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Comparative Physicochemical Characterization of Drinking Water from Select Endpoints of Use and Household Storage Containers in Ulaanbaatar City, Mongolia

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Objectives: The aim of this study was to assess drinking water quality at 12th Khoroo of Sukhbaatar District of Ulaanbaatar, Mongolia. **Methods:** Water samples were collected at four different locations and water sources included a borehole well, plastic containers from two different households and from the drinking water faucet of the Family Health Center. Samples were analyzed for complete physicochemical characterization. Results were compared to the National Standard (MNS 0900:2018), WHO and EPA guideline values. **Results:** Indicators of drinking water quality were within the national and international guideline values in collected water samples except for aluminum (maximum measured value 1.5 mg/l, WHO guideline value 0.2 mg/l) and iron (maximum measured value 13.9 mg/l, WHO guideline value 0.3 mg/l). In addition, some diversity in concentrations was observed depending on water sources. **Conclusion:** Overall, samples for majority of physical and chemical parameters lie within guideline limits as set by WHO except for aluminum and iron. Thus, more research is needed to cover a larger area of the city with full physicochemical and microbiological characterization.

Keywords: Water Supplies, Quality, Water, Mongolia

Introduction

Drinking water contamination with pollutants released from anthropogenic sources is a serious concern in the world. The concerns over drinking water quality are gradually increasing due to the unprecedented population growth, urbanization, and industrial expansion. Generally, pollutants (cations, anions, perchlorate, disinfection by-products, and heavy metals) are posing major threats to water quality and cause considerable adverse impacts on human health[1]. More than half of the population of Mongolia resides in the capital city, Ulaanbaatar[2]. Environmental pollution due to the urbanization is becoming worse, making Ulaanbaatar one of the most polluted cities in the world. Safe drinking water is one of the most important factors that determine health of the population. Even though studies of drinking water quality in Mongolia are sparse, available research warrants further investigations on the higher concentrations of environmental pollutants with inclusion of broader spectrum of emerging chemicals of concerns.

The main water source of Ulaanbaatar city is groundwater, which is collected from wells and then filtered. The water is then distributed through a pipeline system to the urban center. Residents living in peripheral districts collect water using portable containers from kiosks. Most of them serve water from wells tapped into the bedrock aquifer on-site or water delivered by truck[3].

Nriagu et al.reported high uranium (U) concentration in groundwater of Ulaanbaatar[4]. As per their analysis, respectively 5.4% and 10% of water samples had 15 μg/L and 10 μg/L U (WHO guideline value 30 μg/L)[4]. The measured concentrations were markedly different in different parts of the city with mean of 4.6 μg/L range between <0.01 μg/L to 57 μg/L. The highest U concentrations were found in Bayangol (18.6 μg/L) and Bagakhangai (11.3 μg/L) districts whereas the lowest levels were measured in Sukhbaatar (2.4 μg/L) and Chingeltei (1.6 μg/L). Moreover, aluminum (Al) (WHO guideline value 200 μg/L) was measured as high as 209 μg/L and 148.8 μg, respectively in 4 samples from Bagakhangai and 27 samples from Sukhbaatar districts. Concentration of other trace metals such as Co, Mn, Zn, As, Se, Cd and Pb were found below the maximum concentrations in WHO guidelines[1,4].

In Mongolia in 2004, Pfeiffer et al. found elevated levels of arsenic in drinking water in a study corroborated by United Nations Children's Fund (UNICEF)[5]. They reported that five of their 54 drinking water samples were found to contain arsenic levels above 10 μg/L which is maximum permissible limit by WHO[1]. In other studies, arsenic levels were found to exceed WHO guidelines in wells and springs of Gobi Desert region and around mining area of Erdenet city[6,7].

Even though there is an urgent need to examine the present status of drinking water quality in Ulaanbaatar, previous studies have been limited to select chemical, physical or bacteriological parameters. Therefore, the aim of this work is to conduct a complete physicochemical characterization of drinking water from select sources and household storage containers in Ulaanbaatar, Mongolia.

Materials and Methods

Study area

The study area was randomly selected was the 12th khoroo (smallest municipal unit) of District Sukhbaatar, north of central Ulaanbaatar. Sukhbaatar district has a population of 136,569 of which 7,297 people live in the 12th khoroo, where water samples for this study were collected[8].

Sampling

Sampling and analysis were performed during March and April of 2017. Triplicate water samples were collected in polyethylene vials at 4 different locations in the 12th khoroo of Sukhbaatar District. Water sampling points included two plastic containers of two different households, the drinking water faucet of the Family Health Center providing primary health services to the 12th khoroo, and the borehole well that serves potable water to the residents of the 12th khoroo. Water sampling locations were within 10-15 minutes of walking distance from each other.

All well water samples were collected after running the water at high flow for around 2 min and collected in polyethylene bottles after rinsing the bottle and cap three times with the sample and labeled accordingly with representative of the supply source at the sampling points. Water samples were kept frozen until physicochemical analysis.

The Family Health Center was one of water sampling points. It gets its potable water from the 12th khoroo borehole well and it is delivered to the clinic through metal pipe. The clinic staff consisted of four physicians, four nurses and two assistant staff and serves residents of the 12th khoroo. The residents of the 12th Khoroo live in private houses and traditional Mongolian gers (portable round tents covered with felt) in what is known as a ger district. Most homes and gers in ger districts have no municipal water connection, so people get typically their drinking water from public kiosks. The kiosk, where residents of the 12th Khoroo get their water is the location of 12th khoroo borehole well.

Sample analysis

pH and conductivity: pH and conductivity were measured with a Hannah Instrument (Model No. HI3220) CDM210 conductivity meter (Radiometer Analytical), by EPA 150.1 and SM2510B, methods respectively.

Perchlorate: Perchlorate analysis was done by Ion Chromatography (Dionex ICS-3000 and 5000) using EPA 314.0 method.

Total organic carbon (TOC): (TOC) was measured by Teledyne Tekmar, a TOC Fusion Instrument using SM5310C standard method.

Anions: Concentrations of anions (F^-, Cl^-, NO_2^-, NO_3^-, SO_4^-) were determined by ion chromatography (Dionex ICS-3000 and 5000) using to EPA Method 300.0.

Cations: Concentrations of cations (NH_4^+) were determined by ion chromatography (Dionex ICS-3000 and 5000) using in-house method.

Disinfection by-products (DIBPs): Disinfection by-products (Br^-, BrO_3^-, ClO_2^-, ClO_3^-) were measured by Ion-Chromatography (Dionex ICS-3000 and 5000).

Trace metals: Trace metals (Be, V, Cr, Mn, Co, Ni, Cu, Zn, As, Se, Mo, Ag, Cd, Sb, Pb, Th, U, Na, Mg, Al, K, Ca, Fe) were analyzed by ICP-MS using EPA Method 200.8. Method Detection Limit (MDL) values for all analytes were determined by calculating standard deviation of 7 replicates of lowest concentration. MDL was determined for each analyte as:

$$MDL = t_{n-1} \times SD$$

where $t_{7-1} = 3.143$ and SD is associated to 7 standard replicates.

Prior to the analysis of samples, the linear calibration curves of cations, anions, perchlorate, disinfection by-products, TOC, and metals were plotted between known concentrations of standards and instrument responses with correlation coefficient r >0.995. The calibration curve of each analyte was evaluated by a quality control sample containing the analyte at a concentration in the mid-calibration range. Samples were analyzed in a batch of 20 followed by duplicate, spiked and quality control samples. Acceptable criteria for quality control and spike recovery were 90-110%, and for duplicate relative percent difference was <20%. The instrument was recalibrated and the samples in a batch were reanalyzed when associated quality control sample, duplicate and spike recovery exceeded their acceptable limits. All stock standards were purchased from NSI Lab Solutions. All quality control samples were purchased from Environmental Research Associates.

Statistical analysis

The data were analyzed using descriptive statistical methods. 95% confidence interval (CI) was calculated for all water quality parameters. The upper and lower limit of 95% CI of each parameter was compared to national and international guidelines.

Results

Table 1 and 2 summarizes the physicochemical parameters in the water samples of the study area. No significant variation in the values of these parameters was found. Results were compared to threshold limits as per Mongolian Drinking Water Standard (MNS 0900:2019), WHO and US EPA[1,9,10].

The pH values ranged from 7.30 to 7.95 (Table 1). Conductivity of water is an indicator of total salt content in water. The salt concentration ranged from 41.9 to 82.2 μS/cm. The maximum conductivity value (82.2 μS/cm) was found in the sample collected from Family Health Center, while minimum value (41.9 μS/cm) was found in the sample of Household 2. When compared, the pH and conductivity values fell within the national standard, WHO, and US EPA standards for drinking water (Table 1)[1,10].

TOC concentrations ranged from 1.50 to 1.97 ppm. It should be noted that concentrations of disinfection by-products, perchlorate, and NH_4^+ fell below the detection limits (Table 1).

F^- values ranged from 0.29 to 0.30 mg/L and there was no significant variation in its concentration in drinking water samples. The Cl^- concentrations ranged from 1.55 to 2.80 mg/L and were within the permissible limit (250 mg/L) set by WHO and US EPA (Table 1). Nitrate values ranged from 0.12 to 0.32 mg/L. The highest NO_3^- (0.32 mg/L) was found in the sample from the Family Health Center, while minimum concentration (0.12 mg/L) was found in the sample of Household 2. Sulfate (SO_4^{2-}) concentrations ranged from 4.24 to 6.98 mg/L and were within the permissible limit (Table 1) set by different organizations. The highest contamination with SO_4^{2-} was observed in the water from the Family Health Center.

Nearly all heavy metals except Zn, U, Na, Ca, Al and Fe had concentrations below the detection limits. Concentration

Table 1. Physicochemical parameters of drinking water from 12th Khoroo, Sukhbaatar District of Ulaanbaatar, Mongolia

Parameters	Borehole Well	Household 1	Household 2	Health Center	Mean (x)	SD (σ)	95% CI (x±1.96σ)	MNS 0900:2018[9]	WHO Guideline[1]	EPA Threshold[10]
pH (pH units)	7.95	7.75	7.30	7.75	7.7	0.3	7.7±0.54	6.5 - 8.5	6.5 - 9.5	6.5 - 8.5
Conductivity (μS/cm)	65.2	46.3	41.9	82.2	58.9	18.5	58.9±36.3	1000	400	-
Perchlorate (μg/L)	<2.5	<2.5	<2.5	<2.5				-	-	-
TOC (ppm)	1.97	1.59	1.50	1.70	1.7	0.2	1.7± 0.4	-	-	-
Anions										
F^- (mg/L)	0.30	0.29	0.30	0.30	0.3	0.01	0.3±0.01	0.7 - 1.5	1.5	2
Cl^- (mg/L)	2.80	1.88	1.55	1.79	2	0.5	2.0±1.07	350	250	250
NO_2^- (mg/L)	<0.01	<0.01	<0.01	<0.01				1	3	1
NO_3^- (mg/L)	0.15	0.17	0.12	0.32	0.2	0.1	0.2±0.17	50	50	10
SO_4^- (mg/L)	4.94	4.99	4.24	6.98	5.3	1.2	5.3±2.31	500	250	250
Cations										
NH_4^+ (mg/L)	<0.1	<0.1	<0.1	<0.1				1.5	1.5	-
DIBPs										
Br^- (mg/L)	<0.01	<0.01	<0.01	<0.01				-	-	-
BrO_3^- (mg/L)	<0.01	<0.01	<0.01	<0.01				0.01	25	-
ClO_2^- (mg/L)	<0.01	<0.01	<0.01	<0.01				-	<10	-
ClO_3^- (mg/L)	<0.01	<0.01	<0.01	<0.01				0.7	<10	-

of Zn shows a large variation (Table 2); maximum value (73.2 μg/L) was recorded from the Family Health Center sample. Concentrations of Na (1.36-3.39 mg/L) and Ca (4.92-9.25 mg/L) were found to be low compared to standard or guideline values[1,9,10]. Fe concentrations ranged from 3.86 to 13.9 mg/L; the highest Fe (13.9 mg/L) was found in the sample of Family Health Center (Figure 1). Concentrations of Al were 1.5 mg/l and 1.3 mg/l in water samples collected from Household 1 and Household 2, respectively (Figure 1). In general, concentrations of heavy metals fell within the safe limits as shown in Table 2 except Fe and Al. These heavy metals had concentrations above the permissible limit as set by WHO (Fe 0.3 mg/L and Al 0.2 mg/L)[1].

Discussion

Access to safe drinking water is essential to sustain life and a basic human right. Based on WHO drinking water guidelines, safe drinking water must not present any significant risk to health over a lifetime of consumption, even for sensitive populations, such as children, elderly and pregnant women[1]. Thus, drinking water must meet national/international standards and guideline values. The drinking water quality in Sukhbaatar District 12th khoroo of Ulaanbaatar, Mongolia was assessed by analyzing pH, conductivity, cations, anions, perchlorate, disinfection by-products, TOC, and trace metals and compared with Mongolian, WHO, and US EPA standards. The 12th khoroo of Sukhbaatar District is situated in the northern part of the city, away from the automobile salvage yards, scrap metal dealers and other industrial factories. Study samples included water samples from the borehole well that serves water to residents of 12th khoroo, plastic containers stored at two households and the drinking water faucet from the Family Health Center of 12th khoroo. The source of water for the plastic containers and Family Health Center was the 12th khoroo borehole well.

Although the pH of drinking water does not have direct impact on human health, it poses an indirect threat to human health by altering other water quality parameters such as solubility of metal. Our results indicate that the drinking water sources have a basic pH and this may be attributed to basic nature of the soil composition in the study area. However, water pH values were within reference ranges[1,9,10]. Conductivity of water is an indicator of ion content in water, which comes from dissolved salts and inorganic materials. Conductivity is the early

Table 2. Concentrations of trace metals in 12th Khoroo of Sukhbaatar District of Ulaanbaatar, Mongolia (μg/L unless otherwise noted)

Element	Borehole Well	Household 1	Household 2	Health Center	Mean (x)	SD (σ)	95% CI (x±1.96σ)	MNS 0900:2018[9]	WHO Guideline[1]	EPA Threshold[10]
Be	<1	<1	<1	<1				-	12	4
V	<5	<5	<5	<5				-	-	-
Cr	<5	<5	<5	<5				50	50	100
Mn	<5	<5	<5	<5				100	500	50
Co	<5	<5	<5	<5				-	-	-
Ni	<5	<5	<5	<5				20	20	-
Cu	<5	<5	<5	<5				2000	2000	1300
Zn	14.6	14.4	23.3	73.2	31.4	28.2	31.4±55.2	5000	3000	5000
As	<1	<1	<1	<1				10	10	10
Se	<1	<1	<1	<1				40	10	50
Mo	<1	<1	<1	<1				70	70	-
Ag	<1	<1	<1	<1				100	100	100
Cd	<1	<1	<1	<1				3	3	5
Sb	<1	<1	<1	<1				20	5	6
Ba	<5	<5	<5	<5				700	300	2000
Hg	<0.2	<0.2	<0.2	<0.2				1	1	2
Tl	<0.5	<0.5	<0.5	<0.5				-	-	2
Pb	<1	<1	<1	<1				10	10	10
Th	<5	<5	<5	<5				-	0.1	-
U	0.124	0.091	0.095	0.126	0.11	0.02	0.11±0.04	30	30	30
Na (mg/L)	3.39	1.36	2.24	3.06	2.51	0.91	2.51±1.78	200	200	20
Mg (mg/L)	1.16	<1	<1	1.43				30	-	-
Al (mg/L)	<1	1.50	1.30	<1	0.7	0.81	0.7±1.59	0.5	0.2	0.05 - 0.2
K (mg/L)	<1	<1	<1	<1				-	-	-
Ca (mg/L)	7.62	4.92	6.07	9.25	6.97	1.88	6.97±3.69	100	100 - 300	
Fe (mg/L)	4.04	3.86	4.21	13.9	6.5	4.93	6.5±9.67	0.3	0.3	0.3

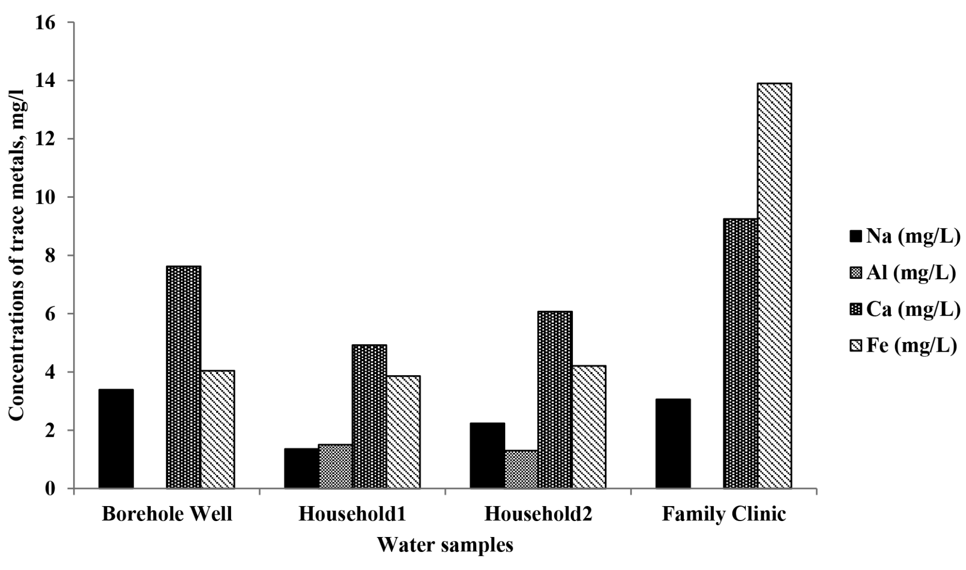

Figure 1. Concentrations of Na, Al, Ca, Fe in drinking water samples

indicator of water system quality and its increase represents water pollution[13]. According to our results, conductivity of water in selected area was within the standard values, indicating minimal if any pollution caused by an effluent discharge.

The high concentration of fluoride (F^-) in water is usually due to the leaching from fluoride-bearing minerals, industrial wastes, fertilizers, and coal combustion. Its deficiency and overexposure can cause adverse effects in teeth and bones[14-16]. Concentrations of F^- were well below the WHO's minimum recommended concentration of 0.7 mg/L for human health, suggesting water fluoridation is needed to avoid adverse effects of F^- deficiency in drinking water.

Chlorides (Cl^-) can occur in water from natural and anthropogenic sources, such as use of inorganic fertilizers, landfill leachates, septic tank effluents, animal feeds, and industrial effluents. Chloride increases corrosivity of water by increasing electrical conductivity and can lead to increased levels of metals in drinking water[1]. The Cl^- concentrations were within the permissible limit, indicating that chlorides had little effect on availability of metals in drinking water in our study.

The source of nitrate (NO_3^-) and nitrite (NO^-_2) in surface and ground water is the aerobic decomposition of organic nitrogenous matter. Higher water NO_3^- intake has been associated with methemoglobinemia, respiratory tract infections and goiter development in children, as well as bladder and ovarian cancer[2]. According to our results, nitrate and nitrite content in drinking water poses no health risk to the residents of 12th khoroo of Sukhbaatar District[11,17,18].

Sulfate (SO_4^{2-}) is released into water from natural and anthropogenic sources. High sulfate content results in gastrointestinal disturbances[19]. Sulfate levels were within the permissible limit (Table 1) set by different organizations[1,9,10].

Total Organic Carbon (TOC) is an indicator of water quality and is used as an indicator for water treatment processes. It is a measure of the total amount of organic matter present in the water[13]. Organic carbon and bromide (Br^-) are precursors to the formation of harmful disinfection by-products[20]. Levels of TOC were less than 2 ppm indicating effective water treatment processes in the study area.

In terms of metal content, the concentrations of Fe and Al were found to exceed the guideline and national standard values[1,9,10]. The remaining heavy metals had levels lower than the health-based guideline values or detection limit of the instruments (Table 2).

Iron (Fe) is an essential element, but its overload or overexposure through drinking water can lead to serious health problems such as hemochromatosis (symptoms such as fatigue, arthritis, heart disease, and diabetes) liver, lung, stomach, and kidney cancers[21]. Our study results indicate that Fe levels were 12.9 – 46.3 times higher than the national standard value (0.3 mg/l). The highest levels of Fe were seen in samples from Family Health Center's drinking water faucet, which is likely due to corroded metal pipe transporting the water from the well to the facility[22]. Iron typically comes from wide a variety of food sources and additional occupational exposure may exist among the residents further increasing their risk of overexposure. Therefore, people who routinely drink water from the Family Health Center's drinking water faucet are at high risk of chronic iron poisoning[23].

Aluminum (Al) is abundant in the earth's crust and is used to make containers and cooking pots and is used in many consumer products such as food additives, antiperspirants, cosmetics[24]. Elevated levels of Al were detected in samples collected from two households. Whereas water samples from borehole well and Family Health Center were within the standard levels. Household samples were collected from the plastic containers in which water was stored for some period of time. It is unclear how the Al contamination occurred, but it was likely caused by the water being exposed to aluminum sometime after it was obtained at the kiosk.

Uranium (U) is an important naturally occurring radioactive material in rocks. It has both chemical and radiological effects and kidneys and lungs are two main target organs of uranium toxicity[25]. Exposure even to extremely low specific radioactivity of natural U in groundwater results in kidney problems and potential toxicity in bones. Results obtained by Nriagu et al.for U in 129 wells in nine sub-divisions of Ulaanbaatar, Mongolia showed that a sizable number of samples exceeded the WHO standard of 15 μg/L[4]. In the present study, samples showed much lower concentrations.

Children are the most susceptible population to lead toxicity due to the behavioral and physiological characteristics[26]. Lead is found in children's toys, paints, batteries and water pipes. Our results indicate that water lead levels from selected sources, were lower than detection limit of the instrument and pose little risk in the water samples studied.

Indicators of drinking water quality, from selected sources, were within the national and international standards except for F^-, Al and Fe. Water contamination can be caused by water storage condition and water distribution system. In addition, microbiological contamination needs further investigation, since pit latrines are widely used, and open defecation commonly occurs in ger districts of Ulaanbaatar. This study provides baseline data for future studies and valuable information to initiate national policies to control pollutants in drinking water. Measures should be taken to address the high levels of iron and aluminum and low level of fluoride.

The present study is limited to spot samples collected from four different locations without covering all types of water distribution systems in the study area. Drinking water quality is not assured to be consistent over time but intermittent. Therefore, samples analyzed within the scope of this study do not reflect on the temporal and spatial characteristics of the water used in the study area. However, the results reported are the product of the state-of-the-art techniques. Though the numbers of water samples was small, assessments conducted have covered the complete physical and chemical characteristics of the water samples.

The findings of this study suggest the need for the extended assessment with the coverage of all types of drinking water sources and its distribution systems for a drinking water supply in Mongolia. The high levels of Al and Fe exceeding national and international guidelines warrants further investigation of the source of these contamination elements. The disparity observed in the levels of these elements and other physicochemical parameters between different storage conditions and water sources warrant future research into the effect of corroded iron pipes, inadequate storage of drinking water in ger districts and the soil composition of the geographic areas.

Conflict of Interest

The authors state no conflict of interest.

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References

1. Edition F. Guidelines for drinking-water quality. WHO chronicle 2011; 38: 104-8.
2. National Statistical Office. Resident population [accessed on 10 October 2018]. Available at: http://www.en.nso.mn.
3. Batsaikhan N, Lee J, Nemer B, Woo N. Water Resources Sustainability of Ulaanbaatar City, Mongolia. Water 2018; 10: 750.
4. Nriagu J, Nam DH, Ayanwola TA, Dinh H, Erdenechimeg E, Ochir C, et al. High levels of uranium in groundwater of Ulaanbaatar, Mongolia. Sci Total Environ 2012; 414: 722-6.
5. Pfeiffer M, Batbayar G, Hofmann J, Siegfried K, Karthe D, Hahn-Tomer S. Investigating arsenic (As) occurrence and sources in ground, surface, waste and drinking water in northern Mongolia. Environ Earth Sci 2015; 73: 649-62.
6. Munkbaatar P, Sukhbaatar I, Hamada E, Morimo R, Hirabaru O. Drinking water quality of Gobi region of Mongolia. Strategic Technologies 2008. IFOST 2008 Third International Forum: IEEE.
7. Battogtokh B, Lee JM, Woo N. Contamination of water and soil by the Erdenet copper–molybdenum mine in Mongolia. Environ Earth Sci 2014; 71: 3363-74.
8. National Statistical Office. Statistical database [accessed on 10 October 2018]. Available at: http://www.1212.mn.
9. MASM. Envioronment. Health protection. Safety. Drinking water. Assessment of water hygiene and safety. MNS 0900 - 2018.
10. Water USEPA. 2004 Edition of the Drinking Water Standards and Health Advisories: United States Environmental Protection Agency, Office of Water; 2004.
11. Ward MH, Mark SD, Cantor KP, Weisenburger DD, Correa-Villasenor A, Zahm SH. Drinking water nitrate and the risk of non-Hodgkin's lymphoma. Epidemiology 1996: 465-71.
12. Li H, Shi A, Li M, Zhang X. Effect of pH, temperature, dissolved oxygen, and flow rate of overlying water on heavy metals release from storm sewer sediments. J Chem 2013; 2013.
13. World Health Organization. Water quality assessments: a guide to the use of biota, sediments and water in environmental monitoring. Cambridge, Great Britian: University press; 1996.

14. Zipkin I, McClure F, Leone N, Lee W. Fluoride deposition in human bones after prolonged ingestion of fluoride in drinking water. Public Health Rep 1958; 73: 732.
15. Li Y, Liang C, Slemenda CW, Ji R, Sun S, Cao J, et al. Effect of long-term exposure to fluoride in drinking water on risks of bone fractures. J Bone Min Res 2001; 16: 932-9.
16. Mandinic Z, Curcic M, Antonijevic B, Carevic M, Mandic J, Djukic-Cosic D, et al. Fluoride in drinking water and dental fluorosis. Sci Total Environ 2010; 408: 3507-12.
17. Gupta SK, Gupta R, Gupta A, Seth A, Bassin J, Gupta A. Recurrent acute respiratory tract infections in areas with high nitrate concentrations in drinking water. Environ Health Perspect 2000; 108: 363.
18. Weyer PJ, Cerhan JR, Kross BC, Hallberg GR, Kantamneni J, Breuer G, et al. Municipal drinking water nitrate level and cancer risk in older women: the Iowa Women's Health Study. Epidemiology 2001: 327-38.
19. Heizer WD, Sandler RS, Seal E, Murray SC, Busby MG, Schliebe BG, et al. Intestinal effects of sulfate in drinking water on normal human subjects. Dig Dis Sci 1997; 42: 1055-61.
20. Richardson SD, Postigo Ch. Abstracts of papers of the american chemical society. Formation of dbps: State of the Science. Washington DC, USA; 2015. p189-214.
21. Huang X. Iron overload and its association with cancer risk in humans: evidence for iron as a carcinogenic metal. Mutat Res-Fund Mol M 2003; 533: 153-71.
22. Sarin P, Snoeyink V, Bebee J, Jim K, Beckett M, Kriven W, et al. Iron release from corroded iron pipes in drinking water distribution systems: effect of dissolved oxygen. Water Res 2004; 38: 1259-69.
23. Amine EK, Hegsted D. Biological assessment of available iron in food products. J Agric Food Chem 1974; 22: 470-6.
24. Agency for Toxic Substances and Disease Registry (ATSDR). Toxicological profile for Aluminum Atlanta, GA: USA. Department of Health and Human Services, Public Health Service [accessed on 12 October 2018]. Available at: https://www.atsdr.cdc.gov/phs/phs.asp?id=1076&tid=34.
25. Agency for Toxic Substances and Disease Registry. Toxicological profile for uranium – An Update Atlanta, Georgia: USA. Department of health and human services. Public Health Service [accessed on 11 October 2018]. Available at: https://www.atsdr.cdc.gov/toxprofiles/tp150.pdf.
26. Praamsma ML, Ganbaatar N, Tsogtbaatar M, Halmambetova E, Malchinkhuu E, Ochir C, et al. Assessment of blood lead levels and associated risk factors among children in Ulaanbaatar, Mongolia. Cen Asi J Med Sc 2016; 2: 195-205.