Applying results of the chemical analyses in determining groundwater quality for drinking, agricultural and industrial uses: The case study Rafsanjan plain, Iran

Mohammad Hossein JAHANGIR1) ABC, Keyvan SOLTANI2) DEF

1) orcid.org/0000-0002-0991-7646; University of Tehran, Faculty of New Sciences and Technologies, 16th Azar St., Enghelab Sq, 1439957131, PO Box: 14155-6619, Tehran, Iran; e-mail: mh.jahangir@ut.ac.ir
2) University of Tehran, Faculty of New Sciences and Technologies, Tehran, Iran; e-mail: keyvan.soltani@ut.ac.ir

Abstract

Based on chemical analyses, the quality of ground waters for drinking, agricultural and industrial purposes was determined in Rafsanjan Plain-Iran. Samples for analyses were taken from 22 wells in 2012. Because of high water hardness and total dissolved solids content, water was found to be unsuitable for drinking purposes. Water quality for agriculture was determined with the use of the Wilcox method. Among the analysed water, 10.33% were attributed to C3-S1 class (high electrolytic conductivity and low sodium adsorption ratio), 59.5% to class C4-S1 (very high EC and low SAR) and 30.17% to class C4-S2 (very high EC and medium SAR). 89.67% of studied wells were unsuitable for agriculture. Because of corrosive water properties all but two wells on Rafsanjan Plain were undesirable for use in the industry. The results of qualitative analyses were presented in GIS and in databases to support making decision and management of groundwater on Rafsanjan Plain.

Key words: water quality, water resources management, groundwater, Rafsanjan plain

INTRODUCTION

Every year 842,000 humans died for unavailability of clean water and contaminated water [CLAUSEN 2011, KAYSER 2015]. Since 1970, the impact of land use on water quality became a big challenge and concern ZHAO et al. [2015], RIMER et al. [1978], WHITE [1976]. Then in 1990 researchers began to analyse the relationship between land use and water quality [JOHNSON et al. 1997]. Recently, with the development of landscape ecology and GIS techniques, in water quality studies have founded new forms and effects of land use, hydrological and geological conditions on water quality were a fundamental consideration, [ALLAN 2004; BOOTH et al. 2004; HATHAWAY, HUNT 2011; MARINONI et al. 2013; RIBOLZI et al. 2011; TU 2013]. It is generally accepted that physical and chemical properties, aquatic environment cannot reflect the real state health of an ecosystem [ZHENG et al. 2014]. Water quality management in the watershed was essential to obtain the water management strategy [ASHTON et al. 1995]. Human sustainable access to safe drinking water is always a vital need. Unfortunately groundwater hydrology due to connections with other water resources was at risk of infection by the destructive process. So access to unsafe and pollution water cause diseases and many problems and damages in social, economic and other fields. The most important factors for water quality determine with using the application, in the various uses [KAYSER et al. 2015]. Access to unsafe and pollution water causing diseases, many problems and damages in social, economic and other fields. In this context, awareness of the water quality resources is one of the basic needs in planning the use of water in agriculture, industry, drinking etc. [ABTAHI et al. 2015; LOBATO et al. 2015]. In addition, today due human activities and various
contaminants entering, the water quality is changed and were an impact on human life and users in various sectors of agriculture, industry etc. The human impact factors on water quality have included time, environment and biological factors, physical and chemical processes involved natural systems etc. One of important factor in this context is the hydrologic cycle that directly affects on the water drainage network affected by contamination sediment, So impact on local flora, fauna and creates many problems too [LOBATO et al. 2015; ZHAO et al. 2015]. In this regard, awareness of water quality and its proper use in any field need to research and monitoring water resources is appropriate, having a comprehensive information, accurate and reliable at the right time periods be an important factor in correct decision and policy making. In this regard, many models and methods for water quality have determined such as Wilcox, Schuler, Piper in various uses including agriculture, industry and drinking. Akhondali and Zarei in 2006 showed the qualitative and hydrochemical faces of groundwater and surface water resources Sdabvalbas (Khuzestan) with charts Piper and Wilcox looked in 2005 [ZAREI, AKHONDALI 2007]. DINDARLO et al. [2006] evaluated the chemical quality of drinking water in Bandar Abbas concluded the amount of sulphate, chloride, sodium, total hardness and nitrate in groundwater source and desirable total dissolved solids (TDS) and calcium were higher than desirable value. In POURMOGHADAS’S [2003] study finds that, groundwaters in Lenjan (Isfahan) city was very hard.

STUDY AREA

Rafsanjan plain with 2,421 km² area is between 54°52' and 56°34' latitude and between 29°51' and 31°31' altitude of 1,400 to 3,443 m wide band in Iran. This basin located in northwestern Kerman Province (Fig. 1). Rafsanjan plain’s lands has mild slope, so that the maximum slope in this area is not more than two percent. In general sphere of influence Rafsanjan plain consists of a paved area at a distance of 15 km to the North, North-West and North-East region is sandy and loamy. This plain only has a few seasonal rivers because it has a desert climate.

To evaluate the quality of underground water, 25 wells in Rafsanjan plain was sampled and analysed. Also sampling was done during field operations In Figure 2 the position of the wells was shown on the map and Thiessen polygons plotted on the map using GIS software. Thiessen polygons method in which the value was sampled location nearest point. In point this way, the boundaries of the neighbouring polygons were equal and each point of the centre point of the polygon was closer than at other points [CROLEY, HARTMANN 1985; RHYSBURGER 1973]. Thiesen polygons (according to the harvest) caused by points that their nearest neighbours were connected by a triangular line. Then the side of the perpendicular to others makes that it was cut node Thiessen polygons. [BRASSEL, REIF 1979]. Finally, the primary lines dividing a region between points removed and Thiessen polygons were completely determined by the placement of sample points. The profile area in each of Thiessen polygons located at the well where were equal, the division was done in GIS software and results in Figure 2 was shown.

As shown in Figure 2, wells dispersed in North-West to the South-East plain the drawn and wells have represented in almost all parts of Rafsanjan plain.

MATERIALS AND METHODS

Table 1 and Figure 3 provided statistical characteristics of the 25 wells in Rafsanjan plain including standard deviation, variation coefficient, variation range etc. One of these parameters was skewed. Skewness of the third torque was normalized. Skewness in the distribution function is a measure of the presence or absence asymmetry. For a perfectly symmetrical distribution of zero skewness and elongation for an asymmetric distribution with positive

Fig. 1. Location of the Rafsanjan plain; source: own elaboration
Applying results of the chemical analyses in determining groundwater quality for drinking, agricultural and industrial uses...

Table 1. Statistical characteristics in terms of chemical components for 25 sample wells in 2012

| Parameter       | EC (dS m⁻¹) | TDS (mg dm⁻³) | pH | Ca²⁺ | Mg²⁺ | Na⁺ | HCO₃⁻ | Cl⁻ | SO₄²⁻ |
|-----------------|-------------|---------------|----|------|------|-----|-------|-----|-------|
| Arithmetic mean | 5703.72     | 3788.44       | 7.78 | 0.62 | 1    | 1.87 | 0.08  | 1.32 | 0.33  |
| Standard deviation | 3798.58   | 2468.19       | 0.33 | 0.65 | 1.02 | 1.27 | 0.05  | 1.25 | 0.22  |
| Variation coefficient (%) | 66.6 | 66.56 | 4.24 | 104.84 | 102 | 67.91 | 62.5 | 94.7 | 66.67 |
| Maximum         | 17950       | 11668         | 8.4 | 2.99 | 4.93 | 5.44 | 0.2   | 5.89 | 1.05  |
| Minimum         | 1256        | 836           | 7.1 | 0.06 | 0.05 | 0.52 | 0.02  | 0.16 | 0.09  |
| Mode            | no mode     | no mode       | 7.8 | 0.499 | 0.378 | 1.648 | 0.052 | no mode | no mode |
| Median          | 4660        | 3029          | 7.8 | 0.42 | 0.7  | 1.43 | 0.05  | 1.01 | 0.25  |
| Variation range | 16694       | 10832         | 1.3 | 2.93 | 4.88 | 4.92 | 0.18  | 5.73 | 0.96  |
| Skewness        | 1.94        | 1.94          | -0.17 | 2.49 | 2.66 | 1.84 | 1.39  | 2.54 | 1.98  |
| Variance        | 14429206.63 | 6091939.76    | 0.11 | 0.43 | 1.04 | 1.62 | 0     | 1.55 | 0.05  |

Explanations: EC = electric conductivity, TDS = total dissolved solids.

Source: own study.

Skewness towards higher values for elongation to the asymmetric distribution with negative skewness is pretty small [TSE 2016]. In the moments obtained in wells sampled all positive skewness other than pH was skewed. The coefficient of variation the distribution per unit is average states [Harvey, Siddique 2000; Mardia 1970].

According to numbers obtained in the statistical analysis, trend of standard deviation and coefficient of variation for the six core element Ca, Mg, Na, K, HCO₃, Cl and SO₄ was drawn. As Table 1, the highest and the lowest of variation coefficient in Ca and HCO₃ observed respectively.

RESULTS

DRINKING WATER WELLS QUALITY

Drinking water should have a good quality of various aspects including physical, chemical, toxins, bacteriological and radiological examined characteristics [Wasana et al. 2016]. Schuler diagram considered for classification terms of drinking water whose concentration of anions and cations in water samples measured. This diagram has classified to good, acceptable, average, inappropriate, quite unpleasant and non-drinking (Tab. 2) [Choramin et al. 2015]. Schuler semi-logarithmic graph used to determine the ability of drinking water. Drinking water shouldn’t have colour, smell or taste, and in terms of elements and chemicals in the allowable range was determined by the health system [WHO 2004]. The chemical and physical properties can be measured in human drinking water for anions, cations and total dissolved solids–total hardness (TDS–TH) classified using Schuler diagram. TDS usually expressed ppm. The amount of TDS and TH is the most important parameter for water quality that these parameters can be calculated as follows [Vingerhoeds et al. 2016].

Table 2. Schuler percents of each classification classes for drinking water in Rafsanjan plain

| Classification | TDS | TH | PH | Na⁺ | Cl⁻ | SO₄²⁻ |
|----------------|-----|----|----|-----|-----|-------|
| Good           | 0   | 94.83 | 8.75 | 91.67 | 95.83 | 100  |
| Acceptable     | 4.17 | 5.17 | 4.17 | 8.33 | 4.17 | 0    |
| Average        | 12.5 | 0    | 8.33 | 0    | 0    | 0    |
| Inappropriate  | 58.33 | 0    | 0    | 0    | 0    | 0    |
| Quite unpleasant | 16.67 | 0    | 0    | 0    | 0    | 0    |
| Non-drinking   | 8.33 | 0    | 0    | 0    | 0    | 0    |

Explanations: TDS = total dissolved solids, TH = total hardness.

Source: own study.
where:

\[ TH = \text{Ca}\left(\text{CaCO}_3/\text{Ca}^{2+}\right) + \text{Mg}\left(\text{CaCO}_3/\text{Mg}^{2+}\right) \]  

(1)

\[ TH = 2.497\text{Ca}^{2+} + 4.115\text{Mg}^{2+} \]  

(2)

Amount of Mg and Ca in mg dm\(^{-3}\):

\[ (\text{Based on CaCO}_3) \ TH = 50(\text{Ca}^{2+} + \text{Mg}^{2+}) \]  

(3)

In this regard, Mg and Ca are expressed in terms of meq and total hardness is mg dm\(^{-3}\).

Groundwater and surface analysis has shown that the soluble salts or total dissolved solids (TDS) between dry and there was water electrical conductivity (EC):

\[ \text{TDS} = 0.64\text{EC} \]  

(4)

TDS in ppm and water EC in dS m\(^{-1}\).

Amount of anions and cations present in samples taken from wells Rafsanjan plain Schuler graph classification water plotted in Figure 2. These values were summarized in Table 2. Also, the statistical parameters of various chemical components for this plain are shown in Figure 3.

In Figure 4, 25 series lines are criteria for water quality recognition for drinking. The diagram illustrates the status of each of the wells for drinking data for 25 wells.

Based on the analyses and achieved Schuler graph based on Table 2, two important parameters in determining the water quality Schuler method was hardness values and TDS. For this purpose, used kriging method in GIS software, the final maps were shown in Figures 5 and 6.

Fig. 4. Schuler diagram drawn for samples taken from wells Rafsanjan plain; source: own study
Applying results of the chemical analyses in determining groundwater quality for drinking, agricultural and industrial uses...

To the importance of water for drinking, using GIS software Rafsanjan plain zoning was using kriging method (Fig. 7).

As seen in Figure 7, there is acceptable quality water for drinking in very small portion of south western plains. The rest is allocated to medium and inappropriate quality. Totally, Rafsanjan plain need to further proper planning and sustainable development in order to create a good quality water requires, specially in inappropriate quality.

**AGRICULTURE WATER WELLS QUALITY**

We used Wilcox analysis to check the quality of water wells for agriculture in Rafsanjan plain. The most important quality criteria for classification of agricultural water were the amount of sodium and salinity (electrical conductivity) because they effect on plants growing, the proportion of irrigation water and the permeability [Darvishi et al. 2016]. Wilcox diagram salt water in the horizontal axis and the vertical axis is dedicated to sodium adsorption ratio (SAR). SAR is archived in 4 classes and calculated by flowed equation.

\[
SAR = \frac{N^{+}}{\sqrt{0.5(Ca^{2+} + Mg^{2+})}} \quad (5)
\]

Used Wilcox and classification method, it was the most practical methods for the classification of agricultural water in hydrology. In the Table 3 and Figure 8 the coordinates of any water in the area was that the C and S letters...
Table 3. The quality classification wells for agriculture

|       | High conductivity C4 | Very high conductivity C5 |
|-------|----------------------|---------------------------|
| S1    | S2                   | S1                        |
| S4    | S1                   | S2                        |
| S5    | S1                   | S2                        |

percentage share of water samples

0 0 30.17 59.5 0 0 10.33

Explanations: S1, S2, S3, S4 = sodium adsorption ratio: low, medium, high, very high, respectively.

Source: own study.

Table 4. Determining the quality and class of each of the sampled wells for agricultural used by Wilcox method

| No. of well | S4R | EC (dS/m) | Water class | Agricultural water quality |
|-------------|-----|-----------|-------------|----------------------------|
| 1           | 2.70| 10 900    | C4-S1       | very salty – unsuitable for agriculture |
| 2           | 2.73| 17 950    | C4-S2       | very salty – unsuitable for agriculture |
| 3           | 2.33| 1 256     | C3-S1       | salty – suitable for agriculture |
| 4           | 2.46| 4 490     | C4-S1       | very salty – unsuitable for agriculture |
| 5           | 1.31| 3 940     | C4-S1       | very salty – unsuitable for agriculture |
| 6           | 1.90| 5 860     | C4-S2       | very salty – unsuitable for agriculture |
| 7           | 1.31| 6 250     | C2-S1       | very salty – unsuitable for agriculture |
| 8           | 3.98| 14 170    | C2-S1       | very salty – unsuitable for agriculture |
| 9           | 1.51| 4 660     | C4-S2       | very salty – unsuitable for agriculture |
| 10          | 2.55| 9 000     | C4-S2       | very salty – unsuitable for agriculture |
| 11          | 1.79| 3 340     | C3-S1       | salty – suitable for agriculture |
| 12          | 1.91| 5 650     | C4-S1       | very salty – unsuitable for agriculture |
| 13          | 4.58| 6 930     | C3-S2       | salty – suitable for agriculture |
| 14          | 1.44| 5 300     | C3-S2       | very salty – unsuitable for agriculture |
| 15          | 2.48| 5 430     | C4-S2       | very salty – unsuitable for agriculture |
| 16          | 2.58| 5 810     | C4-S1       | very salty – unsuitable for agriculture |
| 17          | 1.48| 2 310     | C4-S2       | very salty – unsuitable for agriculture |
| 18          | 1.78| 5 600     | C4-S2       | very salty – unsuitable for agriculture |
| 19          | 1.84| 3 810     | C3-S1       | very salty – unsuitable for agriculture |
| 20          | 2.51| 4 420     | C4-S1       | very salty – unsuitable for agriculture |
| 21          | 2.02| 2 750     | C4-S1       | very salty – unsuitable for agriculture |
| 22          | 3.19| 3 830     | C4-S2       | very salty – unsuitable for agriculture |
| 23          | 2.51| 1 737     | C3-S1       | salty – suitable for agriculture |
| 24          | 1.02| 3 800     | C4-S1       | very salty – unsuitable for agriculture |
| 25          | 1.97| 3 821     | C4-S1       | very salty – unsuitable for agriculture |

Explanations: C = conductivity classes, S = sodium adsorption ratio classes: 1 = low, 2 = medium, 3 = high, 4 = very high.

Source: own study.

Fig. 8. Wilcox diagram for samples taken from wells in Rafsanjan plain; source: own study

The quality and class of each of the sampled wells for agricultural used by Wilcox method

in sodium salt determined. A value of 1, 2, 3 and 4 respectively represent low, medium, high and very high. According to this classification, all water with EC’s less than 250 µmho·cm⁻¹ was very good. According to the agricultural plot to check the water quality can be seen that all the wells in the C4-S2, C4-S1 and C3-S1 located and have high or very high salinity and low to moderate sodium (Fig. 8). The Table 4 was prepared for the scrutiny of water quality for agriculture where 25 wells were sampled for the EC and S4R and water classes were given in a column. According to the specified standard there were two water wells for agricultural use as below:

- very salty – unsuitable for agriculture (C4-S1, C4-S2 classes),
- salty – suitable for agriculture (C3-S1 class).

For use water class C3-S1 should plant type and resistance be considered (Tab. 3).

As shown in Table 4, the quality and class of each of the sampled wells for agricultural used by Wilcox method. Based on Wilcox diagram prepared for the wells Rafsanjan plain and analysis was prepared diagram of the table where

the percentage of each of the classes mentioned (Tab. 3). It was known as the 10.33% water in C3-S1 class and the C4-S1, C4-S2 classes were respectively 59.5% and 30.17%.

In order to study the better water quality and more accurately display EC and S4R in Rafsanjan plain, wells water zoned in the area by used kriging method in GIS software.

**INDUSTRIAL WATER WELLS QUALITY**

Water of vital industries for paper-making, textile, pharmacy etc. that combined production or preparation of...
Applying results of the chemical analyses in determining groundwater quality for drinking, agricultural and industrial uses...

materials or devices used in cooling. The water used in industry can have a corrosive and adverse effects on devices and industrial facilities as well as production quality. Among the important factors that affecting on water in industrial, used calcium concentration and alkalinity. Here, alkalinity index were expressed in terms of CaO (Fig. 9 and 10). The analysis was carried out for 25 wells sampled in Rafsanjan plain showed low quality wells for used in the industry water, apart from well No. 2, all wells with corrosive water that will cause a lot of problems in the manufacturing and industrial machines (Tab. 5).

Table 5. Industrial quality analysis for sampled wells

| No. of wells | Alkalinity according CaO (mg dm⁻³) | C factor PHs | PHs – PH | Industrial water quality |
|--------------|------------------------------------|--------------|----------|-------------------------|
| 1            | 90                                 | 32.73        | 11.36    | 7.9                     | 7.1             | 0.8 | corrosive |
| 2            | 125                                | 59.88        | 11.37    | 7.5                     | 7.7             | −0.2| sedimentation |
| 3            | 12.5                               | 1.19         | 11.30    | 10.1                    | 8.4             | 1.7 | corrosive |
| 4            | 35.3                               | 7.98         | 11.33    | 8.9                     | 7.8             | 1.1 | corrosive |
| 5            | 25.0                               | 5.98         | 11.33    | 9.2                     | 7.7             | 1.5 | corrosive |
| 6            | 40.5                               | 7.98         | 11.34    | 8.8                     | 7.3             | 1.5 | corrosive |
| 7            | 34.5                               | 19.96        | 11.34    | 8.5                     | 7.5             | 1.0 | corrosive |
| 8            | 120                                | 35.92        | 11.36    | 7.7                     | 7.6             | 0.1 | corrosive |
| 9            | 30.6                               | 10.57        | 11.34    | 8.8                     | 7.2             | 1.6 | corrosive |
| 10           | 67.0                               | 15.96        | 11.35    | 8.3                     | 7.8             | 0.5 | corrosive |
| 11           | 24.3                               | 8.98         | 11.33    | 9.0                     | 8.0             | 1.0 | corrosive |
| 12           | 37.9                               | 9.98         | 11.34    | 8.8                     | 7.5             | 1.3 | corrosive |
| 13           | 65.0                               | 6.98         | 11.34    | 8.7                     | 8.0             | 0.7 | corrosive |
| 14           | 31.9                               | 9.98         | 11.34    | 8.8                     | 7.8             | 1.0 | corrosive |
| 15           | 43.4                               | 9.98         | 11.34    | 8.7                     | 7.9             | 0.8 | corrosive |
| 16           | 45.7                               | 8.98         | 11.34    | 8.7                     | 7.5             | 1.2 | corrosive |
| 17           | 17.5                               | 2.99         | 11.32    | 9.6                     | 8.1             | 1.5 | corrosive |
| 18           | 37.9                               | 17.96        | 11.34    | 8.5                     | 7.7             | 0.8 | corrosive |
| 19           | 28.4                               | 3.99         | 11.33    | 9.3                     | 7.8             | 1.5 | corrosive |
| 20           | 31.0                               | 4.99         | 11.33    | 9.1                     | 8.2             | 0.9 | corrosive |
| 21           | 32.7                               | 8.38         | 11.33    | 8.9                     | 8.0             | 0.9 | corrosive |
| 22           | 26.7                               | 1.99         | 11.32    | 9.6                     | 8.2             | 1.4 | corrosive |
| 23           | 32.8                               | 5.48         | 11.33    | 9.1                     | 7.9             | 1.2 | corrosive |
| 24           | 11.9                               | 2.99         | 11.31    | 9.8                     | 8.3             | 1.5 | corrosive |
| 25           | 30.2                               | 6.98         | 11.33    | 9.0                     | 7.6             | 1.4 | corrosive |

Explanations: PH = a measure of how acidic/basic water is; PHs = difference between PH and Langelier Saturation Index (LSI). Source: own study.

CONCLUSIONS

Study the quality of water in various sectors including drinking, agriculture and industry is one of the basic parameters of sustainable development and raise the level of safety of products and the community. In this study, the quality of Rafsanjan plain water wells deliberated to advance the goals of sustainable development and proper management of the resources. The results showed ground-water had a high concentration of salts, which are exploitation of these resources has been faced with serious problems in this plain. Rafsanjan plain Groundwater to drinking had several limitations and restrictions related to total dissolved solids and there are 58.33% inappropriate quality wells in the area. The study also showed wells for agricultural use 10.33% of this water in C₃-S₁ class, 59.5% in
C$_2$S$_1$ class and 30.17% is in C$_2$S$_2$ class. In other words, nearly 90% of Rafsanjan plain water not suitable for farming. The survey also found that except for well No. 2, which was depositing water quality of all wells, were corrosive for used in the industrial sector. Conditions in the Rafsanjan plain for construction of water-related industry were also inappropriate quality. Finally, given the importance of water for drinking, agriculture and industry were more prominent attention to water quality that the government and people in the planning and application of ecological sensitive area must be done.

REFERENCES

ABTAHI M., GOLCHINPOUR N., YAGHMAEIAN K., RAFIEE M., JAHANGH-IRDAD M., KEYVANI A., SAEEDE R. 2015. A modified drinking water quality index (DWOI) for assessing drinking source water quality in rural communities of Khuzestan Province, Iran. Ecological Indicators. Vol. 53 p. 283–291. DOI 10.1016/j.ecolind.2015.02.009.

ALLAN J. D. 2004. Landscapes and riverscapes: The influence of land use on streamecosystems. Annual Review of Ecology, Evolution and Systematics. Vol. 35 p. 257–284. DOI 10.1146/annurev.ecolsys.35.120202.110122.

ASHTON P.J., ZYL F.C, VAN HEATH R.G. 1995. Water quality management in the Crocodile River catchment. Eastern Transvaal, South Africa. Water Science and Technology. Vol. 32 (5–6) p. 201–208. DOI 10.1016/0273-1223(95)00664-8.

BOOTH D.B., KARR J.R., SCHUMAN S., KONRAD C.P., MORLEY S.A., LARSON M.G., BURGES S.J. 2004. Reviving urban streams: Land use, hydrology, and human behavior. Journal of the American Water Resources Association. Vol. 40(5) p. 1351–1364. DOI 10.1111/j.1752-1688.2004.tb01591.x.

BRASSEL K.E., REIF D. 1979. A procedure to generate Thiessen polygons. Geographical Analysis. Vol. 11(3) p. 289–303. DOI 10.1111/j.1538-4632.1979.tb00695.x.

CHORAMIN M., SAFAEI A., KHAJAVI S., HAMID H., ABOZARI S. 2015. Analyzing and studying chemical water quality parameters and its changes on the base of Schuler, Wilcox and Piper diagrams (project: Bamahanshir River). Walia Journal. Vol. 31 p. 22–27.

CLASEN T., PRUSS-USTUN A., MATHERS C.D., CUMMING O., CAIM-DINDARLOU K., ALIPPOUR V., FARSHIDFAR G.R. 2006. Chemical water quality of all wells, were corrosive for used in the industrial sector. Conditions in the Rafsanjan plain for construction of water-related industry were also inappropriate quality. Finally, given the importance of water for drinking, agriculture and industry were more prominent attention to water quality that the government and people in the planning and application of ecological sensitive area must be done.

JOHNSON L., RICHARDS C., HOST G., ARTHUR J. 1997. Landscape influences on water chemistry in Midwestern stream ecosystems. Freshwater Biology. Vol. 37(1) p. 193–208. DOI 10.1046/j.1365-2427.1997.d01-539.x.

KAYSER G.L., AMjad U., DELCANALE F., BARTRAM J., BENTLEY M.E. 2015. Drinking water quality governance: A comparative case study of Brazil, Ecuador, and Malawi. Environmental Science Policy. Vol. 48 p. 186–195. DOI 10.1016/ j.envsci.2014.12.019.

LOHARTO T.C., HAUSER-DAVIS R.A., OLIVEIRA T.F., SILVEIRA A.M., SILVA H.A.N., TAVARES M.R.M., SARAIVA A.C.F. 2015. Construction of a novel water quality index and quality indicator for reservoir water quality evaluation: A case study in the Amazon region. Journal of Hydrology. Vol. 522 p. 674–683. DOI 10.1016/j.jhydrol.2015.01.021.

MARDIA K.V. 1970. Measures of multivariate skewness and kurtosis with applications. Biometrika. Vol. 57(3) p. 519–530. DOI 10.2307/2334770.

MARINONI O., HIGGINS A., COAD P., GARCIA J.N. 2013. Directing urban development to the right places: Assessing the impact of urban development on water quality in an estuarine environment. Landscape and Urban Planning. Vol. 113 p. 62–77. DOI 10.1016/j.landurbplan.2013.01.010.

POURMOGHADAS H. 2003. Study of groundwater quality in Lenjan, Isfahan regional. Scientific Journal of School of Public Health and Institute of Public Health Research. Vol. 1(4) p. 31–40.

RYHNSBURGER D. 1973. Analytic delineation of Thiessen polygons. Geographical Analysis. Vol. 5(2) p. 133–144. DOI 10.1111/j.1538-4632.1973.tb01003.x.

RIBOLZI O., CUNEY J., DAPICARD P., MOUSQUES C., SOULILEBUTH B., PIERRET A., HUON S., SENGATRANUONG O. 2011. Land use and water quality along a Mekong tributary in Northern Lao P.D.R. Environmental Management. Vol. 47(2) p. 291–302. DOI 10.1007/s00267-010-9593-0.

RIMER A.E., NISSEN J.A., REYNOLDS D.E. 1978. Characterization and impact of stormwater runoff from various land cover types. Journal of Water Pollution Control Federation. Vol. 50(2) p. 252–264.

TSE Y. 2016. Asymmetric volatility, skewness, and downside risk in different asset classes: Evidence from futures markets. Financial Review. Vol. 51(1) p. 83–111. DOI 10.1111/fire.12095.

TU J. 2013. Spatial variations in the relationships between land use and water quality across an urbanization gradient in the watersheds of Northern Georgia, USA. Environmental Management. Vol. 51(1) p. 1–17. DOI 10.1007/s00267-011-9738-9.

VINGERHOEDS M.H., NUIJENHUIS-DE M.A., RUEPERT N., VAN DER LAAN H., BREDE W.L., KREMER S. 2016. Sensory quality of drinking water produced by reverse osmosis membrane filtration followed by remineralisation. Water Research. Vol. 94 p. 42–51. DOI 10.1016/j.watres.2016.02.043.

WASANA H.M., ALUTHPADTABENDI D., KULARATNE W.M., WIJEKOON P., WEERASOORIYA R., BANDARA J. 2016. Drinking water quality and chronic kidney disease of unknown etiology (CKDu): Synergic effects of fluoride, cadmium and hardness of water. Environmental Geochemistry and Health. Vol. 38(1) p. 157–168. DOI 10.1007/s10653-015-9699-7.

WHITE C.S. 1976. Factors influencing natural water quality and changes resulting from land-use practices. Water, Air and Soil Pollution. Vol. 6(1) p. 53–69. DOI 10.1007/BF00158715.

WHO 2004. Guidelines for drinking-water quality. Vol. 1. Recommendations. 3rd ed. Geneva. World Health Organization. ISBN 92 4 154638 7 p. 515.
Applying results of the chemical analyses in determining groundwater quality for drinking, agricultural and industrial uses...

Mohammad Hossein JAHANGIR, Keyvan SOLTANI

Zastosowanie wyników analiz chemicznych do określenia jakości wód gruntowych do celów spożywczych, rolniczych i przemysłowych: Przykład wód na Równinie Rafsanjan

STRESZCZENIE

Na podstawie analiz chemicznych w niniejszej pracy określono jakość wód gruntowych wykorzystywanych do celów spożywczych, rolnictwie i przemyśle. Próbki do analiz pobrano z 22 studni w 2012 r. Z powodu dużej twardości i dużego stężenia substancji rozpuszczonych wody nie nadawały się do użycia jako źródła wody pitnej. Przydatność wód do zastosowań rolniczych określono za pomocą metody Wilcoxa. Spottszy analizowanych studni 10,33% przypisano do klasy C3-S1 (duże przewodnictwo EC, mały współczynnik adsorpcji sodu SAR), 59,5% do klasy C4-S1 (bardzo duże EC, niski SAR), a 30,17% do klasy C4-S2 (bardzo duże EC i średni SAR). Z powodu właściwości korodujących wszystkie (poza dwiema) studnie na równinie zawierały wodę nienadającą się do celów przemysłowych. Wyniki analiz jakościowych przedstawiono w systemie GIS i w formie baz danych, które mogą wspierać podejmowanie decyzji i zarządzanie zasobami wody na Równinie Rafsanjan.

Słowa kluczowe: jakość wody, Równina Rafsanjan, wody gruntowe, zarządzanie zasobami wodnymi

ZHANG B., LEI K., LIU R., SONG S., AN L. 2014. Integrated biomarkers in wild crucian carp for early warning of water quality in Hun River, North China. Journal of Environmental Sciences. Vol. 26 p. 909–916. DOI 10.1016/S1001-0742(13)60484-2.