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The Assessment of Chemical Quality of Drinking Water in Hamadan Province, West of Iran

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ABSTRACT

Background: The aim of present work was to evaluate the drinking water quality from various regions including both urban and rural areas of Hamadan Province, western Iran.

Methods: In this cross-sectional descriptive study, the samples were collected for a periods of 12 months between January 25, 2014 and January 25, 2015 from frequently used household taps as well as from municipal and communal water supplies. The main parameters investigated were nitrate, fluoride, pH, turbidity and chlorine.

Results: The maximum and minimum values for nitrate concentrations were measured as 140.80 mg/l and 1.56 mg/l, respectively. Nitrate and fluoride content of samples were higher in wet season than in dry season and their concentration was higher in rural areas rather to urban areas. On average, fluoride contents in both urban and rural areas were well compliance with the WHO guidelines. The pH of all samples of the study regions was in the ranges of 6.25 to 8.41 that were in the standard ranges. Twenty three percent of total samples were exceeded Iranian standards of one NTU for turbidity.

Conclusions: The groundwater of the study area is presently having not serious health risks. However, regarding that disinfection efficiency adversely is affected by turbidity, particular attention and more programs for regular monitoring has to be done, which will not always be done in all regions.

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Introduction

The main sources of drinking water in Hamadan Province, western Iran include mainly ground waters and surface waters (originated from rivers). However, water quality in some of these sources is being degraded by human activities such as wastewater discharges.

Fluoride with a concentration lower than 1.5 mg/l is probably one of the essential elements for human health and certainly is for some mollusks and strong bones[1]. Fluorides exist naturally for about 0.3 g/kg of the Earth's crust, which considered as a main source of it in drinking water and exist in the form of fluorides in a number of mineral[1]. The usual fluoride ion concentrations in natural waters are less than 1 mg/l. The reference dose (RfD) of 0.06 mg/kg/day has proposed by U.S. Environmental Protection Agency (EPA) to protect tooth from severe pitting of the enamel (called dental fluorosis), fractures and skeletal effects in adults[2]. To benefit from protective effects and to minimize the health problems of fluoride, WHO set the guideline value of 0.5 - 1.5 mg/l for concentration in drinking water[1].

Nitrate (NO_3^-) and nitrite (NO_2^-), are another compounds that found in natural systems. Nitrogen is essential for life in the form of building blocks such as deoxyribonucleic acid (DNA), proteins, enzymes, vitamins and hormones[3]. In addition, nitrate is a natural part of the human diet and supplied via drinking water or food, but higher exposures to NO_3^- or NO_2^- could result in health problems[3]. High nitrate intake can usually induce birth defects and cancers especially in agricultural areas having shallow water wells[4, 5]. The most obvious symptom of nitrate poisoning is a bluish color of the skin called cyanosis or blue baby syndrome[5]. As a result, WHO and EPA have set standards and guidelines values for nitrate and nitrite in drinking water such a fluoride. Chloroform concentrations in drinking water of Tehran were in the range of standard values[6]. In nine counties of Texas, USA, more than 50% of samples were not compliance with maximum contaminant level (MCL) of 10 mg/l as NO_3-N[7]. Overuse of nitrogenous fertilizers and the leakages from sewers and landfill are considered the main contamination sources, respectively; the latter is of more importance in urban areas[8, 9].

The main objectives of this study were to evaluate drinking water quality in all geographical regions of Hamadan, western Iran based on a set of specific parameters including nitrate (NO_3^-), fluoride (F^-), chlorine (Cl_2), turbidity and pH.

Methods

Because nitrate and fluoride are colorless, tasteless, and odorless, water must be chemically tested to determine its contamination. To collect required representative samples of the study, the most usual sampling method, random daytime, was used. In this method, drinking water samples were collected at a random moment of the day in a randomly selected location of an area of interest[10] (Figure 1, Table 1). The scientific team members as well as health deputy of the Hamadan University of Medical Science staffs carried out collection and transportation of samples according to instructions and detailed protocols to avoid any contamination during sampling. In addition, for each sample a detailed questionnaire was completed with information regarding its exact origin. Samples were collected for a periods of 12 months between January 25, 2014 and January 25, 2015 from frequently used household taps as well as from municipal and communal water supplies.

Table 1: Populations of the studied area and the proportion of urban to rural

City	Hamadan	Asadabad	Bahar	Tuyserkan	Razan	Kabudrahang	Famenin	Malayer	Nahavand
Populations	710,021	123,081	125,926	107,801	116,154	130,320	43,044	304,701	199,317
Urban (%)	86.4	61.5	48.3	51.4	23.8	19.2	40.6	62.3	52.2
Rural (%)	13.6	38.5	51.7	48.6	76.2	80.8	59.4	37.7	47.8

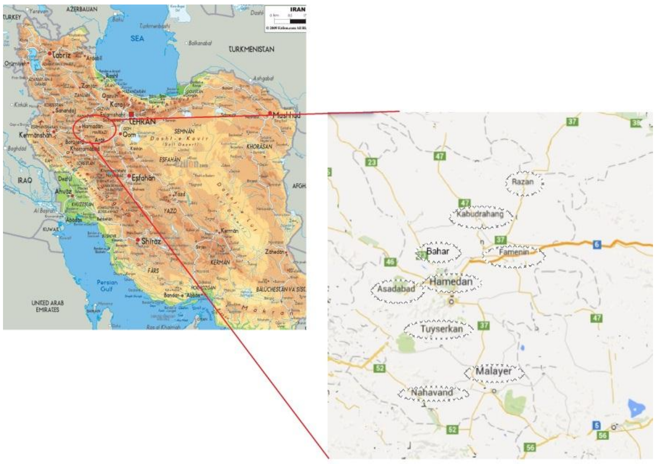

Figure 1: Location map of study area and sampling site

The desired parameters of the study were nitrate (NO_3^-), fluoride (F^-), pH, chlorine and turbidity. The two latter parameters were measured at the sampling sites with 2100P Portable Turbidimeter (Hach company, USA) and DPD chlorine Test Kits (Amkor company, Iran)[11], respectively, but NO_3^- and F^- concentration in the samples were measured in deputy of health water and wastewater laboratory according to standard methods[11]. The samples were kept in in glass vials thoroughly rinsed with distilled water followed by heating in the oven. Lab pH meter (model 827, Metrohm AG, Switzerland) was used to measure the pH of the samples. DR 5000 UV-Vis Spectrophotometer (Hack company, USA) was used to NO_3^- and F^- measurement. To select the appropriate wavelength, a specific concentration of nitrate and fluoride was prepared, then through wavelength scan in the ranges of 190-1100 nm, the maximum wavelengths were determined that corresponds to and 370 and 580 nm respectively for NO_3^- and F^-. These methods have also been used in other studies[12, 13]. After that, different concentration of NO_3^- and F^- were used to obtain calibration curve to find unknown concentrations of parameters in the samples. All experiments were carried out in duplicate. The sample size of the study was in accordance to instructions for sampling frequency of water supplies[14, 15].

The data were analyzed using SPSS software (IBM®, version 20, Chicago, IL, USA). Appropriate statistical analyzing methods such as *t*-test, means of three replicates, standard deviation, standard error of means and linear correlation were calculated for all the parameters analyzed.

Results

The results from the analysis of samples collected from both urban and rural areas (including average, minimum, maximum, median, and standard deviation values) and nitrate and fluoride concentration in different regions of the studied area are displayed in Table 2, Figures 2 and 3, respectively. The number of samples analyzed (N), the applicable Iranian standards and WHO drinking water guidelines and the percentage of samples with concentrations higher than these values are also presented in the table. Overall, 508 samples were analyzed of which about 80% were collected from rural areas because of more potential of pollution sources.

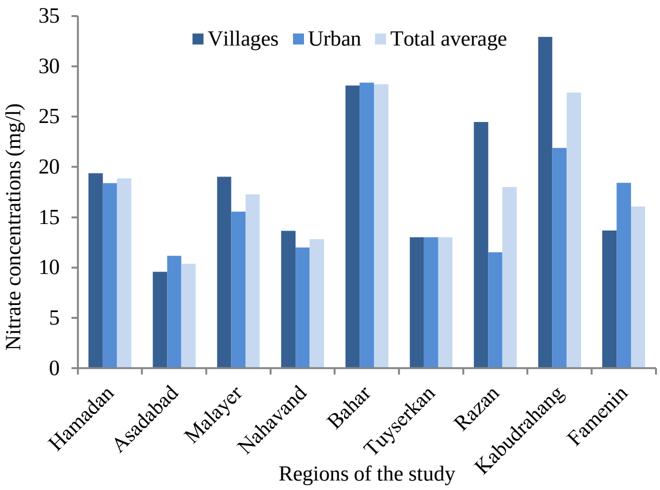

Figure 2: Nitrate concentrations in different regions of the sampling sites

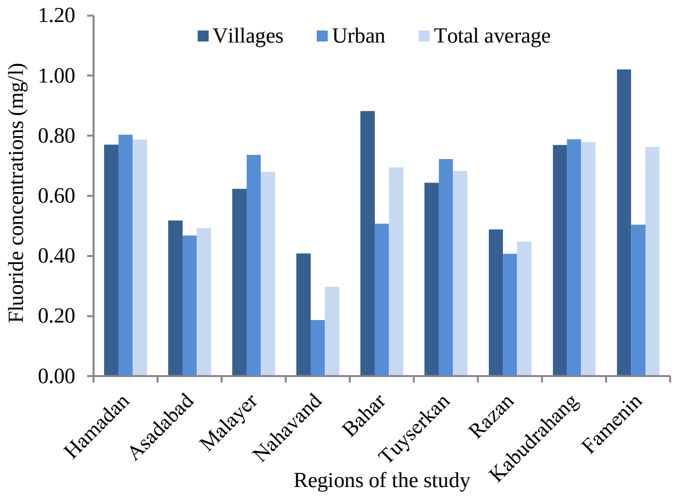

Figure 3: Fluoride concentrations in different regions of the sampling sites

The maximum (140.80 mg/l) and minimum (1.56 mg/l) values for nitrate contents were measured in samples collected from rural areas of Kabudrahang and Hamadan, respectively. The mean average concentrations of nitrate (15.67 mg/l) are well below the Iranian standard values in drinking water of 50 mg/l[14]. On average, fluoride contents in both urban and rural areas were compliant with the WHO guidelines but respectively 40.34% and 49.49% of samples in rural and urban regions of the study had not the minimum fluoride content of 0.5 mg/l. The average maximum nitrate concentrations (> 20 mg/l) were measured in the samples of Kabudrahang > Bahar > Hamadan and > Razan. For nitrate, 3.35% of the samples exceeded the health-based standards of Iran and WHO guideline (50 mg/l)[1]. The contributions of urban and rural samples in this violation were 0 and 4.15 %, respectively. All samples collected from both rural and urban areas of Bahar and urban areas of Malayer, Tuyserkan, Kabudrahang and Famenin had F^- concentrations > 0. The sample collected from a rural area of Tuyserkan showed the maximum fluoride content (4.54 mg/l) which was higher than the guideline values. The maximum fluoride concentrations of > 0.6 mg/l were measured in the samples of Hamadan, Kabudrahang, Bahar, Malayer and Tuyserkan.

Table 2: Distribution of measured parameters in the samples of the study (Values that exceeded the guidelines are indicated in bold)

Parameter	n	Mean	Min	Max	SD	Median	Iranian standards	WHO guidelines	Percentages of violation
Urban areas									
Nitrate (mg/l)	99	16.25	2.20	49.28	4.21	13.64	50.0	50.0	0.0
Fluoride (mg/l)	99	0.53	0.00	2.60	0.48	0.49	0.5, 1.5	1.5	9.1
pH	99	7.72	6.74	8.25	0.06	7.69	6.5, 8.5	6.5, 8.5	0.0
Turbidity (NTU) [a]	99	0.66	0.37	13.60	1.49	0.65	1.0	0.1	18.2
Chlorine (mg/l)	99	0.47	0.00	1.00	0.08	0.50	5.0	5.0	0.0
Rural areas									
Nitrate (mg/l)	409	15.09	1.56	140.80	7.65	12.01	50.0	50.0	4.1
Fluoride (mg/l)	409	0.62	0.00	4.54	0.33	0.63	0.5, 1.5	1.5	5.1
pH	409	7.68	6.25	8.41	0.06	7.70	6.5, 8.5	6.5, 8.5	0.0
Turbidity (NTU)	409	0.71	0.27	4.48	1.19	0.68	1.0	0.1	23.9
Chlorine (mg/L)	409	0.09	0.00	6.00	0.30	0.00	5.0	5.0	0.0
Total average									
Nitrate (mg/l)	508	15.67	1.56	140.80	2.44	12.83	50.0	50.0	3.3
Fluoride (mg/l)	508	0.58	0.00	4.54	0.01	0.56	0.5, 1.5	1.5	5.9
pH	508	7.70	6.25	8.41	0.01	7.70	6.5, 8.5	6.5, 8.5	0.0
Turbidity (NTU)	508	0.69	0.27	13.60	0.92	0.67	1.0	0.1	22.8
Chlorine (mg/l)	508	0.28	0.00	6.00	0.15	0.25	5.0	5.0	0.0

[a] No health-based guideline value for turbidity has been proposed; ideally, however, median turbidity should be below 0.1 NTU for effective disinfection

Discussion

Although mean average concentrations of nitrate (15.67 mg/l) are well below the standard values in drinking water, samples from the urban areas showed relatively higher nitrate concentration rather to rural areas. This shows that the pollution could be resulted from both point sources such as sewerage system of human settlements, probably a result of poor sanitation and latrine construction[16], and non-point sources such as indiscriminate use fertilizers and pesticides in agriculture[17]. As seen in Figure 2 and in terms of geographical distribution, the highest concentrations of nitrates were found in samples from both rural and urban region of Kabudrahang, Bahar, Razan and Hamadan, located in Gharehchay catchment basin and its tributaries[17].

Two main reasons might be envoloed: First, indiscriminate use of fertilizers of potassium nitrate and/or ammonium nitrate (these salts are very soluble and do not bind to soils) and pesticides in these regions are considered one of the most important factors in higher nitrate concentrations in drinking water because runoffs and agricultural effluents from these field could washout nitrate from the soils and transfer it to the lower slopes and finally to the aquifers[17]. Besides, according to the Town and Country Planning report[17], more agricultural activities were done in the areas with low slopes. The mentioned areas have average slopes of less than 5% and constitute more than 50% of total areas of Hamadan characterized by intensive agricultural activity according to this report. Second, the air pollutant such as NO_2, SO_2 and some others resulted from Shahid Mofatteh Power Station due to fossil fuel combustion processes could form wet precipitation (mainly HNO_3 and H_2SO_4) as acid rain[18] and then enter to water bodies around the station and final migration to aquifers. It is clear that water bodies closer to the station is at greater risk of contamination by nitrate pollution. Regarding that mean nitrate concentrations of the samples do not exceed the standard values, it can be attributed to relatively high depth of aquifers in the sampling district (on average 90 meters)[12]. Obvious obstruction in the movement of NO_3^- laden water from surface along soil profiles could be occurring. The similar trend in nitrate content of groundwater with the increases or decreases in depth of the aquifer are observed all over the world[19, 20]. Furthermore, potato having deep and wide rooting pattern is the main agricultural crops in the agricultural areas of Hamadan[17], so it can absorb more mineral nitrate from the soil profile as compared to other crops having shallow rooting pattern, hence, it has a more potential in minimizing nitrate percolation to the groundwater but could not compensate overuse of fertilizers effects[21]. The percolation of NO_3^- to groundwater aquifers through soil profile depends on the quantity of nitrogenous fertilizer applied to soil, the type of cultured crops, seed rate, soil characteristic and precipitation[22]. Seasonal (wet/dry) and regional (urban/rural) variations of nitrate concentrations were assessed for areas of the study.

The *t*-test analysis results showed that NO_3^- concentrations in groundwater were higher in wet season (winter and spring) rather to dry seasons (summer and autumn) (P = 0.014), nitrate in surface was flushed into groundwater in wet season, and rural areas rather to urban areas which is significant for agricultural regions (Kabudrahang, Bahar, Razan) (P< 0.05) and are insignificant for the other regions (P = 0.541) confirming the land-surface origin for the contamination such a fertilizer application. Similar trends reported in the literatures[7, 17, 23].

Nitrate could be reduced to nitrite under anaerobic and acidic conditions, while NO_2^- has more health effects. Thus WHO guideline value for nitrite (NO_2^-) is 0.2 mg/l for long time exposure and 3 mg/l for short time exposure. Because NO_2^- needed to be determined within 48 h[24], there was not possible to be conducted and hence no data is available, but as a role of thumb, the more the concentrations of nitrite, the more the concentration of nitrite. Previously, NO_3^- was determined in the common groundwater contaminant in the area under study. In Bahar (Hamadan), the main form of nitrogen polluting surface and groundwater was nitrate [12]. Two main reasons of this condition were expressed solubility and mobility of nitrate in the aqueous solution that the latter is related to anionic form of it[12].

As said previously, fluoride occurs naturally in waters and is essential ion for good health but the threat to public health could occur as a result of long-term consumption of water containing excess fluoride resulted in the development of bone diseases; dental fluorosis, only in developing teeth, before their eruption from the gums, and other postulated detrimental effects, such as immunotoxicity, carcinogenicity, teratogenicity, renal toxicity and gastrointestinal tract toxicity[25]. Despite the fact that the average concentrations of fluoride for all the regions examined did not exceed guideline value of 1.5 mg/l, elevated concentrations were found in 5.90% of total samples that can cause skeletal fluorosis[1]. The adverse health effects of high F^- concentrations were reported in many continents of the world such as Asia (including Pakistan, China), south Asia (republic of India), Africa and America (Mexico)[26]. Fluoride in groundwater may be due to the presence of fluoride bearing minerals like apatite, fluorite, micas, biotite. The weathering of these minerals through rainwater and subsequently percolation to the downstream could increases fluoride concentration in groundwater[27]. Other factors that affect F^- content of groundwater are temperature, pH, presence of other ions or colloids and its concentrations, composition of precipitation, mineralogy of the watersheds, anion exchange capacity of aquifer materials, geological structure as well as climate. Hence, if these conditions occur, fluoride concentration could be greater than the recommended permissible concentrations[28, 29]. Therefore, fluoride content in drinking water varies around the world. Jalali assessed geological structures of Hamadan basement rocks and observed that it mainly consist of granites, schist, dolomite, limestone and plagioclase mineral. There was shale, sandstones and marls containing limestone and the soils profiles were calcareous[12]. The lower fluoride content in drinking water of the district, on average more than 40% of samples in both rural and urban areas, having lower concentrations of F^- than guideline values, may be attributed to the absence of fluoride bearing rocks in these areas. Rural areas had higher fluoride concentration than urban areas (P = 0.176). Fluoride supplements can be used to compensate low fluoride content in the case that drinking water has a low F^- concentration via topical delivery system by sucking or chewing tablets[30]. Fluoride could prevent or even reverse dental caries via different three topical mechanisms[31].

Results of our study showed that the groundwater of the study area is presently had not health risks but some anthropogenic activities resulted from urbanization and marginalization had a positive influence on its loading with NO_3^- and F^- in the future which may not service with appropriate sewage collecting and disposal system.

The pH of all samples of the study regions ranges from 6.25 to 8.41, which were in the standard ranges of 6.5 – 8.5. The pH of the water has no direct effect on human health, therefore there is no health based guideline for pH, although a range of 6.5–8.5 is often suggested because aquatic life is negatively affected below pH 6.0, so changes in the pH value of water are important to many organisms and some species may die out if it changes even slightly[32]. Additionally at low pH, the water is corrosive and can cause wear to equipment, furthermore, the pH of an aqueous solution can affect the solubility of many compounds in it hence influences chemical reactions of important constituents of water such as salts[20]. Water should be preferably slightly alkaline to assure protection of metallic pipe work and fittings from corrosion.

Institute of Standards and Industrial Research of Iran (ISIRI) set the one NTU as a standard value for turbidity[14]; about 77% of the samples complied with this value (Table 2). On average, turbidity of urban areas samples was slightly higher than that of rural areas but it was not significant (P = 0.129). There was evidence of slight seasonality, where dry seasons turbidity content of the samples was more than the wet seasons (P = 0.533). The latter could be attributed to excessive water withdrawals in dry seasons and thus further concentrated of turbidity. Although, turbidity does also not have a health based guideline, but it was shown that *E. coli* could more survive in turbid waters and disinfection of these types of waters has a low efficiency, so WHO recommended that the turbidity of drinking water should ideally be below 0.1 NTU[1] and all of the samples were above this guideline. Thus it was concluded that drinking water of the sampling area not fully compliance with turbidity standards.

Conclusions

The water quality from the different regions in Hamadan displayed a wide range of water quality. Although the nitrate, pH and chlorine were in the ranges of standards, but the measured maximum concentration of nitrate was about three times more than Iranian standard values. Furthermore, overexploitation and improper water source management could worsen the situation in the future. On average, more than forty percent of samples did not contain the minimum fluoride guideline concentration of 0.5 mg/l. The most important parameter of concern was turbidity, in which about 23% of total samples not in accordance with Iranian standards that must be reduced to have effective disinfection. Further detailed study is still required to trace out the potential of the other contaminant such as heavy metals, disinfection by products such as trihalometanes (THM), sulfates, phosphates, and so on.

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Conflict of interest statement

Authors have no conflict of interests.

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