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Chemical Variations of Ground Water Affected by the Earthquake in bam region

Malakootian, M. [1*] **and Nouri, J.** [2]

[1] Department of Environmental Health, School of Public Health, Kerman University of Medical Sciences, Kerman, Iran

[2] Department of Environmental Management, Graduate School of the Environment and Energy, Science and Research Branch, Islamic Azad University, Tehran, Iran

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ABSTRACT: An earthquake with magnitude Ms = 6.5 on the Richter scale occurred in December 26th, 2003 in Bam Region in southeastern part of Iran. This study investigates the chemical variations of the groundwater resources in the effected region. For this purpose, 30 wells were selected and chemical compounds, in terms of cations (Ca+2, Mg+2, Na+, K+); anions (HCO_3, SO_4, Cl, NO_2), as well as EC, TDS and pH were analysed from Winter 2004 to Spring 2006. Results were compared with the ones obtained from winter 2003 to winter 2004. Then, using T-test, results of before and after the earthquake was investigated. The experiments were carried out according to the Standard Method of water and wastewater which showed during the after earthquake most chemical parameters considerably increased rather than before the earthquake date. These changes reached their peak in the first year and Summer 2004 after the earthquake. The rate of variations was estimated about 17.5 - 88.3 % throughout the Bam and Baravat plains and 7-65.5% in wells water. It can also be considered that the fluctuation of underground waters chemical characteristics after the earthquake could be mainly due to different factors as follows: A) change in water levels as a result of earthquake, B) change in water temperature that will cause more solubility, C) change in water pressure trapped in rocks and aquifers and D) mixing with water of neighboring aquifers. The rate of fluctuations of different parameters in selected wells also showed a negative trend after the earthquake.

Key words: Bam and Baravat plains, Bam earthquake, Groundwater variations, Well

INTRODUCTION

Earthquake can severely affect groundwater (Stephens 2006). Ground layers movement influence quality and quantity of groundwater aquifers (Nitcheva *et al.* 2000; Wang *et al.* 2004; Babel and Opiso, 2007). On the other hand, earthquake may cause very small cracks in rocks which lead to separation of electrons from atoms and movement of groundwater aquifers. Changes in ground topography after earthquake can cause ground layers to move to a similar level with polluted aquifers which may change chemical composition of groundwater's (Nitcheva *et al.* 2000; Maxwell *et al.* 2001; Kirimizitas *et al.* 2003; Nwuche and Ugoji, 2008; Igbinosa and Okoh, 2009; Ziari and Gharakhlou , 2009). Immediately, before and after earthquake, there are some hydrological indicators such as color, temperature and odor change, as well as changes in chemical composition and level of surface and groundwater's (Esposito *et al.* 2001; Chjeng *et al.* 2003; Sato *et al.* 2004; Hsu *et al* , 2005; Zhu-Zhuan *et al.* 2007; Mahvi, 2008; Vafaeinezhad *et al.*, 2010). For example, radon produced due to radioactive decay of trace amount of uranium present in rocks increases in groundwater resources (springs and wells) before earthquake (Singh *et al.* 1999; Rafee *et al.*, 2007; Malakootian *et al.*, 2009; Shah *et al.*, 2009; Gharakhlou *et al.*, 2010). Thus, when cracks are made in rocks and water penetrates into them, radon transportation increases in flowing water which can be a pre-indicator of earthquake (Kuo *et al.* 2006). Also, changes in amount and level of groundwater, as well as hydrological changes in ground level and appearance or disappearance of springs have been reported over 2000 years earlier (Kitagawa *et al.*1996; Chia *et al.* 2001; Manga 2001; Matsumoto *et al.* 2003; Panjeshahi and Ataei, 2008) An earthquake of magnitude Ms = 6.5 on the Richter scale and a focal point of about 8 km occurred on 26th December 2003 at 1:56'GMT and 5:26' local time in Bam City, along Bam Fault located in southeastern of Iran (Fig. 1). Any major earthquake, at least in past

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*Corresponding author E-mail: m.malakootian@yahoo.com

2500 years was not recorded (Ashtiany 2004; Nadim *et al.* 2004). Many aftershocks were recorded after this earthquake from 26th December 2003 to the 22th November 2004. Besides, earthquake and geotechnical phenomena such as land slides and earth recession were observed (Eeri 2004; Elmay *et al.* 2009; Nouri *et al.*, 2010). This study was carried out to investigate the effect of earthquake on chemical quality of groundwater resources in Bam and Baravat plains.

MATERIALS & METHODS

Bam earthquake occurred in the margin of Lut desert in the south- eastern of Iran (Fig.1) (Nadim et al. 2004; Kerman Regional Water Company 2003). Average altitude of the study area from sea level is 960 m and total area is 9927 km^2 with a 4357 km^2 plain. (Kerman Regional Water Company 2003). This area has hot and arid climate. The plain is comprised of alluvial deposits related to the fourth geological era and the main groundwater resources(Eeri, 2004; KRWC, 2002). The topographical feature of the city is the volcanic hills located at the north and south west of Bam. Total amount of annual rainfall is not considerable (60 mm/y) especially during the years of 2003 to 2006 (Table 4) (Lashkaripour *et al.* 2007). Underground water was extracted mainly using deep wells and Qanats. Before Bam earthquake, there were about 126 active Qanats at the area that supply 50 % of the city water demand (Amini, *et al.* 2004; KRWC, 2002). The rest of the required water was supplied by deep wells (150-200 m depth) (Amini, *et al.* 2004). Firstly, regarding the region condition, 20 piezometric wells, drilled by Kerman regional water company to study the water table condition and chemical quality, were selected. These wells were located in center (Zone 2) and east (Zone 3) of plain (Fig. 2). Most of the underground waters in this area are used for agriculture purposes. Also, 10 wells used for drinking water supply of Bam city were chosen. These wells were located in west part of plain (Zone 1) and near main fault and an epicenter location of 29.00 N, 58.34 E (Fig. 2) (Nadim *et al.* 2004). Field investigations, geographical, geological and topography maps showed that well sites are proper to reveal the groundwater conditions of plain. In order to study the changes of drinking and piezometric water wells located in the plain after the earthquake, one sample was taken 5th day of each month from winter 2004 to spring 2006 and following parameters were determined: K^+, $Na^{+,}$ Mg^{+2}, Ca^{+2}, SO_4^{-2}, NO_3^-, HOC_3^-, TH (total hardness) and total dissolved solids (TDS). The data has been extracted from winter 2003 to winter 2004 that samples also has taken 5th day of each month from the previous study (Malakootian *et al.*, 2004). Then, maximum, minimum and mean of these parameters were calculated for any of the drinking and piezometric water wells to compare the average amounts in the different seasons after the earthquake until 2006. Meanwhile, the average chemical quality of water wells was studied in different seasons till spring 2006 after the earthquake and compared with autumn 2003 (before the earthquake). Then, the maximum, minimum and average rate of each parameter in the drinking water wells was compared to Iranian standard for drinking water which is based on WHO guidelines (ISIRI, 1997; Malakootian *et al.* 2007). The same comparison was made for agricultural wells. All the experiments were performed according to Standard Methods for examination of water and wastewater (APHA, 1998). Using SPSS Software and T-test, a comparison was made between concentration of different water chemical quality in autumn 2003, before the earthquake and different seasons till spring 2006 (after the earthquake).

RESULTS & DISCUSSION

Results of maximum, minimum means and standard deviation of chemical quality of groundwater in all wells throughout the Bam and Baravat plain, drinking and piezometric wells before and after earthquake from 2003 to 2006 are shown in Table 1, 2 and 3. The trends of mean concentration of measured parameters in different season of all years before and after earthquake are shown in Figures 3, 4, 5, 6, 7 and 8. Concentration changes in different parameters show that chemical quality follows a negative and unsuitable trend both for drinking and agriculture purposes from west to east (Fig. 2). EC and T.D.S mean change curve (Fig. 3) and average concentration of different cations and anions in underground water throughout Bam and Baravat plain (Fig. 4) point to meaningful and considerable fluctuations in underground water chemical quality after the earthquake (Table1).

All the mentioned changes can be considered as the consequences of earthquake in December 2003. Moreover, aftershocks of the earthquake which caused an increase in the water level and fluctuations (Hsu *et al.*, 2005; Lashkaripour *et al.*, 2007; Maxwell *et al.*, 2001; Zhu-Zhuan *et al.*, 2007) resulted in more minerals solved in water. Comparing mean season parameters of different chemicals in underground water in Bam and Baravat plain in autumn 2003 (before the earthquake) with the scales recorded in winter, spring, summer and autumn of 2004 represented a considerable increase in many parameters. This increase comes to peak rank during the first year and summer of 2004 after earthquake. In other words, the range of increase was 17.5 % to 88.3 % in different parameters throughout the plain. Water quality showed various fluctuations that can be considered mainly due to continuous occurrence of aftershocks (93 aftershocks from 26th December 2003 until 22th November 2004); (Woith *et* *al.*, 1999). Statistical study and analyzing the data represent a meaningful change in different parameters such as concentration of cations and anions and EC and T.D.S measured in autumn 2003 (before the earthquake) with the ones recorded after earthquake in different seasons until spring 2006. Since then, as the number of aftershocks decreased, the rate of such changes and fluctuations in water chemical quality followed a natural routine. But, water source showed a useless and negative trend because of drought and lack of water feeding sources mismanagement in planting and harvesting and soil abuse. To find out the earthquake effects on underground water chemical quality in Bam and Baravat plain, used for drinking, especially those which mainly located near the main fault and epicenter and in west part (Zone 1), some parameters such as mean change curve of EC, TH and T.D.S have been considered in different seasons (Fig. 5). In addition, other mean parameters of chemical quality of these ten water wells (Fig. 6) located in a distance of 10 km from main fault and epicenter (Fig. 2) was studied during different seasons. The findings

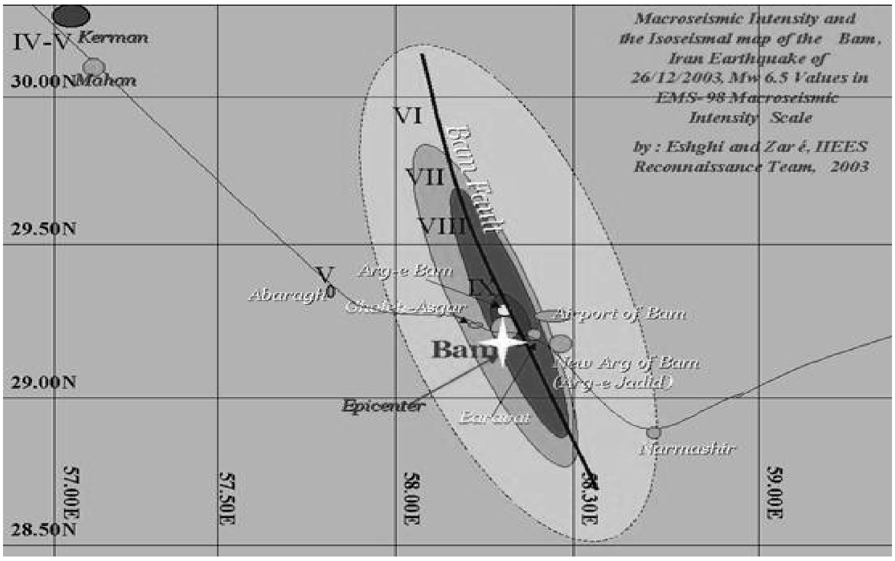

Fig. 1. Location of earthquake in Bam and Baravat plain

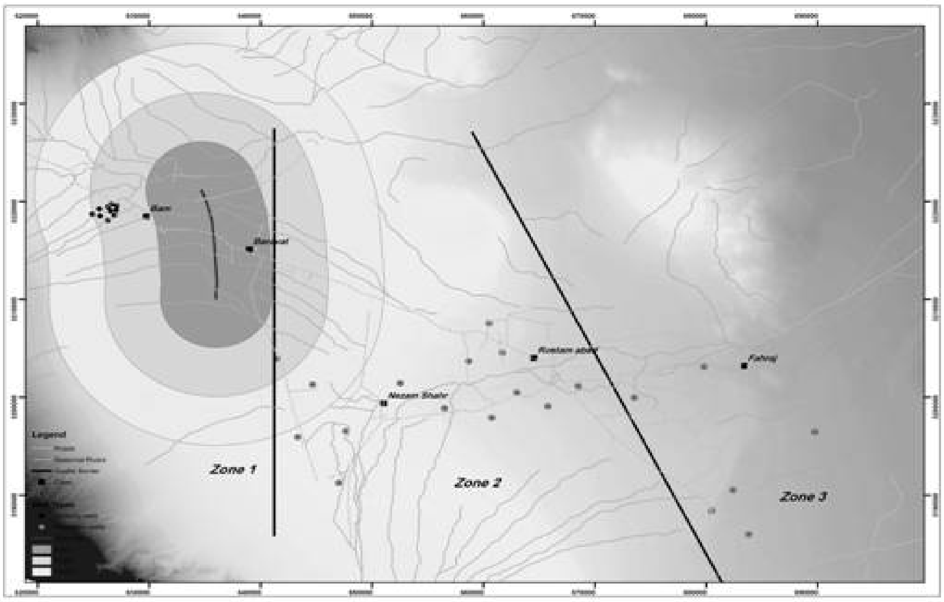

Fig. 2. Location of drinking and piezometric (agricultural) wells, different zones, main fault and epicenter in Bam and Baravat plain

Table 1. Chemical compounds of groundwater in wells and drinking water and piezometric throughout the Bam and Baravat plains during the various years, before and after earthquake of December 2003 (From 2003 to 2006)

Seasons	State	pH	EC (μmhos/cm)	TDS (mg/L)	Ca^{+2} (mg/L)	Mg^{+2} (mg/L)	Na^{+} (mg/L)	HCO_3^{-} (mg/L)	SO_4^{-2} (mg/L)	Cl^{-} (mg/L)
Winter 2003	Mean	7.54	1253.4	788	101.4	20.6	251	317.2	464	423
	S.D.	0.3	814	505.7	72	15.2	182.8	61	267.8	257.3
Spring 2003	Mean	7.69	1410	878	113.1	21.6	239	318.2	471.5	543
	S.D.	0.37	888.6	530.6	67.8	11.2	119.5	68	271.7	360
Summer 2003	Mean	7.7	1436	902	173.5	41	332.5	304	490	627
	S.D.	0.52	890.2	528	111.2	23.8	162.6	58	313.5	415
Autumn 2003	Mean	7.68	1353.2	797	175.6	54.5	323.7	270.7	499	598
	S.D.	0.44	514.9	349.5	114	34.3	163	53.7	324.8	404.2
Winter 2004	Mean	7.9	1572	1043	186.2	77.5	424.3	379.2	635.4	683.8
	S.D.	0.6	998	422	107.8	49.3	238.4	125.7	403.7	457.7
Compare to Autumn 2003	P_Value	0.111	0.135	0.017	0.704	0.035	0.054	0	0.141	0.43
	T	-1.629	-1.514	-2.462	-0.381	-2.156	-1.97	-4.491	-1.49	-0.794
Spring 2004	Mean	8.33	1600	1025	201.3	86.7	485.3	433.6	697.6	672.4
	S.D.	0.42	649	430	127.3	57.7	289.2	164	483.5	462
Compare to Autumn 2003	P_Value	0	0.109	0.028	0.398	0.01	0.018	0	0.059	0.495
	T	-5.994	-1.629	-2.251	-0.851	-2.688	-2.447	-5.339	-1.932	-0.686
Summer 2004	Mean	8.29	1700	1101.6	237.6	90.7	609.8	459	799	703
	S.D.	0.62	679	332	150.1	61.2	380.6	173.9	518.3	488.7
Compare to Autumn 2003	P_Value	0	0.03	0.001	0.067	0.005	0	0	0.008	0.362
	T	-4.306	-2.224	-3.457	-1.860	-2.91	-3.909	-6.093	-2.775	-0.919
Autumn 2004	Mean	7.6	1552.8	943	195	66.3	369	402	745	724.7
	S.D.	0.35	604	403	122.5	41.4	183	153.3	516	475.4
Compare to Autumn 2003	P_Value	0.828	0.176	0.138	0.513	0.216	0.288	0	0.025	0.252
	T	0.218	-1.371	-1.504	-0.658	-1.251	-1.072	-4.642	-2.308	-1.155
Winter 2005	Mean	7.58	1361	850	139	28.7	289	338.5	453	432
	S.D.	0.45	730.7	471.5	121.2	21.3	189.6	175.2	420.7	404.7
Compare to Autumn 2003	P_Value	0.322	0.965	0.594	0.171	0	0.377	0.011	0.578	0.072
	T	0.997	-0.044	-0.536	1.38	3.827	0.889	-2.608	0.559	1.822
Spring 2005	Mean	7.11	1450	960	181.7	38.8	424	445	698	640.6
	S.D.	0.72	780	476	99.5	20.43	201.1	187	414.6	397
Compare to Autumn 2003	P_Value	0	0.367	0.11	0.79	0.019	0.007	0	0.007	0.605
	T	5.173	-0.906	-1.619	-0.268	2.444	-2.79	-7.814	-2.759	-0.518
Summer 2005	Mean	7.66	1417.5	882.2	148.6	21.12	391	321.5	642	506
	S.D.	0.4	816	458	83.8	14	234.3	101.2	427.6	352
Compare to Autumn 2003	P_Value	0.849	0.71	0.358	0.226	0	0.139	0.001	0.055	0.263
	T	0.191	-0.373	-0.925	1.227	5.341	-1.491	-3.49	-1.951	1.133
Autumn 2005	Mean	7.33	1302.5	817	134	70.6	377.8	339.7	649.2	610
	S.D.	0.36	835	595.5	75.8	40.7	178	106	430.6	383
Compare to Autumn 2003	P_Value	0	0.763	0.864	0.063	0.037	0.14	0	0.044	0.876
	T	4.038	0.302	-0.172	1.913	-2.132	-1.486	-4.691	-2.05	-0.156
Winter 2006	Mean	7.34	1317	842.2	79	40.5	416	408.6	659.45	593
	S.D.	0.28	846	587	31.2	24.1	200.6	178.1	393.3	361.5
Compare to Autumn 2003	P_Value	0	0.829	0.705	0	0.038	0.012	0	0.041	0.951
	T	4.035	0.217	-0.38	4.734	2.138	-2.589	-6.468	-2.068	0.061
WHO guideline for drinking water		8	2000	1500	250	50	200	-	400	500

Table 2. Chemical compounds of groundwater in wells and drinking water of Bam city throughout the Bam and Baravat plain during different seasons, before and after earthquake of December 2003 (From 2003 to 2006)

Season	State	pH	EC (μmhos/cm)	TDS (mg/L)	T.H (mg/L)	Ca^{+2} (mg/L)	Mg^{+2} (mg/L)	Na^{+} (mg/L)	K^{+} (mg/L)	HCO_3^- (mg/L)	SO_4^{-2} (mg/L)	Cl^- (mg/L)	NO_3^- (mg/L)
Winter 2003	Mean	7.34	682	502	139	27.5	12.06	108.6	7.77	221.5	127.5	104.5	7
	S.D.	0.267	31	42.87	22.5	1.17	1.28	13.47	1.08	8.06	24.44	13.5	0.76
Spring 2003	Mean	7.83	831	609	162	30	20.9	101.01	13.35	248.37	130.21	92.058	9.05
	S.D.	0.242	229	163.4	94	3.3	13.68	25.23	4.82	59.50	33.93	17.96	3.21
Summer 2003	Mean	8	869	634	160	38	13	129.29	4.36	235.33	92.54	105.91	8.966
	S.D.	0.29	275	205.6	69	15	6	38.85	1.17	12.16	29.68	49.192	4.0005
Autumn 2003	Mean	8.1	777	449.5	137	33	13	118.58	4.55	205.54	87.32	89.83	7.658
	S.D.	0.073	141.5	93.2	21	6	3	21.72	1.014	14.57	25.93	30.50	0.57
Winter 2004	Mean	7.9	963	683.3	194	52	16	129	4.89	221.25	122.6	109.3	9.1
	S.D.	0.3	168	233.8	25	8	2	10.47	0.87	14.529	17.025	27.59	1.214
Compare to Autumn 2003	P_Value	0.249	0.008	0.006	-	0	0.001	0.154	-	0.015	0.001	0.115	-
	T	1.294	-2.929	-3.219		-6.783	-3.668	-1.494		-2.644	-3.947	-1.642	
Spring 2004	Mean	8.1	886	571	168	42	13.75	126.7	4.14	229	108.75	98.25	8.61
	S.D.	0.1	312	154.5	58	1401	4.26	41.69	1.455	25.23	33.163	40.88	2.614
Compare to Autumn 2003	P_Value	0.512	0.039	0.031	-	0.061	0.442	0.194	-	0.009	0.092	0.573	
	T	0.666	-2.198	-2.333		-2.031	-0.783	-1.338		-2.878	-1.763	-0.572	
Summer 2004	Mean	8	1020	744	178	47	13.95	144.58	4.9	243.25	144.08	121.6	10.13
	S.D.	0.2	176	100	38	10	2.717	22.66	0.825	14.8	24.86	38.45	1.098
Compare to Autumn 2003	P_Value	1	0.001	0	-	0	0.241	0.009	-	0	0	0.035	-
	T	0	-3.723	-7.468		-4.272	-1.204	-2.868		-6.274	-5.472	-2.247	
Autumn 2004	Mean	7.6	864.5	521	143.4	35.7	13.4	132	5.3	214.4	99.3	117.5	7.5
	S.D.	0.37	14.52	51.38	30.2	7.8	2.8	4.3	1.08	11.8	10.24	38.3	0.47
Compare to Autumn 2003	P_Value	0.003	0.049	0.029	-	0.313	0.534	0.68	-	0.116	0.155	0.063	-
	T	3.657	-2.204	-2.329		-1.032	-0.633	-1.966		-1.638	-1.499	-1.959	
Winter 2005	Mean	7.8	891	540.4	140	40.38	13.7	135.37	4.9	216.2	113.35	109	8.015
	S.D.	0.28	139.5	130.5	14.2	12.1	2.74	20.48	1.01	23.3	19.3	26.15	2.32
Compare to Autumn 2003	P_Value	0.001	0.022	0.017	-	0.046	0.206	0.023	-	0.148	0.001	0.037	-
	T	3.731	-2.386	-2.528		-2.06	-1.285	-2.371		-1.476	-3.596	-2.155	
Spring 2005	Mean	7.9	974.6	656.1	175	42.3	16.75	145	4.1	239.02	126	122	10.89
	S.D.	0.25	290	187.6	58.76	14.1	5.18	47.41	1.4	73.27	33.2	42.54	3.9
Compare to Autumn 2003	P_Value	0.01	0.005	0	-	0.004	0.012	0.68		0.23	0.001	0.020	-
	T	2.708	-2.942	-4.744		-3.08	-2.617	-1.877		-2.387	-3.621	-2.426	
Summer 2005	Mean	7.2	950	560	137	41.1	12.91	139	3.8	206	103	97	8.1
	S.D.	0.26	180.33	123.23	28.93	11.05	3.39	31.37	0.99	14.8	22.68	30	2.1
Compare to Autumn 2003	P_Value	0.017	0.005	0.008	-	0.019	.81	0.041	-	0.923	0.053	0.496	-
	T	2.484	-2.979	-2.8		-2.449	-0.241	-2.111		-0.098	-1.992	-0.686	
Autumn 2005	Mean	7.24	786.7	470	125.9	38.6	17.65	146	4.7	211	100	112.7	7.2
	S.D.	0.21	110.43	41.23	43.42	3.17	5.26	8.97	1.07	10.78	5.84	36.5	0.64
Compare to Autumn 2003	P_Value	0	0.813	0.494	-	-	0.007	0.001	-	0.183	0.120	0.06	-
	T	8.98	-0.238	-0.703			-3.207	-4.226		-1.354	-1.682	-1.934	
Winter 2006	Mean	7.5	806	507	149	37.1	12.6	137.8	5	222.3	109.3	108.8	7.7
	S.D.	0.3	203.7	106.6	28.28	8.89	3.49	33.53	0.93	37.95	32.26	36.8	0.55
Compare to Autumn 2003	P_Value	0	0.651	0.111	-	0.129	0.945	0.074	-	0.147	0.048	0.149	
	T	9.17	-0.456	-1.63		-1.549	-069	-1.834		-1.179	-2.042	-1.473	
WHO guideline for drinking water		8	1500	1500	500	250	50	200	-	-	400	500	50

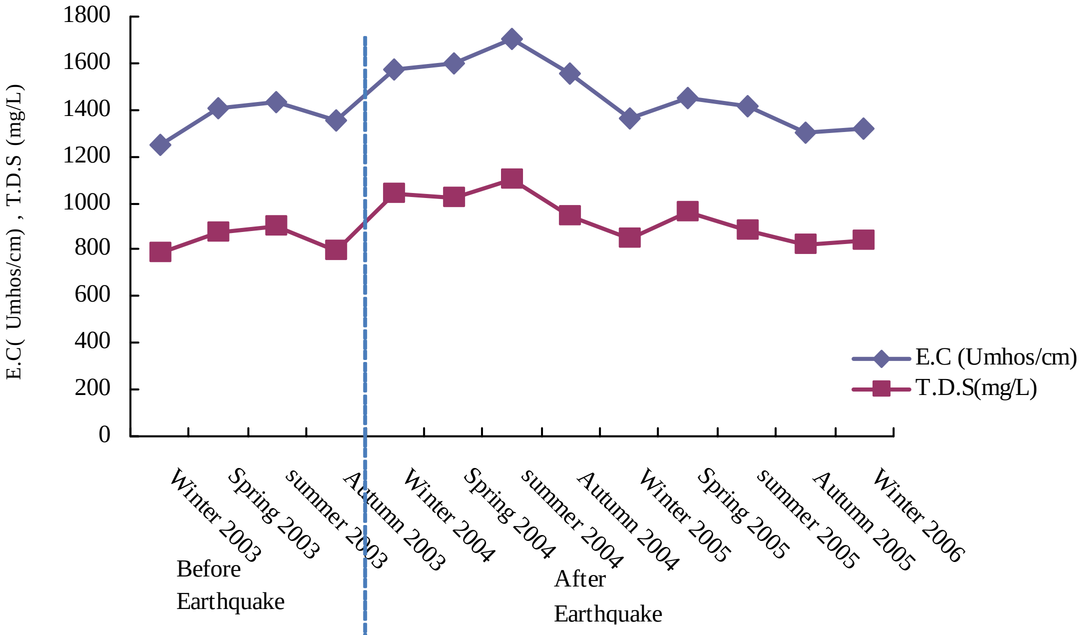

Fig. 3. Variations of EC and T.D.S in underground water throughout the Bam and Baravat plains during the various seasons before and after earthquake of December 2003 (From 2003 to 2006)

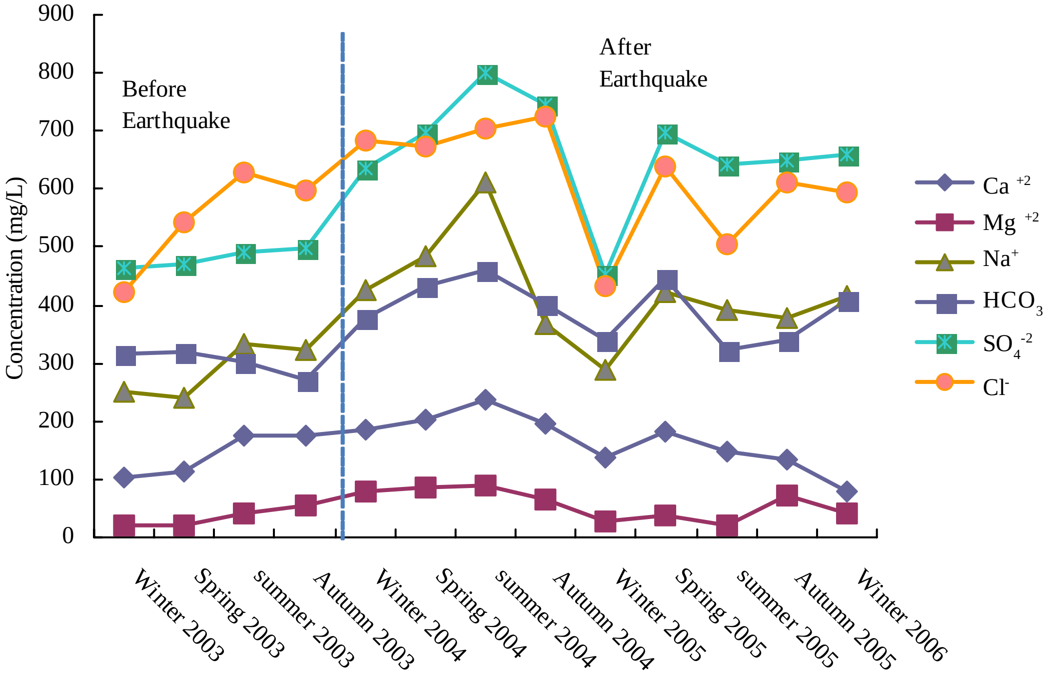

Fig. 4. Variations of different cations and anions in underground water throughout Bam and Baravat plains during different seasons before and after earthquake of December 2003 (From 2003 to 2006)

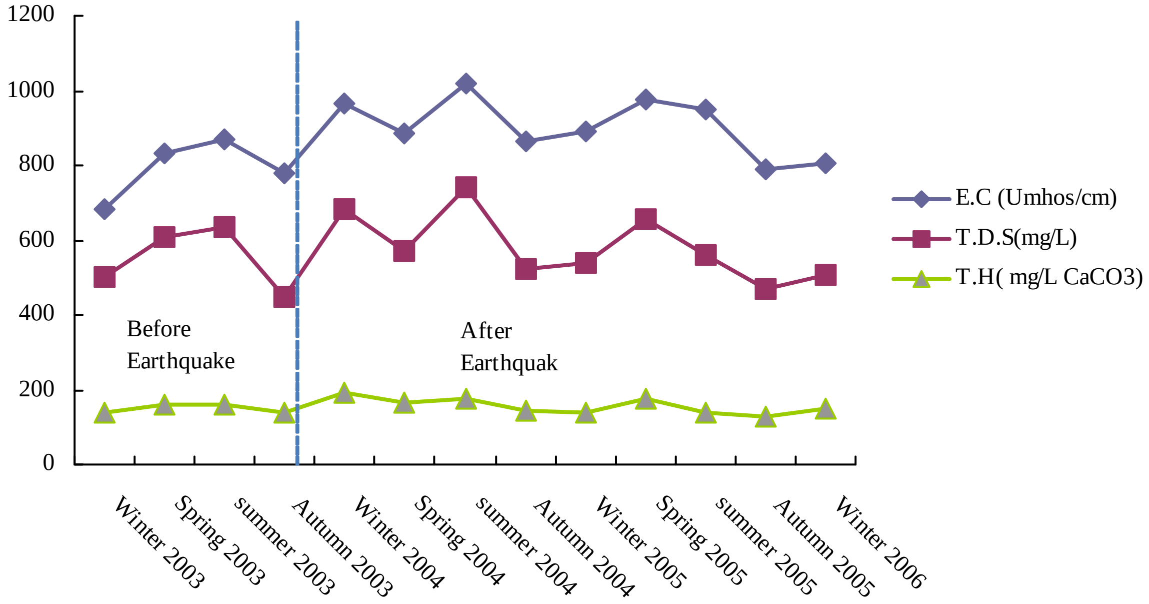

Fig. 5. Variations of EC, T.H and T.D.S of groundwater wells and drinking water of throughout the Bam and Baravat plains during the various seasons before and after earthquake of December 2003 (From 2003 to 2006)

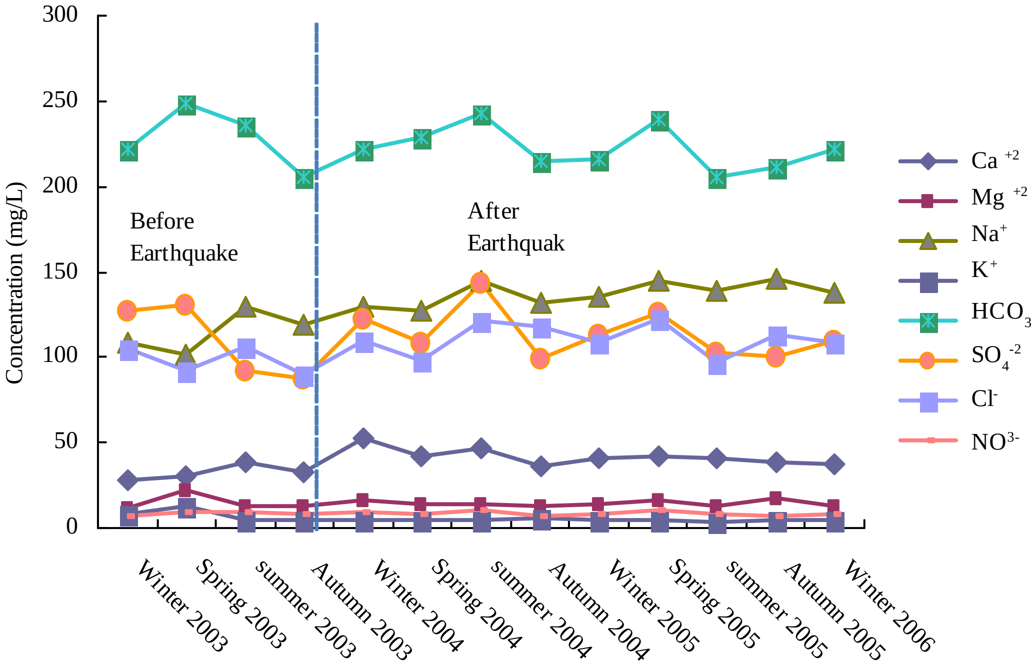

Fig. 6. Variations of different cations and anions of underground water in wells and drinking water throughout Bam and Baravat plains during the various seasons before and after earthquake of December 2003 (From 2003 to 2006)

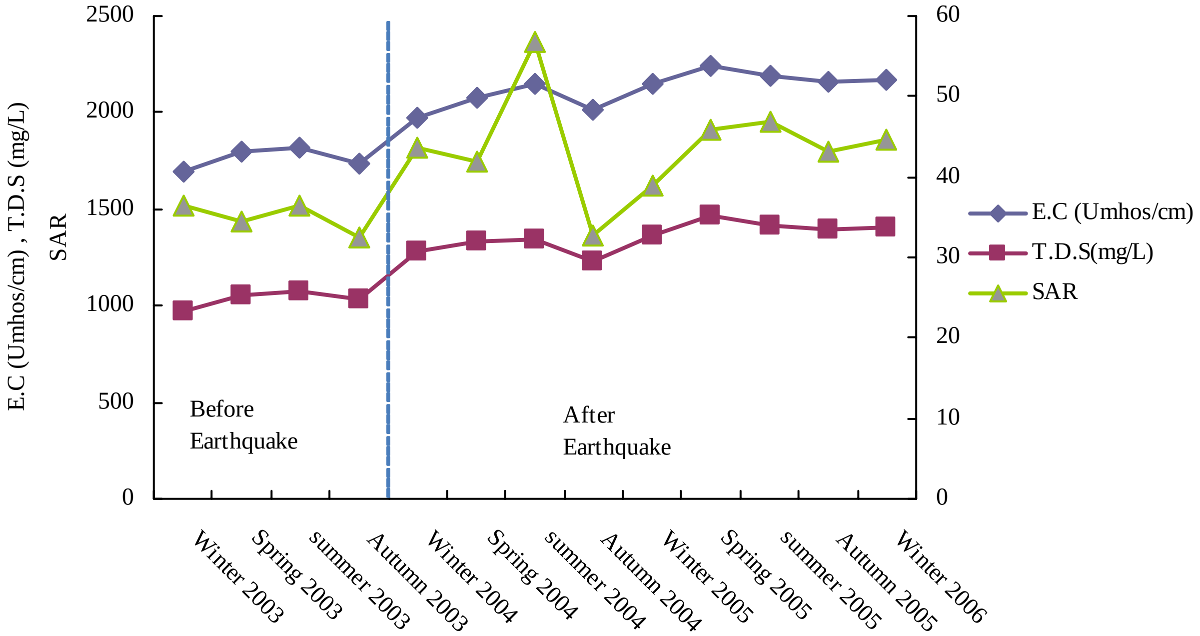

Fig. 7. Variations of EC, T.D.S and SAR of groundwater in agricultural piezometric wells throughout the Bam and Baravat plains during the various seasons before and after earthquake of December 2003 (From 2003 to 2006)

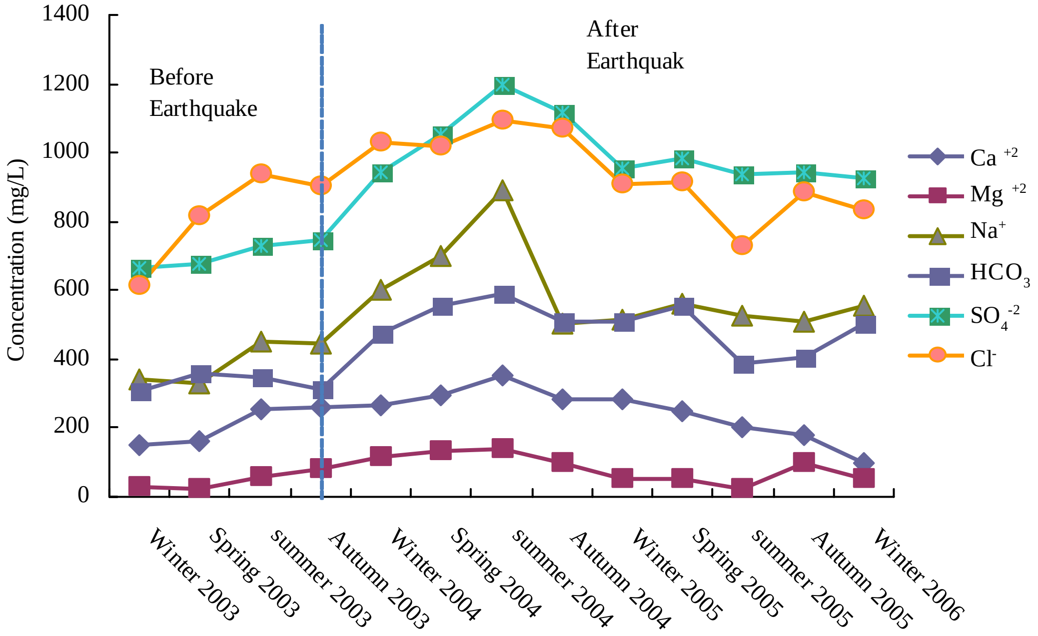

Fig. 8. Variations of different cations and anions of underground water in agricultural piezometric wells throughout Bam and Baravat plains during the various seasons before and after earthquake of December 2003 (From 2003 to 2006)

Table 4. Annual and monthly precipitations (mm) in Bam and Baravat plains before and after earthquake of December 2003 (From 2003 to 2006)

Year	JAN	FEB	MAR	APR	MAY	JUN	JULY	AUG	SEP	OCT	NOV	DEC	Annal
2003	1.7	1	14	3.6	0	0	4	0	0	0	0	0	24.3
2004	7.7	0.2	0	2	11	0	0	0	0	0	0	25	45.9
2005	1.4	27.8	12.6	5.2	17.7	3	0	0	0	0	0.1	0	67.8
2006	11.4	1.6	0	5.9	0	0	0	0	0	0	15.1	0	34

point to an identical change in chemical quality of water in wells throughout the plain. On this basis, all parameters reached their highest rank ranged between 7-65.5% in the first year after the earthquake. The maximum scale of chemical quality of mentioned water wells and their average concentration were compared in different seasons after the earthquake till spring 2006 according to Iranian Standard and WHO guideline. Results showed that none of the recorded chemical parameters did exceed the scale approved for drinking water. However there were meaningful increases and concentration changes in different parameters between autumn 2003, before the earthquake, and autumn 2005 (Institute of Standard and Industrial Research of Iran 1997; WHO 2003). It is worth to mention that Iran is located on earthquake belt and the chemical quality of underground waters is severely affected. Analysis of underground waters saved as potable water is highly crucial to find out the chemical changes and purifying the water, if necessary. Although the wells in west part are much closer to main fault and epicenter, but it receives the least chemical quality changes compared to central and east part because of soil specific context (Amini *et al.* 2004). The chemical quality variations were analyzed for piezometric wells to find out their quality for agriculture purposes. The selected wells were mostly located around Rostam Abad City, north east of plain stretches toward Shureh Gaz River and far from earthquake epicenter (Zones 2 and 3). The mean change curve of T.D.S, EC and SAR (Fig. 7) and different parameters (Fig. 8) in different seasons after earthquake showed a negative and useless trend in the water of these wells during the study period. The water of these wells was not of good quality due to sodium absorption rate (SAR), electricity conductivity and T.D.S (Fig.7) and it was not suitable for agriculture purpose according to Wilcox category scale. These negative chemical changes in parameters can infer bad quality of crust layers in central and east part of the plain that caused a fluctuation in water level and more minerals solve in water. The negative character of plain can worsen this condition. Generally, the chemical changes in underground water parameters are considered as the consequences of different factors after an earthquake as follows: A) Water level fluctuations affected by an earthquake that will lead to more contacts with rocks of higher layers, B) Water temperature fluctuations and as a result more solubility, C) Change in pressure on water reservoirs surrounded with water ponds and D) Mixing with the water of neighboring aquifers as the consequences of an earthquake. Although the precipitation rate is considered as an effective factor on underground water quality, the evaluation of the precipitation rate variations in preearthquake season (Fall 2003), as well as season with the most negative water quality variations (summer of 2004) indicated zero precipitation rate in both seasons. Thus precipitation has not had any effect on the water quality variations (Table 4).

In the second year of the earthquake, however, when quality of water started to improve, the precipitation rate also increased significantly (67.8mm), so its positive effect on the water quality improvement can not be ignored. In an investigation about geo-chemical changes happened in Tjornes earthquake in Northern Ireland in December 2002, it was found that there was a %14 to %19 increase in different parameters such as Ba, Ca, K, Li, Mo, Na, Rb, S, Si, Sr, Cl^- and $SO4^{2-}$ during second to 9th weeks after the earthquake (Claesson et al. 2004). Chloride (Cl^-) and sulfate ($SO4^{2-}$) ion concentrations underground issued from two wells near the epicenter of the Kobe earthquake in Japan (17th January 1993) increased substantially after earthquake (Tsunogai *et al.* 1995). These results are identical and consistent with ones found in Bam and Baravat plain after the earthquake. Sheng-Rong Song *et al.* (2003) showed groundwater chemical anomaly before and after Chi-Chi earthquake occurred on 21th September 1999 in central of Taiwan. The data shows that the concentration of sulfate and nitrate have increased steadily after March to July 1999 before earthquake and they decreased to about 10% - 20%, respectively till after the earthquake due to underground water dilution while getting mixed with surface and underground water sources (Shenrong e*t al*,. 2003; Nakane and Haidary, 2010).

CONCLUSION

The main reason of this inconsistency in parameters with the ones found in Bam and Baravat plain can be considered as shortage in annual precipitation, lack of surface waters in the region, inadequate variety in aquifers and a continuous drought before and even after the earthquake. These factors can be probably named as the main reasons of underground water dilution. In a physiochemical investigation of underground waters in an earthquake happened in southwest of Turkey in

1995, a considerable electrical conductivity was observed, particularly in water close to earthquake center. The study of chemical changes occurred after earthquakes in 1976 and 1980 in the US, close to Hayward Fault, showed some changes in electrical conductivity of underground waters (King *et al.* 1994). Remarkable consistency has been observed between the results of this study and the Bam and Baravat plain earthquake, regarding the changes happened in different parameters.

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