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Microbiological and Physicochemical Properties of the Potable and Utility Water in and Around Afyonkarahisar, Turkey

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Abstract: In the present study, several microbiological and physicochemical properties of the potable/utility water in central Afyonkarahisar and its counties were investigated. A total of 162 potable/utility water samples collected in June to August 2011 were used as the study material. Drop plate method was used for Total Aerobic Mesophilic Bacterial (TAMB) counts and psychrotrophic microorganism counts whereas membrane filtration method was used in the identification of *Pseudomonas* sp., enterobacteria, enterococcus, coliform bacteria, *E. coli* and *Cl. perfringens*. The microbiological findings of the study indicated that the total aerobic mesophilic bacterial counts in wells were <1 cfu/100 mL in 32% of all samples and <1cfu/250 mL in utility and spring-tap water samples. The aerobic bacterial count was 1-10 cfu/250 mL in 35% of the utility water samples, 11-100 cfu/250 mL in 24% and 101-300 cfu/250 mL in 9% whereas it was 1-10 cfu/250 mL in 56% of spring/tap water samples and 11-100 cfu/250 mL in 7% in addition to the fact that no samples were identified to have bacterial counts in the range of 101-300 cfu/250 mL. The well water bacterial count was determined as 1-10 cfu/250 mL in 46% of the samples, 11-100 cfu/250 mL in 15% of the samples and 101-300 cfu/250 mL in 11% of the samples. The psychrotrophic organism count was determined as <1 cfu/100 mL in well water samples and <1 cfu/250 mL in spring/tap water samples in 40% of the cases. The aerobic microorganism count was determined as 1-10 cfu/250 mL in 41% of the utility water samples as 11-100 cfu/250 mL in 13% and 101-300 cfu/250 mL in 7% whereas the aerobic microorganism count was determined as 1-10 cfu/250 mL in 50% of the spring/tap water samples and as 11-100 cfu/250 mL in 6% in addition to <1 cfu/250 mL in 101-300 cfu/250 mL range. The well water samples were determined to have 1-10 cfu/100 mL of aerobic microorganisms in 41% of the samples, 11-100 cfu/100 mL in 17% of the samples and 101-300 cfu/100 mL in 7% of the samples. The water samples (utility/spring-well water) collected from Afyonkarahisar and its provinces were determined to be contaminated by coliform bacteria (17%, 28 samples), enterobacteria (15%, 24 samples), enterococcus bacteria (12%, 20 samples), *E. coli* (7%, 12 samples), *Pseudomonas* sp. (13%, 21 samples) and sulfite reducing microorganisms-*Cl. perfringens* (14%, 23 samples) in the study. All the samples under investigation were determined to be clear, odorless with specific taste and color although some samples did not comply with the legislation in terms of the microbiological criteria. The results of the physicochemical analysis indicated that the average pH, turbidity (NTU), conductivity (μohm/cm) and total hardness (French Hardness Degree, f^0) values of the 162 samples were 7.28; 0.497; 362.11; 22.78, respectively. The average nitrite, nitrate, arsenic, chlorine, ammonium, floride, calcium and sulfate concentrations of the samples were determined as 0.09 mg L^{-1}, 17.25 mg L^{-1}, 0.26 μg L^{-1}, 0.83 μg L^{-1}, 0.15 mg L^{-1}, 0.94 mg L^{-1}, 18.11 mg L^{-1} and 20.42 mg L^{-1} respectively.

Key words: Physical properties of water, chemical properties of water, microbiological properties of water, NTU, chiorine

INTRODUCTION

The main purpose of establishing standards regarding water quality is to eliminate undesirable occurrences that might impose potential threat to public health. Removal of particles and chemicals water is especially important in order to prevent situations which might endanger public health (Anonymous, 1996). Approximately 1.1 billion people comprising 17% of the world population in 2002 cannot access healthy water resources as reported by the World Health Organization (WHO, 2002). It has been reported that having access to

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clean water remains among the most significant problems of the time due to an increase in world population and water consumption as well as due to climate changes (Guler and Cobanoglu, 1994; Anonymous, 2004a). Nearly 4 million contaminated potable water based diarrhea cases are diagnosed annually due to the limited availability of water to be used for personal hygiene and provision of it through insufficient sanitation and 2.2 million of these cases end up being casualties and deaths were more common among children below age 5 (WHO, 2000). The microbial quality of potable water remains among threatening basic issues in health. Potable water usually gets contaminated during the production, distribution and processing. The contaminating agents on the base or the surface of the water are caused by natural materials percolating from the soil, materials resulting from agricultural activities, leakage from sewage treatment facilities, industrial activities, uncontrolled leakage from wastelands, chemical accidents or disasters. Among the naturally formed contaminants, arsenic and manganese are formed by the inorganic compounds that stem from natural mineralization (Van Leeuwen, 2000).

It was reported that all members of a population including toddlers and people with health issues who are considered to belong to a potentially high risk group may be affected by possibly contaminated potable water. The presence of microorganisms in water was reported to be associated with inefficient or ineffective water treatment procedures, contamination following treatment or the presence of excessive amounts of organic materials in water (Mintz *et al.*, 1995).

The data available from the World Health Organization suggested that 80% of all diseases emerging in developing countries stem from drinking water. Contagious diseases spread through water possess a significant weight in causes of infant deaths (Watson, 1996). WHO (1992) reported that half of the population in most countries was affected by diseases which would be associated with shortages in available potable water or microbiological contamination of water. Although, the health risk associated with the presence of chemicals in water was reported to be less significant than that associated with microbiological contaminants in water, their significance would increasingly become apparent (Guler and Cobanoglu, 1994).

Water pollution is defined as the contamination of water with harmful materials including chemical, physical, bacteriological or radioactive components in measurable amounts or in amounts that would adversely affect health. It was reported that water was the material which would be polluted the most during the period starting at when it leaves its source until it reaches the time for its end use and the most frequently encountered pollution in water would be microbial contamination stemming from defecation waste with an associated risk of dangerous epidemics especially in urban areas. Fecal organisms are investigated in the evaluation of microbiological quality of potable and utility waters. Although, coliform bacteria were reported among the best indicators of contamination, the presence of *E. coli* in drinking and potable waters would point towards fecal contamination (Anonymous, 2008).

Legislation on Water for Human Utilization specified that *E. coli*, enterococcus and coliform bacteria should be undetectable in 100 mL of potable and utility water samples; *E. coli*, enterococcus and coliform bacteria as well as the fecal coliform bacteria; *P. aeruginosa* should be undetectable in 250 mL of drinking water whereas Salmonella should not be detected in 100 mL of water sample and *Cl. perfringens* should not be detected in 50 mL of water sample (Anonymous, 2004b).

In the present study, the microbiological, physical and chemical contamination of potable and utilization water (network/spring-tap/well) was investigated in Afyonkarahisar and its surroundings.

MATERIALS AND METHODS

The microbiological, physical and chemical quality of potable and utility water samples (network/spring-tap/well) in Afyonkarahisar and its surroundings (Basmakci, Bayat, Bolvadin, Cay, Cobanlar, Dazkiri, Dinar, Emirdag, Evciler, Hocalar, Ihsaniye, Iscehisar, Kiziloren, Sandikli, Sincanli, Sultandagi, Suhut) was investigated in the present study during June to August of 2011. For this purpose, 54 different network, 54 well, 54 spring/tap water samples (Sampled randomly, 3 in total, one of each type from every urban area) were collected as the material adding up to a total of 162 different water samples. The method of sampling and the selection of sample collection bottles were conducted as indicated in TS 266. The microbiological analysis of the samples that were transported to the laboratory in cool chain (+4°C) was conducted prior to the chemical analyses.

Microbiological analyses: Samples were analyzed for their total aerobic mesophilic bacteria, psychrotrophic bacteria counts, *Pseudomonas* sp., enterobacteria, enterococcus, coliform, *E. coli* and *Cl. perfringens* loads. The detection of *Pseudomonas* sp., enterobacteria, enterococcus, coliform, *E. coli* and *Cl. perfringens* in water samples (Presence-absence) was carried out through membrane filtration and the total aerobic mesophilic bacterial load and the total psychrotrophic aerobic bacterial load were determined by the Drop Plate Method.

Membrane Filtration Method: Water sample of known volume (100 mL for utility (well) water and 250 mL for potable (network-spring-tap) water) was filtered through the sterile membrane filter (Pore size 0.45 μm) placed in the membrane filtration equipment.

Pseudomonas sp. was identified via inoculation onto CFC Agar (Oxoid CM 559-CFC-Selective supplement-Oxoid SR 103) through membrane filtration, incubation at 30°C for 24-48 h followed by the oxidase test conducted on the formed colonies (Oxidase paper, Merck, 13303). The colonies with positive test results were evaluated as *Pseudomonas* sp.

The presence of enterobacteria was tested on Violet Red Bile Lactose-Glucose Agar (Oxoid CM0487) that of enterococcus bacteria were tested on Slanetz Bartley Agar (Oxoid CM 377) (Anonymous, 1993; FDA, 1998) and that of coliforms was tested on Violet Red Bile Lactose Agar (Oxoid CM0107) by placing filters in the petri dishes and by being incubated for 24 h at 37°C. The colonies with red-pink colored precipitates were evaluated as yielding positive test results. The presence of *E. coli* in both the potable water and the utility water was tested by placing the filters on TBX (Tryptone Bile X-glucuronide-Oxoid, CM0945) agar and incubating at 44.5°C for 24 h. The green colonies that were suspected for having *E. coli* growth were tested for Indol, Methyl red, Voges Proskauer and Citrate (IMVIC) (Rhodehamel and Harmon, 2001).

Filtered potable and utility water samples of 50 mL each were placed on Tryptose Sulfite Cycloserine Agar (Oxoid CM 0587-Selective supplement SR 0088E) (Anonymous, 2004a) and were incubated at 46°C for 20-24 h for the identification of *Cl. perfringens*. The black lecithinase (+) colonies that were formed were tested via Gram staining, catalase, mobility, nitrate reduction, acid phosphatase and CAMP tests (Anonymous, 2001).

Physical and chemical analyses

Physical analyses: Total hardness, turbidity, pH, conductivity, color, taste and odor characteristics of the water samples were investigated. The total hardness was determined spectrophotometrically (Merck Spectroquant Multy UV Spectrophotometer) and pH was determined using Thermo Orino 3 Star pH meter (25±3°C). The conductivity of water was determined using a conductometer (Zeta-Meter 3.0) and the turbidity was measured using a turbidometer (VELP-115). The color, taste and odor analyses were conducted organoleptically (FDA, 1998).

Chemical analyses: Nitrite, nitrate, arsenic, chlorine, ammonium, fluoride, calcium and sulfate concentrations were measured spectrophotometrically (Merck Spectroquant Multi UV Spectrophotometer).

RESULTS AND DISCUSSION

A total of 162 water samples (3 from each location; network, spring and well water samples at every location) were collected from the city center of Afyonkarahisar and its surrounding town centers during June to August 2011 and were used as the material. The study results of the microbiological analysis conducted on the network, spring/tap and well water samples which were collected in Afyonkarahisar were displayed in Table 1-5.

The results of the physicochemical analyses indicated that all samples were clear, odorless with specific color and taste and thus complying with the legislation. The results of the physicochemical analysis of the samples were provided in Table 6 and 7.

Table 1: The percent ratio and the quantitative distribution of the total number of aerobic and psychrotrophic microorganisms in potable and utility water samples in Afyonkarahisar

		Coliform		Enterobacteria		Enterococcus		*Pseudomonas* sp.	
Water source	N	n	%	n	%	n	%	N	%
Network (cfu/250 mL)	54	9	17	7	13	5	9	8	15
Spring/Tap (cfu/250 mL)	54	4	7	4	7	3	6	5	9
Well (cfu/100 mL)	54	14	26	12	22	12	22	8	15

N: Number of samples; n: number of samples with positive test results in N; '-': Not detected in N

Table 2: The percent ratio of several indicator microorganisms in potable and utility water samples collected in Afyonkarahisar

			Quantitative bacterial contamination							
			No microbial growth		1-10**		11-100**		101-300**	
Bacteria	Water source	N	n	%	n	%	n	%	n	%
Aerobic mesophilic bacteria	Network	54	17	32	19	35	13	24	5	9
	Spring/Tap	54	20	37	10	56	4	7	-	-
	Well	54	15	28	25	46	8	15	6	11
Psychrotrophic bacteria	Network	54	21	39	22	41	7	13	4	7
	Spring/Tap	54	24	44	27	50	3	6	-	-
	Well	54	19	35	22	41	9	17	4	7

N: Number of samples; n: number of samples with positive test results in N; '-': Not detected in N; *(<1 cfu/100-250 mL); **(cfu/100-250 mL)

Although, none of the samples were determined to have arsenic concentration above the limits allowed in the legislation (10 μg L^{-1}) in 7 of the town well water samples arsenic was detected at an average concentration of 0.83±2.12 μg L^{-1}. In 5 of the town well water samples the ammonium concentration exceeded the limit allowed in the legislation (0.5 mg L^{-1}). Fluorine concentration was below the maximum allowable limit in all samples (1.5 mg L^{-1}). The calcium concentration was determined as 21.33, 14.69 and 20.64 mg L^{-1} in city center network, spring/tap water and well water samples respectively and as 20.10, 14.91 and 19.08 mg L^{-1} in town network, spring/tap water and well water samples, respectively.

The microbiological data obtained from this study indicated that 32% of all of the well water samples had <1 cfu/100 mL total mesophilic bacteria and network, spring/tap water samples had <1 cfu/250 mL. Aerobic microorganism content was determined to be in the range of 1-10 cfu/250 mL in 35% of the network water samples, 11-100 cfu/250 mL in 24%, 101-300 cfu/ 250 mL in 9% of the samples and in the range of 1-10 cfu/250 mL in 56% of the spring/tap water samples and in the range of 11-100 cfu/250 mL in 7% of the samples whereas no samples in the range of 101-300 cfu/250 mL could be detected. In 46% of the well water samples the

Table 3: The percent ratio of *E. coli* in the samples

Water source	N	*E.coli* n	%
Network*	54	3	6
Spring/Tap*	54	2	4
Well**	54	7	13

N: Number of samples; n: number of samples with positive test results in N; *(cfu/50 mL); **(cfu/100 mL)

Table 4: The percent ratio of *Cl. perfringens* in the samples

Water source	N	*Cl. perfringens* n	%
Network*	54	8	15
Spring/Tap*	54	3	6
Well*	54	11	20

N: Number of samples; n: number of samples with positive test results in N; *(cfu/50 mL)

Table 5: Distribution of the index and the indicator microorganisms in samples throughout the city center and nearby town centers

Settlements	Water source	N	Aerobic mesophilic bacteria n	%	Psychrotrophic bacteria n	%	Coliform n	%	Enterobacteria n	%
City centers	Network	3	1	33	1	33	-	-	-	-
	Spring/Tap	3	1	33	1	33	-	-	-	-
	Well	3	2	66	2	66	1	33	1	33
Town centers	Network	51	36	71	32	63	9	18	7	14
	Spring/Tap	51	33	65	29	57	5	10	4	8
	Well	51	37	73	33	65	13	25	12	24

Settlements	Water source	N	Enterococcus n	%	*E. coli* n	%	*Pseudomonas* sp. n	%	*Cl. perfringens* n	%
City centers	Network	3	-	-	-	-	-	-	-	-
	Spring/Tap	3	-	-	-	-	-	-	-	-
	Well	3	1	33	-	33	-	-	1	33
Town centers	Network	51	5	10	3	6	8	16	9	18
	Spring/Tap	51	3	6	2	4	5	10	3	6
	Well	51	11	22	7	17	8	16	10	20

N: Number of samples ; n: number of samples with positive test results in N; '-': Not detected in N

Table 6: Results of several physical analyses conducted on the water samples

Settlements	Water source	Degree of hardness (°f)	pH	Turbidity*	Conductivity**
City center	Network	26.43	7.13	0.207	125.83
	Spring/tap	19.10	7.10	0.215	172.28
	Well	18.87	7.12	0.890	526.13
Town centers	Network	30.27	7.15	0.147	425.91
	Spring/tap	16.64	7.40	0.174	260.48
	Well	21.65	7.32	1.800	415.38

*NTU: Nephelometric Turbidity Unit; **μohm/cm

Table 7: Results of several chemical analyses conducted on the water samples

Settlements	Water source	N	Nitrite (mg L^{-1})	Nitrate (mg L^{-1})	Arsenic (μg L^{-1})	Ammonium (mg L^{-1})	Fluorine (mg L^{-1})	Calcium (mg L^{-1})	Sulfate (mg L^{-1})	Free chlorine (mg L^{-1})
City center	Network	3	4.33±7.50	5.83±5.25	<5	0.47±0.80	<0.10	21.68±7.70	7.40±8.20	0.13±0.11
	Spring/tap	3	5.26±9.12	5.60±9.69	-	0.03±0.05	0.05±0.10	14.69±4.48	4.07±7.04	<5
	Well	3	34.67±30.20	27.40±1.7	-	0.28±0.11	-	20.64±0.10	18.53±17.35	0.05±0.02
Town centers	Network	51	47.76±50.37	13.66±11.80	-	0.11±0.11	0.12±0.22	20.09±4.87	25.97±19.11	0.16±0.17
	Spring/tap	51	25.85±37.16	12.78±10.76	-	0.04±0.07	0.07±0.10	14.91±2.90	9.18±7.99	0.05±0.07
	Well	51	206.96±135.36	26.42±11.93	0.83±2.12	0.29±0.14	0.0±0.19	19.08±3.44	27.95±21.40	0.04±0.02

aerobic microorganism concentration was in the range of 1-10 cfu/100 mL in 15% it was in the range of 11-100 cfu/100 mL and in 11% it was in the range of 101-300 cfu/100 mL.

In 40% of the samples, the psychrotrophic organism content was determined to be <1 cfu/100 mL in well water samples and it was <1 cfu/250 mL in network and spring-tap water samples. Aerobic microorganism content was determined to be in the range of 1-10 cfu/250 mL in 41% of the network water samples, 11-100 cfu/250 mL in 13%, 101-300 cfu/250 mL in 7% of the samples and in the range of 1-10 cfu/250 mL in 50% of the spring/tap water samples and in the range of 11-100 cfu/250 mL in 6% of the samples whereas <1 cfu/250 was attained in the range of 101-300 cfu/250 mL. In 41% of the well water samples the aerobic microorganism concentration was in the range of 1-10 cfu/100 mL in 17% it was in the range of 11-100 cfu/100 mL and in 7% it was in the range of 101-300 cfu/100 mL. Alisarli and Turkyilmaz and Kaya reported that the total aerobic mesophilic bacterial counts in water samples that they investigated complied with standards. On the other hand, Agaoglu, Gunduz, Gunsen, Kemiksiz, Keven, Patir, Sonmez and Yalcin reported that the total microbial counts for some of the water samples that they have studied (potable, utility, spring etc.) did not comply with the potable water and foodstuff legislation of the Turkish Standards Institute.

Studies conducted in Turkey, Yucel and Kurdal, Patir, Sonmez, Kivanc, Kuscuoglu, Agaoglu, Gunsen, Alisarli, Alemdar and Kurt reported that water samples were contaminated with coliform bacteria in a range of 7.69-88%. The 162 samples that were analyzed in the present study were determined to be contaminated with enterobacteria and coliform bacteria at a ratio of 15% (24 samples) and 17% (28 samples), respectively. Alisarli, Alemdar, Bilgel, Cakmak, Kivanc, Keven, Turkyilmaz, Kaya and Patir reported that the water samples they analyzed were contaminated with *E. coli* at a ratio of 7-54%. In the present study, 7% of the samples (12 samples in total) was identified to have a positive test result for *E. coli.* The enterococcus ratio for all the samples in the study was determined as 12% (20 samples). Similarly, Alemdar, Alisarli, Yalcin and Patir reported that the water samples they analyzed were contaminated with enterococcus at a ratio of 3-50%.

The positive test ratio for *Cl. perfringens* in the samples was determined as 14% (23 samples). None was detected in the city center network and spring/tap water samples whereas 33% of the well water samples tested positive whereas 18% of the network water samples, 6% of the spring/tap water samples and 20% of the well water samples in the towns tested positive for the same organism. In that respect, the well samples in the city and the town samples did not comply with the legislation. Similarly, Alisarli and Alemdar reported the ratio of the sulfur reducing anaerobic bacteria to be in the range of 10-24%.

The microbial contamination of water was reported to stem from water collection and storage tanks (Mintz *et al.*, 1995), during its transfer from transport tanks to storage tanks (Lindskog and Lindskog, 1988) or because of its transfer via dipping a hand-held object in it rather than flowing or pouring from a location (Hammad and Dirar, 1982; Swerdlow *et al.*, 1997). Once the water was contaminated, the design of the water tanks (Patel and Isaacson, 1989) and the length of the period until consumption (Roberts *et al.*, 2001) also affected the survival rate of the bacteria.

The results of the physical analysis of the city and town water samples were in compliance with the legislation (Anonymous, 2004b). The hardness value of the network, spring/tap and well water samples were determined as 30.060, 16.770 and 21.490 f° (Hard water), respectively.

Although, the generally accepted criterion for the determination of the hardness of water is the calcium levels in water, it is determined by the dissolved salts of both calcium and magnesium. These are transferred into water from the soil. Water contains dissolved calcium, magnesium, bicarbonate, sulfate, chlorine and trace amounts of nitrate salts. Calcium bicarbonate and calcium sulfate play a significant role in water hardness. In the present study the hardness of the water was determined as 30.06, 16.77 and 21.49°f for the network, spring/tap and well water samples, respectively. Kocak reported that the hardness value of town utility waters varied in the range of 3.70-19.50°f (average 8.09°f). Can determined the total hardness value of potable water samples in the range of 3.40-12.00°f and that of tap water in the range of 8.21-10.53°f whereas Bilgin determined the hardness value of the potable utility water samples collected from various locations along the line to fall between 12.3 and 16.8°f. On the other hand, Yalcin reported the hardness range of potable water samples as 18-50°f, Esen reported a range of 17-72.5°f, Kahraman reported utility water hardness as 30.48°f and well water hardness as 32.40°f, Yildiz reported potable water harness in the range of 17.5-22.5°f in storage tanks. The water hardness values determined in the present study were in accordance with the results of earlier conducted studies in broad terms.

Previously conducted studies reported pH ranges of 6.95-8.48; 6.64-7.78 (7.22 on average) for potable-utility waters. Values ranging between 6.0-7.7 for drinking waters and between 6.5-8.2 and 6.71-8.21 in spring waters were reported. In the present study, the average pH values for total network, spring-tap water and well water samples were determined as 7.15, 7.39 and 7.31, respectively. These values were in compliance with the range ≥6.5 and ≤9.5 stated in the legislation. Additionally, the conductivity of the analyzed water samples were 409.24, 255.58 and 421.53 while the turbidities were 0.150, 0.177 and 1.165 for total network, spring-tap water and well water samples, respectively.

Nitrite was detected in 101 of the total number of samples (62%) in the present study. The central distribution water samples were measured to have a concentration of 0.1 mg L^{-1} whereas it was above the legislatively allowable limit of 0.50 mg L^{-1} (Anonymous, 2004a) (0.51 mg L^{-1}) in 4 town center well waters. Other similar studies Esen, Buyukyoruk reported nitrite at a concentration ranging within 0.013-0.1 mg L^{-1} in well-tap and potable waters while Can and Yalcin did not detect any nitrite in either all or some of the water samples that they have analyzed. Bilgin, Yalcin and Buyukyoruk reported nitrate concentrations in the range of 5.59-27.83 mg L^{-1} in the water samples that they analyzed. Nitrate was detected in 130 of the total number of samples (80%) in the present study. The central distribution water samples were measured to have a concentration of 12.94 mg L^{-1} whereas it was above the legislatively allowable limit of 50 mg L^{-1} (58.03 mg L^{-1} on average) in 4 town center well waters.

The highest allowable arsenic concentration in water was stated as 10 μg L^{-1} in the legislation (Anonymous, 2004b). In the present study, arsenic was detected in 6 samples (4%). It was not detected in the central distribution water samples whereas it was detected in town well water samples (6.17 μg L^{-1}) although, it was below the allowable limit. Donderici reported the presence of arsenic in one of the 61 spring water samples that they analyzed (5.6%) and the measured concentration was above the allowable limits. In the present study, 108 of all samples were identified to have ammonium (67%). Although, the concentration did not exceed the allowable limits (0.50 mg L^{-1}) in the water samples collected from the central distribution (0.12 mg L^{-1}), it was measured as 0.54 mg L^{-1} in town well water samples. In previous conducted studies, Esen, Kocak reported a range of fluorine concentration in water (0.01-1.10 mg L^{-1}). In the present study, fluorine was detected in 46 samples (28%) and its concentration was determined as 0.02 mg L^{-1} in water samples collected from central distribution network and as 0.1 mg L^{-1} in town water samples.

Calcium (Ca) and sulfate (SO_4) are among the most frequently encountered elements and compounds in water. The permanent hardness of water was reported to be generally caused by the sulfates and the chlorides of the alkaline earth metals. Calcium dissolves into water through the dissolution of the limestone via rain, underground water and through washing off from the soil. Water with high Ca content was reported to be unsuitable for drinking or industrial utilization purposes.

Calcium was detected in all samples collected in the study and it was determined to be present at an average concentration of 18.89 mg L^{-1} in city central distribution and 18.03 mg L^{-1} in town water samples. Previously conducted studies reported calcium concentrations in the range of 0.44-27.84 and 33.60-78.40 mg L^{-1}. The sulfate concentration was 10 mg L^{-1} on average in city waters and 21.04 mg L^{-1} in town waters. In the present study, chlorine concentration was 0.06 mg L^{-1} in city waters and 0.1 mg L^{-1} in town waters on average. The allowable limit of 0.50 mg L^{-1} was exceeded in 4 town well water samples (0.56 mg L^{-1}). Previous conducted studies reported chlorine concentrations in the range of <0.2-102 mg L^{-1}.

CONCLUSION

As a conclusion, it was determined that the town waters, especially the well waters in towns did not comply with the legislation with respect to the presence of index and indicator microorganisms. The water with the highest hygienic quality was the spring/tap water followed by the utility and well water. The pH values of the total network, spring/tap and well water samples in the study were in compliance with the legislation (7.15, 7.39 and 7.31, respectively). The nitrite (0.51 mg L^{-1} on average) and nitrate (58.03 mg L^{-1} on average) concentrations were above the maximum allowable limits 0.50 and 50 mg L^{-1}, respectively (Anonymous, 2004a, b) in 4 town well water samples. Arsenic was not detected in city central distribution network whereas it was detected, although still below the allowable limits in town well water samples (6.17 μg L^{-1} on average). Ammonium was detected in all samples that were collected in the study. While the concentration did not exceed the allowable limits (0.50 mg L^{-1}) in the city (0.12 mg L^{-1}), the ammonium concentration was measured as 0.54 mg L^{-1}, town well water samples. The average fluorine concentration in city water was 0.02 mg L^{-1} and it was 0.1 mg L^{-1} in town water samples. Calcium was detected in all samples that were collected in the study and chlorine concentration was determined to exceed the allowable limit of 0.50 mg L^{-1} in 4 town well water samples (0.56 mg L^{-1}).

In this regard, use of the potable and the utility water in Afyonkarahisar and surrounding towns was determined to impose a risk for public health. The frequent water shortages in Afyonkarahisar would cause negative pressure in the water distribution network causing an increased susceptibility for external contamination which in return would contaminate the utility water itself.

Water gets contaminated through the contaminants that are encountered or formed during production, distribution and processing. The contaminating agents on the base or the surface of the water are caused by natural materials percolating from the soil, materials resulting from agricultural activities, leakage from sewage treatment facilities, industrial activities, uncontrolled leakage from wastelands, chemical accidents or disasters. Organic compounds such as pesticides, disinfectants and disinfectant side products are pollutants that emerge through human activities. Concordantly, the routine physical, chemical and microbiological analyses of city water distribution network and specifically the well waters should be conducted by authorized institutions and organizations. Regular cleaning and disinfection of the wells and the routine water sample scans should be conducted. Additionally, wells that were damaged by natural disasters including earthquakes should be identified and sanitized via boring. Rehabilitation of the water distribution systems, regular chlorination of utility water and monitoring of the chlorine levels of water resources are important in the provision of hygienic water to the public.

REFERENCES

Anonymous, 1993. Microbiology-general guidance for the enumeration of enterobacteriaceae without resuscitation-MPN technique and colony-count technique. ISO 7402:1993, International Organization for Standardization, Geneva, Switzerland.

Anonymous, 1996. Guidelines for Drinking-Water Quality: Volume 2-Health Criteria and Other Supporting Information. 2nd Edn., World Health Organization, Geneva, Switzerland, ISBN: 9241544805.

Anonymous, 2001. Microbiology of food and animal feeding stuffs-horizontal method for the enumeration of β-glucuronidase-positive *Escherichia coli*-part 2: Colony-count technique at 44°C using 5-bromo-4-chloro-3-indolyl β-D-glucuronide. ISO 16649-2:2001. International Organization for Standardization, Geneva, Switzerland.

Anonymous, 2004. Water sanitation and hygiene links to health facts and figures. November 2004, World Health Organization, Geneva, Switzerland.

Anonymous, 2004. Water, sanitation and hygiene links to health, facts and figures. World Health Organization. Geneva. http://www.who.int/water_sanitation_health/publications/facts2004/en/index.html.

Anonymous, 2008. Guidelines for Drinking-Water Quality [Electronic Resource]: Incorporating 1st and 2nd Addenda, Vol. 1, Recommendations. 3rd Edn., World Health Organization, Geneva, Pages: 515.

FDA, 1998. Bacteriological Analytical Manual. 8th Edn., Association of Official Analytical Chemists International, Gaithersburg, USA.

Guler, C. and Z. Cobanoglu, 1994. Su Kirliligi. Environmental Health Resource Series No. 12, Republic of Turkey Ministry of Health, Health Project Coordination Office, TR Ministry of Health General Consulate of Basic Health Services, Ankara, ISBN: 975-7572-60-8.

Hammad, Z.H. and H.A. Dirar, 1982. Microbiological examination of sabeel water. Applied Environ. Microbiol., 43: 1238-1243.

Lindskog, R.U. and P.A. Lindskog, 1988. Bacteriological contamination of water in rural areas: An intervention study from Malawi. J. Trop. Med. Hyg., 91: 1-7.

Mintz, E.D., E.M. Reiff and R.V. Tauxe, 1995. Safe water treatment and storage in the home. A practical new strategy to prevent waterborne disease. J. Am. Med. Assoc., 273: 948-953.

Patel, M. and M. Isaacson, 1989. Survival of Vibrio cholerae in African domestic water storage containers. S. Afr. Med. J., 76: 365-367.

Rhodehamel, E.J. and S.M. Harmon, 2001. Bacteriological analytical manual: Chapter 16 *Clostridium perfringens*. January 2001. U.S. Food and Drug Administration, USA.

Roberts, L., Y. Chartier, O. Chartier, G. Malenga, M. Toole and H. Rodka, 2001. Keeping clean water clean in a Malawi refugee camp: A randomised intervention trial. Bull. World Health Organ., 79: 280-287.

Swerdlow, O.L., G. Malenga, G. Begkoyian, D. Nyangulu and M. Toole *et al*., 1997. Epidemic cholera among refugees in Malawi, Africa: Treatment and transmission. Epidemiol. Infect., 118: 207-214.

Van Leeuwen, F.X.R., 2000. Safe drinking water: The toxicologist's approach. Food Chem. Toxicol., 38: S51-S58.

WHO, 1992. Our planet, our health. Report of the WHO Commission on Health and Environment, World Health Organization, Geneva.

WHO, 2000. The World Health Report: Making a Difference. World Health Organization, Geneva.

WHO, 2002. Water engineering development centre. World Health Organization, Geneva.

Watson, A., 1996. Prediction game. Nature, 381: 386-386.