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ORIGINAL PAPER

The physicochemical characteristics of well water samples in Lavasanat region, Iran

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ABSTRACT

The present study aimed to evaluate the quality of well water in Lavasanat region, Iran in order to achieve a comprehensive zoning map in a geographical information system (GIS) environment and improve the efficacy of water use during July-November 2016. To this end, samples were collected from the water wells in the villages of Kond Olya, Kond Sofla, Amin Abad, Anbaj, Zard Band, and Barg Jahan for chemical and physical analyses, including the measurement of hardness, acidity, electrical conductivity (EC), and turbidity, as well as the presence of anions (e.g., NO_3 and HCO_3) and cations (Ca and Mg). The obtained results indicated that the EC of the well water samples in Kond Olya and concentration of magnesium in the samples collected from Kond Olya and Anbaj were higher than the standard level of 1053 (1800 µs and 30 mg/l, respectively). Moreover, the turbidity of the samples collected from Kond Olya was slightly higher than the standard value during the humidity period. According to the results, the pH, total hardness, and concentrations of calcium and nitrate in all the studied water wells were below the standard level of 1053 during humid and dry periods. Therefore, it could be concluded that the water quality in Lavasanat (especially Kond Olya region) has been affected by human activities (e.g., release of household and agricultural sewage). It is strongly recommended that the water wells in Kond Olya village be purified in order to prevent the possible health damages in the residents of this area.

Keywords: Physico-chemical quality, GIS, Nitrate, Total dissolved solids, Turbidity

Introduction

According to statistics, approximately one-third of the world's population use groundwater for drinking.[1] However, lack of drinking water resources, along with the occurrence of droughts and destructive impacts of human activities on the surrounding environment, are considered to be severe environmental challenges regarding the use of freshwater resources within recent decades. In addition to the scarcity of freshwater resources, water is also exposed to contamination, causing water-related issues to become one of the most important limitations in the human life.[2] The rapid growth of population and urbanization, industrialization, and exploitation of land cover have led to numerous hazardous environmental consequences, and water pollution is one of the most momentous consequences of these activities.[3] Several studies have been focused on the detailed description of the potential adverse health effects associated with the poor quality of water.[4] However, the investigation of the sources of pollutants and providing practical solutions to reduce the concentrations of various pollutants is not feasible unless possible changes and deviations from the standard (INSO, 1053) are properly recognized. Such measures are known to be extremely costly and time-consuming.

The geographical information system (GIS) is a practical tool for water quality mapping, which is also essential to the

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evaluation and identification of environmental changes.[5] Due to the qualitative and quantitative constraints of water supplies that have resulted from frequent droughts in recent years, it is of utmost importance to develop comprehensive quality maps in a GIS environment for the efficient use and management of water resources. Furthermore, such measures help environmental managers to decide on effective development by considering the quantitative and qualitative aspects of drinking water supplies in accordance with environmental principles.[6] Use of the GIS has greatly facilitated the assessment of natural resources and environmental concerns, including groundwater sources.

Pollutants may leak from landfill sites and poorly-constructed sewage systems. Groundwater could be polluted by drainage from farmlands and industrial areas.[7] Moreover, the residents of an area play a key role in the contamination of groundwater resources by releasing various chemicals into the sewage or ground surface waters.[8] On its path from the soil surface to aquifers, water seepage may contain various minerals and organic materials depending on the type of soil and concentration of contaminants. In addition, it is likely that contaminants such as oil pollutants reach ground water sources and contaminate the water through the ground surface or sewage well pollution.

Given the importance of water, this issue has long concerned researchers.[9, 10] For instance, Nas *et al.* conducted a GIS-based study to investigate the nitrate pollution of groundwater in Kenya city (Turkey), reporting that the nitrate concentrations in the city center was growing steadily. Furthermore, the findings of the mentioned research indicated that the mean nitrate concentrations were 2.2 mg/l in 1998 and 16.1 mg/l in 2001.[11] In another study in this regard, Ramesh and Elango assessed the groundwater quality and its suitability for irrigation purposes in India in terms of salinity, sodium adsorption, and carbonate. According to the obtained results, most of the groundwater samples were not appropriate for drinking and agricultural purposes.[12] On the other hand, Abbasnia *et al.* evaluated the groundwater quality in the south of Iran based on the GIS, concluding that the water in the studied area was suitable for agricultural applications.[10]

The present study aimed to evaluate the water quality of the wells in the villages of Lavasanat region, Iran considering the physical and chemical parameters in a GIS environment in order to provide a omprehensive zoning map for improving the efficiency of water supply use.

Materials and Methods

Site description

This study was conducted in Lavasanat region, located in Tehran province, Iran. The coordinates of the region were 35 5' N, 51 4' E, with the elevation of 1,700-1,850 meters above the sea level. The average annual precipitation in this region is within the range of 380-450 millimeters, with the annual temperature estimated to be above 14 °C. The geological formations in the region consist of shale, dolomitic sandstone, and limestone from the first Cambrian period to the Quaternary alluvial deposits. In total, there are 1,557 water wells in Lavasanat, 1,387 of which are categorized as semi-deep wells, and 170 are considered to be deep wells.[13] The average depth of the semi-deep and deep wells in this area is 27.86 and 69.14 meters, respectively.

Water wells

In the present study, the selected water wells were in the villages of Kond Olya, Kond Sofla, Amin Abad, Anbaj, Zard Band, and Barg Jahan, all of which are the main sources of drinking water for the surrounding villages. Therefore, the health of the residents is largely influenced by the quality of the well water. Moreover, these wells are equipped with sanitary protection, which prevents sewage from directly entering the wells at high concentrations. Therefore, the quality of the water in these wells could represent the quality of the groundwater sources in Lavasanat region (Fig. 1).

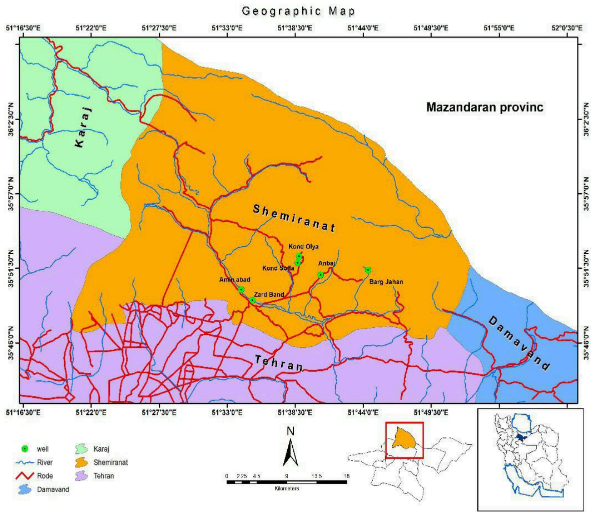

Fig. 1. Location of wells in studied area

Experimental procedures

Sampling was performed in dry and humid periods during July-November 2016. The map layer of the study site was prepared based on the influential factors in the quality of well water, such as topography, political boundaries, and roads. Afterwards, the geographical position of each well was determined using GPS and mapped in a GIS environment. For the physicochemical analysis of the well water, 30 samples were collected from each well (total: 180), which was the minimum number of the samples for the assessment of water quality.[14] The measurements were performed in a laboratory in order to examine the physicochemical properties of water, including hardness, pH, electrical conductivity (EC), and turbidity, as well as the presence of anions (e.g., NO_3 and HCO_3) and cations (e.g., Ca and Mg). The results of the measurements were added to the map of the studied area as descriptive data. The analyses and measurements performed on the samples were based on the Standard Methods for the Examination of Water and Wastewater (1998).[15]

At the next stage, the Kriging interpolation function was applied to perform the qualitative modeling of the water wells in the selected regions.[16] Kriging is an advanced geostatistical procedure, which incorporates spatial autocorrelation into continuous variables for the interpolating of the values obtained at the locations where they have not been measured. This technique has been extensively used in the studies regarding water resources.[17]

Data analysis was performed in SPSS version 20 and Excel software version 2013 using descriptive statistics (mean, maximum, and minimum). In addition, one-sample t-test was applied to estimate the mean of a single group against a known standard value for each parameter.

Results and Discussion

Electrical conductivity (EC)

According to the obtained results, the highest EC value was observed in the water wells in Kond Olya region, where the values were mostly higher than the standard 1053. However, the water wells in the other areas had lower EC than the standard. Furthermore, the EC values were slightly higher in the dry period compared to the humid period (Figs. 2 & 3). According to the results of one-sample t-test, the EC in Kond Olya region during both periods was significantly higher than the standard value ($P<0.05$), while 0.3% of the area had higher EC than the standard value (Fig. 3).

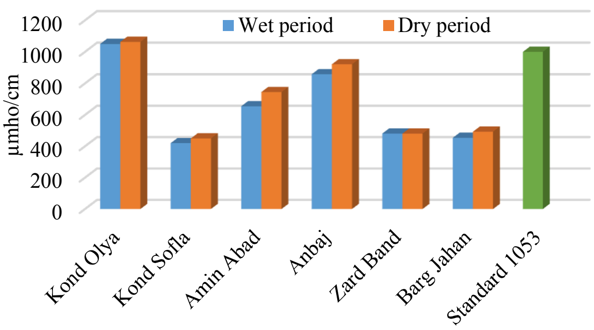

Fig. 2. EC values in various studied water wells

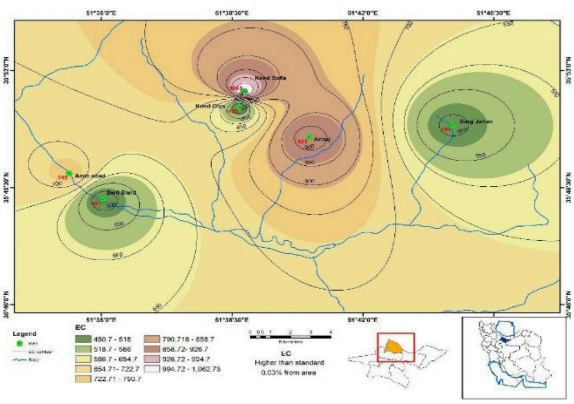
Fig. 3. EC values in various studied water wells

Measurement of pH

According to the obtained results, the pH of the water in all the studied water wells was lower than the maximum range of the standard 1053. Although the values were generally similar in the dry and humid periods, the values obtained in Barg Jahan, Zard Band, and Amin Abad regions were observed to be lower in the humid period compared to the dry period. However, the pH values were lower in the dry period compared to the humid period in the regions of Anbaj, Kond Olya, and Kond Sofla (Figs. 4 & 5).

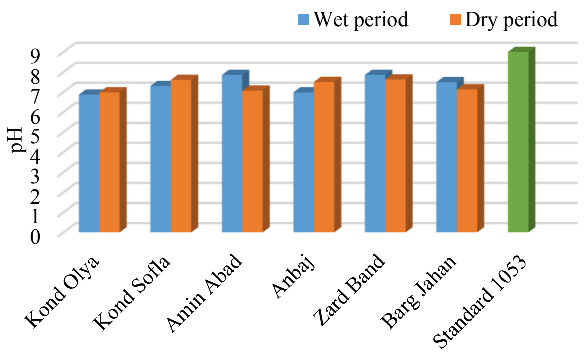

Fig. 4. Results of pH measurement in studied water wells

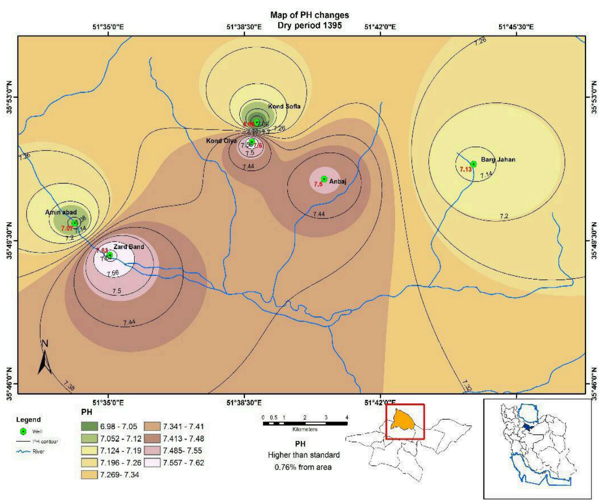

Fig. 5. Results of pH measurement in studied water wells

Total hardness

The total hardness values were observed to be below the standard 1053 during the humid and dry periods in the studied regions (Figs. 6 & 7). With the exception of the water wells in Zard Band region, the studied water wells had higher hardness during the dry period compared to the humid period. In addition, the highest value of total hardness was observed in Kond Olya region, while the water wells in Kond Sofla and Barg Jahan regions had the lowest values of total hardness.

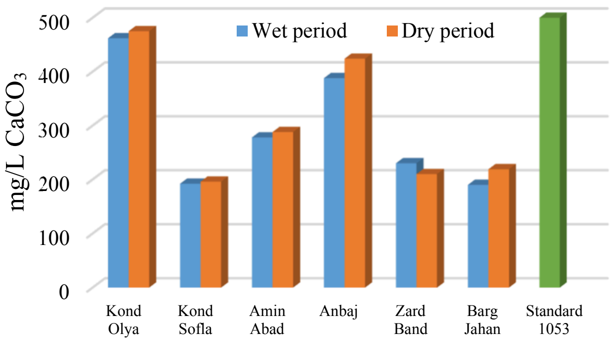

Fig. 6. Total hardness of studied water wells

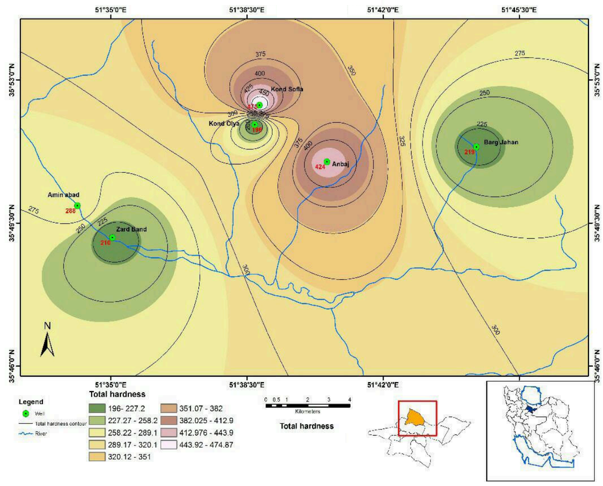

Fig. 7. Total hardness of studied water wells

Turbidity

According to the findings of the current research, the turbidity of the water wells in the regions of Kond Sofla, Amin Abad, Zard Band, Barg Jahan (both humid and dry periods), Anbaj, and Kond Olya (dry period) were significantly below the standard 1053. However, during the humid period, the turbidity value was observed to be significantly higher in Kond Olya and Anbaj regions compared to the other water wells. On the other hand, the turbidity of the water wells in Kond Olya region was slightly higher than the standard value during the humid period (Figs. 8 & 9).

The results of one-sample t-test indicated that the turbidity of the well water in Kond Olya region was significantly higher than the standard value during the humid period (P<0.05). Furthermore, the obtained results demonstrated that 0.38% of the area had higher turbidity than the standard value (Fig. 9).

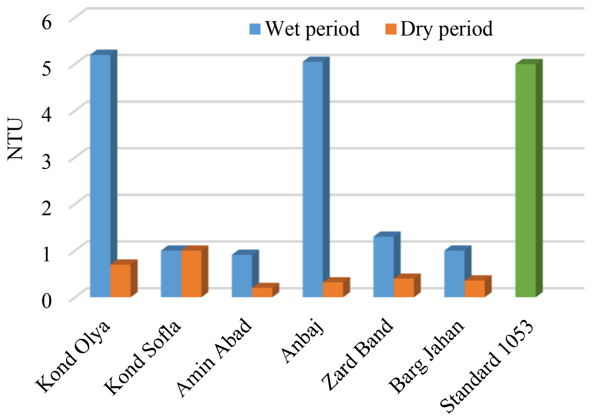

Fig. 8. Turbidity values of studied water wells

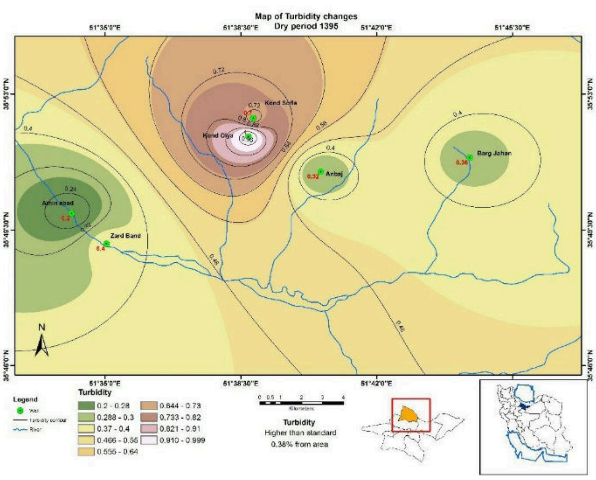

Fig. 9. Turbidity values of studied water wells

According to the results of the present study, soil cohesion increased due to the presence of soil layers with high clay content in Kond Olya and Anbaj regions, as well as the propagation of groundwater to these layers during the humid period. Soil cohesion is closely correlated with the clay content of soil.[18, 19] However, due to the declined water level in summer, soil cohesion may also decrease, causing the soil particles to drop into water wells, thereby increasing their turbidity. It is also notable that the proximity of water wells to seasonal rivers could increase their turbidity.[20] The adjacency of the water wells in Anbaj and Kond Olya regions to seasonal flooding was observed to increase the possibility of the entry of muddy waters into the wells, which in turn increase turbidity, which has also been reported in the current literature.[21] Several studies have demonstrated a close correlation between suspended sediment concentration and water turbidity.[22] However, in the regions of Zard Band, Amin Abad, and Barg Jahan, the presence of sand layers between the wells and rivers acted as a natural refining system, thereby preventing the flow of muddy water into the wells.[23]

Cations

Magnesium (Mg)

According to the results of the present study (Figs. 10 & 11), the concentration of magnesium in the water wells of Kond Olya and Anbaj regions was higher than the standard limit. On the other hand, the minimum values of magnesium concentration were observed in Kond Sofla region during the humid period and Zard Band region during the entire period. In general, the magnesium concentration in the water wells in Kond Olya, Amin Abad, and Zardband regions was higher during the humid period, while higher concentrations of this cation were observed in the regions of Kond Sofla, Anbaj, and Barg Jahan during the dry period. According to the statistical analysis, the concentration of magnesium was significantly higher in the water wells in Kond Olya region during the humid period and Anbaj region in both periods compared to the standard limit (P<0.05). In this regard, the findings indicated that 1.2% of the area had magnesium concentrations of higher than the standard level (Fig. 11).

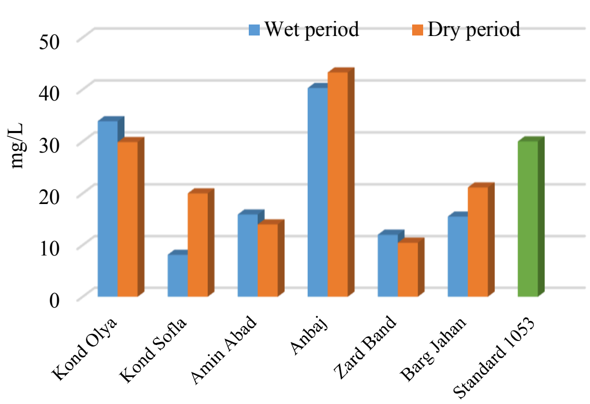

Fig. 10. Magnesium concentration in various water wells

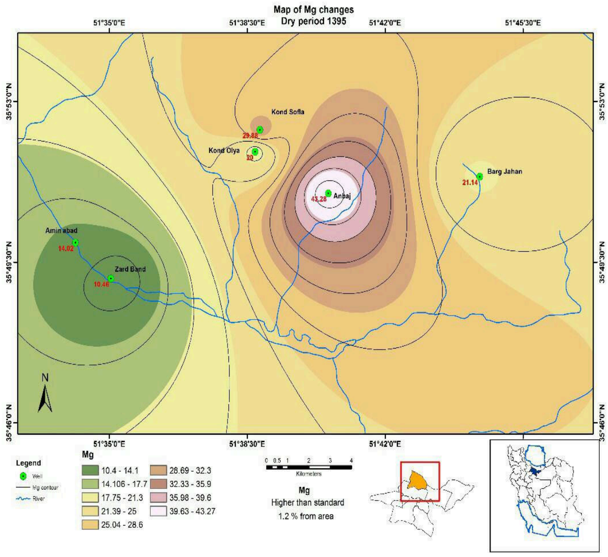

Fig. 11. Magnesium concentration in various water wells

Calcium (Ca)

As is depicted in Figs. 12 and 13, the concentration of calcium was below the standard range in all the studied water wells. Furthermore, the obtained results indicated that calcium concentration was generally lower during the humid period compared to the dry period, with the exception of the water wells in Zard Band region, which showed higher values during the humid period. In addition, the maximum and minimum calcium concentration values were detected in Kond Olya region during the dry period and Barg Jahan region during the humid period.

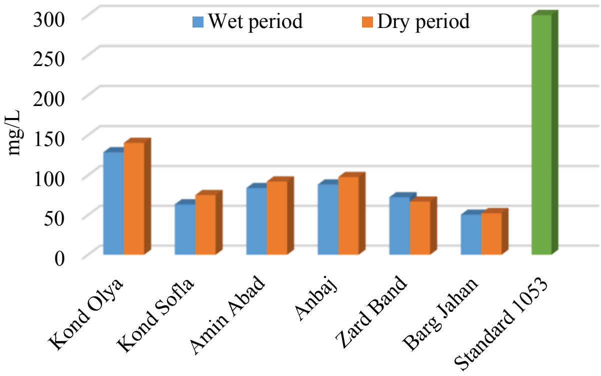

Fig. 12. Calcium concentration in various water wells

According to the findings of the current research, the increased calcium concentration in Kond Olya village due to the geological formation of Kond in conjunction with gypsum-marl compounds ($CaCO_3$) led to the increased concentration of Ca^{2+}, as well as the EC and hardness of the groundwater. Therefore, it could be concluded that there was a significant correlation between EC and the rising trend of Ca^{2+} in the water wells of this village, which is in line with the results of the previous studies in this regard.[24, 25] For instance, Rao reported a direct correlation between EC and Ca^{2+}.[24] As mentioned earlier, this finding could be due to the geological characteristics of the area. Similar to the dry period, calcium had a rising trend in the water wells of Kond Olya region during the humid period, and the causes of this increment are similar in both the dry and humid periods. Our findings also demonstrated that the same trend could be observed with total dissolved solids, EC, and total hardness.

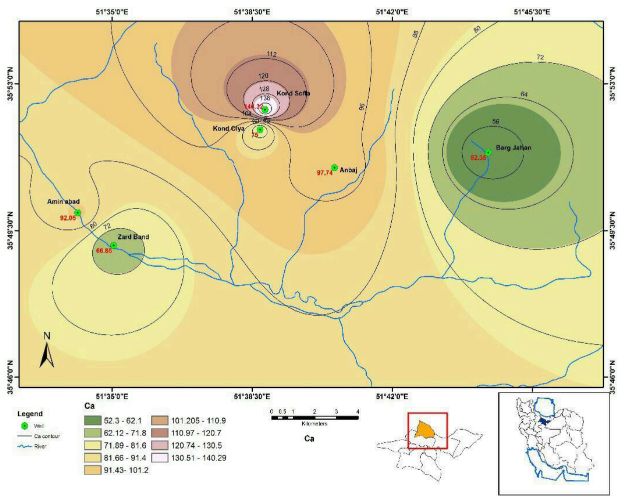

Fig. 13. Calcium concentration in various water wells

Anions

Nitrate (NO_3)

In the current research, the concentration of NO_3 was measured in all the water wells and observed to be significantly lower than the standard 1053. This finding is of paramount importance considering that NO_3 is a marked parameter in the assessment of water quality. As is shown in Figs. 15 and 16, the water wells in the regions of Kond Sofla (humid period) and Anbaj (humid and dry periods) had the minimum and maximum NO_3 concentration, respectively.

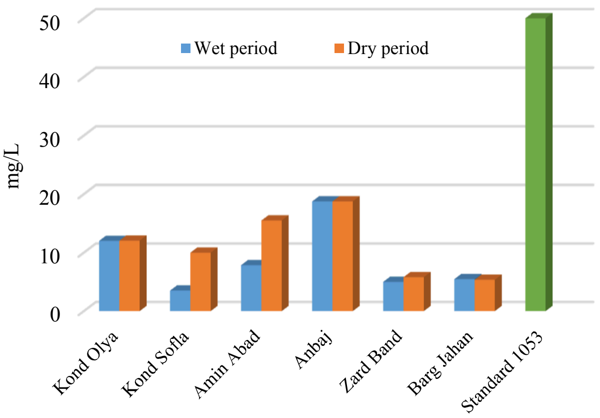

Fig. 14. Nitrate concentration in various water wells

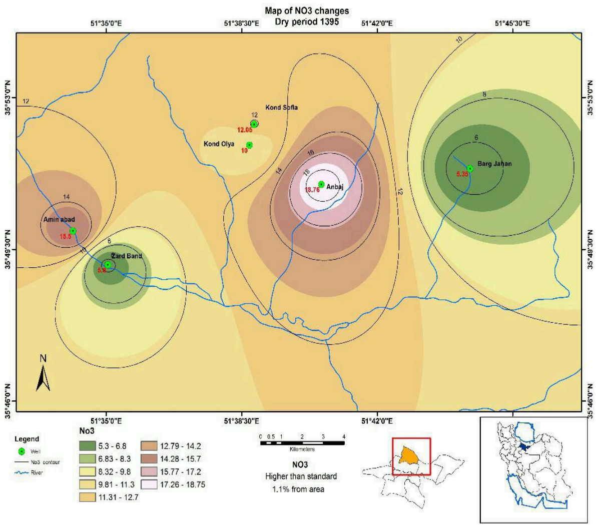

Fig. 15. Nitrate concentration in various water wells

Since the water wells in Anbaj village are located at the lower side of the village, surface water and household wastewater easily flow into the aquifers. This highlights the effects of human activities on the increased concentration of NO_3 in the water wells of Anbaj region. In a similar research, Bouchard *et al.* reported that human activities could increase the concentration of nitrate in groundwater, and similar results have also been reported by other researchers.[26] Increased NO_3 concentration could also be attributed to the agricultural activities within and in the vicinity of the village, which release large amounts of nitrate through agricultural runoff into the surface and subsurface water flow. In Poland, Lawniczak *et al.* observed high nitrate concentrations in groundwater in agricultural catchments.[27]

Bicarbonate (HCO_3)

According to the findings of the current research, the concentration of HCO_3 in the studied water wells was mostly similar during the humid and dry periods (Figs. 16 & 17). However, the difference between the dry and humid periods in this regard was relatively significant in the water wells of Anbaj and Zard Band regions. Moreover, the water wells in Anbaj and Barg Jahan regions had the maximum and minimum concentration of HCO_3, respectively.

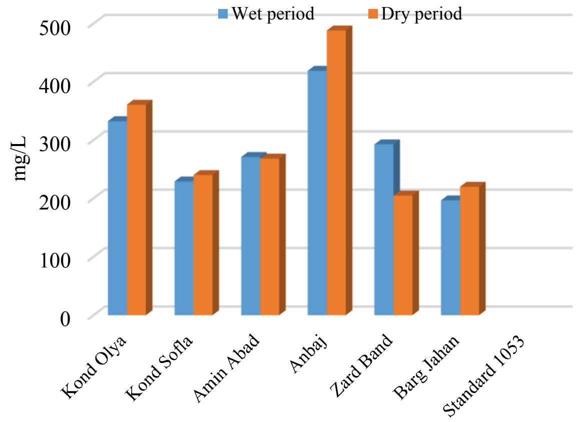

Fig. 16. Bicarbonate concentration in studied water wells

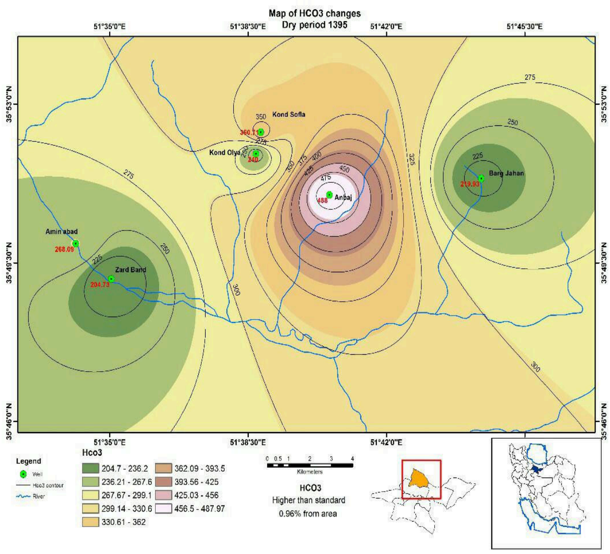

Fig. 17. Bicarbonate concentration in studied water wells

In Anbaj village, green rocks (green tuff) are ubiquitous, and their exposure to weathering leads to the release of large amounts of bicarbonate.[28] Therefore, there is a high possibility for the entry of bicarbonate into the water resources throughout the area, and the carbonization of water resources is associated with the increased pH of water.[29]

Conclusion

According to the results, changes in the quality of drinking water are mostly associated with human activities, which mainly include the release of household sewage and agriculture. For instance, the water wells in Anbaj region are typically located within or in the vicinity of residential areas and could be directly affected by such activities. Therefore, the direct and indirect effects of human activities variably affect the quality of drinking water, especially in terms of nitrate concentration, which was relatively lower in the mentioned area compared to the water wells in the other villages.

References

1. Khosravi R, Eslami H, Almodaresi SA, Heidari M, Fallahzadeh RA, Taghavi M, *et al.* Use of geographic information system and water quality index to assess groundwater quality for drinking purpose in Birjand City, Iran. Desalination Water Treat 2017;67(1):74-83.
2. Petersen L, Heynen M, Pellicciotti F. Freshwater Resources: Past, Present, Future. International Encyclopedia of Geography: People, the Earth, Environment and Technology: People, the Earth, Environment and Technology, 2016;2:1-11.
3. Shukla AK, Ojha CSP, Mijic A, Buytaert W, Pathak S, Garg RD, *et al.* Population growth, land use and land cover transformations, and water quality nexus in the Upper Ganga River basin. Hydrol Earth Syst Sci 2018;22(9):4745-70.
4. Wolf J, Hunter PR, Freeman MC, Cumming O, Clasen T, Bartram J, *et al.* Impact of drinking water, sanitation and handwashing with soap on childhood diarrhoeal disease: Updated meta-analysis and meta-regression. Trop Med Int Health 2018;23(5):508-25.
5. Nath BK, Chaliha C, Bhuyan B, Kalita E, Baruah DC, Bhagabati AK. GIS mapping-based impact assessment of groundwater contamination by arsenic and other heavy metal contaminants in the Brahmaputra River valley: A water quality assessment study. J Clean Prod 2018;201:1001-11.
6. Tiwari K, Goyal R, Sarkar A. GIS-based spatial distribution of groundwater quality and regional suitability evaluation for drinking water. Environ Process 2017;4(3):645-662.
7. Kumari R, Datta PS, Rao MS, Mukherjee S, Azad C. Anthropogenic perturbations induced groundwater vulnerability to pollution in the industrial Faridabad District, Haryana, India. Environ Earth Sci 2018;77(5):187-92.
8. Hobbie SE, Finlay JC, Janke BD, Nidzgorski DA, Millet DB, Baker LA. Contrasting nitrogen and phosphorus budgets in urban watersheds and implications for managing urban water pollution. Proc Natl Acad Sci 2017;114(16):4177-82.
9. Şener Ş, Şener E, Davraz A. Evaluation of water quality using water quality index (WQI) method and GIS in Aksu River (SW-Turkey). Sci Total Environ 2017;584:131-44.
10. Abbasnia A, Radfard M, Mahvi AH, Nabizadeh R, Yousefi M, Soleimani H, *et al.* Groundwater quality assessment for irrigation purposes based on irrigation water quality index and its zoning with GIS in the villages of Chabahar, Sistan and Baluchistan, Iran. Data Brief 2018;19:623-31.
11. Nas B, Berktay A. Groundwater contamination by nitrates in the city of Konya, (Turkey): A GIS perspective. J Environ Manage 2006;79(1):30-7.
12. Ramesh K, Elango L. Groundwater quality and its suitability for domestic and agricultural use in Tondiar river basin, Tamil Nadu, India. Environ Monit Assess 2012;184(6):3887-99.
13. Anonymous. Water Statistics of Tehran Province. Abfatehran Company, 2015; 416 p.
14. Anonymous. Protocols manual for water quality sampling in Canada. Canadian Council of Ministers of the Environment. 2016; 180 p.
15. Standard Methods. Standard Methods for the Examination of Water and Wastewater. In: Greenberg, A.E., Clesceri LS, Eaton AD. (Eds.), APHA-AWWA-WEF, 20th ed., Washington, DC. 1998.
16. McLeod L, Bharadwaj L, Epp T, Waldner C. Use of principal components analysis and kriging to predict groundwater-sourced rural drinking water quality in Saskatchewan. Int J Environ Res Public Health 2017;14(9):1065-73.
17. Liang CP, Chen JS, Chien YC, Chen CF. Spatial analysis of the risk to human health from exposure to arsenic contaminated groundwater: A kriging approach. Sci Total Environ 2018;627:1048-1057.
18. Kim D, Nam BH, Youn H. Effect of clay content on the shear strength of clay–sand mixture. Int J

Geo-Eng 2013;9:19-27.
19. Abdi E, Babapour S, Majnounian B, Amiri GZ, Deljouei A. How does organic matter affect the physical and mechanical properties of forest soil?. J For Res 2018; 29(3): 657-662.
20. Barakat A, El Baghdadi M, Rais J, Aghezzaf B, Slassi M. Assessment of spatial and seasonal water quality variation of Oum Er Rbia River (Morocco) using multivariate statistical techniques. Int Soil Water Conserv Res 2016;4(4):284-92.
21. Pettit NE, Jardine TD, Hamilton SK, Sinnamon V, Valdez D, Davies PM, *et al.* Seasonal changes in water quality and macrophytes and the impact of cattle on tropical floodplain waterholes. Mar Freshw Res 2012;63(9):788-800.
22. Niu Q, Xia M, Ludsin SA, Chu PY, Mason DM, Rutherford ES. High-turbidity events in Western Lake Erie during ice-free cycles: Contributions of river-loaded vs. resuspended sediments. Limnol Oceanogr 2018;63(6):2545-62.
23. Sheets RA, Bossenbroek KE. Ground-water flow directions and estimation of aquifer hydraulic properties in the lower Great Miami river buried valley aquifer system, Hamilton area, Ohio. US Department of the Interior, US Geological Survey; 2005.
24. Rao NS. Seasonal variation of groundwater quality in a part of Guntur District, Andhra Pradesh, India. Environ Geolo 2006;49(3):413-29.
25. Li P, Qian H, Wu J, Zhang Y, Zhang H. Major ion chemistry of shallow groundwater in the Dongsheng Coalfield, Ordos Basin, China. Mine Water Environ 2013;32(3):195-206.
26. Bouchard DC, Williams MK, Surampalli RY. Nitrate contamination of groundwater: sources and potential health effects. J Am Water Works Assoc 1992;84(9):85-90.
27. Lawniczak AE, Zbierska J, Nowak B, Achtenberg K, Grześkowiak A, Kanas K. Impact of agriculture and land use on nitrate contamination in groundwater and running waters in central-west Poland. Environ Monit Assess 2016;188(3):172-80.
28. Hosseinzadeh Talaee P. Analysis of groundwater quality in the northwest of Iran. Desalination Water Treat 2015;56(9):2323-34.
29. Kumar S, Loganathan VA, Gupta RB, Barnett MO. An assessment of U (VI) removal from groundwater using biochar produced from hydrothermal carbonization. J Environ Manage 2011; 92(10): 2504-12.