Resources and Environment 2014, 4(3): 168-172
DOI: 10.5923/j.re.20140403.05

Evaluation and Assessment of Drinking Water Quality in Shahrekord, Iran

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Abstract The aim of this study was to determine the physico-chemical and microbiological quality of drinking water quality in Shahrekord. For this purpose, 235 samples water from were taken either at the consumer's tap, or from well water. The analysis showed that concentration levels of total coliform bacteria (mean: 9±5 MPN/ 100 ml) exceeded the limits and F^-(mean: 0.20±0.1mg/L) below the desirable limits of WHO and Iran in certain wells, while *E.coli*, pH, turbidity, total hardness, $SO4^{2-}$, Cl^-, Mg^{2+}, NO_3^-, TDS, Ca^{2+}, Sb, Se, V, Cr, Zn, As, Mo and Cu were well within the limits. Our results show that the physical and chemical quality of the waters of Shahrekord was high quality.

Keywords Drinking water quality, Microbiological, Physico-chemical

1. Introduction

Safe and good quality drinking water is one of the most important human needs.

Physical, chemical and biological characteristics of water are considered as a main health controlling factor and the state of disease in the living organisms (Kazi *et al. 2009*).

Surface water includes water that flows across the land in the form of streamlets, springs, streams and rivers or it collects to form ponds, lakes and seas. In contrast, groundwater is located in aquifers underground and links with surface water through penetration and springs. Anthropogenic activities such as urbanisation, industrialization, agriculture and deforestation influence the characteristics. Anthropogenic chemicals that adversely affect drinking water quality are most commonly polar to semi-polar, organic compounds that are present in environmental waters at concentrations in the pg/L to µg/L range and are commonly referred to as micropollutants. With increase of micropollutants being identified in water resources, new strategies are needed to provide cost-effective and sustainable remediation solutions (Munab *et al. 2009*; Muhammad *et al. 2011*). Degradation of water quality due to agricultural activities is a global problem of surface water.

Supply of drinking water is important to the development of any country, but when polluted it may become the source of undesirable materials hazardous to human health. Potable water supports public health and ensures economic growth. Water contaminated can cause social and economic damages through water-related diseases such as Dysentery, Typhoid fever, Hepatitis A, Poliomyelitis, Vibrio Illness, *E. coli* Infection and increases medical treatment costs (Mohsin *et al. 2013*; Rossi *et al. 2012*).

Governments of many developing countries consider the provision of safe water supplies as one of their major responsibilities. In developing countries most of the people do not have access to safe drinking water. Drinking water contaminated with animal and human feces is the major route of transmission of pathogens to human beings. Alternative water supply, deficiency chlorination and sewage flooding seem to be associated with self-reported diseases (Abu-Amr and Yassin. 2008; Emmanuel *et al. 2009*).

Most of the parameters selected for analysis are obligatory from the Directive, comprising both physicochemical (such as pH, conductivity and total dissolved solids-TDS) and chemical properties which are related to the treatment of water itself and its hardness (Cl^-, Na^+, K^+, Ca^{2+} and Mg^{2+}), heavy metals (Cd, Pb, Cu, Cr and Ni), ions (F^-, NO^{2-}, NO^{3-}, Br^-, $PO4^{3-}$, $SO4^{2-}$ and NH^{4+}) as well as dissolved organic carbon (DOC). Has significant adverse effects on human health either through deficiency or toxicity due to excessive intake. Nitrate (NO_3) and nitrites (NO_2) are found naturally in water (Jordao *et al. 2002*) and the toxicology of nitrate to humans is mainly attributable to its reduction to nitrite. The major biological effect of nitrite is its involvement in the oxidation of normal hemoglobin to methaemoglobin, which is unable to transport oxygen to the tissues. The dominant human health risk associated with nitrate consumption is considered to be of methaemoglobinaemia by nitrate-derived

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Published online at http://journal.sapub.org/re

nitrite (Van Busse *et al. 2012*). Heavy metal concentrations in water can be attributed to both geogenic and anthropogenic sources. The excessive ingestion of all these heavy metals including Cd, Cr, Co, Hg, Ni, Pb and Zn has carcinogenic effects on human health (Gilani *et al. 2013*; Shah et al. 2012). The main sources of potable water for urban communities in Shahrekord are wells and surface water (64% ground water and 36% surface water). The purpose of this study was to investigate the level of drinking water contamination with anions, heavy metals and coliform bacteria water in study area.

2. Materials and Methods

2.1. Study Area

Shahrekord is the capital city of Chaharmahal and Bakhtiari Province, Iran. It is the largest city in the province. Shahrekord enjoys a cold semi-arid climate with hot summer days, mild summer nights, cool winter days and cold winter nights. The annual average temperature in Shahrekord is about 5.11°C, but the minimum and maximum absolute temperatures recorded in Shahrekord during the last 30 years have been -32°C and 42°.

2.2. Sampling

A total of 230 samples were collected from 36 wells and tap water. Samples were collected from the source in 500 mL plastic bottles (washed three times with the sample water prior to collection).

2.3. Analytical Measurements

Water temperature was measured on the site using mercury thermometer. pH was measured using digital pH meter (Model Metrohm, pH Lab 827.). Total alkalinity was determined by the titration using 0.01N hydrochloric acid and methyl orange as indicator according to standard methods. Turbidity was measured by Nephelometer using 0.02 NTU standards. Total hardness, Magnesium, and Calcium were measured by EDTA titration method. Total alkalinity was measured by Acid titration method. Chloride was measured by Argentometric titration method. Sulphate was measured by Turbidity spectrophotometric method. Fluoride was measured by SPADNS spectrophotometric method. Nitrate was measured by Brucine sulphate spectrophotometric method. Nitrite was measured Diazotisation spectrophotometric method. Bicarbonates: The concentrations of bicarbonate was measured by the neutralization of a certain volume of water by hydrochloric acid (0.1 N). The endpoint was determined by colored indicators. Sodium and potassium were measured by Flame photometric method. Total dissolved solids (TDS) were measured using Salinometer (Thermo Electron Corporation, model: Orion 150A+, USA). Water samples were digested according to the method described in APHA (APHA, 2005). Trace elements (Sb, Se, V, Cr, Zn, As, Mo and Cu) were measured by Atomic absorption spectrophotometric method.

To prevent contamination, all materials associated with trace metal sampling and analyses were thoroughly acid cleaned before use. Glassware and Teflon vessels were treated in a solution 10% v/v nitric acid for 24 h and then washed with distilled and deionized water. Total Coliforms and E.coli were measured by Most probable number (MPN) method.

3. Results and Discussion

3.1. Physico-chemical Parameters

The data in Table 1 showed that temperature of the water ranged from10.7 to 17.5℃ (mean: 14.5±1℃). The pH of the water ranged from7.3 to 8.4 (mean: 7.6±0.21). pH was below the WHO and Iran acceptable level. This is consistent with the studies carried out by Jabeen et al. (2013) and Gordon et al. (2012). The pH of drinking water has no immediate direct effects on human health but has some indirect health effects by bringing changes in other water quality parameters such as solubility of metals and survival of Pathogens (Zabed *et al. 2014*).

The Turbidity value is below the permissible limits of 0.4-2.5NTU. The mean value is 0.94 with standard deviation of 0.35. The contents of TDS ranged from 99.6 to 445.7 mg/L (mean: 251.6±66.6 mg/L). TDS was below the Iran acceptable level. Bicarbonate also records high concentration. A mean measurement of 269.85±51.6 mg/L with min and max value of 121.24 and 307.8 respectively was reported. The presence of bi-carbonate speaks of the nature of rock type in the area. Alkalinity (as $CaCO_3$) is not a pollutant. It is a total measure of the substances in water that have acid neutralizing ability. The mean value for Alkalinity is 179±25mg/L $CaCO_3$. The permissible limit is 50mg/L. Nitrate recorded a mean value of 15.5mg/L. Min 7.4mg/L and Max is 25.6mg/L. The standard deviation is 7.7 these values are within the acceptable limits for drinking water. Normally, nitrate pollution is associated with leaching from industrial and sewage effluents, fertilizers and treated distillery effluent for crop irrigation are main responsible sources (Singh *et al. 2012*). Nitrite ranged from 0.001 to 2.7mg/L with a mean value of 0.89±0.08 9.5mg/L.

The water hardness ($CaCO_3$) depends on anions such as, bicarbonate, sulphate and chloride and major cations, such as calcium and magnesium, which are all below the permissible limits. The water was classified as soft (0–75 mg/L $CaCO_3$), moderately hard (75–150 mg/L $CaCO_3$), hard (150–300mg/L $CaCO_3$) and very hard (>300 mg/L $CaCO_3$) (Chidya et al., 2011). The total hardness values ($CaCO_3$) of the samples varied from 90 to 220mg/L and a mean value of 191.6±32 mg/L. The class of hardness in this study was moderate to hard the water hardness has no known adverse effects in the environment (Dhal *et al. 2011*), but high hardness creates problems for daily human uses. Previously, several research works have demonstrated that many factors change the quality of drinking water and cause health problems (Khan *et al. 2013*; Agwu *et al. 2013*).

Chloride is mainly obtained from the dissolution of salts of hydrochloric acid as table salt (NaCl), $NaCO_2$ and added through industrial waste, sewage, sea water etc. Surface water bodies often have low concentration of chlorides as compare to ground water. According to WHO and Iran standards concentration of chloride should not exceed 250 and 400 mg/l, respectively. In this study chloride ranged from 31 to 110.9mg/1 with an average value of 51.34±14.6 mg/1. Thus, all the samples have lower concentration of chloride (Table 2). Sulfate concentration in natural water ranges from a few to a several hundred mg/l but no major negative impact of sulfate on human health is reported. Sulfate ranged from 20 to 75mg/1 with an average value of 25±11.7 mg/1. The Iran and WHO drinking water standards have established 400 and 500 mg/l, respectively. About 95% calcium in human body stored in bones and teeth. The high deficiency of calcium in humans may caused rickets, poor blood clotting, bones fracture etc. and the exceeding limit of calcium produced cardiovascular diseases.

Calcium ranged from 20.6 to 35.9 mg/l with an average value of 18.9±4.8 mg/l. Human body contains about 25g of magnesium (60% in bones and 40% in muscles and tissues). Magnesium ranged from 11.8 to 28.9mg/l with an average value of 21.5±2.8 mg/1. Sodium is a silver white metallic element and found in less quantity in water. Proper quantity of sodium in human body prevents many fatal diseases like kidney damages, hypertension, headache etc. Sodium ranged from 10.7 to 50.9 mg/1 with an average value of 17±7.7 mg/1. Potassium is necessary for living organism functioning hence found in all human and animal tissues particularly in plants cells. The total potassium amount in human body lies between 110 to 140 g. It is vital for human body functions like heart protection. Results show that the concentration of potassium in study ranges from 1.6-7.9mg/1 with an average value of 4.5±1.7 mg/l.

Table 1. Physical and chemical parameters of the collected water samples

Parameter	Unit	Min	Max	Mean±SD	Iran permissible limit	WHO permissible limit
Temperature	℃	10.7	17.5	14.5±1	-	-
pH	-	7.3	8.4	7.6±0.21	6.5-9	6.5-8.5
Turbidity	NTU	0.4	2.5	0.94±0.35	≤1	≤5
Total alkalinity	mg/L($CaCO_3$)	86.6	210	179±25	-	-
Total hardness	mg/L($CaCO_3$)	90	220	191.6±32	500	-
Calcium hardness	mg/L($CaCO_3$)	70	201	151.6±28	-	-
Total dissolved solids	mg/L	99.6	445.7	251.6±66.6	1500	-
Bicarbonates	mg/L	121.24	307.8	269.85±51.6	-	-
Chloride	mg/L	31	110.9	51.34±14.6	400	250
Sulfate	mg/L	20	75	25±11.7	400	500
Nitrate	mg/L	7.4	25.6	15.5±7.7	50	50
nitrite	mg/L	0.001	2.1	0.89±0.08	3	3
Fluoride	mg/L	0.19	0.28	0.20±0.1	1.5	1.5
Calcium	mg/L	20.6	35.9	18.9±4.8	-	100-300
Magnesium	mg/L	11.8	28.9	21.5±2.8	-	-
Sodium	mg/L	10.7	50.9	17±7.7	200	200
Potassium	mg/L	1.6	7.9	4.5±1.7	-	-

Table 2. Trace metal and microbiological parameters of the collected water samples

Parameter	Unit	Min	Max	Mean±SD	Iran limit	WHO limit
Arsenic	µg/L	0.011	0.19	0.08±0.01	10	10
Zinc	µg/L	0.004	0.029	0.021±0.02	-	-
Copper	µg/L	4.5	26.9	17.8±3.5	2000	2000
Chromium	µg/L	0.091	0.38	0.2±0.1	50	50
Antimony	µg/L	0.041	4.8	0.11±0.52	20	20
Molybdenum	µg/L	1.02	5.5	3.8±0.75	70	-
Vanadium	µg/L	0.11	0.99	0.45±0.11	10	-
Selenium	µg/L	0.12	1.2	0.95±0.35	10	40
Total coliform	MPN/100mL	0	37	9±5	0	0
E.coli	MPN/100mL	0	4	0.89±2.6	0	0

Fluoride ranged from 0.19 to 0.28mg/l with a mean value of 0.20±0.1 mg/L. Low fluoride intake is also a potential consideration with regard to the loss of fluoride from the bones. The optimal drinking water concentration of fluoride for dental health is generally between 0.5 and 1.5mg/land depends upon the volume of drinking water consumed as well as intake and exposure from other sources. This low fluoride content of water resources in Iran was also observed by Mesdaghinia et al. (2010) and Mohebbi et al. (2013) wherein the nationwide mean fluoride concentration in groundwater resources was found to be 0.47±0.28 mg/L.

3.2. Heavy Metals and Trace Elements

Arsenic concentration ranged from 0.011 to 0.19 µg/L with mean content of 0.08±0.01 µg/L in potable water (Table 2). Zinc concentration in drinking water ranged from 0.004 to 0.029 With mean content of 0.021±0.02 µg/L. Zinc concentration ranged from4.5 to 26.9 µg/L (mean: 17.8±3.5 µg/L) in potable water.

Chromium concentration ranged from0.091 to 0.38 µg/L (mean: 0.2±0.1µg/L) in drinking water samples. Concentration of Antimony was found in the range of 0.041 to 4.8 µg/L (mean: 0.11±0.52 µg/L) in potable water samples. Molybdenum was found in the range of 1.02–5.5µg/L (mean: 3.8±0.75 µg/L) in drinking water. Concentration of Vanadium ranged from0.11 to 0.99 µg/L (mean: 0.45±0.11µg/L) in drinking water. The level of Selenium was found in the range of 0.12–1.2 µg/L (mean: 0.95±0.35 µg/L) in potable water samples.

The As, Zn, Cu, Se, Cr, Mo, Sb and V contents were found below the permissible limit Iran and WHO guidelines for drinking water (Table 2). The distribution of average metal concentrations in the drinking water was found in the order of Cu > Mo> Se > V >Cr > Sb> As >Zn.

3.3. Microbiological Quality

Table 2 shows the mean values of coliform bacteria and E.coli in drinking water collected from the study area. All drinking water samples collected from Shahrekord, were analyzed for coliform bacteria and E.coli. Coliform bacteria ranged from 0 to 37 and mean: 9±5per 100 mL. *E.coli* bacteria ranged from 0 to 4 and mean: 0.89±2.6 5per 100 mL. In Shahrekord, total coliform bacteria in drinking water samples generally exceeded the permissible limit (0 per 100 mL) set by Iran and WHO. In Shahrekord, drinking water sources were contaminated with coliform bacteria may be due to leakage/discharge from septic tanks, lack of sewage and solid waste disposal systems which were the main threats to water resources. Coliform bacteria may not cause disease, but used as one of the indicators of pathogenic contamination that can cause diseases such as intestinal infections, dysentery, hepatitis, typhoid fever, cholera and other illnesses (Emmanuel *et al. 2009*).

4. Conclusions

Water samples studied in different water distribution systems revealed that almost all of the physicochemical parameters and microbiological indicators are in good status, expressing its suitability for drinking purpose. Major problems identified were that of high total coliform bacteria and low Fluoride, The importance of regular monitoring of groundwater and surface water sources are emphasized. Some of the wells in this study contained total coliform indicator bacteria which were in excess of WHO and Iran recommended guidelines for drinking water. Poor maintenance of the wells is the likely reason for the contamination. The water was classified as moderately hard (75–150 mg/L $CaCO_3$) to moderately hard (150–300mg/L $CaCO_3$).

ACKNOWLEDGMENTS

This research has been supported by Shahrekord University of Medical Sciences.

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