CHANGES IN PHYSICAL AND CHEMICAL INDICES OF GROUNDWATER IN MINAB PLAIN, IRAN, CAUSED BY WATER LEVEL DECLINE

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Abstract- This study set out to investigate changes in physical and chemical indices of groundwater in Minab Plain caused by groundwater level decline. To this end, 12 groundwater samples were drawn from different wells across this plain between 22 November and 22 December 2015. Then, the parameters of acidity, electrical conductivity, and temperature were measured in situ and the major anions and cations at the Regional Water Laboratory of Hormozgan. Comparison of these parameters with EC and Cl, and other parameters measured in 2006 indicates increased concentrations of EC, Cl, Na, HCO3, TDS, as well as TH, and decreased concentration of SO4 over time. In addition, groundwater level and reservoir capacity decreased by 11.33 m and 287.179 million m^3, respectively, resulting in lower groundwater quality and higher groundwater salinity. The characteristics and quality diagrams of water and maps were evaluated using AQ.QA and GIS. Comparison of the concentrations of major cations and anions in the regional groundwater showed the dominant cationic and anionic conditions were (Na>Mg>Ca>K) and (Cl>HCO3>SO4>CO3), respectively. Results suggested that the regional waters had good, acceptable, and average qualities for drinking. In terms of agricultural use, the dominant cations in the regional groundwater were Na followed by Mg.

Keywords- Minab Plain, groundwater quality decline, groundwater level decline.

I. INTRODUCTION

Water quality assessment is typically conducted on the basis of the hydrochemical analysis [1 and 2]. Although the developing countries primarily attempt to find underground water suitable for drinking, agriculture, and industry, the quality of aquifers is overlooked in many projects [3].

Due to decreasing the reservoir capacity in Esteghlal Dam (Minab, Iran), excavation of Minab's Riverbed has started in 2002-2003 and continued up to now to supply drinking water for Bandar Abbas; the result was the severe depletion of groundwater of the area [4]. Further, this aquifer provides drinking water for Minab and surrounding villages and for agricultural purposes in hundreds of hectares of land in downstream areas. Considering the importance of water quality in the health of residents and essentiality in continuous measurement of different water parameters, this study was conducted to assess the changes in physical and chemical indices of groundwater in Minab Plain for different uses. Among other works conducted in this field of study are the assessment of underground water quality in Iranshahr Plain by Rahnamarad et al. [5], and impact of geological formation on water quality by Lashkaripour [6].

In this research, the effects of the decline in groundwater levels, such as ground settlement, drought, cracks in houses, abandoned houses, as well as the reduction in the quality of underground water for different uses and socio-economic problems, and the environmental impacts are discussed.

II. LOCATION OF MINAB PLAIN AND GEOLOGY

The Minab Plain is located in Hormozgan province in the south of Iran. (Fig.1). The plain has an area of 652.5 km^2, which approximately 373.940 km^2 of this area is located in the study area. The area has a gentle topography and extends up to the sea with a very low slope (0.5%). The maximum heights of the plain is 90 m. Minab River is the main river with tributaries originating from highlands of Rudan [7]. Minab Plain is an alluvial plain = covered by 405 km^2 of Quaternary sediments. The sediments from old to new include terraces unit and old alluvial fans, central alluvium (Qt1a) with a thickness of 6.6 km^2 in the southeastern of plain, terraces unit and new alluvial fans (Qt2) with a thickness of 126.3 km^2 in whole of the plain.

III. METHODOLOGY

In order to the assess the changes in physical and chemical indices of groundwater in Minab Plain, 12 groundwater samples were drawn from different wells to investigate major cations and anions in the water on December 2015 (Fig. 2). Next, the parameters of acidity,electrical conductivity, and temperature were measured in the field and all samples were carried to the laboratory. The main anions and cations such as Na^+, Ca^{2+}, K^+, Cl^-, HCO^{3-}, SO_4^{2-}, and CO_3^{2-} were measured at the Regional Water Laboratory of Hormozgan by the standards of World Health Organization [9] and [10]. In addition, for quality assessment of the region's groundwater for agricultural use, values of sodium absorption ratio

(SAR), sodium percentage (Na %), residual sodium carbonate (RSC), and magnesium hazard (MH), and Wilcox diagram [11] (Na% versus electrical conductivity) were used. To determine the quality of the region's groundwater for drinking purposes, the samples were assessed using the descriptiveanalysis.

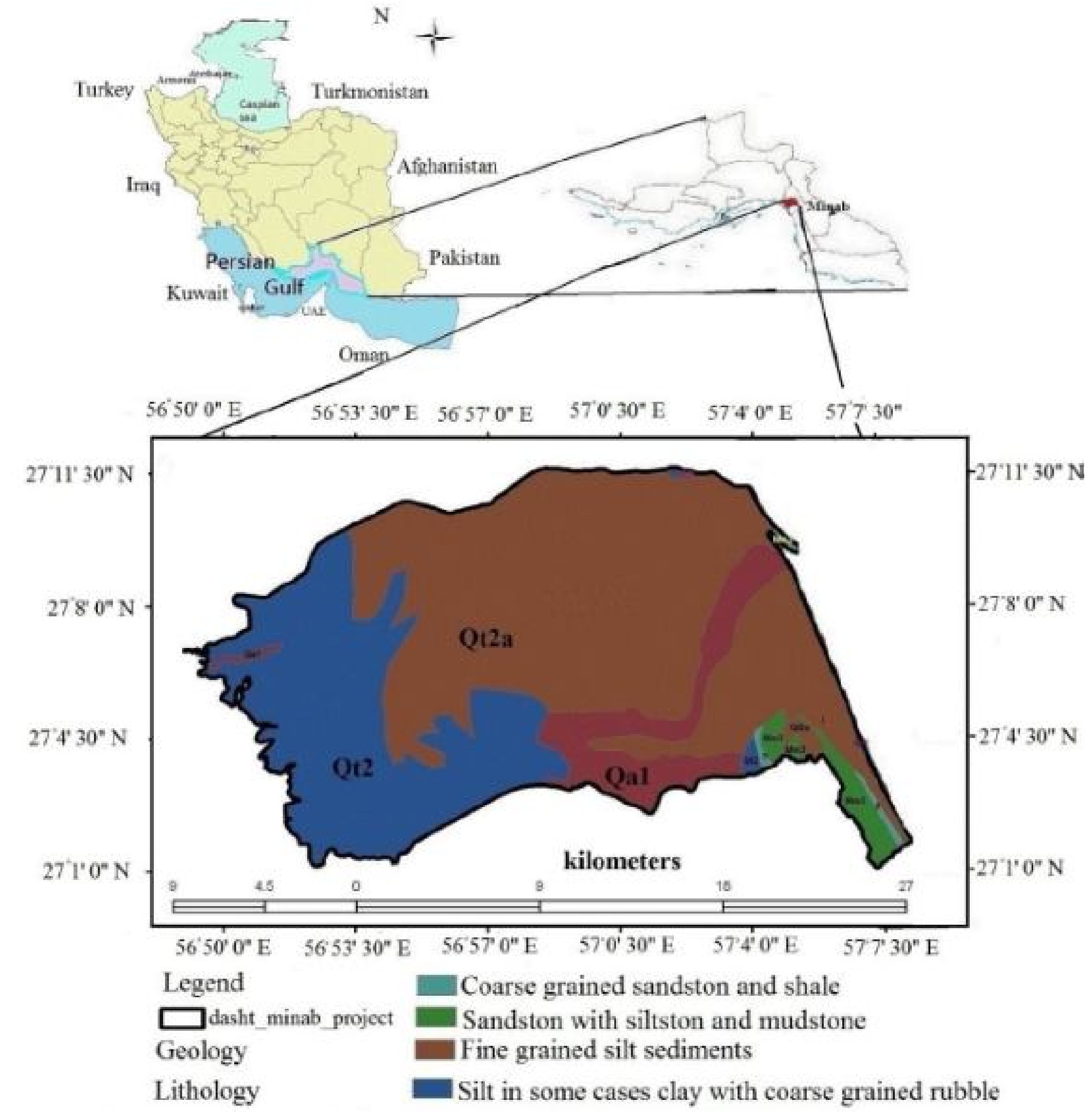

Fig.1.The geological map with location of Minab Plain (from the geological map of Minab, 1: 250,000) [8].

IV. CHEMICAL ANALYSIS

In this study, 12 water samples were evaluated and for each sample, 14 quantity parameters were assessed. Next, the mean, standard deviation, the coefficient of variation, maximum, minimum, mode, median, variance, and variation range (Table 1-4) were compared with analysis von December 2006 water samples. Although PH is not a water chemical quality index, it is measuredbecause of the importance of this parameter. Experiments show that the mean, standard deviation, coefficient of variation, maximum, minimum, median, variance and range of PH are 7.9, 0.17, 2.15, 8.21, 7.61, 7.9, 0.029, and 0.6, respectively. Comparison of these values with December 2006 measurements indicates the reduced value of PH and a basic PH for all samples. A comparison of these parameters value in drinking water in Minab Plain with national standards is shown in Table 4. Based on this table, it can be stated that PH and calcium are in a standard range. Nevertheless, the values of electrical conductivity, total dissolved solids, chloride, and sodium are 50, 42, 67, 41, and 100% higher than the maximum allowable value, respectively.

The electrical conductivity measurements fall in the range of 1271 to 3112 µ mho/cm, with 33.33% of water samples falling in the desired threshold, 16.67% falling in the allowable area, and 50% of water samples being higher than the allowable value.

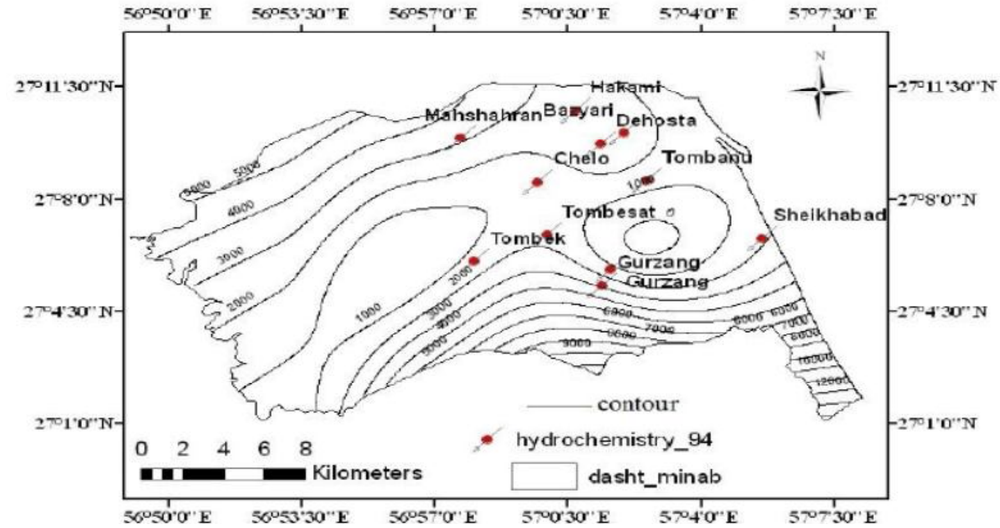

Fig. 2. Sampling points and EC isovalue curves in the study area (December 2015).

Fig. 3. The effects of the declining groundwater levels in Minab Plain. .A) Drought formation, B) Crack formation in house, C) Land subsidence, D) Crack formation in road.

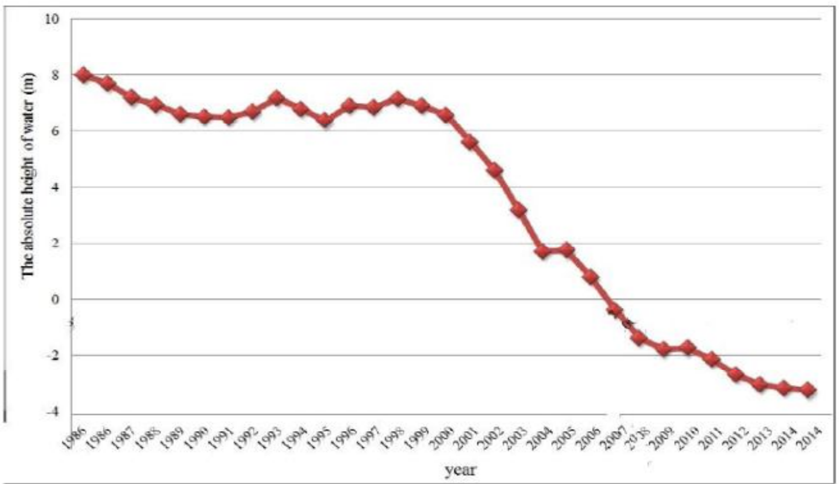

Fig.4. A hydrograph of Minab Plain in the past 28 years.

Table 1: Summary of water sample analysis taken from wells in Minab Plain on December 2015 (concentrations unit: TDS= meg/1, electrical conductivity= µmhos/cm, and total hardness=mg/l)

Wells	Location of wells (Fig. 2)	Parameters											
		TDS	EC	PH	TH	SAR	Na%	Na^+	Ca^{2+}	Mg^{2+}	Cl^-	HCO_3^-	SO_4^{2-}
W1	Gurzang	813	1271	8.21	176	6.96	72.49	9.2	1.28	2.21	6.7	2.9	3.1
W2	Tombesat	1067	1667	7.95	208	8.71	75.19	12.52	1.6	2.53	9.9	3.1	3.66
W3	Gurzang	1804	2818	7.86	368	10.92	74.1	20.86	2.87	4.42	20	3.2	4.97
W4	Bazyar	1593	2489	7.61	448	7.59	64.32	15.99	2.55	6.32	10.5	9.6	4.78
W5	Mahshahran	1992	3112	7.86	464	10.2	70.42	21.88	2.24	6.95	17.5	7.1	6.5
W6	Chelo	867	1355	8.01	208	6.54	69.47	9.4	1.6	2.53	5.8	5.6	2.14
W7	Tombanu	874	1365	8.01	160	8.28	76.66	10.45	1.6	1.58	7.2	3.3	3.14
W8	Dehosta	1689	2639	7.62	448	8.3	66.35	17.49	2.87	6	14	7.1	5.28
W9	Hakami	1688	2628	7.92	400	9.26	69.94	18.43	2.24	5.68	14.5	6.4	5.47
W10	Tombek	897	1401	8.15	160	8.57	77.26	10.81	1.6	1.58	6.6	3.7	3.7
W11	Sheikhabad	1194	1866	7.89	272	8.07	71.08	13.25	1.6	3.79	8.4	5.6	4.65
W12	Zahuki	1451	2279	7.82	352	8.44	69.33	15.78	2.24	4.79	12.5	6	4.28

Table 2: The statistical characteristic of various indices of chemical quality of underground water resources in Minab Plain on December 2015. (concentrations unit: TDS in meg/1, electrical conductivity in µmhos/cm, and total hardness in mg/l)

Parameters	TDS	EC	PH	TH	Na^+	K^+	Ca^{2+}	Mg^{2+}	HCO_3^-	CO_3^{2-}	Cl^-	SO_4^{2-}
number of samples	12	12	12	12	12	12	12	12	12	12	12	12
the mean	1327	2074	7.9	305	14.7	0	2.02	4.03	5.3	0	11.1	4.3
standard deviation	405.01	632.3	0.17	115.46	4.2	0	0.52	1.84	2	0	4.42	1.16
Coefficient of variation	30.52	30.2	2.15	37.86	28.57	0	25.74	45.66	37.74	0	39.82	26.98
Maximum	1992	3112	8.21	464	20.9	0	2.87	6.95	9.6	0	20	6.5
Minimum	813	2171	7.61	160	9.2	0	1.28	1.58	2.9	0	5.8	2.14
Mode	-	-	7.86	160	-	0	1.6	1.58	7.1	0	-	-
Median	1322.5	2972.5	7.9	280	14.51	0	1.92	4.1	5.6	0	10.2	4.46
Variance	164037	399805	0.029	13332	17.7	0	0.27	3.41	4.03	0	19.5	1.35
variation range	1179	1841	0.6	304	11.7	0	1.59	5.37	6.7	0	14.2	4.36

Table 3: The statistical characteristic of various indices of chemical quality of underground water resources in Minab Plain on December 2006 (concentrations unit: TDS in meg/1, electrical conductivity in µmhos/cm, the total hardness in mg/l) [12].

parameters	TDS	EC	PH	TH	Na+	K^+		Ca^{2+}	Mg^{2+}	Cl^-	HCO_3^-	CO_3^{2-}	SO_4^{2-}
number of samples	34	34	34	34	34	34		34	34	34	34	34	34
the mean	837.94	1356.4	8.03	18.41	7.88	0		2.55	2.93	5.17	3.54	0.09	4.75
standard deviation	422.17	619.64	0.26	9.49	4.19	0		1.08	1.74	3.13	0.98	0.28	3.23
Coefficient of variation	50.28	45.68	3.24	-	53.17	0		42.35	59.39	60.54	27.68	311.1	68
maximum	1655	2586	8.6	35.31	18.64	0		5.58	5.52	8.9	5.05	1.5	14.17
minimum	0	364	7.35	5.9	1.39	0		1.27	0.31	0.3	0.95	0	0.47
Mode	372	-	8.35	-	-	0		2.19	4.1	8	4.2	0	2.1
Median	960	1521.5	8.02	-	9.41	0		2.87	3.78	5.7	3.88	0	5.38
Variance	178229	383943	0.07	-	17.57	0		1.16	3.01	9.8	0.96	0.08	10.43
variation range	1655	2222	1.25.	29.4	17.25	0		4.31	5.21	8.6	4.2	1.5	13.27

Table 4: Descriptive statistics of the physical and chemical factors of groundwater resources in the study area in December 2015 and a comparison with national 1053 and international standards. WHO, 2008

parameters	minimum	maximum	mean	Iran water standard 1053		World health organization standards	Percentage of water samples in the standard range		
				maximum desired threshold	the maximum allowable value		Desirable	standard	higher than standard
TDS (mg/l)	813	1992	1327	100	1500	500	-	58	42
EC (µmhos/cm)	1271	3112	2074	1500	2000	1400	33.33	16.67	50
PH	7.61	8.21	7.9	6.5-8.5	6.5-9	6.5-8.5	100	-	-
TH (mg/lCaCO_3)	160	464	305	300	500	200	50	50	-
Na (mg/l)	212	502	337	200	200	200	-	-	100
Ca (mg/l)	25.65	57.51	40.56	300	400	75	100	-	-
Mg (mg/l)	19.2	84.48	50.26	30	150	50	25	75	-
Cl (mg/l)	205.65	709	394.65	250	400	200	25	33.33	41.67
SO_4 (mg/l)	102.8	312.1	206.8	250	400	200	75	25	-

CONCLUSIONS

Minab groundwater level is declined every year due to the large extractions so that it has been dropped to 11.33 m over a period of 28 years and the reservoir capacity has been decreased by 287.179 mm^3 (Fig. 3). The excess pumping of Minab Plain aquifer has had undesirable consequences such as reducing the volume of water reserves, mandatory increase the wells depth, drying the resources, land settlement, creating fissures in the ground and buildings, damages to the facility, drying gardens and farms, adverse economic and social consequences and reducing the groundwater quality (Fig.4). Evaluating the correlation between electrical conductivity and water quality indicators suggested that there is a considerable relation between the electrical conductivity and the total dissolved solids. There is a good relation between magnesium and the EC, as well. Considering the obtained correlation coefficient it can be represented a good relationship between electrical conductivity chloride and electrical conductivity with the concentration of sodium in groundwater of Minab Plain, however, there is no relationship between bicarbonate ion and the electrical conductivity. The results of evaluating the ratio between the ions in water of area show that these ratios have been increased compared to those in 2006.

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