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Natural and human-induced impacts on coastal groundwater

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ABSTRACT: Groundwater is the main source of potable water in most areas of Mazandaran province, like Sari and Babol city. Thus the safety of groundwater supplies is very important in these regions. Unfortunately attention to groundwater quality has remained limited in Iran. In recent years, the growth of industry, technology, population, and water use has increased the stress upon both land and water resources of Mazandaran province. The main pollutants of groundwater in Mazandaran province are domestic, industrial and agricultural wastewater discharges. In addition, contribution of municipal and rural solid wastes in deterioration of groundwater quality of the Mazandaran province is considerable. The quality of several water wells in Mazandaran province was investigated in this research. In tested water wells, the concentrations of Cu, Cr, Zn and NO_3 are within WHO standard limits, but Pb, Se and Cd concentrations are often exceeding the WHO maximum permissible standard values. Results show that the current quality of groundwater in Mazandaran province does not present immediate health related concerns. However, the quality of water wells in Mazandaran province is not reliable because of relatively high rate of various pollutants discharges into groundwater resources. Consequently, establishment of both monitoring programs and appropriate regulations to minimize uncontrolled discharges into groundwater resources is necessary for conservation of this valuable source of water supply in Mazandaran province.

Key words: Groundwater quality, Contaminant discharge, Heavy metals, Monitoring, Pollution

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INTRODUCTION

The Caspian Sea, as the largest land-locked water body on earth, with an area of 425,000 km^2 and a water volume of 78,700 km^3, is of high global environmental significance. The Caspian Sea is bordered by Russia (Dagestan, Kalmykia, Astrakhan Oblast), Azerbaijan, Kazakhstan, Turkmenistan (Balkan Province), and Iran (Guilan, Mazandaran and Golestan provincesKajiwara, *et al.*, 2003). The ecosystems in the Caspian Sea and basin are closely linked to the coastal groundwater and depend on the aquifer functions for ecological and social services. Large deltas provide critical habitats for biodiversity and fisheries resources, and are also critical sinks and buffers for chemical contaminants in river and groundwater inflows accumulated in sediments and wetlands. The important groundwater dependent ecological functions that include the support of lagoons and pools along the entire coastline, relate closely to the dynamics of the coastal aquifers. Of the total Caspian Sea inflow (about 300 km^3/yr), with contained contamination transport, into the Caspian Sea, about 25-40 percent (75-120 km^3/yr) consists of groundwater. While the contribution of groundwater to the water balance of the Caspian Sea is unknown, groundwater represents a significant share of the Caspian Sea inflows, and contributes to the water balance and the sea fluctuations through river runoff and as direct seepage into the Sea.

The province of Mazandaran is 23,701 km^2 in the north of Iran, bordering the Caspian Sea is to the north, the provinces of Tehran and Semnan lie to the south. To the west it has common borders with Gilan province, and to the east stands the province of Golestan. The province covers an area of 23,833 km^2. Mazandaran province is geographically divided into two parts: the coastal

plains, and the mountainous areas. The Alborz Mountain Range surrounds the coastal strip and plains of the Caspian Sea like a huge barrier (Fig. 1). There is often snowfall during most of the seasons in the Alborz regions, which run parallel to the Caspian Sea's southern coast, dividing the province into many isolated valleys. It has a population of 2818831(Ministry of Energy, 1990; Pars Ab Tadbir, 2004; Mazandaran Regional Water Company, 2003).

Both surface and ground water resources are used as a source for potable, industrial, and irrigation water in Mazandran province. Sari is the provincial capital with about 220,000 inhabitants. Most of the population is connected to the water supply network. The total water demand of the city is 51,800 m^3/d and is supplied from 19 wells, which are scattered inside and around the city, tapping the Tajan river aquifer and Tajan alluvial cone. The total water production of these wells is 1,060 L/s (91,584 m^3/d). The second important city of Mazandaran provine is Babol. The current population of Babol is estimated at 180,000 inhabitants. The total water demand of Babol city is 41,796 m^3/d and is supplied from a well field located 38 km toward south west of Babol, near Amol town. The well field, called Amol well field, taps the aquifer of the Haraz River basin, wherein 12 wells provide a total water supply capacity of 1,080 L/s (93,000 m^3/d) (Mehrdadi and Baghvand, 2006; Mehrdadi and Baghvand, 2005).

The safety of groundwater supplies is very important in north of Iran close to Caspian Sea, however the attention to groundwater has remained limited and there are gaps in groundwater information and management elements in the national water resources and environmental action water plans, with inadequate regulatory frameworks and institutional resources for groundwater management and monitoring in Iran. In this research we investigate the natural and human-induced impacts on coastal groundwater in Mazandaran province. The quality of many wells was studied to achieve the careful awareness about the current status of groundwater quality in Mazandaran province.

MATERIALS & METHODS

After conducting comprehensive investigation on situation of water supplies in Mazandaran province and determination of main sources of groundwater pollution in this area, several water wells were tested to reveal the real quality of groundwater supplies in the project area. Water samples were collected from different wells in Sari and Babol cities. Water samples were processed for physical and chemical quality. Also in this investigation, data on groundwater quality from Mazandaran Regional Water Company and Department of Environment was collected and used in the present study. In addition, some preliminary statistical operations were conducted on measured parameters to facilitate interpretation of them.

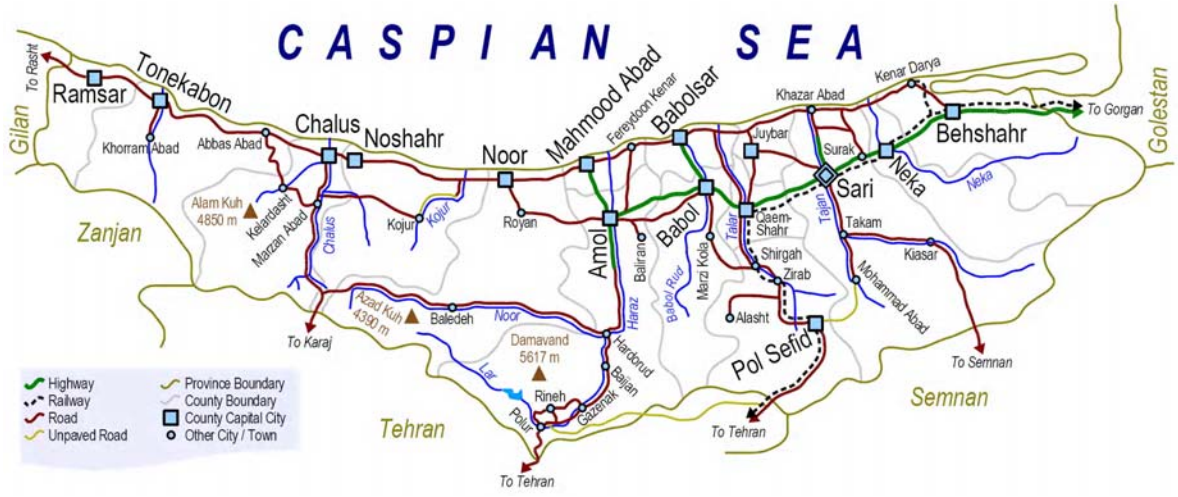

Fig. 1. The map of lower, middle and upper lands of Mazandaran province

Table 1. The condition of water resources in Mazandaran province (million m^3)

The potential of water resources			The exploitation of water resources			The potential of water resources development		
Surface	sub-surface	total	surface	sub-surface	total	surface	sub-surface	total
4900	1700	6600	1550	1100	2650	2900	350	3250
47%	26%	100%	58%	42%	100%	89%	11%	100%

Ref: Pars Ab Tadbir, 2004; Mazandaran Regional Water Company, 2003

The experimental analysis was made according to standard method. The water quality results from different wells were compared with WHO standards as well as local standards.

RESULTS & DISCUSSIONS

Groundwater is a principal drinking water supply in the coastal zone in all the Caspian countries as well as for Mazandaran province. The groundwater dependent coastal areas include the principal cities and intermediate villages in north of Iran, especially in Mazandaran province. However, with groundwater pollution and salinization, poor drinking water is a general social and health problem in Mazandaran province. In the middle and lower lands areas of Mazandaran province 63.1% of the total water consumed is provided from groundwater resources (springs and wells), and 36.9% from surface sources. The groundwater is used in different sectors as following: agriculture 87.8%, drinking 11.4% and industry 0.9%. The groundwater is the main source for drinking in lower and middle lands of Mazandaran province (Pars Ab Tadbir, 2004). The condition of water resources in Mazandaran province is presented in Table 1.

In 2003, there were 27 water wells in Sari, however only 19 wells are currently in operation. The groundwater level is ranging from -8 to -15 meters. The average depth of these wells is 120 meters. Total amount of water obtained from these wells is 820 liters/sec (0.82 m^3/sec). Due to decrease in groundwater level and penetration of salty water toward southern area, total dissolved solids (TDS) of some of the wells have considerably increased. Some of wells have been closed on account of this deterioration and even some due to increase in nitrate concentration. Groundwater quality in the lower lands has degraded heavily in recent years due to slope influence of saline water and high evaporation. Therefore in lower lands of Mazandaran province, the groundwater abstraction must be restricted and action must be taken to push back the saline intrusion line with increased groundwater recharge (Pars Ab Tadbir, 2004; Mazandaran Regional Water Company, 2003).

Iran's groundwater resources have been over-exploited, often at the expense of deteriorating water and land quality (Ghadiri, *et al.*, 2006). However, not all groundwater problems are caused by over-extraction. Pollutants released to the ground can work their way down into groundwater.

In recent years, the growth of industry, technology, population, and water use has increased the stress upon both land and water resources of Mazandaran province.

The main pollutants of water in Mazandaran province are domestic, industrial and agricultural wastewater discharges. Moreover, municipal and rural solid wastes pollute the water sources in this area (Pars Ab Tadbir, 2004; Mazandaran Regional Water Company, 2003; Caspian Environment Program, 2006; NCAP, 2002). The majority of wastewater in north of Iran discharges in to surface waters with the reminder discharging into the groundwater or absorption wells. At present, there are not any wastewater collection and treatment facilities in Mazandaran province and in most of the cities and villages in this province; wastewater is discharged into absorbing wells. However, recently the wastewater collection and wastewater treatment plan project has been started for implementation in this area. In some areas, wastewater is directly discharged into the rivers According to Mazandaran and Golestan Regional Water Authority (MGRWA) and the earlier studies for preparation of the irrigation and drainage network, the amount of water returned from agricultural areas into the Amol-Babol valley to surface and groundwater is about 470 million and 80 m^3, respectively.

The dominant crop is rice. Water from the fields is commonly released between mid-august to early September. Before this, when paddy fields

are water logged, the effluent seeps through to the shallow groundwater. Agricultural wastewater contains high levels of phosphate, nitrogen, potash and pesticides. Since the sub-surface waters in the area have not been surveyed completely, the exact amounts of fertilizer and pesticide infiltrated are not known. However the amount of pollution would be quite significant because of the short distance between effluent and groundwater Table. Agrochemicals are subsidized by the government of Iran (GOI) to facilitate increased production. While fertilizer subsidies remain high, the subsidies for chemicals for pests, weeds and disease control have declined in recent years as a result of a policy to reduce the negative environmental impacts from use of these chemicals.

Table 2. Average annual fertilizer application per ha in Mazandaran province

Fertilizer	Paddy (kg/ha)	Dry land farming (kg/ha)	Citrus (kg/ha)
Nitrate	207	122	200
Phosphate	180	139	405
Potash	77	187	304
Total	464	448	909

Ref: Pars Ab Tadbir, 2004; Mazandaran Regional Water Company, 2003; Caspian Environment Program, 2006

Table 3. Total Pesticides Used in North of Iran

No.	Pesticides	Guilan (Amount)		Mazandaran & Golestan (Amount)		Total (Amount)		Total	
		Lit	Kg	Lit	Kg	Lit	Percent	Lit	Percent
1	Herbicides	577026	14156	683558	39672	1260584	42.9	53828	2.07
2	Insecticides	152433	526325	775541	1369393	927974	31.6	1895718	73.1
3	Fungicides	28642	89755	114468	503313	143110	4.8	593068	22.8
4	Tickicides	155842	1990	447147	-	602989	20.5	1990	0.07
5	Rodenticides	-	-	70	1022	70	0	1022	0.03
6	Snailicides	-	-	-	14976	-	-	14976	0.5
7	Miticides	999	6200	-	24290	999	0.03	30490	1.1
8	Fumigates (No)	352638		500000		852638		-	

Ref: Pars Ab Tadbir, 2004; Mazandaran Regional Water Company, 2003; Caspian Environment Program, 2006

Table 4. Quantity of pesticides used based on Cropping Type in Mazandaran province

Type of pesticide	Paddy (kg/ha)	Dry farming (kg/ha)	Gardening (kg/ha)
Pesticide	5.1	1.7	8.5
Fungicide	1.7	3.2	2
Tickcide	-	1.5	3
Herbicide	15	5.5	8
Total	21.8	11.9	21.5

Ref: Pars Ab Tadbir, 2004; Mazandaran Regional Water Company, 2003

Average amounts of fertilizer applied in paddies, dry land farming and citrus production is shown in Table 2. Theamounts of pesticides being used in north of Iran (Mazandaran, Gilan and Golestan provinces) are listed in Table 3. Mazandaran province uses 35% of the total amount of pesticides used in Iran. The amount of various pesticides used for the main cropping patterns in Mazandaran province is presented in Table 4.

Pollution from pesticides increases the levels of metals (for example Cu, Zn, Cr) and poisonous substances in water and soil. In addition, the handling of pesticides poses a health hazard for farmers.Some of rivers have been converted to dumping sites for all types of wastes arising from industrial, agricultural and municipal activities, which will end to surface and groundwater pollution (Abduli, 1994 and 1997).

Table 5. Heavy metals concentrations in Sari water wells

Well Number	Pb (µg/L)	Cu (µg/L)	Cr (µg/L)	Zn (µg/L)	Se (µg/L)	Cd (µg/L)
EA	8.2	2.0	0.8	17	12.7	2.3
8	13.1	8.0	2.9	134	11.6	2.4
5(2)	18.5	3.0	0.6	13	11.3	2.8
11	11.2	1.0	0.2	12	11.7	2.4
12	11.3	3.0	0.5	28	18.3	2.7
9	13.1	2.0	3.6	26	17	2.1
6	22.6	9.0	4.5	24	15.9	3.7
1	19.4	5.0	3.9	54	17	2.7
4	7.4	3.0	3	10	18	3.2
7	18.9	4.0	4	14	23.8	3.5
10	15.1	8.0	3.8	25	22.4	3.2
KP	12.5	2.0	31	9	21.4	3
MM	16.3	5.0	5.9	12	18.7	3.3
Maximum	22.6	9.0	31	134	23.8	3.7
Minimum	7.4	1.0	0.2	9	11.3	2.1
Mean	14.4	4.2	4.9	29	16.9	2.8
Std. Deviation	4.543	2.619	8.017	33.745	4.180	0.494
Iran Standard	50	-	50	-	10	5
WHO Standard	10	2000	50	3000	10	3

Table 6. Range of qualitative parameters in Sari water wells

Parameter	pH	Total Hardness (mg/L $CaCO_3$)	EC (µmohs)	NO_3-N (mg/L)
Range	7.03-7.36	135-508	754-1924	9.24-32.4
Std. Deviation	8.634E-2	90.690	294.960	6.815

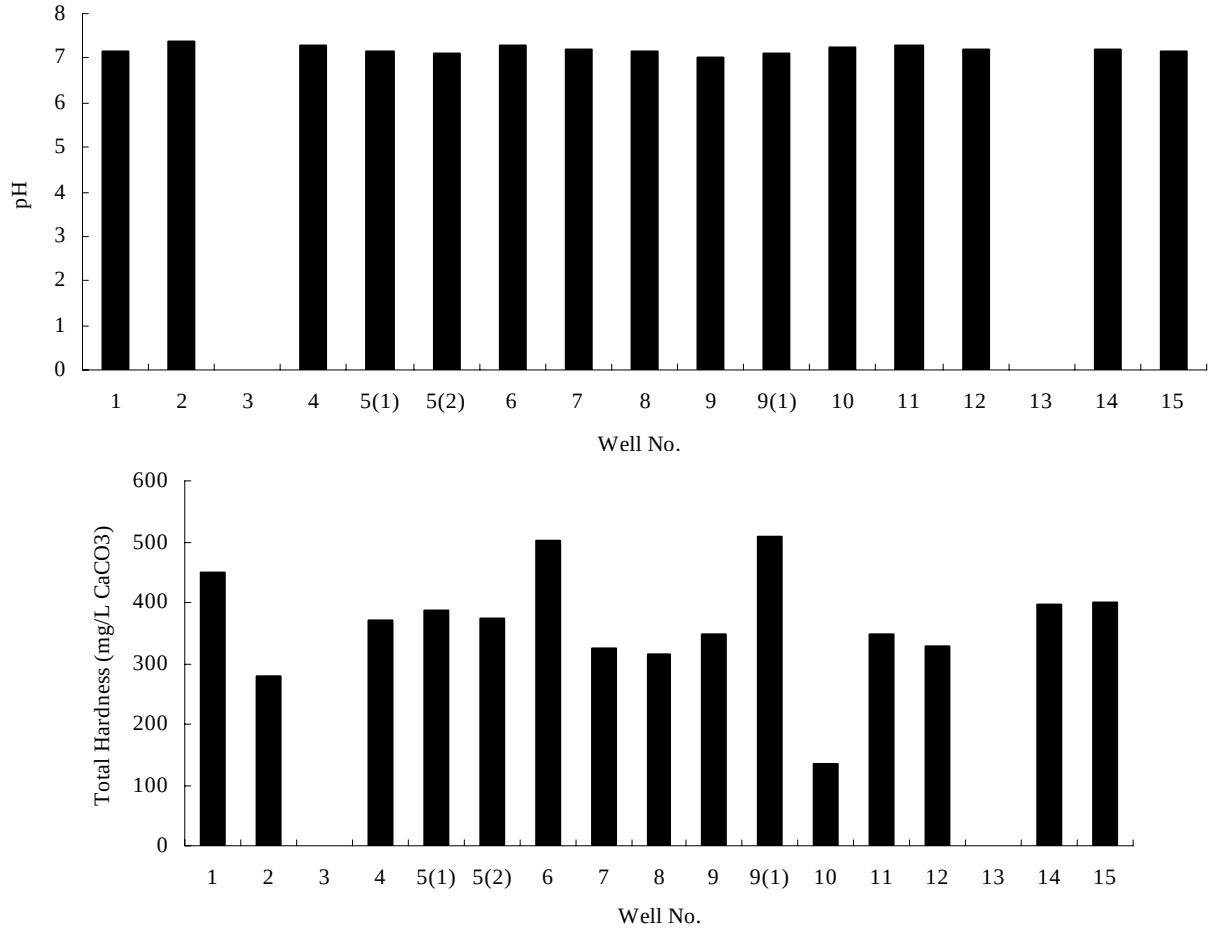

Fig. 4. Total Hardness of Sari water wells

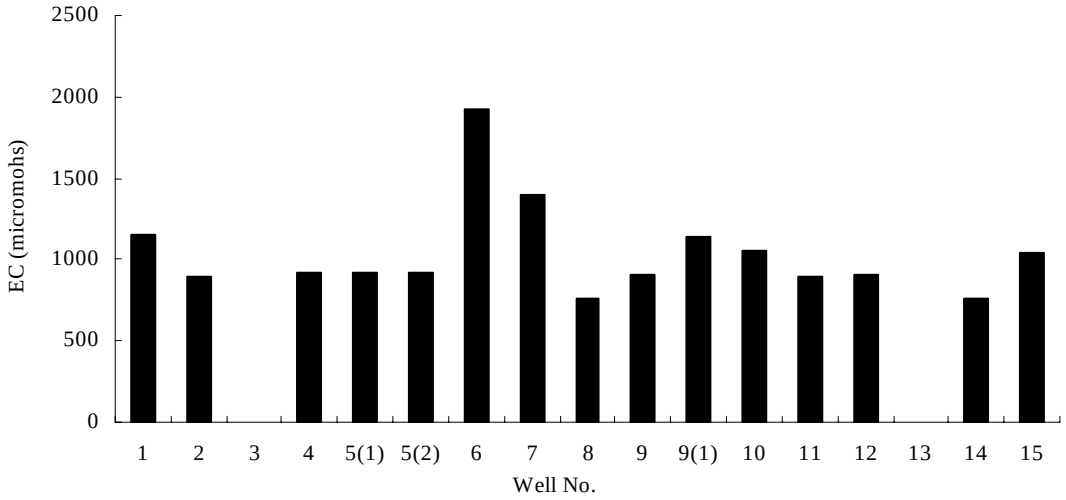

Fig. 5. EC of Sari water wells

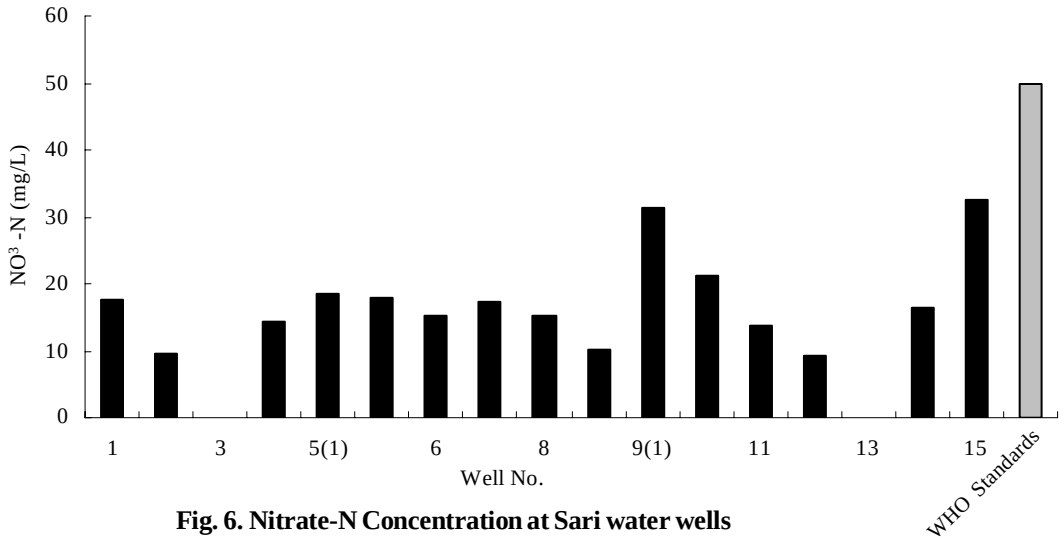

Fig. 6. Nitrate-N Concentration at Sari water wells

At present, disposal of rural solid waste is not carried out in a proper planned manner, and waste is mainly disposed in lands adjacent to the villages, into the rivers and sometimes trenches surrounding the villages.

The quality of water wells in some important cities of Mazandaran province close to Caspian Sea was investigated in this study. The results of groundwater sampling and analysis on these water wells are presented in Tables 5 and 6. Table 5 represents the concentrations of heavy metals in 13 water wells in Sari area. The acceptable limits for these elements are also mentioned. The range of some qualitative parameters in tested Sari water wells are given in Table 6.

Values of pH, total hardness, electrical conductivity and nitrate concentration were measured for collected samples from 17 water wells of Sari area. The detailed results on well water sampling in Sari area are illustrated in Figs. 3 to 6. The results on heavy metals and other parameter on Sari water wells when compared with the WHO standards show that Cu, Cr, Zn and NO_3 are within limits but values for Pb, Se and Cd are often touching the WHO maximum permissible standard values. However Pb and Cd are within national standard limits of Iran. Test results on some qualitative parameters and range of heavy metals concentrations on tested Babol water wells are given in Tables 7 and 8, respectively (tested wells in experiments related to Table 7 were different from that of Table 8). The detailed results of well water sampling for Pb, Cr, Se, and Cd in Babol area are illustrated in Figs. 7 to 10. Concentrations

of Zn and Cu in Babol area wells are almost negligible comparing to WHO standards.

Table 9 shows the wastewater generated by different sections in lower lands of Mazandaran province. The results on heavy metals and other parameter on Babol water wells in compare with the WHO standards indicate that Cu, Cr, Zn and NO_3 are within acceptable limits but values for Pb, Se and Cd are often exceeding the WHO maximum permissible standard values.

The results also show that all concentrations are within Iranian standards limits for determined heavy metals except for Selenium. Thus the obtained results indicate that the quality of groundwater in Sari area is almost similar to that of Babol area. It is noticeable that US EPA drinking water quality standard for Selenium is 50 µg/L which is greater than all the Selenium measurements recorded in Sari and Babol area. Therefore there is no imminent health risk from using these wells in regard with Selenium contamination. The available and collected data in this study indicates that groundwater quality in the upper watershed and middle lands of the Mazandaran province close to the Caspian Sea is reasonably good. Total dissolved solids and major ion content are all within acceptable thresholds for both agricultural and drinking water supply.

The quality of groundwater in the lower lands of Mazandaran province is progressively poor, with high levels of all contaminants measured. Most of the wells in this area are shallow and are used for both agricultural and drinking purposes. As a result they suffer from pollution due to a range of factors, including; leaching of pesticides and fertilizers, leaching from solid waste dumps and landfills,

Table 7. Water quality of Babol water wells

Well Number	pH	Total Hardness (mg/L $CaCO_3$)	Turbidity (NTU)	EC (µmohs)	NO_3-N (mg/L)
A1	7.68	375	1	850	13.4
A2	7.66	380	1	860	16
A3	7.67	390	1	910	18.1
A4	7.60	405	0	910	12.7
A5	7.58	405	1	912	16.9
A6	7.62	385	1	870	14.9
A7	7.61	410	0	925	12.6
A8	7.70	390	1	850	14.7
A9	7.68	390	2	851	13.7
A10	7.61	390	1	866	10.9
A11	7.95	390	0	900	13.7
A12	7.57	425	0	938	14.6
Maximum	7.95	425	2	938	18.1
Minimum	7.57	375	0	850	10.9
Average	7.66	394.6	0.75	886.8	14.35
Std. Deviation	0.1006	14.054	0.621	32.178	1.982
WHO Standards	-	-	5	-	50

Table 8. Heavy metals concentrations in Babol water wells

Chemical	Concentration range (µg/L)	Std. Deviation	Chemical	Concentration range (µg/L)	Std. Deviation
Pb	15-38	5.962	Zn	0-51	14.649
Cu	0-26	7.479	Se	13-19	1.597
Cr	0.6-5.1	1.302	Cd	2.7-3.8	0.316

Table 9. Different sources of effluent discharges into surface and groundwater resources in Mazandaran province

Area name	Agricultural effluent		Household effluent		Industrial effluent	
	Discharge into surface water (%)	Discharge into groundwater (%)	Discharge into surface water (%)	Discharge into groundwater (%)	Discharge into surface water (%)	Discharge into groundwater (%)
Amol-Babol-Babolsar	83.3	16.7	49.4	50.6	73.8	26.2
Ghaemshahr-Joybar	40	60	53	47	71.8	28.2

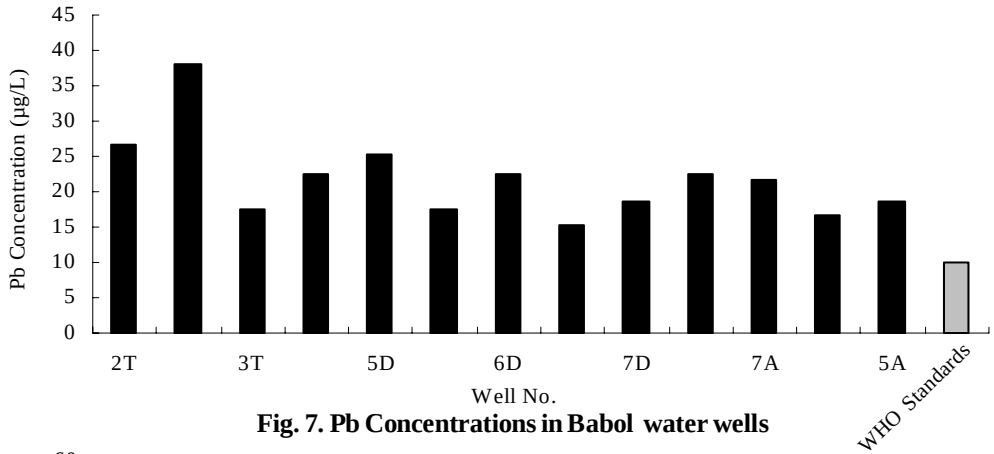

Fig. 7. Pb Concentrations in Babol water wells

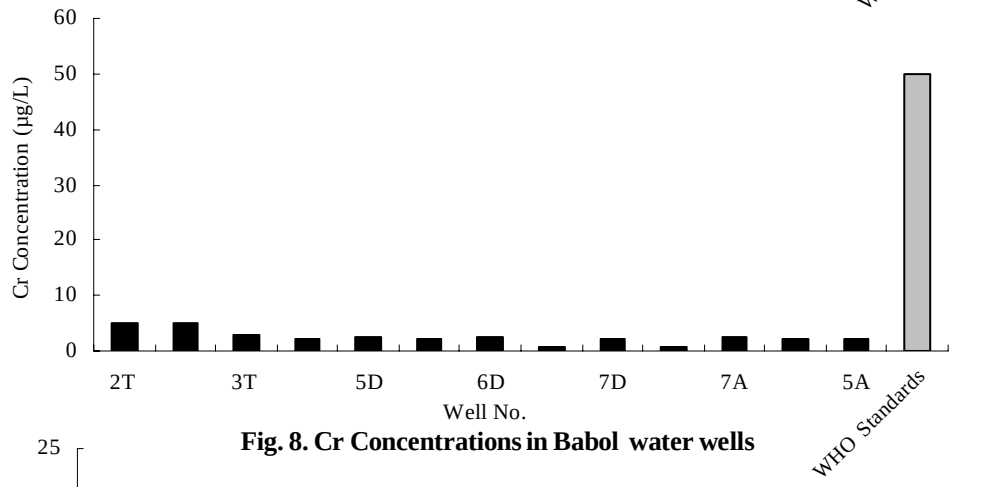

Fig. 8. Cr Concentrations in Babol water wells

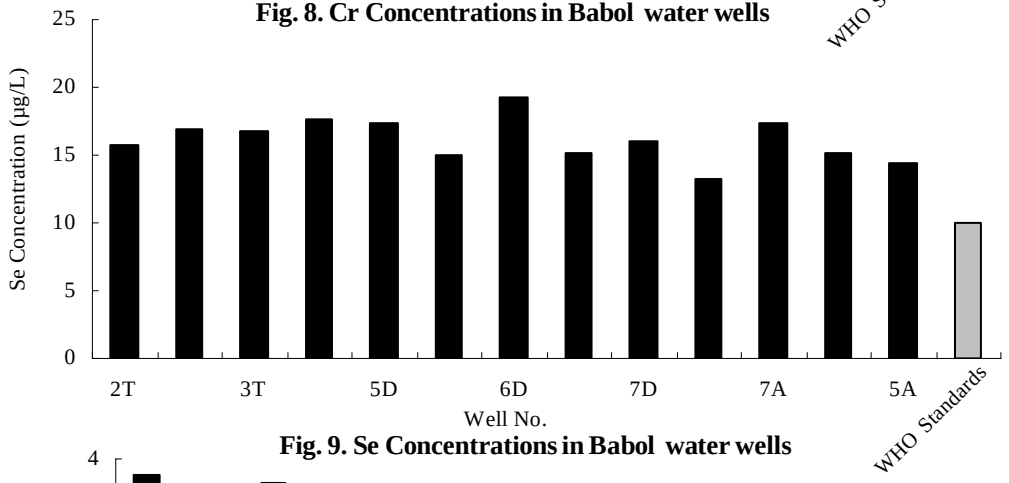

Fig. 9. Se Concentrations in Babol water wells

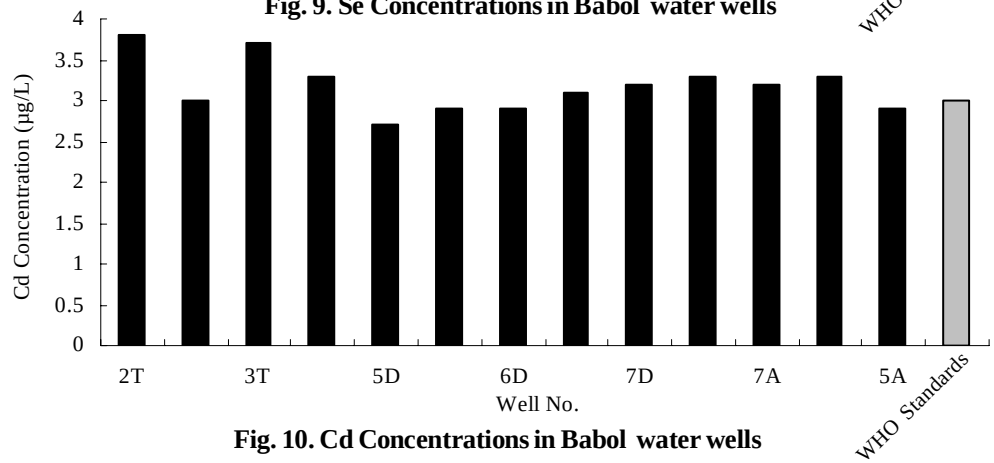

Fig. 10. Cd Concentrations in Babol water wells

wastewater discharge into absorption wells as mentioned in former sections in detail.

A major limitation of the available data is the general lack of information about microbiological contamination. Moreover, since drinking water in the area is frequently disinfected with chlorine, more data are required concerning residual chlorine levels in groundwater contaminated by domestic wastewater.

CONCLUSION

Groundwater is the main source of drinking water in some areas of Mazandaran province. Main sources of groundwater pollution in Mazandaran province include municipal and rural wastewater, agricultural wastewater, industrial wastewater and municipal/rural solid waste.

The obtained results show that the quality of groundwater in Sari area is almost similar to the quality of groundwater in Babol area. The concentrations of Cu, Cr, Zn and NO_3 of both Sari and Babol area wells are within WHO standard limits, but the concentrations of Pb, Se and Cd are often exceeding the WHO maximum permissible standard values for both Sari and Babol water wells. The current quality of groundwater in Mazandaran province does not present immediate health related concerns. However, the quality of water wells in Mazandaran province is not reliable, in general. Therefore, continuous monitoring will be required to prevent contamination of groundwater resources by serious sources that mentioned in this text. As a practical step, GOI has reduced subsidies and restricted the availability of pesticides, which cause many environmental problems, based on a policy to reduce negative environmental impacts and promote biological pest control. These practical actions should be developed and continued to insure the protection of valuable resources of groundwater as well as surface water. Collected information shows that limited data are available regarding to biological quality of ground water resources. In general, the quality of groundwater resources was slightly studied in Iran. Further studies on quality of groundwater resources and establishment of strict monitoring programs to protect this valuable groundwater resources in Iran (specially north of Iran) is Strongly recommended.

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