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Groundwater pollution assessment in urban areas of Qom City

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ABSTRACT

Nowadays it's vital to pay attention more seriously to the urban environmental risks because of its effects on citizens' lives. One of these problems is groundwater pollution which threatens much valuable water resources. Drinking water in Qom City is provided from different resources, such as watersheds and water wells which are located within the city. Although there is a shortage of water supply, according to the extreme water demand, these wells are used to provide city drinking water. Unfortunately, Sewage collection network in this city has not been completed yet and only a small amount of municipal wastewater is collected by the sewer network. As a result the city aquifer has been contaminated by the wastewater infiltration through the septic tanks scattered across the city. In order to assess the amount of contamination in water wells in urban areas of Qom City, sampling and testing of 24 deep wells which are scattered in the city was performed on December 2013. The meseared qualitative parameters consist of color, T, TU, TSS, pH, EC, TDS, DO, BOD_5, COD, Total Alkalinity, CO_3, HCO_3, Total Hardness, Ca, Mg, SO_4, Cl, Na, K, NH_4, NO_2, NO_3, PO_4, Br, I, TC, FC, FS, HPC, Fe, Hg, Pb, Co, Cd, Ni, As, Zn, B, Cu, Mn, Sn, Ba, and Sr. In this study, the drinking water physical, chemical and microbiological specifications guidelines of Iranian Standards and Industrial Research and the World Health Organization standards were used to evaluate the amount of the aquifer pollution. The results indicate that the aquifer in Qom is polluted widely by B, NO_3, TC, FC and HPC.

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INTRODUCTION

Unfortunately, urban environment had been studied less than countryside, because in the past, environmental activities were more about protecting suburbs and natural environments from contamination and many researches have been performed about it, so it is time to focus on urban environmental issues according to the population growth in cities center (Botkin and Keller, 2003). Water chemical, physical, biological, and radiological characteristics are described by water quality expression which its measurement is related to the requirements of one or more biotic species or to any human need or purpose (Johnson *et al.,* 1997). Although water quality is relative and cannot definitely be defined numerically, nowadays the

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problem has been solved to some extent by different qualitative indexes, indicators and standards. Sources of water pollutants are divided in to two main categories natural and anthropogenic groups. Water can be naturally polluted by natural disasters such as volcanoes and earthquakes or by other resources like sulfate springs. Anthropogenic pollution is the result of human society's existence which directly or indirectly causes water pollution such as municipal wastewater, various industries wastes, agricultural drainage, livestock production, landfill leakage, acid rain and, and so om (IRI, Issue No: 522, 2010).

The groundwater contamination as a unique water supplying source of millions of people in all over the world, can effect on human health, industry, agriculture and the environment (Jousma *et al.,* 2011). Unfortunately, not many people are well aware of the harmful effects of groundwater pollution (Davis *et al.,* 2011). Groundwater quality should be monitored regularly in order to have no unspecified polluted resource and also avoid it from contamination because restoring contaminated aquifer would be costly, difficult and even in some cases impossible (Tredoux *et al.,* 2004). Water quality could be assessed by analyzing different physio-chemical parameters such as temperature, color, odor, turbidity, suspended solids, conductivity, radioactivity, pH, dissolved cations and anions, hardness, free residual chlorine, heavy metals, rare elements, linear and cyclic organic matter, nitrogen compounds, phosphorus compounds, dissolved oxygen, biochemical oxygen demand, chemical oxygen demand or biological parameters like total coliform, fecal coliform, Escherichia coli, enterococci, chlorophyll a, Periphytons, and zooplanktons, phytoplanktons and nematod. Due to the fact that availability of safe drinking-water is a basic human right, essential to ensure his health therefore, in order to access the risk management strategies development and implementation to supply healthy drinking water by preventing the entry of lethal compounds into water resources, different standards and guidelines have been established. The quality and quantity of drinking-water standards vary from country to country, and there is no unique universal approach because each country requirements differ from another one, so the standards should be adjusted according to the needs of each country (WHO, 2011). The World Health Organization standards (WHO, 2011), the European Union standards (Directive, 1998), the United States environmental protection agency standards (EPA, 2012), and the Canadian standards (Health Canada, 2017) are from most prestigious Drinking Water Standards in the world.

This study has been carried out in Qom City of Iran in 2017.

MATERIALS AND METHODS

Study area

Alluvial aquifer of Qom is about 500 square kilometers. The Qamrud seasonal river flows in the northeast part of the city and after about 10 kilometers exists the city borders. On the margins of the Qomrud River, the city has been developed so that the size of the city and its suburbs are now about 100 square kilometers. General groundwater flow direction on the urban areas is from northwest to southeast (Rahimi *et al.,* 2017). Proper recharge of the mentioned river (in the past decades before the Qomrud River dried up) and permeable sediments in its channel have caused most drinking water wells are located on the river channel. Qom drinking water is supplied by different resources, such as Upstream of Dez River, panzdeh-e Khordad dam, adjacent aquifer wells (Aliabad plain) and the scattered water wells in the city. Although there are shortages of adequate water supplying resources, water wells in the city are still used to provide water demands. According to the locations of water wells in the city, aquifer quantitative and qualitative protection in this section is essential. In urban areas of developing countries, most aquifers are vulnerable due to the penetration of large amount of urban pollutants to the groundwater as a result of lacking wastewater collection systems and treatment plants (Chilton 1999). The sewage collection network in Qom has not been completed yet. There is a challenge that the development of a sewage collection system greatly reduces the amount of aquifer recharge from return drinking water, and if we don't do it, the pollution increased in the aquifer. In this study, in order to determine the groundwater quality the effective parameters on water quality has been measured and to accomplish this 24 deep wells that mostly selected from potable water wells, were sampled. An accurate assessment of pollutants distribution in the whole city was needed, as some of the selected sampling wells do not have drinking usage because the wells are dispersed in the city area are not all drinking types. The sampling took place on 2013 and all the samples were analyzed by certified laboratory. The study area and sampling site is shown in Fig. 1. The analyzed parameters include color, T , TU, TSS, pH, EC, TDS, DO, BOD_5, COD, total alkalinity, CO3, HCO3, total hardness, Ca, Mg, SO_4, Cl, Na, K, NH_4, NO_2, NO_3, PO_4, total coliform(TC), fecal coliform(FS), fecal streptococci(FS), heterotrophic plate count(HPC), Fe, Hg, Pb, Co, Cd, Ni, As, Zn, B, Sn, Cu, Mn, Ba and Sr. In this study, Iranian drinking water standards (Physical and Chemical Properties (ISIRI No:1053, 2010 ; ISIRI No:1053, 2013), drinking water standard-feature Microbiology (ISIRI No:1011, 2010), and WHO standard (WHO, 2011), were used to evaluate the contamination of the Qom city aquifer.

In order to implement this research, the diagrams were designed to inspect and interpret the tables of chemical data visually, so the achieved data could be compared with the Maximum Contaminant Level (MCL) to assess the amount of water pollution .The measured and analyzed physio-chemicals parameters of Qom's deep wells are reported in Table 1.

RESULTS AND DISCUSSION

Physical parameters

Total Dissolved Solid (TDS)

Total Dissolved Solid (TDS) is a general indicator of water quality which can demonstrate the possibility of water using in different applications.

The groundwater Total Dissolved Solid (TDS) of Qom aquifer is shown in the Fig. 2 .Accordingly, TDS of all wells was higher than the Maximum contaminant level (2000mg/L) and varies between 2390 to 5580 mg/L, with the average amount of 3480mg/L.

pH

The pH varies between 6.8 and 7.9 with an average range of 7.22 which is in the admissible limit according to the Iranian drinking water standard.

Turbidity (TU)

Turbidity indicates the amount of suspended solids in the water indirectly. In fact it can be an indicator of identifying the drinking water microbial contamination. The maximum admissible level (MAL) and maximum contaminant level (MCL) of turbidity according to the Iranian standard is respectively, 1 and 5 NTU. According to the WHO guidelines, if the moderate degree of turbidity on NTU scale does not exceed from 5 in a single sample, the water would be free of bacteria and the virus by the absolute probability of 99.99% if free residual chlorine after 30 minutes would be 0.5 mg/L and the water pH would be less than 8. The turbidity of groundwater aquifer in Qom is shown in the Fig. 3. Among the samples, turbidity pollution in 6 wells which include 5 drinking

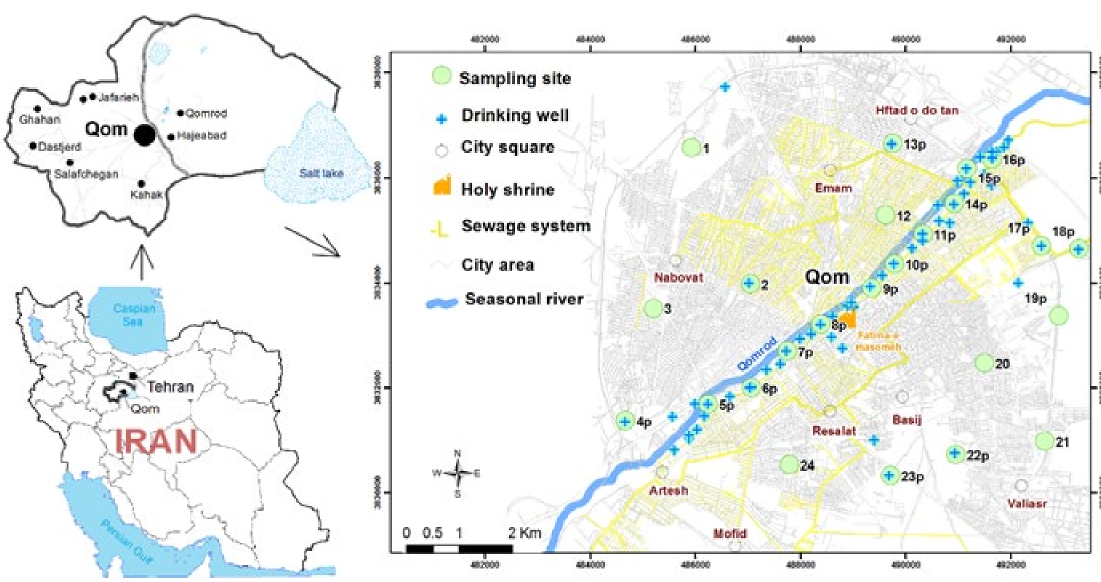


Fig. 1. The study local and samplings

Table 1. The measured and analyzed physio-chemicals parameters of deep wells located in Qom City

CODE	Color	T	Turb.	TSS	pH	EC	TDS	DO	BOD	COD	T Alk	HCO_3	TH	Ca	Mg	SO4	Cl	Na	K	NH_4	NO_2	NO_3	PO_4	I	Br	TC	FC	FS	HPC	Fe	Hg	Pb	Co	Cd	Mn	Cu	Ni	As	Zn	Ba	Sr	B	Sn
	-	^0C	NTU	mg/lit	-	ms/cm	mg/lit																			MPN/100ml			CFU/ml	µg/lit													
1	Clear	18.4	3.7	3	7.2	8310	5380	4.9	2	4	500	610	1176	259	127	1490	1560	1302	24	0.02	0.02	33	<0.01	<0.05	2.34	0	0	0	80	274	<2	<50	<30	<30	<30	<30	<30	<5	<30	<10	7483	3390	<50
2	Clear	20.7	1.2	Nil	7.1	4440	2945	4.1	5	10	610	744	686	118	94	545	731	700	15	0.04	0.01	141	<0.01	<0.05	3.3	0	0	0	6300	<30	<2	<50	<30	<30	<30	<30	<30	<5	<30	10	3204	1800	<50
3	Clear	18.4	0.7	Nil	7.0	5780	3775	6.8	4	7	435	531	882	127	136	1090	970	903.5	17	0.04	0.01	88	<0.01	<0.05	2.68	9	0	0	>6500	<30	<2	<50	<30	<30	<30	<30	<30	<5	<30	10	5233	2600	<50
4p	Clear	18.5	1.7	Nil	7.0	5750	5580	6.0	<1	<1	195	238	1960	456	198	1910	1774	1207	70	0.05	0.01	43	<0.01	<0.05	1.74	0	0	0	>6500	103	<2	<50	<30	<30	43	<30	<30	<5	<30	10	11238	2200	<50
5p	Clear	18.5	9.4	6	7.1	4490	2960	5.2	2	3	460	561	784	157	94	700	783	650	17	0.05	0.02	182	<0.01	<0.05	2.01	110000	11000	0	90	210	<2	<50	<30	<30	<30	<30	<30	<5	<30	<10	4702	2510	<50
6p	Clear	16.3	2.0	Nil	7.1	4320	2790	6.4	<1	<1	315	384	902	196	99	750	783	565.7	15	0.03	0.01	91	<0.01	<0.05	1.6	0	0	0	0	102	<2	<50	<30	<30	<30	<30	<30	<5	<30	<10	5034	1480	<50
7p	Clear	18.2	1.7	Nil	7.1	4730	3075	5.8	<1	<1	465	567	931	236	82	660	870	643	19	0.03	0.01	97	<0.01	<0.05	2.71	11	0	0	3200	61	<2	<50	<30	<30	<30	<30	<30	<5	<30	<10	5471	2300	<50
8p	Clear	17.2	1.7	Nil	7.4	4580	2955	4.9	4	8	455	555	980	236	94	640	818	595	18	0.04	0.01	94	<0.01	<0.05	2.35	23	9	0	0	88	<2	<50	<30	<30	<30	<30	<30	<5	<30	<10	5977	2060	<50
9p	Mudy	18	146.0	48	7.0	4795	3075	4.5	<1	<1	415	506	1156	314	89	670	905	570	19	0.04	0.02	87	<0.01	<0.05	2.73	460	64	0	>6500	290	<2	<50	<30	<30	<30	<30	<30	<5	<30	20	7317	1490	<50
10p	Mudy	17.4	31.9	22	7.1	4700	3025	4.3	2	4	457	558	1107	216	136	730	800	568	18	0.03	0.01	103	<0.01	<0.05	2.42	0	0	0	60	190	<2	<50	<30	<30	<30	<30	<30	<5	37	20	5671	2130	<50
11p	Clear	18	1.0	Nil	7.2	5490	3510	5.0	<1	<1	370	451	1215	346	85	890	1023	695	19	0.03	0.01	51	<0.01	<0.05	2.51	23	9	0	20	110	<2	<50	<30	<30	<30	<30	<30	<5	35	10	6303	1740	<50
12	Clear	20	0.8	Nil	7.0	5170	3370	5.9	3	6	480	586	882	157	118	820	905	770	17	0.2	0.01	70	<0.01	<0.05	2.8	15	9	0	300	<30	<2	<50	<30	<30	<30	<30	<30	<5	<30	<10	4564	2380	<50
13p	Slightly Clear	20.3	13.2	8	7.2	7050	4650	4.5	2	4	555	677	784	196	71	1200	1252	1237	15	0.03	0.01	13	<0.01	<0.05	1	0	0	0	>6500	273	<2	<50	<30	<30	<30	<30	<30	<5	<30	<10	4261	3850	<50
14p	Clear	17.2	1.0	Nil	7.1	4580	2900	6.1	<1	<1	285	348	1078	255	106	700	905	550	15	0.05	0.01	40	<0.01	<0.05	2.73	0	0	0	50	63	<2	<50	<30	<30	<30	<30	<30	<5	<30	20	5645	1370	<50
16p	Clear	18	1.6	Nil	7.1	5570	3530	5.4	<1	<1	285	348	1029	236	106	990	1046	794	17	0.02	0.01	36	<0.01	<0.05	2.75	0	0	0	200	93	<2	<50	<30	<30	<30	<30	<30	<5	<30	10	5703	1650	<50
15p	Clear	19	0.7	Nil	7.1	6200	3975	4.7	<1	<1	465	567	1029	216	118	960	1148	950	18	<0.01	0.01	41	<0.01	<0.05	0.75	0	0	0	5500	<30	<2	<50	<30	<30	<30	<30	<30	<5	<30	<10	5536	2620	<50
17p	Clear	17.6	2.5	Nil	7.2	5410	3405	6.0	4	8	320	390	882	177	106	780	1088	850	14	0.03	0.01	42	<0.01	<0.05	2.71	0	0	0	62	195	<2	<50	<30	<30	<30	<30	<30	<5	<30	<10	4475	1410	<50
18p	Clear	18	3.5	Nil	7.2	5530	3560	7.2	<1	<1	335	409	853	177	99	990	989	875	16	<0.01	0.01	56	<0.01	<0.05	2.75	4	0	0	70	185	<2	<50	<30	<30	<30	<30	<30	<5	<30	<10	4519	1810	<50
19p	Clear	17.2	1.2	Nil	7.5	5070	3235	6.6	<1	<1	300	366	1009	185	132	940	930	660	17	<0.01	0.03	79	<0.01	<0.05	0.65	93	23	0	>6500	62	<2	<50	<30	<30	<30	<30	<30	<5	<30	<10	5482	1460	<50
20	Clear	20	0.9	Nil	7.1	4595	3020	3.8	1	3	535	653	833	196	82	630	793	645	22	0.07	0.01	94	<0.01	<0.05	2.77	0	0	0	0	51	<2	<50	<30	<30	<30	<30	<30	<5	<30	<10	5151	1700	<50
21	Clear	17.4	0.6	Nil	7.4	4410	2840	6.8	<1	<1	350	427	854	146	118	735	800	600	15	0.06	0.01	53	<0.01	<0.05	2.12	11	0	0	20	<30	<2	<50	<30	<30	<30	<30	<30	<5	<30	<10	4221	1470	<50
22p	Clear	16.7	2.2	Nil	7.2	6650	4230	6.7	<1	<1	340	415	1441	354	134	1250	1222	827.6	25	<0.01	0.01	71	<0.01	<0.05	2.73	0	0	0	60	73	<2	<50	<30	<30	<30	<30	<30	<5	<30	<10	6900	1660	<50
23p	Muddy	19	38.6	27	7.2	4730	3120	5.4	<1	<1	485	592	931	196	106	840	731	640	17	<0.01	0.01	101	<0.01	<0.05	2.73	23	9	0	0	198	<2	<50	<30	<30	<30	<30	<30	<5	<30	<10	3100	2210	<50
24	Clear	17.5	7.5	4	7.0	4490	2845	7.1	<1	<1	300	366	882	157	118	720	870	600	15	0.08	0.02	80	0.04	<0.05	2.19	3	0	0	>6500	<30	<2	<50	<30	<30	<30	<30	<30	<5	<30	<10	5444	1550	<50

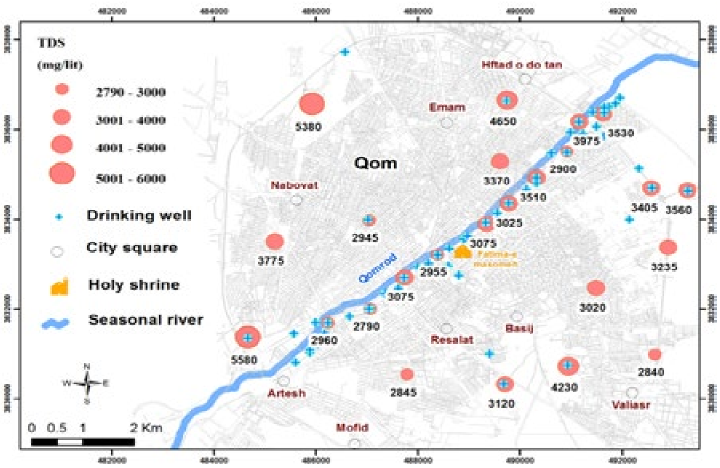


Fig. 2. Groundwater TDS in Qom urban areas

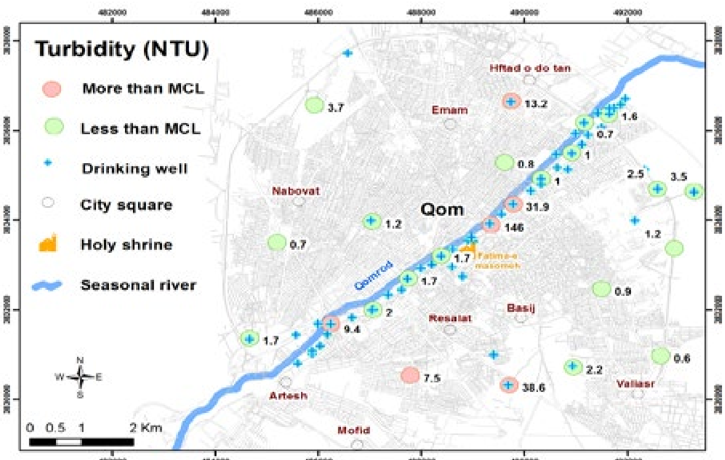


Fig. 3. Groundwater turbidity in Qom urban areas.

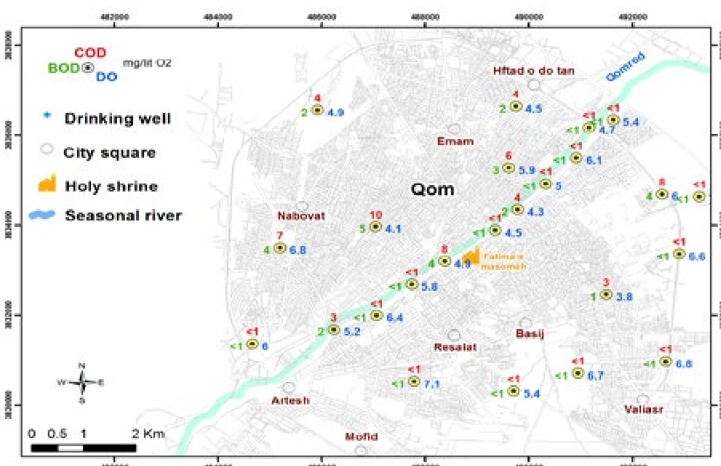


Fig. 4. DO, BOD and COD concentration of groundwater in Qom urban areas

water wells has been observed. According to the measurement, the turbidity in the sample 9p is 146 NTU.

Dissolved Oxygen (DO)

The maximum oxygen that can be dissolved in the water at the normal temperature of 25° C is 9 mg/L. The higher the temperature is, the less dissolved oxygen will be solved. The presence of organic matter in the water increases the amount of chemical, and biochemical oxygen demand and reduces the amount of DO .In the Fig. 4, DO, BOD and COD concentrations of groundwater in Qom city is shown. According to experiments on December 2013, the DO concentration of groundwater samples was between 3.8 to 7.2 mg/L with the mean concentration of 5.6 mg/L.

Biochemical Oxygen Demand (BOD)

To determine the degree of water contamination, the amount of oxygen needed to oxidize organic matter is usually measured instead of the amount of organic matter in the water. BOD is the rate of organisms' oxygen consumption in the solution. If the BOD is low, water is clean and free of organisms, or that organisms in the water are dead and do not need to consume oxygen.

In relatively pure water, BOD5 is in the range of 1 to 5 mg/L but if BOD5 exceeds 20 mg/L, public health is at risk. As it is shown in the Fig. 4, on December 1392, the amount of BOD5 in deep wells varies from 1 to 5 mg/L. The mean BOD5 in the groundwater samples is 2.90 mg/L.

Chemical Oxygen Demand (COD)

COD test is used to measure the amount of oxidizable pollutants in the water or wastewater. The COD test can be calculated at a short time of about three hours. In this experiment, the amount of COD in deep wells was between 3 to 10 mg/L with the average of 5.7 mg/L.

Major ion

According to the Iranian drinking water standards the maximum allowable concentrations of Ca, Mg, Na, SO4 and Cl are 300, 30, 200, 250 and 400 mg/L, respectively.The minimum concentration of the mentioned cations and anions in the Qom aquifer are 71, 118, 550, 545 and 731 mg/L, respectively. In all the measured samples the above anions exceeded the standards but Mg and Na, also in four samples, Ca, were beyond the Maximum contaminant levels.

Nitrate (NO_3)

The main source of nitrate (NO_3) production as a widespread and common pollutant agent of ground water is human and urban activities (Goulding, 2000). In fact as the more municipal wastewater is produced, the more nitrate contamination of water resources occurs (Freeze and Cherry, 1979). In order to investigate the effect of septic tanks on the groundwater contamination, the amount of this anion existence can be analyzed (Lu *et al.,* 2008). High levels of nitrate in the drinking water can reduce the oxygen transfer capacity in humans' bodies. In fact methemoglobinemia which binds oxygen tightly

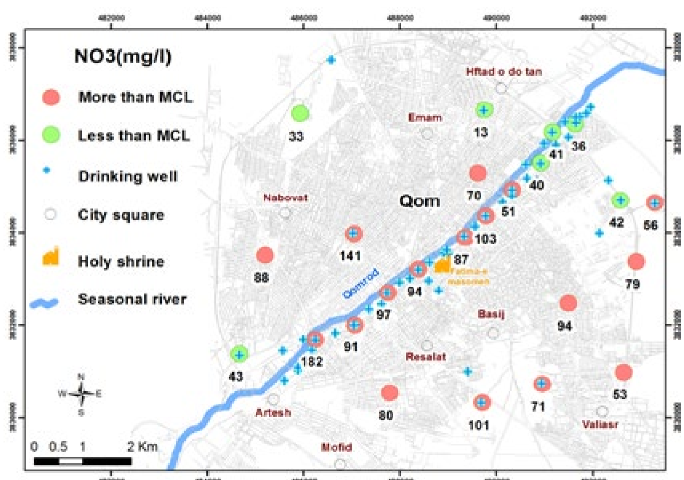


Fig. 5. Groundwater NO_3-in Qom urban areas

and does not release it is the production of nitrite and hemoglobin reaction in red blood cells. This substance results in oxygen transport blocking and will cause blue baby syndrome in infants (Rahimi *et al.,* 2017). In adults, NO_3 in the body is converted into a carcinogen called nitrosamine, which increases the risk of gastrointestinal and bladder cancers. Additionally, excessive levels of nitrate in drinking water can cause goiter diseases, birth defects, gastric cancer and methemoglobinemia in humans (Majudar and Gupa, 200). Based on WHO and Iranian standards, maximum concentration of nitrate in drinking water is 50 mg/L. Distributions of nitrate concentration in sampling areas, on December 2013, are illustrated in the Fig. 5. In this picture, samples were polluted by nitrate concentrations of more and less than maximum level of standards are shown with red and green colors, respectively. The Nitrate concentrations in the samples vary in the rage of 13 to 182 mg/L with the average amount of 75 mg/L. The results show 17 samples out of 24 specimens are polluted. According to the Fig. 5, wide areas of the city have been polluted with nitrate, except the narrow part which is located in the north and west of the city's border. The main reason of decreasing nitrate in some samples is the main direction of groundwater flow in this region which is from the northwest to the south-east.

Nitrite (NO_2)

According to the Maximum contaminant level of nitrite in the Iranian standard which is 3 mg/L, Qom groundwater with minimum, average and maximum concentrations of 0.007, 0.012 and 0.301 mg/L, respectively, is not polluted with this anion.

Ammonium (NH_4)

Ammonium (NH_4) as an indicator of groundwater pollution with urban municipal wastewater (Paul *et al.,* 2004) had the minimum and maximum concentrations of 0.02 and 0.2 mg/L, respectively with the mean concentration of 0.05 mg/L in the plain. According to the maximum level of ammonium in the Iranian standards which is 1.5 mg/L, this ion the Qom aquifer are in admissible limit.

Iron (Fe)

In WHO standard iron is not categorized as a pollutant substance, just in the cases that its concentrations is higher than 0.3 mg/L, it can cause discoloration or turbidity in the water (giving an objectionable reddish-brown color to the water) or stainin clothes and dishes (WHO, 2011).The measured concentrations of iron in the samples were between 0.05 and 0.29 mg/L which is in the admissible limit. The maximum amount of Fe in the Iranian standard is 0.3 mg/L.

Zinc (Zn)

Zinc concentration in Qom groundwater is less than 0.03 mg/L. In comparison with Iranian standard with maximum level of 3 mg/L, this ion is in the admissible limit.

Heavy metals are often assumed to be highly toxic or damaging to the environment. Some are always toxic but some others are dangerous if only their concentration exceeds the standards. Chromium, Arsenic, Cadmium, Mercury, and lead at excessive concentrations, are the most harmful elements because of their pure or combined forms toxicity and their widespread distribution in the environment. Disposal and reuse of industrial wastewater is one of the most important ways of entering these elements into the environment (Mapanda *et al.,* 2005). Heavy metals are usually at the concentrations of less than 1–2 µg/L in the natural water. However, in the waters, particularly the ground waters, where there are sulfide mineral and sedimentary deposits deriving from volcanic rocks, the heavy metals concentrations can be significantly elevated (WHO, 2011).

Arsenic (AS)

Arsenic as a cumulative substance in the body can enter to humans' body by aquatic organisms 'consumption. It is difficult to get rid of this element after entering the body (Huntsman-Mapila *et al.,* 2006). The MCL of this element is 0.01 mg/L according to the WHO and Iranian drinking water standards. The arsenic quantity in the Qom aquifer is less than 0.005, so there is no contamination of this element in the groundwater.

Boron (B)

Boron compounds which are used in the manufacture of glass, soaps and detergents and as flame retardants. Naturally occurring boron is present in groundwater. The surface water borate contents can be increased by the wastewater discharges because Perborate is a source of active oxygen in many detergents, laundry detergents, cleaning products, and laundry bleaches. Poisoning B occurs more frequently through absorption by contaminated water and food in humans (Mara, 2004). High levels of B in humans cause negative effects on male genitalia and the development of malignant tumors in them, etc. The concentration of B in the aquifer of Qom is illustrated in Fig. 6. The MCL of this element in Iranian standard is 0.07 mg/L but in WHO guidelines the MCL of B varies from 0.5 to 2.4 mg/L. The minimum, average and maximum of this element in Qom ground water was 1.4, 2 and 3.8 mg/L, respectively, so according the Iran's standard, all samples were polluted but due to the WHO guidelines there were only five polluted samples. This amount of B might be related to the leakage of soaps and detergents from the septic tanks.

Barium (Ba)

The primary resource of Ba in the water is nature. The toxicological end-point of greatest concern to humans appears to be its potential to cause hypertension (WHO, 2011). According the WHO and Iranian standards, the MCL of this element is 0.7 mg/L .The Ba concentration in Qom groundwater was less than 0.02 mg/L, so there is no Ba pollution.

Mercury (Hg)

Hg is present in inorganic form in the surface water and groundwater at the concentrations of usually below 0.5 µg/L. Excessive amount of this element can causes acute oral poisoning and even damage kidney in humans (WHO, 2011). In Qom aquifer, the Hg concentration was less than 0.002 mg/L which due to the WHO and Iranian standards (MCL = 0.006 mg/L), so there is no Hg pollution.

Nickel (Ni)

Small amount of Ni in food is necessary for the body, but when it exceeds from MCL, it will have adverse effects on humans' body. According to the International Agency for Research on Cancer (IARC) inhaled nickel compounds are carcinogenic to humans; also metallic nickel is possibly carcinogenic. Ni Concentration in the city aquifer was less than 0.03 mg/L which is less than maximum contaminant level mentioned in WHO and Iranian standards (=0.07 mg/L).

Lead (Pb)

Pb is one of the most harmful elements to human health which can causes various diseases such as neurodevelopmental effects, mortality (mainly due to cardiovascular diseases), impaired renal function, hypertension, impaired fertility and adverse pregnancy outcomes (WHO, 2011).

The Pb concentration in Qom aquifer was less than 0.05 mg/L that in comparison with the maximum contaminant level mentioned in WHO and Iranian standards (=0.01 mg/L), unfortunately the groundwater is polluted by this element.

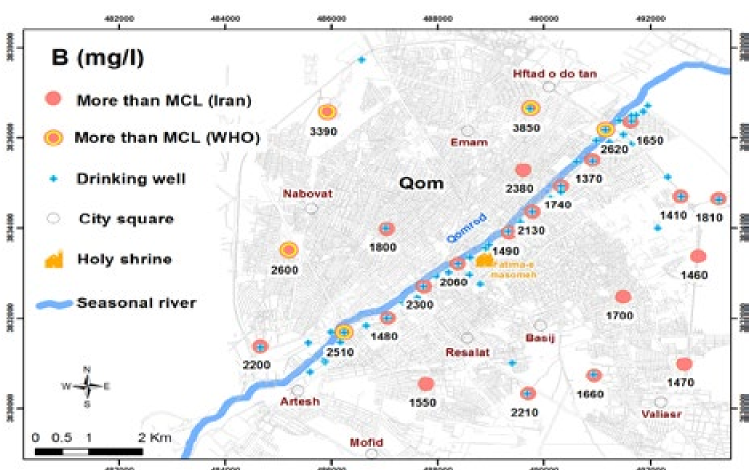


Fig. 6. Boron concentration in Groundwater of Qom urban areas

Cadmium (Cd)

Cadmium with 10–35 years biological half-life in humans, accumulates primarily in the kidneys. There is evidence that cadmium is carcinogenic by the inhalation route, and IARC has classified cadmium and cadmium compounds in Group 2A as probably carcinogenic to humans. According to the WHO and Iranian standards, the MCL of this Contaminant is 0.003 mg/L. The concentration of Cd in Qom was less than 0.03 mg/L. Unfortunately Cd concentration was ten times higher than the maximum allowable amounts. As a result, according to the experiments which were performed on 2006, Qom aquifer has Pb and Cd contamination (Rahimi *et al.,* 2018).

Indicator organisms

Bacteria, parasites and viruses cause water pollution (Bilton, 2005). The main aim of groundwater microbiological studies is the health hazards of fecal contaminants (Clay, 1990). So that the incorrect disposal of municipal wastewater and the lack of primary treatment prior to disposal to the ground increases the risk of microbial pollution of groundwater (Tim and Mostaghimi, 1991).The most various and important microbes in the water are bacteria's. The presence of coliform bacteria in the groundwater is an indicator of the surface water or surface activities impacts, because the source of coliform is in the surface of earth. Escherichia coli as the most suitable indicator of fecal contamination (WHO, 2011) exist in humans and animals bodies in very large numbers and are rarely found in the absence of fecal pollution. There are more than 3 million total coliforms per 100 mg of raw sewage. The presence of Escherichia coli and coliforms, as the earlier known bacteria in the stool than the others, in the groundwater can be a reason of water contamination with human and animal wastewater (ICMSF,1998). The Escherichia coli lifetime outside the human body can last only 21 days, so they can be used as an indicator to determine the recent sewage contamination. The presence of coliform in groundwater can indicate the presence of other pathogenic microorganisms and its contamination by municipal wastewater (Hosetti and Kumar, 2002). Most Probable Number (MPN) is a useful indicator to count the bacteria in the water or wastewater samples, so if the MPN number is 0 t0 2, the water is clean, less than 10 is good water, less than 100 is suspected water, less than 1000 is contaminated water and less than 10,000 is highly contaminated water. The Total Coliform (TC), Fecal Coliform (FC) and Fecal Streptococci (FS) of Groundwater in Qom are shown In the Fig. 7. Total coliform bacteria include a wide range of aerobic, facultative and anaerobic bacteria, Gram-negative and non-spore-forming bacilli capable of growing in the presence of relatively high concentrations of bile salts with the fermentation of lactose and production of acid or aldehyde within 24 hours at 35–37 °C.(WHO, 2011). Traditionally, coliform bacteria were regarded as Escherichia, Citrobacter, Klebsiella and Enterobacter categories, but the group is more heterogeneous and includes a wider range of genera, such as Serratia

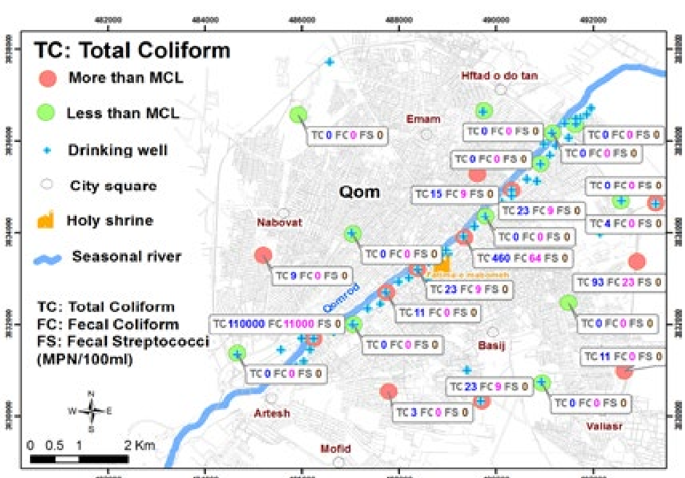


Fig. 7. TC, FC and FS of Groundwater in Qom urban areas

and Hafnia. The total coliform group include both fecal and environmental species. The existence of TC among 24 samples was negative for the 12 samples (where seven of the samples were drinking water wells) and positive for the rest of them. Among 12 samples with TC existence, three water samples were in good order, seven were in suspected category, one was infected and the last one was contaminated. The maximum TC contamination of 110000 MPN / 100cc was observed in the 5p drinking well. Escherichia coli (or, alternatively, thermotolerant coliforms) recognition is based on the production of acid and gas from lactose or the production of the enzyme β-glucuronidase at 44–45 °C and after 24 hours. The most coliform of fecal is Escherichia coli, Klebsiellapneumoniae (WHO, 2011). The Fecal Coliform (FC) tests results were positive for 4 wells among the 24 which five of them were drinking wells. The sub group intestinal enterococci consist of the species Enterococcus faecalis, E. faecium, E. durans and E. hirae. This group was separated from the rest of the Fecal Streptococci (FS) because they are relatively specific for fecal pollution. FS is used to identify the source of water pollution. If the FC ratio to FS is greater than 4, then the source of contamination is human infection. If the FC ratio to FS is less than 0.7, the source of pollution is animal contamination. The results of FS existence tests of all samples were

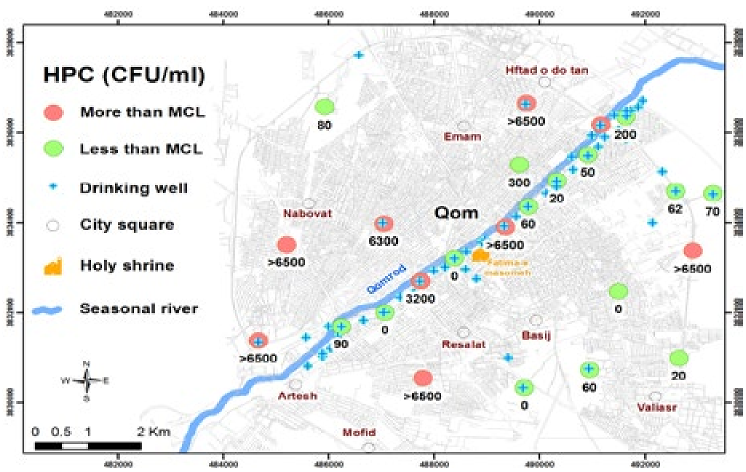


Fig. 8. Groundwater HPC index in Qom urban areas

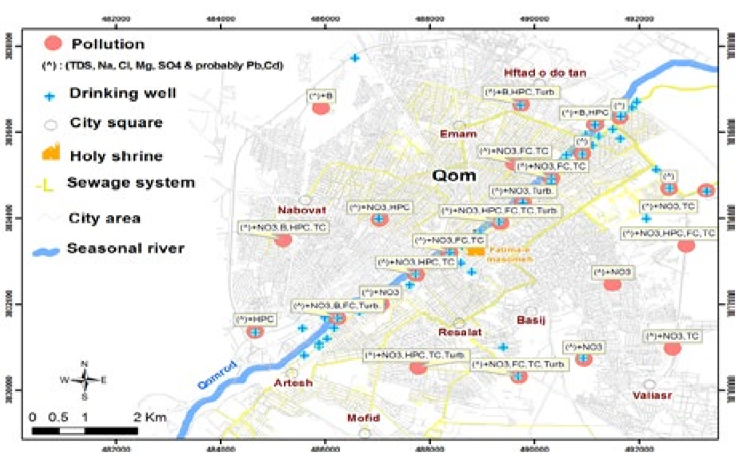
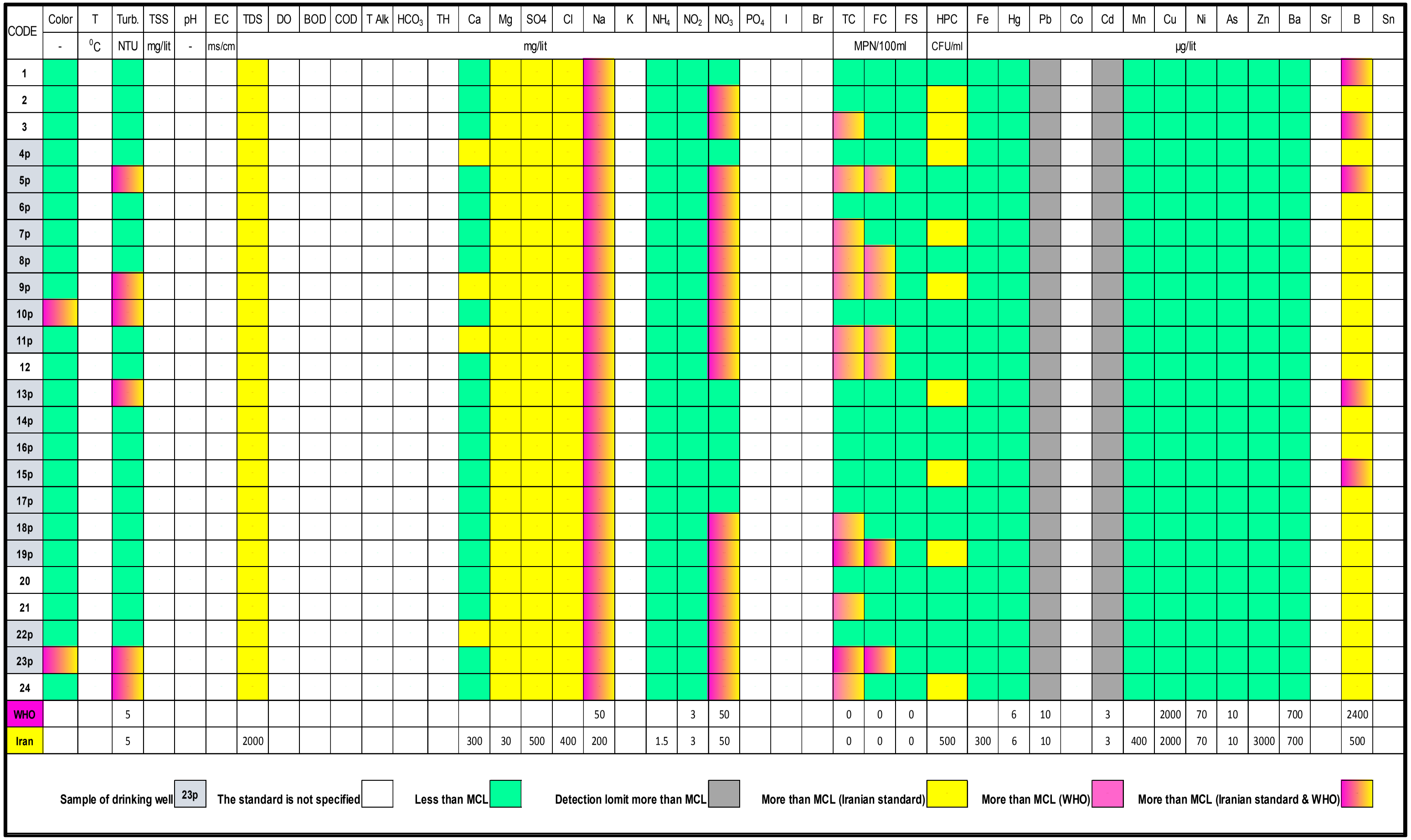


Fig. 9. Groundwater pollutants in Qom urban areas

Fig. 10. Ground water samples of Qom urban areas analysis comparison with the WHO and Iranian Standards



negative, so the source of contamination in the city is human feces. Nowadays, heterotrophic bacteria, called HPC index, are considered as complementary to the coliform index in the water quality control. In order to express the overall microbial status of the water, a qualitative parameter of HPC is used which is an estimate of the total number of bacteria present in water. HPC has not been recognized as an appropriate indicator to determine the pollution of groundwater caused by the impact of sewage (Paul *et al.,* 2004). The maximum permissible HPC has not been specified by the US Environmental Protection Agency. The virtual maximum (other than zero) cannot be considered as an effective parameter on the health because HPC contains any harmful pathogen (pathogen) and harmless bacteria, so water at any level of HPC may be high, low, or without pathogenic agents. The HPC index in the Qom aquifer is illustrated in the Fig. 8. The HPC analysis results of 24 samples were positive in all of them that in 9 samples, they were more than 500 CFU / ml. The pollutants are shown in the Fig. 9 for each well. According to the results of analyzes, concentrations of TDS, Ca, Mg, Na, Cl, SO4 and possibly Pb and Cd concentrations in all wells are higher than MCL and the concentration of B, NO3, TC , FC and HPC pollutants are more than MCL in some wells. Qom ground water samples analysis comparison with the WHO and Iranian DWS is shown in Fig. 10.

According to the experiments in this research, the average aquifer TDS in Qom was 3480 mg/L which has been greater than the maximum contaminant level of 2000 mg/L. Turbidity pollution has been observed in some samples mostly included drinking wells. On December 2013, the BOD5concentration in deep wells varied from 1 to 5 mg/L which cause to assume water relatively pure of this parameter. The ions concentrations of Mg, Na, Cl, and SO4were more than the maximum allowable level but calcium (Ca) was greater than admissible limit just in 4 wells. The results show that 17 samples out of 24 were contaminated with nitrate (NO3), so all the city except a narrow part in the north and west, are polluted. The average amount of nitrate was 75 mg/L. The concentrations of pH, NO2 and NH4 in the groundwater were in admissible limit due to the Iranian standard. In fact nitrite and ammonium are converted to nitrate by the nitrification processes. The concentration of non-toxic heavy metals like iron (Fe) and zinc (Zn) were less than the MCL. No toxic contamination of As, Ba, Hg and Ni has been observed in the aquifer of Qom. There is an evidence of Pb and Cd contamination presence in the natural origin of Qom aquifer in 2006, but because of laboratory detection limit, more tests are required to detect these pollutants. Boron (B) as a toxic pollutant has the average concentration of 2 mg/L in Qom city. Compared to Iran's standard, all samples are polluted with B, but according to the WHO standard, only five samples are polluted .Increasing this chemical element in the sewage is the result of sweeteners existence in the cleaners and detergents.

Half of the samples (12 samples) which include seven of drinking wells were polluted of total coliforms (TC), also the results of the fecal coliforms (FC) tests in six water samples were positive, which include five of drinking water wells. The results of the Fecal Streptococci (FS) test were negative for all the samples. The fecal contamination source was human fecal. The measured HPC index was higher than zero in 20 samples and higher than 500 CFU/ml in 9 samples. According to the correlation coefficient between measured parameters, the resource of TDS, major ions and possibly Pb and Cd was natural. The inappropriate quality of the main ions in the city aquifer is the result of salt and gypsum sediments dissolving from eroded geological formations in the area.

No correlation between TDS, B, NO3, TC, FC and HPC exists that indicate anthropogenic pollutants resources associated with scattered wastewater wells in the city. The main concern in public health is vulnerable aquifer usage for drinking purposes without any purification or disinfection processes which increases the risk of drinking water pollution. Contaminated groundwater usage by humans, may pose significant risks to human health and the environment. Despite the High depth of 42 meters from the ground level, pollutants have infiltrated to the ground water. Qom is located on alluvial fan. Coarse-grained and permeable sediment of alluvial fan cause pollutants to penetrate quickly to the ground water and polluted the aquifer. Therefore, as soon as possible it is necessary to complete the sewage collection network and wastewater treatment plant to prevent the leak of sewage into the city aquifer and groundwater.

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CONFLICT OF INTERESTS

The author declares that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy have been completely observed by the authors.

ABBREVIATIONS

As	Arsenic
B	Boron
Ba	Barium
BOD5	Biochemical Oxygen Demand
Br	Bromine
Ca	Calcium
Cd	Cadmium
CFU	Colony-Forming Unit
Cl	Chlorine
Co	Cobalt
CO_3	Carbonate
COD	Chemical Oxygen Demand
Cr	Chrome
Cu	Copper
DO	Dissolved oxygen
EC	Electrical Conductivity
EPA	US Environmental Protection Agency
EU	European Union
FC	Fecal Coliforms
Fe	Iron
FS	Fecal Streptococci
HCO_3	Bicarbonate
Hg	Mercury
HPC	heterotrophic Plate Count
I	Iodine
ISIRI	The Institute of Standards & Industrial Research of Iran
K	Potassium
MAL	Maximum Admissible Level
MCL	Maximum Contaminant Level
MCM	Million Cubic Meters
Mg	Magnesium
mg/L	Milligram per Liter
Mn	Manganese
Na	Sodium
NH4	Ammonium
Ni	Nickel
NO2	Nitrite
NO3	Nitrate
NTU	Nephelometric Turbidity Units
Pb	Lead
pH	Potential of Hydrogen
PO4	Phosphate
Sn	Tin
SO4	Sulfate
Sr	Strontium
T	Temperature
TC	Total Coliforms
TDS	Total Dissolved Solid
TSS	Total Suspended Solids
TU	Turbidity
WHO	World Health Organization
Zn	Zinc
µg/L	Microgram per Liter

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