ANALYSIS OF YEREVAN DRINKING WATER QUALITY

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ABSTRACT

Since one of the most important public health measures is drinking water quality, it is priority for investigations in any country throughout the world. There are two major water quality concerns: chemical contamination, arising from natural and anthropogenic sources, which pose chronic health risks; and microbiologic, which is responsible for many of the acute disease outbreaks in the world (Nash, 1993).

The purpose in conducting a second phase of the Yerevan Water Quality Study was to verify the findings of prior investigations provided in late 1995. The study consisted of collecting 64 water samples from the eight districts in the city of Yerevan. The results show that the most serious problem of Yerevan drinking water is contamination by microorganisms (total and fecal coliforms). Coliform bacteria were detected in 34.4% of samples (N=22) at a count of more than 3 MPN/l (Most Probable Number in 1 liter) of which 45.5% contained fecal coliforms, which is 15.6% of all samples. The results of other microorganisms (Giardia liamblia and Salmonella) were negative in all analyzed samples. Chlorine was detected in varying concentrations and in many samples was absent suggesting that chlorination should be better controlled, which could lead to lower levels of bacteria in some cases.

Two samples exceed the US EPA (Environmental Protection Agency) and GOST (the former standards of the USSR) standards for total dissolved solids. Toxic organic compounds (VOCs and THMs) were detected, but at concentrations below their respective MCLs. Fluoride levels are below the recommended optimal levels. These results prove the need for universal water fluoridation program in Yerevan as a first dental public health intervention.

These results indicate that sanitary control and water supply system maintaining organizations should improve the monitoring system of water quality.

INTRODUCTION

Drinking water quality has become a serious problem in Yerevan during recent years. Some cases of diarrheal diseases were registered in several districts of Yerevan due to using of pipe water. The latest outbreak of 500 cases of enteric diseases were reported in Khorurtayin and Shengavit districts of Yerevan in April 1996 (Department of Statistics and Sanitary-Epidemiology Control Department of Ministry of Health of Republic of Armenia). According to preliminary data of ERMC and CHSR of the AUA, some parameters exceed EPA and GOST acceptance levels (Kurkjian et al., 1995). These were included bacteriological (coliforms), some inorganic (nitrates, total dissolved solids), and organic (trihalomethanes, VOCs) parameters. The results of this first study merited follow-up analyses.

Yerevan drinking water sources are groundwater sources of which 9,710 liters are from springs and 7,740 liters originate under artesian conditions. The sources of drinking water differ for each district. Engineers have estimated that 30-50% (or greater) of water supply is lost due to leaks in water pipes. The water distribution and sanitary systems are in poor condition. Water mains and sewage lines are corroding and leaking, and microbial contamination of drinking water is resulting.

The only treatment for drinking water in Yerevan is chlorination, which is provided irregularly. There is a large possibility for contamination from industrial discharges, runoff from agricultural lands, and cross-contamination of water and sewage lines.

YEREVAN DRINKING WATER SUPPLY SYSTEM

Yerevan obtains its water for domestic use from groundwater sources (Table 1). All sources are essentially outside the city and within a radius of 60 km from the city (Sanasarian, 1995). Drinking water is transmitted from 11 pumping stations to the city through 25 transmission mains with a total length of 734 km. The total length of the drinking water distribution network in Yerevan is 1,930 km. There are more than 1,000 local pumps for houses. At present, Yerevan is divided into 26 drinking water distribution zones

METHODS AND MATERIALS

Drinking water was collected from taps at different locations and times from homes, apartments and public water fountains in Yerevan. The water sources have been identified and water distribution maps have been reviewed in order to determine which facilities service the various districts in Yerevan, and to determine the locations of loops and storage areas. A sampling plan has been developed to identify specific locations for sample collection. The sampling may be biased due to water distribution schedules, and refusal to be allowed to collect water samples (total 22). Response rate was 75.3%.

Water samples were collected on May 6, 7, 13 and 14, 1996, from 16 different points each day located in the eight separate districts of the city: Khorurtayin, Miasnikian, Spandarian, Arapkir, Erebouni, Mashtots, Shahumian, and Shengavit. Eight samples were obtained from different points in each of the eight districts (total 64). Each sample was collected in separate, pre-cleaned jars after a 2-3 minute flush. Each sample was approximately 0.5 liter in volume. Water samples for VOCs' analysis were preserved by 0.2 ml HCL per one liter and for nitrates by 2 ml H_2SO_4 per one liter. Special jars were requested from the US for these parameters. Bacteriological samples were collected with special latex gloves to avoid cross-contamination. Sampling protocol and chain of custody documentation were maintained throughout.

The following parameters were measured:
Physical and chemical parameters (field determined):
1. temperature
2. pH
3. conductivity
4. salinity
5. turbidity

6. dissolved oxygen

Inorganic compounds:
1. nitrates
2. total dissolved solids
3. fluoride
4. free available chlorine (Cl_2, HClO, ClO^-)
5. combined available chlorine (Cl_2, NH_2Cl, $NHCl_2$)

Microorganisms
1. total amount of coliforms;
2. fecal coliforms (only for samples with high total coliform results);
3. protozoa Giardia lamblia;
4. salmonella

Organic contaminants
1. total amount of Volatile Organic Compounds (VOCs), including trihalomethanes (THMs).

The content of free chlorine was determined in all 64 samples by "Chlorine free, CN-70-T" analyzer. Physical parameters (pH, conductivity, turbidity, dissolved oxygen, temperature and salinity) of drinking water were analyzed by U-10 (HORIBA) water quality checker for all 64 samples. The sampling and analysis were carried out according to methods of GOST and EPA.

The samples were collected by investigators of ERMC of the AUA and the Armenian Republican Center for SanEpidemiologic control. The analyses were performed in the laboratories of the Armenian Republican Center for SanEpidemiologic Control. Some randomly chosen samples for nitrate and TDS (8 samples each), and organic parameters (16 samples) were determined in the US (Environmental Health Laboratories in South Bend, IN).

LABORATORY METHODS

1. *Method of sanitary bacteriological analysis:* The basis of this test is to detect aerobic or facultative anaerobic, Gram-negative, rod-shaped, non-spore-forming bacteria that ferment lactose with the production of acid and gas within 24 to 48 hours of incubation at 35^0 C. The membrane filter test (MFT) is done by filtering a 100 ml sample through a membrane filter that retains the bacteria. The membrane is placed on the surface of coliform medium in a petri dish and incubated for 24 hours at 35^0 C. If coliforms are present, they will produce characteristic colonies on the surface of the membrane that can be readily counted with the unaided eye or under a low-power microscope.

2. *Method for determination of combined available chlorine.*

a) Water samples are collected according to GOST 4979-49 and GOST 2874-73.
b) The quantity of water samples must be no less than 500 ml.
c) Samples are not preserved and must be determined directly after the collection.

This test is based on the ability of different types of chlorine to change the colorless diethilparaphenlendiamin to stained type, which is again changed to colorless type by the iones of iron.

3. *Method of photometric determination of fluoride content*
1. Samples of water are collected according to GOST 24481-80.
2. The volume of water samples must be no less than 200ml.
3. Samples are collected into plastic jars and are not preserved.

This method is based on the ability of fluoride to form blue, soluble compound which consists of lantan, alizarincomplexon and fluoride.

4. *Method for determination of total solids content.*

The amount of dry residue characterizes the total content of dissolved, non-volatile mineral and partly organic compounds.
1. Samples of water are collected according to GOST 2874-82 and GOST 4979-49.
2. The volume of water sample must be no less than 300 ml.

Determination of dry residue is performed on the day of sample collection. 250-500 ml of filtered water is evaporated in pre-dried china cup. Then the cup with dry residue is placed in the thermostat at the temperature of 10ºC and dries until mass is constant.

RESULTS AND DISCUSSION

The results of the field-determined parameters are presented in Table 2. The pH of most of the samples was greater than 7.0; all the samples tested within EPA's allowable limits (6.5 - 8.5). The turbidity of all samples is equal to zero, with the exception of one sample, where turbidity is four. It is higher than EPA's MCL, but it is within acceptable limits of WHO (Table 2). Salinity and conductivity are within the lowest levels. Dissolved oxygen varies from 6.95 to 13.49 mg O_2/l.

The results of the inorganic analysis are presented in Table 3. Total dissolved solids for two samples (samples 13, 36) exceed the EPA's MCL of 500 mg/l (Table.3); nevertheless, this does not appear to be a serious problem because they do not exceed WHO's acceptable limit of 1000 mg/l.

Although nitrogen is an essential element for all forms of life, studies have shown that excessive levels of nitrate greater than 10 mg/l in drinking water may cause infant methemoglobinemia, or "blue-baby syndrome", in which the oxygen-carrying capacity of hemoglobin is blocked, or results in the formation of nitrosamines which are potential digestive tract cancers (Nash, 1993).

The major sources of nitrogen are industrial and urban waste, as well as nitrogen fertilizers and manure in agriculture, which are widely used in Armenia. It is also known that levels of nitrate are generally much higher in ground waters than in surface waters (Nash, 1993). Yerevan drinking water sources are ground water sources, and consequently this investigation has undertaken a more detailed analysis for nitrates.

Eight samples from 64 were analyzed in the USA laboratories for cross verification. All results for nitrate nitrogen are within acceptable limits (10 mgN/l). It should be noted that a difference in nitrogen concentrations was detected for four samples analyzed in the Armenian and the U.S. laboratories (Tables 3 and 4). The results from the analysis conducted in Yerevan for samples 3, 11, 26, and 35 are lower than the results of the U.S. laboratory, but both results are below the MCL.

Fluoride analysis was provided only for 35 randomly selected samples (Table 3). The concentration of fluoride detected in the samples is below the optimal level. The results range from 0.10 to 0.44 mg/l (Table 3). These results are approximately in the same range as results from the first study of drinking water in Yerevan (Kurkjian et al., 1996). The recommended optimal level of fluoride in community drinking water is 0.7 to 1.2 mg/l, depending on the area's climate.

Fluoride is a normal constituent of all diets and is an essential nutrient. When the concentration is optimum, the caries rate in children is 60% to 65% below the rates in communities with little or no fluorides in their water supplies (Okun, 1991). Preliminary studies in Armenia have shown high level of caries among the Armenian population, especially among children (Armenian Ministry of Health, Department of Statistics 1995). Excessive fluorides in drinking water supplies produce unsightly dental fluorosis, which increases with increasing fluoride concentration. The optimal fluoride level in drinking water differs from place to place, varying with amounts of fluorides in food and with climatic conditions, because the amount of water and therefore the amount of fluoride ingested by children is influenced by temperature (Okun, 1991). Today, 64% of the people in the U.S. who obtain water from a community water supply drink fluoridated water (U.S. Department of Health and Human Services 1988). More than 150 published fluoride studies worldwide, spanning more than 40 years, have documented the efficacy, safety, and cost-effectiveness of community water fluoridation.

Analysis for free and combined available chlorine was also performed (Table 2). Combined available chlorine is the total amount of free chlorine, mono- and dichloramines (NH_2Cl, $NHCl_2$). The chlorination which is often used to disinfect public water supplies, may cause reactions with organic contaminants and lead to the formation of new dangerous compounds (Montgomery, 1985; Jorgensen, 1989). Therefore, is very important to keep chlorination level at an acceptable concentration.

Combined available chlorine was not detected in all 64 samples. In one sample (sample 1) the concentration of free chlorine is 1.5, which is three times higher than GOST standards (0.3-0.5 mg/l); and in two samples (samples 7 and 8), the concentration of free chlorine is 0.3-0.4 mg/l, which is within the range limits of GOST standards. In nine samples the free chlorine was not detected (Table 2).

Total coliform measure remains the most useful indicator of drinking water microbial quality (Drinking Water and Health, 1977; Tate 1990). Different types of E. coli have been identified as causes of outbreaks of diarrhea, which in complicated cases can cause death (Cliver, 1990). The preliminary study conducted in 1995 in Yerevan revealed the problem of contamination of drinking water in Yerevan by sewage water (Kurkjian et al., 1996). Coliform bacteria were detected in 22 samples (34.4%) at a count of more than 3 MPN/l (most probable number per one liter). The coli-index in these 22 samples varies from 4 to 240. Samples with a high amount of coliform were with a very low level of chlorine except for sample 1, where free chlorine was detected at a level of 1.5 mg/l, which is higher than GOST's acceptable limit.

All samples with coli-index higher than 3 were tested for fecal coliform. Fecal coliforms provide stronger evidence of the possible presence of fecal pathogens than do total coliforms. Fecal coliforms are a subgroup of total coliforms, distinguished in the laboratory through elevated temperature tests (43 to 44.5^{0}C, depending on the test). Fecal coliforms were detected in 10 of the samples from 22 (45.5%), which is 15.6% of all samples. The presence of fecal coliform in water indicates that in some places drinking water is contaminated by the sewage system. It is highly likely that coliforms are entering the distribution system through water line breaks; coliform colonies may also occur where pipes are corroded or in storage areas. Furthermore, water temperature above 50 F accelerates growth of certain organisms; therefore, results of samples collected during summer months exhibit higher numbers of microorganisms than samples collected during winter time (Kurkjian et al., 1996).

It is apparent that the chlorination method currently employed does not provide appropriate control, which leads to variations in chlorine concentration. The analytical results indicate that coliform bacterial contamination is occurring, and residual chlorine is not present in sufficient concentration to disinfect the drinking water that reaches the public through the distribution system.

Giardiasis, caused by a flagellated protozoa, Giardia lamblia, has emerged as one of the most important waterborne infectious diseases in the world. All samples were analyzed for G. lamblia. It was not detected in all 64 samples. All samples were also analyzed for Salmonella. There is not Yerevan drinking water contamination by Salmonella according to this current study (Table 3).

The results of drinking water analysis for organic parameters are presented in Table 5. The analyses for 16 samples were performed in USA laboratories. Ten different types of trihalomethanes (THMs) and VOCs were found. In two samples (samples 19 and 22) the analyses do not reveal a detectable level of THMs and VOCs. The analysis for 14 samples reveal detectable levels of THMs and VOCs, but in all samples the results are less than their current respective MCLs (Table 5). The most frequently detected organic products in Yerevan drinking water are bromoform and dibromochloromethane, the former of which was revealed in 14 samples and the latter in 12 samples (Table 5). Significantly, there is a dramatic difference between the chloroform levels detected during the first study and this one. In the first study, detected chloroform levels were analyzed from only two samples, with levels of 48 and 65 μg/l. Though within acceptable limits of EPA (100ug/l), they are significantly higher than acceptable limits of WHO (30 μg/l) (Kurkjian et al., 1996). In this study the chloroform was detected from 16 samples. Only in two samples (samples 35 and 38) the concentrations were 0.1 and

0.2 µg/l respectively (Table 5). This difference of detected chloroform levels can be explained by a different quantity of residual chlorine, because chloroform is a by-product of chlorination, or by pipe brakes where chloroform can enter the water system from waste water as a degradation product of carbon tetrachloride.

As is mentioned above the chlorination which is often used to disinfect public water supplies, may cause reactions with organic contaminants and lead to the formation of new dangerous compounds, which are suspected carcinogens. The THMs are also associated with a wide array of subtle health effects, such as fatigue, irritability, nausea, and irritation of the eyes, lungs, and skin that could easily be attributed by medical personnel to many other causes (Jorgensen, 1989).

CONCLUSIONS

The comprehensive drinking water analysis presented above provides data about risks to public health in Yerevan. The study shows that some contaminants exceed the U.S. Environmental Protection Agency's MCLs and the GOST standards; other results did not exceed MCLs, but indicate the presence of toxic organic compounds (VOCs and THMs).

Total dissolved solids for two samples exceed the EPA's MCL of 500 mg/l; nevertheless, this does not appear to be a serious problem because they do not exceed WHO’s acceptable limit of 1000 mg/l.

All results for nitrate nitrogen are within acceptable limits (10 mgN/l). It should be noted that a difference in nitrogen concentrations was detected for four samples analyzed in the Armenian and the U.S. laboratories. Nitrates in drinking water can be a serious problem and should be continually monitored.

The fluoride levels detected are well below the optimum level. The results indicate that a water fluoridation program should be developed by public health authorities as a preventive technique to reduce dental caries.

The serious problem for Yerevan drinking water is the presence of coliforms. Coliform bacteria were detected in 22 samples (34.4%) at a count of more than 3 MPN/l (most probable number per one liter). The coli-index in these 22 samples varies from 4 to 240. Fecal coliforms were detected in 10 of the samples from 22, which is 15.6% of all samples. The presence of fecal coliform in water indicates that water is contaminated by the sewage system. Samples with a high amount of coliform were with a very low level of chlorine except for one sample. The chlorination method currently employed does not provide appropriate control, which leads to variations in chlorine levels and in many locations, chlorine was undetectable.

Coliform should be monitored, and where detected, the water should be resampled and analyzed for fecal coliform, E. coli and other bacteria, protozoans, and viruses. Based on the results, further action may be warranted.

Total THMs are within the MCL levels. Ten different types of trihalomethanes (THMs) and VOCs were found. The most frequently detected organic products in Yerevan drinking water are bromoform and dibromochloromethane, the former of which was revealed in 14 samples and the latter in 12 samples. Even though VOCs in this study did not exceed the MCLs, individual organic compounds should be targeted for analysis in subsequent studies as very low levels of certain organic chemicals in drinking water are suspected or known to cause cancer and other maladies. The source(s) of VOCs should also be determined.

Finally, development of a water-quality management plan is the first and most important step toward water pollution control. A plan should be developed and implemented which consists of the protection of water sources from contamination, and appropriately treating drinking water prior to use.

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Table 1. Yerevan drinking water sources.

Sources	**Capacity (m^3/s)**	**Remarks**
1. Araratian 1,2	3,150	Artesian well water
2. Araratian 3,4	4,590	-------//--------
3. Katnakhpyur	2,850	Spring water

4. Arzni	1,700	-------//--------
5. Shor-Shor	810	-------//--------
6. Aparan	1,090	-------//--------
7. Garni	1,340	-------//--------
8. Arzakan-Gyumush	1,200	-------//--------
9. Arindj	310	-------//--------
10. Dsaravakhpyur	240	-------//--------
11. Dzorakhpyur	170	-------//--------
Total	**17,450**	

Table 2. Yerevan drinking water physical parameters

Sample #	**Temperature (^oC)**	**pH**	**Dissolved oxygen (mg O_2/l)**	**Conductivity (mS/cm)**	**Turbidity (NTU)**	**Salinity (%)**
EPA	**-**	**6.5-8.5**			**1(monthly)**	

WHO	**-**	**6.5-8.5**			**<1 to 5**	
Erebuoni district						
1	15.8	7.09	9.45	0.523	4	0.02
2	15.7	7.09	11.11	0.503	0	0.02
3	15.0	7.03	10.71	0.504	0	0.02
4	14.6	6.94	10.04	0.502	0	0.02
5	16.4	6.94	7.80	0.569	0	0.02
6	17.3	7.05	11.80	0.505	0	0.02
7	14.8	6.94	14.17	0.506	0	0.02
8	16.6	7.55	12.98	0.125	0	0.00
Shengavit district						
9	15.9	**6.23**	8.26	0.559	0	0.02
10	15.2	6.64	9.14	0.511	0	0.02
11	15.2	6.67	8.03	0.521	0	0.02
12	15.8	6.67	8.02	0.677	0	0.02
13	15.9	6.80	9.46	0.684	0	0.02
14	15.5	6.41	7.64	0.648	0	0.02
15	15.2	7.06	8.58	0.614	0	0.02
16	18.7	7.10	8.10	0.505	0	0.02
Khorurtayin district						
17	11.7	7.61	8.59	0.157	0	0.00
18	9.8	7.75	9.41	0.130	0	0.00
19	10.7	**6.38**	6.95	0.139	0	0.00
20	11.0	7.01	11.42	0.138	0	0.00
21	13.8	7.40	11.00	0.138	0	0.00
22	14.1	7.70	8.97	0.146	0	0.00
23	13.0	7.67	7.74	0.140	0	0.00
24	10.9	7.40	10.83	0.136	0	0.00
Arabkir district						
25	10.8	7.13	12.51	0.142	0	0.00
26	14.5	7.14	11.27	0.383	0	0.01
27	13.2	7.51	9.55	0.484	0	0.01
28	13.0	7.20	9.49	0.478	0	0.01
29	13.3	7.29	9.82	0.434	0	0.01

Table 2. Yerevan drinking water physical parameters (continued)

30	13.2	7.47	9.30	0.457	0	0.01
31	12.6	7.40	9.71	0.431	0	0.01
32	15.3	7.20	10.18	0.436	0	0.01
Spandarian district						

33	19.2	**6.47**	10.27	0.440	0	0.01
34	14.1	7.22	11.41	0.398	0	0.01
35	13.4	7.41	11.41	0.406	0	0.01
36	15.3	7.65	11.41	0.716	0	0.03
37	16.9	7.67	10.24	0.137	0	0.00
38	12.2	7.80	13.49	0.114	0	0.00
39	12.6	7.61	10.98	0.118	0	0.00
40	12.7	7.55	9..95	0.113	0	0.00
Miasnikian district						
41	14.5	7.22	10.72	0.492	0	0.01
42	12.4	7.86	11.26	0.144	0	0.00
43	13.2	7.57	9.68	0.129	0	0.00
44	16.0	7.40	10.55	0.447	0	0.01
45	13.8	7.56	10.60	0.447	0	0.01
46	11.9	7.45	10.21	0.123	0	0.00
47	14.0	7.48	10.31	0.120	0	0.00
48	15.0	7.30	10.46	0.138	0	0.00
Mashtots district						
49	15.6	7.60	10.75	0.468	0	0.01
50	16.9	7.62	10.83	0.193	0	0.00
51	13.6	6.81	11.85	0.297	0	0.01
52	13.5	6.70	11.92	0.347	0	0.01
53	13.5	6.60	13.45	0.350	0	0.01
54	14.4	7.18	9.34	0.292	0	0.01
55	14.3	7.20	9.71	0.186	0	0.00
56	12.2	7.13	12.56	0.184	0	0.00
Shahumian district						
57	15.0	**6.34**	12.05	0.322	0	0.01
58	16.6	6.82	7.88	0.466	0	0.01
59	16.0	7.00	10.12	0.348	0	0.01
60	16.3	6.83	12.32	0.467	0	0.01
61	17.5	6.85	7.36	0.477	0	0.01
62	16.2	7.01	9.35	0.472	0	0.01
63	16.4	6.75	7.83	0.536	0	0.02
64	16.0	6.87	8.13	0.483	0	0.01

Note: All results were field-determined using a Horiba U-10 water analyzer.

Table 3. Yerevan drinking water bacteriological and inorganic parameters

Sample #	Total Coliforms (MPN/ 1000ml)	Fecal coli forms	Giardia lamblia	Salmonella	Free chlorine (mg/l)	Combined Available Chlorine	Nitrates (mgN/l) as nitroge	Fluoride (mg/l)	Total dissolved solids (mg/l)

							n		
GOST	**3**				**0.3-0.5**			**0.7-1.2**	
EPA MCLs	**0**	**0**					**10**	**0.8-1.24**	**500**
WHO	**0 - 10**	**0**					**10**	**1.5**	**1000**
Erebuoni district									
1	**240**	+	N.D.	N.D.	1.5	N.D.	2.8	0.25	414.0
2	**23**	-	N.D.	N.D.	0.5	N.D.	2.8	-	402.0
3	**43**	+	N.D.	N.D.	0	N.D.	2.8	0.25	401.0
4	< 3	-	N.D.	N.D.	0	N.D.	2.8	-	405.0
5	< 3	-	N.D.	N.D.	0.2	N.D.	3.1	-	470.0
6	< 3	-	N.D.	N.D.	0.04	N.D.	2.6	0.26	418.0
7	7	-	N.D.	N.D.	0.3	N.D.	2.5	0.27	420.0
8	**43**	-	N.D.	N.D.	0.4	N.D.	1.1	-	121.0
Shengavit district									
9	< 3	-	N.D.	N.D.	0.15	N.D.	1.1	0.25	434.0
10	< 3	-	N.D.	N.D.	0.1	N.D.	2.8	0.25	386.0
11	< 3	-	N.D.	N.D.	0.15	N.D.	2.6	0.12	391.0
12	< 3	-	N.D.	N.D.	0.15	N.D.	2.8	-	514.0
13	< 3	-	N.D.	N.D.	0.1	N.D.	2.8	0.25	**520.0**
14	9	-	N.D.	N.D.	0.2	N.D.	2.7	0.25	483.0
15	**15**	+	N.D.	N.D.	0.1	N.D.	3.0	0.25	481.0
16	**15**	+	N.D.	N.D.	0.1	N.D.	2.7	0.26	388.0
Khorurtayin district									
17	**23**	-	N.D.	N.D.	0.1	N.D.	1.1	0.20	137.0
18	< 3	-	N.D.	N.D.	0.1	N.D.	1.0	-	128.0
19	< 3	-	N.D.	N.D.	0.1	N.D.	1.0	0.20	123.0
20	< 3	-	N.D.	N.D.	0.1	N.D.	1.0	-	132.0
21	**240**	+	N.D.	N.D.	0.05	N.D.	1.0	0.22	113.0
22	**240**	+	N.D.	N.D.	0.1	N.D.	1.0	-	110.0
23	**240**	+	N.D.	N.D.	0	N.D.	1.2	0.20	113.0
24	4	-	N.D.	N.D.	0	N.D.	1.1	-	110.0
Arabkir district									
25	9	+	N.D.	N.D.	0.1	N.D.	1.2	0.27	210.0
26	< 3	-	N.D.	N.D.	0.05	N.D.	2.7	-	238.0
27	< 3	-	N.D.	N.D.	0.1	N.D.	3.3	0.27	330.0

Key: N.D. - not detected
+ - detected (positive)

Table 3. Yerevan drinking water bacteriological and inorganic parameters (continued)

28	< 3	-	N.D.	N.D.	0.05	N.D.	3.0	-	313.0
29	< 3	-	N.D.	N.D.	0.05	N.D.	2.8	0.27	281.0
30	< 3	-	N.D.	N.D.	0.05	N.D.	2.8	-	334.0
31	< 3	-	N.D.	N.D.	0.1	N.D.	2.9	0.27	284.0

32	< 3	-	N.D.	N.D.	0	N.D.	2.8	-	286.0
Spandarian district									
33	< 3	-	N.D.	N.D.	0	N.D.	2.8	0.22	327.0
34	< 3	-	N.D.	N.D.	0.05	N.D.	3.0	-	310.0
35	< 3	-	N.D.	N.D.	0.05	N.D.	2.7	0.25	315.0
36	< 3	-	N.D.	N.D.	0	N.D.	3.5	-	**546.0**
37	< 3	-	N.D.	N.D.	0.05	N.D.	1.2	0.20	114.0
38	< 3	-	N.D.	N.D.	0.1	N.D.	1.1	-	108.0
39	< 3	-	N.D.	N.D.	0.1	N.D.	1.1	0.20	110.0
40	< 3	-	N.D.	N.D.	0.1	N.D.	1.1	-	94.0
Miasnikian district									
41	< 3	-	N.D.	N.D.	0.1	N.D.	3.0	0.44	305.0
42	< 3	-	N.D.	N.D.	0	N.D.	1.2	-	98.0
43	**23**	-	N.D.	N.D.	0.05	N.D.	1.2	0.25	258.0
44	< 3	-	N.D.	N.D.	0.05	N.D.	3.0	-	324.0
45	< 3	-	N.D.	N.D.	0.1	N.D.	3.0	0.25	322.0
46	< 3	-	N.D.	N.D.	0.15	N.D.	1.1	-	90.0
47	4	-	N.D.	N.D.	0.1	N.D.	1.1	0.10	86.0
48	< 3	-	N.D.	N.D.	0	N.D.	1.3	-	100.0
Mashtots district									
49	< 3	-	N.D.	N.D.	0.1	N.D.	3.0	0.30	328.0
50	< 3	-	N.D.	N.D.	0.1	N.D.	2.1	-	186.0
51	**23**	-	N.D.	N.D.	0.1	N.D.	2.2	0.20	281.0
52	**23**	-	N.D.	N.D.	0.05	N.D.	2.1	-	296.0
53	**43**	-	N.D.	N.D.	0.05	N.D.	2.1	0.30	309.0
54	**93**	+	N.D.	N.D.	0.05	N.D.	2.1	-	246.0
55	< 3	-	N.D.	N.D.	0.05	N.D.	2.2	0.25	171.0
56	< 3	-	N.D.	N.D.	0.05	N.D.	2.1		184.0
Shahumian district									
57	9	-	N.D.	N.D.	0.05	N.D.	2.2	0.25	272.0
58	< 3	-	N.D.	N.D.	0.1	N.D.	2.4	-	392.0
59	< 3	-	N.D.	N.D.	0.05	N.D.	2.5	0.27	296.0
60	< 3	-	N.D.	N.D.	0.1	N.D.	2.5	-	380.0
61	**75**	+	N.D.	N.D.	0.05	N.D.	2.5	0.27	379.0
62	< 3	-	N.D.	N.D.	0.05	N.D.	2.4	-	373.0
63	< 3	-	N.D.	N.D.	0.05	N.D.	2.3	0.27	424.0
64	< 3	-	N.D.	N.D.	0.05	N.D.	2.5	-	375.0

Table 4. The results of nitrates and TDS analyzed in the US

Sample #	Nitrates (mgN/l)	Total Dissolved Solids (mg/l)
GOST	**10**	
EPA	**10**	**500**
WHO	**10**	**1000**

Erebuoni district		
3	3.4	340
Shengavit district		
11	3.4	400
Khorurtayin district		
19	1.3	200
Arabkir district		
26	3.9	370
Spandarian district		
35	4.1	320
Miasnikian district		
42	1.1	140
Mashtots district		
51	2.3	280
Shahumian district		
58	2.7	370

Table 5. Yerevan drinking water organic parameters (VOCs and THMs)

Districts	***Erebuoni***		***Shengavit***		***Khorurtayin***		***Arabkir***		***Spandarian***		***Miasnikian***		***Mashtots***		***Shahumian***			
Sample #	**3**	**6**	**11**	**13**	**19**	**22**	**26**	**29**	**35**	**38**	**42**	**45**	**51**	**54**	**58**	**61**	**EPA MCL**	**WHO MCL**
Parameters	**µg/l**																**µg/l**	**µg/l**
Bromodichloromethane	-	0.1	-	-	-	-	-	-	-	0.4	0.1	-	-	-	-	-	100	-
Bromoform	2.2	3.8	0.7	0.7	-	-	1.4	1.5	2.8	0.5	0.6	2.8	0.2	0.3	2.7	0.9	100	-
Carbon tetrachloride	-	-	-	-	-	-	0.2	0.2	0.2	-	-	0.2	-	-	-	-	5	3
Chloroform	-	-	-	-	-	-	-	-	0.1	0.2	-	-	-	-	-	-	100	30
Dibromochloromethane	0.7	0.9	0.2	0.2	-	-	0.2	0.2	0.3	0.8	0.4	0.4	-	0.1	0.3	-	100	-
Ethylbenzene	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.2	-	700	-
Tetrachloroethylene	-	-	-	-	-	-	-	-	-	-	-	0.3	-	-	-	-	5	10
Trichloroethylene	-	-	-	-	-	-	0.3	0.3	-	-	-	0.4	-	-	-	-	5	30
Total Xylenes	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.3	-	1000	-
n-Propylbenzene	-	-	-	-	-	-	-	-	-	-		-	-	-	0.2	-	-	-