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*Original Research Article*

# Assessment of Drinking Water Quality in Public Primary Schools in a Metropolitan Area in Ankara, Turkey

Bilal Bakır[1], Mustafa Alparslan Babayigit[1], Ömer Faruk Tekbaş[1], Recai Oğur[1], Abdullah Kılıç[2], Serdar Ulus[3]

[1]Department of Public Health, [2]Department of Microbiology,
Gulhane Military Medical Academy, Ankara, Turkey.
[3]The Turkish Naval Force, Naval Medical Research Center, İstanbul, Turkey.

Corresponding Author: Mustafa Alparslan Babayigit

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## ABSTRACT

**Introduction:** Drinking water quality affects the children's health directly. Assessment and prevention of waterborne diseases are crucial for primary prevention, especially for children. The main aim of this study is to investigate the quality of drinking water in primary schools of a metropolitan area in Ankara.
**Materials and Methods:** Water samples of 31 primary schools in a metropolitan area of Ankara were collected to determine the quality of drinking water. From each school, at least two bottles of water samples were gathered and analyzed within 24 hours**.** Each sample was analyzed for physical and chemical properties, and microbiological detection.
**Results:** As a source of drinking water, 93.5 % of the primary schools used community water system. The physical and chemical parameters were within allowable limits, except cadmium and lead levels. More than 30-year-old school buildings, which were 24.1% of all 54 buildings, had higher and statistically significant averages of lead (0.016±0.013 mg/l) levels compared to the others(0.006±0.01 mg/l).Microbiologic reproduction was not determined in water samples and also *Cryptosporidium* and *Giardia* parasites were not detected.
**Conclusion:** Lead contaminated plumbing materials of old school buildings should be treated and drinking-water quality monitoring should be continually maintained.

***Key words:*** Primary schools; water microbiology; chemical water pollutants

## INTRODUCTION

A healthy and safe school environment encompasses the physical surroundings, the psychosocial, learning, and health-promoting environment of the school, which emphasizes disease prevention and health promotion for both students and staff. [1-3] Hygienic practices, such as accessing to sanitation and the providing clean water are all important contributors to children's health. [4]

Diseases related to the contamination of drinking water constitute a major burden on human health. [5] Pollutants in drinking and potable water can be detrimental to the health of susceptible individuals, such as children, the elderly, pregnant women, those who have chronic diseases etc. For example, waterborne infectious agents, such as cholera and typhoid that affect society may lead to many epidemics. [3,4] Nitrites from well water and other water supplies may cause methemoglobinemia via the conversion to nitrite as a result of bacterial and metabolic influences. [3,6-9] The nitrosamines that result from the reaction of nitrates and amines have been shown to be carcinogenic in animal studies. [10-14] Long-term exposure to cadmium from water and nutrients was reported to cause kidney dysfunction. [15] Arsenic trioxide, which is an important toxin for which exposure from drinking water is relevant, may lead to an increased risk of melanosis, hyperkeratosis, arsenicosis, fetal loss, cardiovascular/cerebrovascular diseases and liver, kidney, lung, skin and bladder cancer in a dose-dependent manner. [3,16,21] Lead, which can be taken into the body as a result of the corrosion of drinking water supply systems covered with lead, may also lead to health problems in the form of learning and behavioral disorders, such as mental retardation. [3] When exposed to high doses of lead, damage occurs in the brain, the red blood cells, and the kidney. [22]

Children may be more exposed to certain toxicants than adults due to their behavior, diet, and metabolic and physiologic characteristics. Children take in more air, water, and food per unit of body weight per day than adults. [23] In addition, school-aged children may spend up to many hours in and around school facilities; thus, close attention must be paid to this microenvironment [24] Schools are high-risk environments due to both the complex nature of their drinking water systems and the vulnerability of the users. [5] For this reason, the best way to ensure a safe water supply is to provide water from a reliable source, like local municipality, and establish a monitoring and surveillance system to ensure that the water is safe for consumption. [25]

In this study, the physical, chemical, and microbiological parameters of the water supplies for 31 public primary schools were examined to determine the quality of the drinking water provided to the students and school staff.

## MATERIALS AND METHODS

### *Participants and Study Design*

This cross-sectional study was conducted in the primary schools in the Keçiören district of Ankara between November 2008 and May 2009. Of the 83 public primary schools, 31 schools were selected using a random sampling method.

Sample collections were started at the schools in the morning on workdays. Water collection was carried out in accordance with the Standard Methods procedures. [26] At least two bottles of water samples (one bottle from the toilet and the other bottle from the water storage tank) were collected from each school, with a total of 62 samples. Samples were collected in sterile 200-ml polyethylene sampling bottles (Fisher, Pittsburgh, Pa.) containing 10% sodium thiosulfate. Samples were transported to the Gulhane Medical School Public Health Laboratory on ice and analyzed within 24 hours. For the *Giardia* and *Cryptosporidium* analyses, coarse particles were removed by simple filtration. During passage through 45 nm nylon micro-filters, microorganisms were transferred into the filters. These filters were transferred into 10 ml sterile tubes, and 1 ml of distilled water was added. The tubes were vortexed for 30 seconds, and the water samples in the tubes were transferred into 1.5 ml sterile microcentrifuge tubes via micropipette. The tubes were maintained in a deepfreezer (-20°C) until the time of processing.

### *Instrumentation*

A portable comparator and a Micro TPI turbidimeter (HF Scientific, Fort Myers, FL, USA) were used to measure the active chlorine and turbidity levels. A soap solution and a hydrometric burette were used to analyze the hardness of the water samples. Conductivity and pH levels were detected using a Multi-Analyser F460 (QiS, Oosterhout, The Netherlands).

Cadmium, lead, arsenic, and chromium levels were detected using a Spectroquant NOVA 60 and Spectroquant TR 320 (Merck, Darmstadt, Germany). Fluorine, chlorine, nitrite, nitrate, sulfate, phosphate, lithium, sodium, ammonium, magnesium, potassium, and calcium levels were analyzed using a Dionex (Sunnyvale, CA, USA) ICS-1000 (ion chromatography system).

For the analysis of the total coliform bacteria, the samples were initially filtered using a membrane filtration device (Millipore, Bedford, MA, USA) and subsequently inoculated into Tryptone Glucose Extract Broth (Millipore). The cultures were incubated for 24 h at 36°C in an incubator, and colonies were counted as colony forming units (CFUs) at the Gulhane Medical School Public Health Laboratory.

To isolate DNA from microorganisms, the freeze-thawing method was used. All of the microcentrifuge tubes were incubated for 20 minutes in a deepfreezer (-20°C) and then immediately studied for 10 minutes in a hot water bath (+60°C). This freeze-thawing procedure was repeated 3 times. After this procedure, the microcentrifuge tubes were centrifuged at 10,000 rpm and +4°C for 10 minutes. Thus, particles other than nucleic acids and substances that can inhibit the PCR process were precipitated. The supernatant was used as a DNA source for PCR.

Real-time PCR was performed using 12.5 microliters of the SYBR Green mixture (Qiagen, Mississauga, ON, Canada), 0.5 microliters of primer and 11.5 microliters of the DNA sample. The following PCR conditions were used: 5 minutes at 95°C, 30 seconds at 95°C, 35 seconds at 60°C and10 minutes at 72°C. PCR reactions were performed using anMx3500 Real Time PCR device (Stratagene, La Jolla, CA). The primers were synthesized according to previously reported investigational data. [27]

The required administrative permissions related to this study were obtained from the Dean of Gulhane Medical School and the Ankara Provincial Directorate of National Education. Ethics approval (2007/97) was also obtained from the Gulhane Medical School Ethics Committee. Because the study included just some environmental analysis including drinking water quality, children’s consent was not required.

***Statistical Methods***

Continuous variables were expressed as the mean ± standard deviation, and categorical variables were denoted as numbers or percentages, where appropriate. The Kolmogorov-Smirnov goodness of fit test was used to test the distribution of the data. The Mann-Whitney U test was used to compare continuous variables. The collected data were analyzed using Statistical Package for Social Sciences version 15.0 (SPSS Inc., Chicago, IL, USA). A two-tailed p value less than 0.05 was accepted to be statistically significant.

## RESULTS

All but two of the primary schools were using the community water system (CWS). Of the primary schools, 93.5% (29 schools) had a tank for water storage. All of the physical parameters (pH, turbidity, conductivity, hardness, and color) were within the national standards, except active chlorine levels of eight schools.

The chemical parameters, such as arsenic, chromium, fluoride, chloride, sulfate, potassium, magnesium, and calcium, were within the allowed limits. For all of the schools, the cadmium levels in the drinking water were above the standard level of 0.005 mg/l; the drinking water at 12.9% of the schools exceeded the acceptable lead levels for primary schools (Table 1).

**Table 1. Chemical parameters of drinking water quality at primary schools in the district of Keçiören in Ankara.**

| School number | Lead | Cadmium | Arsenic | Chromium | Fluorine | Chlorine | Nitrite | Sulfate | Phosphate | Lithium | Sodium | Ammonium | Potassium | Magnesium | Calcium |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 0.00 | 0.066 | 0.00 | 0.00 | 0.17 | 8.40 | 0.00 | 2.03 | 30.20 | 0.00 | 0.009 | 11.06 | 0.00 | 3.26 | 10.66 |
| **2** | 0.00 | 0.180 | 0.00 | 0.00 | 0.12 | 7.94 | 0.00 | 2.85 | 28.43 | 0.00 | 0.005 | 9.54 | 0.24 | 2.88 | 4.60 |
| **3** | 0.00 | 0.506 | 0.00 | 0.00 | 0.16 | 10.51 | 0.00 | 1.38 | 28.18 | 0.00 | 0.006 | 10.13 | 0.00 | 2.93 | 9.16 |
| **4** | 0.00 | 0.082 | 0.00 | 0.00 | 0.14 | 9.74 | 0.00 | 1.80 | 30.52 | 0.00 | 0.010 | 10.10 | 0.00 | 3.89 | 9.12 |
| **5** | 0.00 | 0.073 | 0.00 | 0.02 | 0.16 | 9.03 | 0.00 | 2.13 | 27.50 | 0.00 | 0.008 | 11.71 | 0.00 | 3.73 | 9.34 |
| **6** | 0.00 | 0.157 | 0.00 | 0.00 | 0.11 | 6.62 | 0.83 | 2.21 | 26.39 | 0.00 | 0.008 | 10.97 | 0.00 | 3.29 | 9.36 |
| **7** | 0.00 | 0.312 | 0.00 | 0.01 | 0.00 | 10.90 | 0.00 | 2.36 | 31.40 | 0.00 | 0.010 | 12.70 | 0.48 | 4.70 | 8.74 |
| **8** | 0.00 | 0.279 | 0.00 | 0.00 | 0.17 | 67.39 | 0.00 | 6.51 | 105.94 | 0.00 | 0.011 | 37.57 | 0.81 | 4.22 | 11.48 |
| **9** | 0.00 | 0.274 | 0.00 | 0.00 | 0.11 | 8.58 | 0.00 | 1.35 | 29.31 | 0.00 | 0.007 | 10.19 | 0.00 | 3.02 | 9.55 |
| **10** | 0.03 | 0.220 | 0.00 | 0.00 | 0.09 | 8.82 | 0.00 | 1.30 | 27.34 | 0.00 | 0.008 | 10.43 | 0.00 | 3.04 | 9.01 |
| **11** | 0.00 | 0.064 | 0.00 | 0.00 | 0.12 | 7.62 | 0.00 | 1.43 | 24.71 | 0.00 | 0.005 | 8.00 | 0.00 | 2.56 | 7.44 |
| **12** | 0.02 | 0.121 | 0.00 | 0.00 | 0.09 | 6.84 | 0.00 | 0.89 | 30.83 | 0.00 | 0.006 | 8.53 | 0.55 | 3.22 | 7.51 |
| **13** | 0.00 | 0.056 | 0.00 | 0.02 | 0.11 | 9.54 | 0.00 | 1.62 | 28.64 | 0.00 | 0.006 | 9.81 | 0.00 | 2.88 | 8.41 |
| **14** | 0.03 | 0.149 | 0.00 | 0.00 | 0.13 | 9.12 | 0.00 | 1.44 | 27.75 | 0.00 | 0.000 | 10.14 | 0.00 | 3.16 | 10.42 |
| **15** | 0.00 | 0.056 | 0.00 | 0.00 | 0.08 | 9.83 | 0.00 | 1.66 | 34.17 | 0.00 | 0.000 | 11.41 | 0.00 | 2.90 | 9.07 |
| **16** | 0.00 | 0.258 | 0.00 | 0.00 | 0.14 | 6.96 | 0.00 | 0.92 | 28.10 | 0.00 | 0.005 | 8.55 | 0.00 | 2.94 | 7.44 |
| **17** | 0.01 | 0.076 | 0.00 | 0.01 | 0.13 | 8.72 | 0.00 | 4.27 | 24.91 | 0.00 | 0.004 | 7.87 | 0.61 | 2.33 | 6.75 |
| **18** | 0.00 | 0.181 | 0.00 | 0.00 | 0.10 | 8.02 | 0.00 | 1.19 | 24.53 | 0.00 | 0.005 | 8.14 | 0.00 | 2.91 | 7.31 |
| **19** | 0.02 | 0.037 | 0.00 | 0.01 | 0.12 | 7.18 | 1.25 | 1.56 | 24.90 | 0.00 | 0.006 | 7.74 | 0.00 | 2.51 | 6.88 |
| **20** | 0.00 | 0.186 | 0.00 | 0.00 | 0.22 | 44.77 | 0.00 | 1.08 | 66.31 | 0.00 | 0.008 | 30.33 | 0.61 | 3.10 | 7.96 |
| **21** | 0.07 | 0.392 | 0.00 | 0.02 | 0.08 | 8.81 | 0.00 | 1.43 | 27.74 | 0.00 | 0.010 | 10.46 | 0.00 | 3.06 | 9.64 |
| **22** | 0.00 | 0.247 | 0.00 | 0.00 | 0.37 | 87.83 | 0.00 | 0.78 | 124.70 | 0.00 | 0.009 | 41.82 | 0.33 | 3.61 | 11.34 |
| **23** | 0.00 | 0.146 | 0.00 | 0.00 | 0.09 | 9.51 | 0.00 | 0.84 | 25.90 | 0.00 | . | . | . | . | . |
| **24** | 0.00 | 0.305 | 0.00 | 0.02 | 0.09 | 10.10 | 0.00 | 2.00 | 28.40 | 0.00 | 0.008 | 12.20 | 0.37 | 3.95 | 8.77 |
| **25** | 0.00 | 0.340 | 0.00 | 0.00 | 0.12 | 9.40 | 0.00 | 1.48 | 0.00 | 0.00 | . | . | . | . | . |
| **26** | 0.03 | 0.343 | 0.00 | 0.00 | 0.12 | 8.60 | 1.80 | 1.99 | 39.10 | 0.00 | 0.008 | 11.09 | 0.00 | 5.73 | 10.82 |
| **27** | 0.00 | 0.156 | 0.00 | 0.00 | 0.10 | 7.76 | 0.00 | 2.49 | 27.32 | 0.00 | 0.004 | 9.46 | 0.24 | 2.92 | 4.60 |
| **28** | 0.00 | 0.079 | 0.00 | 0.00 | 0.09 | 9.88 | 0.00 | 2.08 | 28.10 | 0.00 | 0.008 | 12.30 | 0.35 | 3.96 | 9.00 |
| **29** | 0.02 | 0.302 | 0.00 | 0.00 | 0.08 | 9.68 | 0.00 | 1.57 | 33.43 | 0.00 | 0.000 | 10.15 | 0.00 | 3.06 | 9.72 |
| **30** | 0.01 | 0.124 | 0.00 | 0.01 | 0.13 | 7.32 | 0.00 | 1.34 | 26.74 | 0.00 | 0.006 | 10.70 | 0.00 | 2.81 | 7.69 |
| **31** | 0.02 | 0.185 | 0.00 | 0.00 | 0.11 | 8.92 | 0.00 | 1.46 | 26.57 | 0.00 | 0.000 | 10.04 | 0.00 | 3.03 | 9.89 |

*National limit values of drinking water quality, which were defined according to the regulations on water intended for human consumption, are listed below:

| | | | |
|---|---|---|---|
| Lead 0.025 mg/l | Cadmium 0.005 mg/l | Arsenic 0.01 mg/l | Chromium 0.05 mg/l |
| Fluorine ≤1.5 mg/l | Chlorine ≤250 mg/l | Nitrite ≤0.5 mg/l | Sulfate ≤250 mg/l |
| Phosphate N/A | Lithium N/A | Sodium ≤200 mg/l | Ammonium N/A |
| Potassium N/A | Magnesium N/A | Calcium N/A | |

A total of 54 school buildings (24.1%) were 30 or more years old. The schools that had buildings more than 30years old had significantly higher average lead concentrations in the tap water samples (0.016±0.013 mg/l) compared to the schools that had buildings less than 30years old (0.006±0.01 mg/l) ($p<0.05$) (Figure 1).

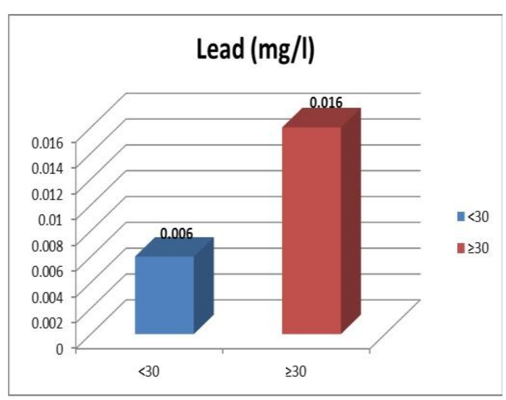


**Figure 1. The schools that had ≥30-year-old buildings had higher average lead concentrations in the tap water samples.**

Of all of the school water storage tanks, 42.8% had lead concentrations above the standard levels. According to the principals, 19.3% of the schools (6 schools) had rarely experienced a water outage in the previous six months. Of the primary schools, 93.5% (29 schools) had a tank for water storage; the number of schools whose tanks had received no periodic maintenance for more than two years was 6 (19.9%). Only 5 schools (16.1%) actively integrated their water tanks into the CWS.

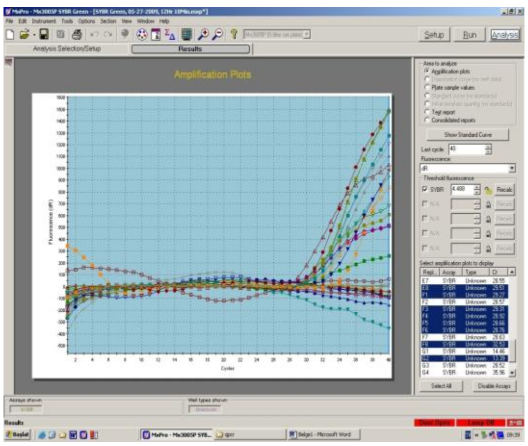


**Figure 2. PCR analysis of tap water samples for *Cryptosporidium.***

Any microbiological reproduction was not detected in the CWS or tanks of any of the primary schools in the study. With respect to the water analysis for parasites, *Cryptosporidium* and *Giardia* parasites were not detected in any water samples (Figures 2,3).

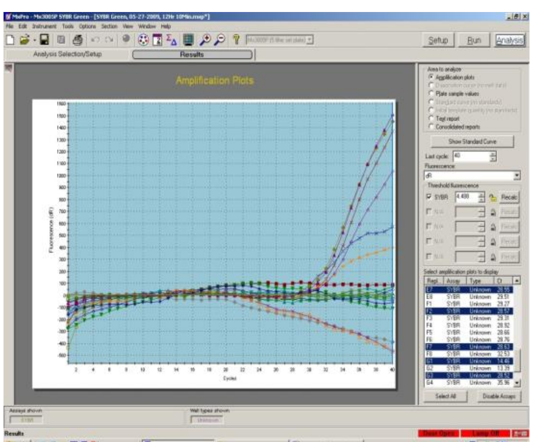


**Figure 3. PCR analysis of water storage tank samples for *Giardia.***

## DISCUSSION

Infants and young children are at the greatest risk of waterborne diseases, especially when living in unsanitary conditions. [5] Therefore, the availability of a clean and sufficient water supply is a primary consideration when selecting a site for new school construction. [25] World Health Organization (WHO) recommends that each country must review its needs and capacities when developing a regulatory framework and establish effective monitoring programmes for verification, including surveillance of drinking-water quality. [5] In Turkey, drinking water quality standards are regulated by the Turkish Ministry of Health, who gives responsibility to the local authorities to follow the water quality standards continuously.

Similar to our findings, most schools in the United States obtain their water from a community water system. Schools obtaining water from a community water system rely on the public water supplier to provide safe drinking water. Because contamination occurs after the water enters school buildings, schools are encouraged to regularly test and flush drinking water outlets. [28] EPA regulations [29] and WHO Drinking Water Quality Guidelines [5] require monitoring of substances such as coliform bacteria, organic and inorganic chemicals. Because the presence of these organisms indicates inadequate treatment, total coliforms should be absent immediately after disinfection. [4] State and/or local health authorities should be consulted for technical information and advice regarding the bacteriological quality of water. Analysis should also be conducted to monitor the levels of chemicals in the water. [30] The potential health consequences of microbial contamination necessitate that the control of microbial contamination must be of paramount importance and must never be compromised. [5] In our study, any microbiological reproduction was not detected in the CWS or tanks of the primary schools.

In a study from Taiwan, the drinking water quality of 42 schools in Pingtung County was investigated with respect to the water sources, the treatment facilities, the location of the schools and the different grade levels. Only 45% of schools were found to use tap water as the main source of drinking water, and the unqualified rate of microbes in the water was 26.2%. All parameters related to physical and chemical properties (i.e., pH value, turbidity, soluble total solid, total hardness, and free available residual chlorine), and metal contents(i.e., Mn, Zn, Cu, Fe, Mg and Ca) met the domestic standards, except the turbidity of schools under the junior high school level that used tap water was slightly higher than the standard value. [31] The physical parameters in our study were similar; the active chlorine levels of water tanks at 5 schools (16.1%) and the drinking water chlorine levels of 19 schools (90%) were found to be out of the limit values.

Of all of the schools, 12.9% exceeded the acceptable lead levels for primary schools. The older buildings had significantly higher average of lead concentrations in the tap water samples. Having high levels of lead in the water might be attributed to the use of lead pipes in plumbing. In adults, 10% of the lead can be absorbed by oral intake, and this ratio rises to 50% for children. Lead accumulates in the body until it reaches toxic levels. These levels can lead to chronic lead poisoning. The most important effects of lead in the blood emerge in the nervous system, gastrointestinal tract, and kidneys. Chronic lead poisoning reduces intellectual capacity and IQ and causes learning disabilities, including attention deficit hyperactivity disorder. [32] The Lead and Copper Rule (LCR) was developed by the Environmental Protection Agency (EPA) to protect public health by minimizing lead and copper levels in drinking water. The most common source of lead and copper in drinking water is the corrosion of plumbing materials. Plumbing materials that can be made with lead and copper include pipes, solder, fixtures, and faucets. The concentration of lead or copper in tap water determines whether a system may be required to install corrosion control treatment, collect water quality parameter samples, collect source water samples, replace lead service lines, and/or deliver public education about lead. [22]

In the USA, an important lead regulation was enacted in 1988 to protect the health of children. The Lead Contamination Control Act (LCCA) was designed to assist schools in implementing measures to test for and reduce lead contamination in drinking water from water coolers and other sources. The LCCA required the EPA to publish a guidance document and testing protocol to assist schools in determining the source and extent of lead contamination in their drinking water. The LCCA required the EPA to identify and publish a list of brands and models of water coolers that contained lead, including those with lead-lined tanks. [33] Turkish regulations concerning drinking water quality only provide the limit values without giving any details concerning the imposed civil and criminal penalties related to the manufacture and sale of lead-containing water coolers and lead-lined tanks. These regulations must be developed further to include these details.

At all of the schools, the cadmium levels in the drinking water were above the standard level of 0.005 mg/l. Cadmium occurs naturally in soil and rocks. In addition, coal and mineral fertilizers have also contained cadmium. Cadmium is a stainless steel material that is wear-resistant and used in the paint industry for battery, plastic, and metal coating. Cadmium can also be taken into the body via oral intake from contaminated water. Oral intake of large amounts of cadmium causes nausea and vomiting and may even lead to death. Chronic diseases can also occur due to long-term and low-dose exposure as a result of accumulation in the body. Accumulation in the kidney causes kidney damage and hypertension. In addition, a loss of bone density and bone diseases may be seen, especially in children. [15,34] Arsenic, cadmium and lead have been reported to cause cancer, nephrotoxicity, central nervous system disorders and cardiovascular disease in humans and to be associated with a well-defined pathway for metal exposure from water. [35]

***Limitations***

Due to transportation difficulties, time limitations, and other factors, this study could not be conducted at all primary schools in Ankara. The fact that this study was implemented only in public primary schools might be a restriction. Because the schools' settlements were in urban areas, there was no opportunity for comparison with rural (i.e., slum area or village) schools. As a project supported by the Scientific and Technological Research Council of Turkey (TÜBİTAK) (Project No.: 108S013), water quality this study was planned to assess various environmental risk factors in primary schools, such as electromagnetic radiation, noise, illumination, temperature indoor air quality, most of which were previously published. [36-38] All of these measurements were conducted at the same time. Because this paper was part of such a large project, we had no opportunity to collect data concerning school achievement and/or health symptoms related to drinking water pollution due to insufficient budget and time. This limitation might also be a restriction for assessing the real exposure levels of the students and staff of primary schools.

## CONCLUSION

The main findings of this study were; (1) schools that had buildings that were more than 30 years old had significantly higher average lead concentrations in the tap water samples, (2) any microbiological reproduction was not detected in the CWS or tanks of the primary schools, (3) *Cryptosporidium* and *Giardia* parasites were not detected in any water samples. As a conclusion of this study, lead contaminated plumbing materials of old school buildings should be treated and drinking-water quality monitoring should be continually maintained in primary schools. School authorities have a legal and moral responsibility for this action to provide a safe and sanitary water supply for schools. The availability of a clean and sufficient water supply is a primary consideration for school-aged children.

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***Conflict of interest:*** none declared.

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