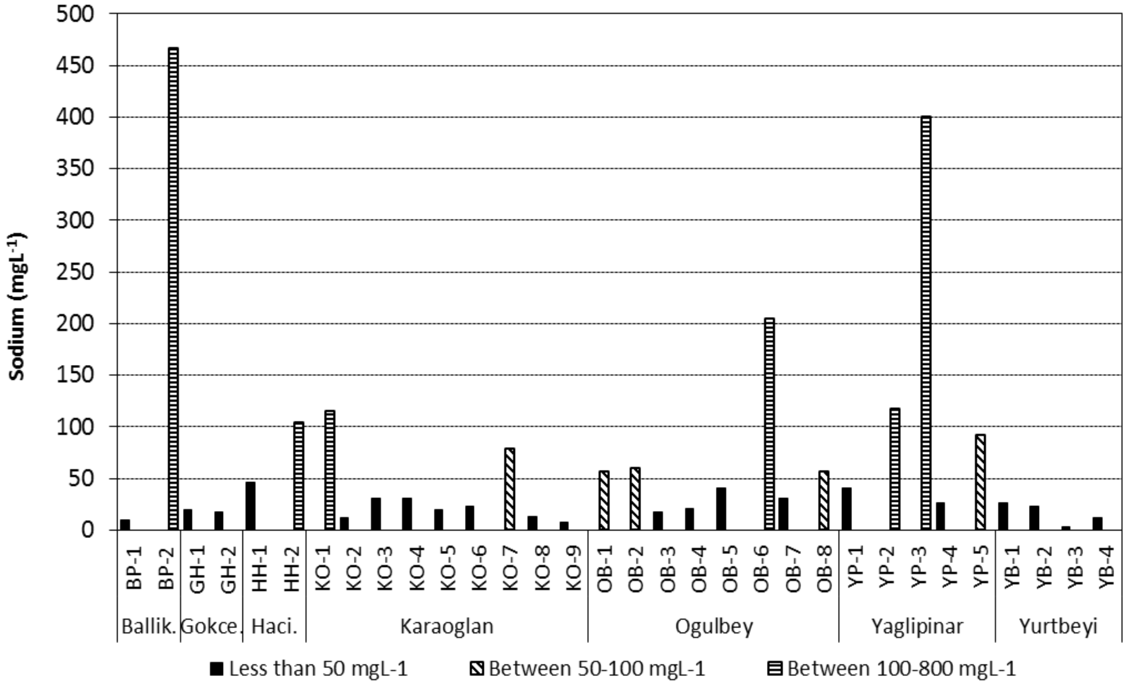


Figure 8. Sodium concentrations of samples

Sodium concentrations are given in Figure 8. As seen, sodium concentrations were less than 50 mgl^{-1} for 21 samples (66%), which indicates no risk for livestock and cattle, but low risk for poultry (Table 2). For five samples (KO-7, OB-1, OB-2, OB-8, YP-5), sodium was between 50-100 mgl^{-1}, which means these waters may have diuretic effects for poultry. These waters may affect performance of poultry if they contain high sulfates and chlorides in the water. For six samples (BP-2, HH-2, KO-1, OB-6, YP-2, YP-3), sodium was very high, i.e., 100-800 mgl^{-1}. These levels indicate health risk for cattle, especially when high sulfates are present in water. When sodium concentrations are considered together with sulfate concentrations, it can be stated that samples BP-2, OB-6 and YP-3 have the highest health risk for livestock, so these waters either need proper treatment to meet the relevant standards or be avoided from consumption.

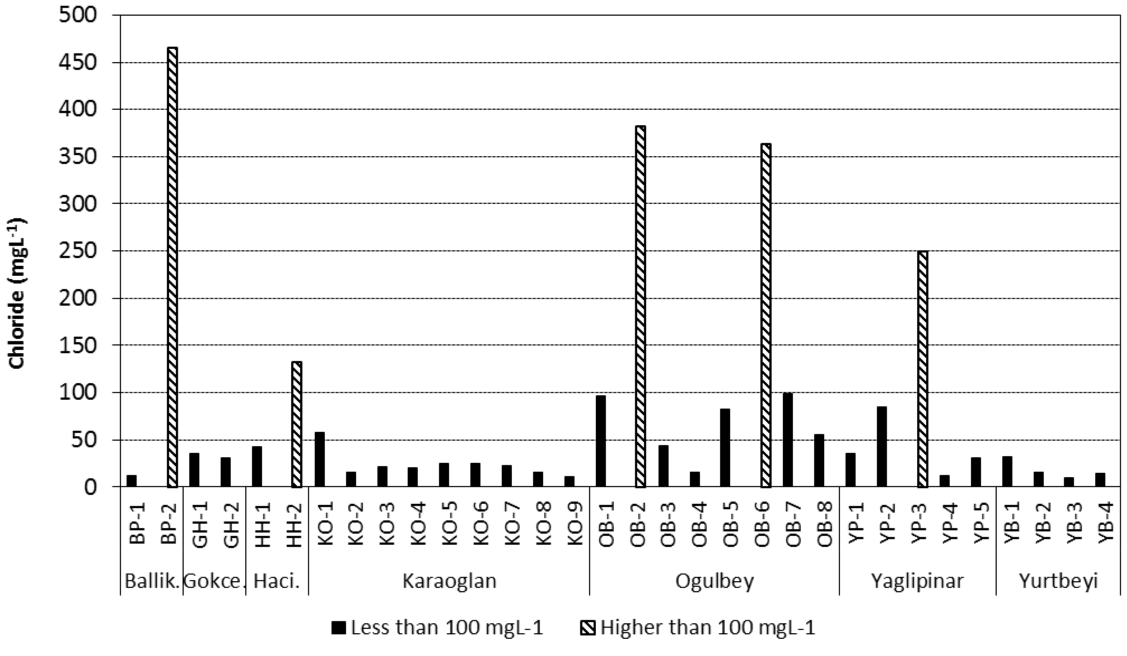


Figure 9. Chloride concentrations of samples

Chloride concentrations were also measured (Figure 9). As seen, 27 samples (84%) had chloride less than 100 mgl-1. Only five samples (BP-2, HH-2, OB-2, OB-6, YP-3) exceed this level. So, combined with high sulfate and high sodium levels, these samples with high chloride levels are expected to cause health risks for livestock.

Although there is no criteria for hardness in livestock drinking water, calcium concentrations were also measured (Figure 10). As seen, only two samples, BP-2 and OB-6 have calcium levels higher than the limit of 100 mgl^{-1} (Table 2). So, it can be concluded that all waters are acceptable regarding calcium contents.

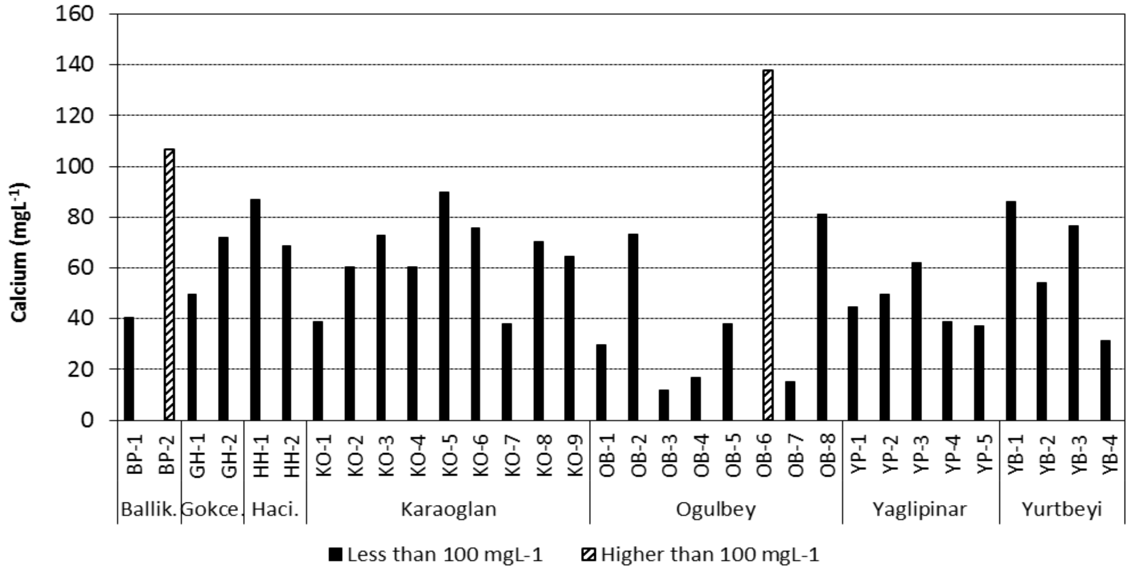


Figure 10. Calcium concentrations of samples

Heavy metal contents of selected samples are given in Table 4. Arsenic is a toxic element known to be poisonous for a long time. Its toxicity depends on its chemical form, inorganic oxides are considerably more toxic than organic forms. This element usually occurs in water as inorganic oxides [11]. The upper limit of arsenic in livestock drinking water is recommended to be 0.2 mgl^{-1} by [11] (Table 2). It should be noted herein that, after recent studies documented arsenic is a human carcinogen, WHO decreased the standard in human drinking water from 0.05 mgl^{-1} to 0.01 mgl^{-1} [35]. But there seems to be no attempt to reevaluate the standard of arsenic in livestock drinking water. According to Table 4, As concentrations in the samples are below the recommended value.

Table 4. Heavy metal contents of selected samples

Sample	AS	Cd	Co	Hg	Cr	Cu	Fe	Mn	Pb	Zn
	(ppm)	(ppm)	(ppm)	(ppb)	(ppb)	(ppb)	(ppb)	(ppb)	(ppb)	(ppb)
BP-1	< 0.01	< 0.01	0.0012	0.04	3.45	< 5.00	2.15	< 2.00	< 3.00	45.32
GH-1	< 0.01	< 0.01	0.0012	0.04	3.54	< 5.00	2.99	57.24	< 3.00	11.22
HH-2	< 0.01	< 0.01	< 0.001	0.054	3.4	< 5.00	7.24	< 2.00	3.47	10.10
KO-3	0.0018	< 0.01	< 0.001	0.22	5.76	< 5.00	2.87	< 2.00	< 3.00	< 2.00
KO-5	0.011	< 0.01	< 0.001	0.084	4.45	5.56	4.12	6.27	< 3.00	132.85
OB-1	0.015	< 0.01	< 0.001	0.027	5.03	< 5.00	1.65	< 2.00	6.07	2.59
OB-7	0.01	< 0.01	0.0024	0.021	5.14	< 5.00	1.91	< 2.00	3.10	< 2.00
YP-1	0.015	< 0.01	0.0014	0.047	2.46	< 5.00	3.44	< 2.00	< 3.00	9.16
YB-1	0.024	< 0.01	0.0017	0.015	4.85	< 5.00	21.28	< 2.00	3.42	2.52

Cadmium is another toxic element and it is not an essential one. NAS [11] suggested that the upper limit of Cd in livestock drinking waters should be below 0.01 mgl-1. According to Table 4, Cd is not detected in our samples. Cobalt is part of the vitamin B12 molecule and it is an essential nutrient. NAS [11] suggested an upper limit of 1 mgl^{-1} of cobalt in livestock waters in view of its toxicity and the maximum value is only 0.0024 mgl^{-1} in our samples. Copper is another essential trace element and it does not accumulate at excessive levels in muscle tissues. NAS [11] recommendation is 0.2 mgl^{-1} as an upper limit for copper in livestock waters (Table 2). This element was detected in one sample, KO-5 as 5.56 ppb (Table 4) and it is below the safe limits. Lead is a toxic element and animals don't need this element in their nutritions. NAS suggested an upper limit of 0.05 mgl^{-1} lead in livestock waters. The lead concentration in selected samples was 3-6 ppb, which is below the limit. Mercury is another toxic element and it tends to affect brain, liver and kidney in animals. The maximum allowable limit for mercury in livestock waters was set to 0.01 mgl^{-1} so that humans would not be exposed to as much as 0.5 mgl^{-1} of mercury through the consumption of animal tissue [11]. The highest mercury concentration was detected as 0.22 ppb for KO-3, which is also below the upper limit.

Zinc is relatively nontoxic to animals but still an upper limit of 25 mgl^{-1} is recommended by NAS [11] in livestock waters. The highest lead concentration was 133 ppb for KO-5, and all samples were below the upper limit. Chromium in drinking water is not absorbed by animals even in its soluble forms. Most of chromium in animal body is excereted in the feces and it does not seem to concentrate in animal tissue. Cr concentration of 1 mgl^{-1} in the drinking water of livestock is the upper limit according to NAS [11], and as seen from Table 4, the results are below the suggested limit.

According to the water quality data presented in this paper, it can be said that groundwater resources sampled in Golbasi (SEPA) were not affected from heavy metal contamination to a significant extent. Therefore, none of the heavy metal concentrations exceed the upper limits suggested by NAS [11]. On the other hand, agricultural activities were found to adversely affect the livestock drinking water sources in Golbasi SEPA district, as mostly evidenced fom the nitrate levels of samples.

4. Discussion and Conclusion

This study puts forward the existing situation in terms of water quality used for livestock production in Golbasi Special Environmental Protection Area of Turkey. The analysis of samples taken from 32 points revealed that only half of the samples are suitable for livestock production. The most problematic parameter, whose presence makes some of the samples unsafe for livestock consumption, is nitrate nitrogen. Actually, excessive levels of nitrates (> 40 mgl^{-1}) are present in 15% of the samples. Considering all the parameters studied, it can be concluded that the most polluted water resources are BP-2, HH-2, OB-2, OB-6 and YP-3. These waters should not be consumed directly by the livestock. Continuous/routine monitoring of these water resources should be performed in order to them safely.

Golbasi Special Environmental Area is suffering from water scarcity and water quality problems. In recent years, there has been an increasing demand for groundwater resources especially for agricultural activities. Indeed, drilling new wells is not allowed anymore in an attempt to protect the groundwater resources in the region. In near future water quality and quantity may adversely affect the agricultural activities in terms of finding suitable water resources for livestock production. Therefore, these resources should be protected and a regulation about drinking water quality for livestock should urgently be put in force in Turkey.

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