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Sensitivity Analysis of Groundwater Quality around Peat Swamp Forest Region to Examine Trend Analysis of Physicochemical Parameters

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Abstract: The aim of this study was examine sensitivity analysis of groundwater quality around peat swamp forest region to determine trend analysis of physicochemical parameters. In order to achieve this goal, samples were taken from Ziarat spring, the nearest hydrometric station around Suteh PSF from 1998 to 2015. The parameters such as TDS, EC, pH and major ions including SO_4, Mg, HCO_3, Ca, Na, Cl, and K of the Ziarat spring were analyzed. To examine the trend analysis of physiochemical parameters, the winter's model of time series analysis has been used. The order of abundance of ions are HCO_3> Cl> Na> SO_4> Ca> Mg> K. The trend analysis of pH demonstrates a decreasing trend (from alkaline to acidic) but EC and TDS trends show a rising trend. According to sensitivity analysis by using the response analysis of factorial analysis and Pareto charts, the most important factor for pH was Na×HCO_3 and then a combination of Ca, Mg and HCO_3. For EC, the most important factor was calcium and then the K×SO_4 factor and for TDS, it was the K × SO_4 and then the K × Ca factor. Determinative ions based on the singular sensitivity analysis pH are in the following order Ca > HCO_3> Mg> SO_4> K> Na > Cl. Meanwhile, for EC, the determinant ions are in the following order Ca > Mg> SO_4> HCO_3> Na >K> Cl and the determinant ions for TDS are followed by K> Cl > HCO_3> Ca > Mg> SO_4> Na.

Keywords: Groundwater Quality, Physiochemical Parameters, Sensitivity Analysis, Trend Analysis, Ziarat Spring

1. Introduction

Suteh peat swamp forest (PSF) is located in the Ziarat jungle, in the southern part of Golestan province. Peats and swamps obtain water mostly from surface water, precipitation, and groundwater sources. Springs can play an important role in supplying swamp water. Assessment of water quality and trend analysis of springs near swamps may provide some useful information about swamps changes.

Since the 1930s, the quality of water has been one of the most important subjects of environmental sciences. Since the 1980s, global water quality changes have been added to water quality sciences [1]. Recently, an increasing consciousness has been represented in the world about the impact of human activities on water resources [2]. Groundwater is threatened by many agents that may be due to natural processes or anthropogenic factors [3].

Generally, water quality indicators have been classified into 3 groups: physical, chemical, and biological that each include a number of water quality parameters [4].

The study of water quality can include two sides, water quality characteristics and parameter changes [5]. Physicochemical factors of Groundwater Changes mainly show complicated fluctuations due to many components [6]. There are two kinds of analyses that we can use to predict trends in water resources: time series and multivariate [7]. In addition, Autoregressive analysis, Markov analysis and Rescaled range analysis can be applicable to predict trends.

In many researches like Zhao et al. 2007 [8]; Yang et al. 2009 [9]; Liang 2011 [10], time series analysis has been used for the estimation, management and prediction of water resources. Moreover, many water quality models have been made by using physicochemical parameters and trend and time series analysis [11].

The results that have been presented in this study are based on physicochemical groundwater quality parameters determined in the Ziarat spring near the peat swamp forest area south of Golestan province, during a period of seventeen years (1998-2015). On the basis of this data, elements such as pH, EC, TDS, magnesium, calcium, potassium, sodium, sulfate, chloride, and bicarbonate in the Ziarat spring were analyzed and the trend changes of various parameters based on the winter's model of time series analysis has been determined. In addition, the sensitivity analysis of EC, TDS and pH based on physiochemical water quality parameters has been examined. The aim of the research was to distinguish spatial patterns in long term water quality variability and determine the value of this variability. This article first examines physicochemical parameters of the spring. The second phase requires making and discussing the variations trends. The third step determines sensitivity analysis of variations based on single parameters and in the final step we study the sensitivity of multiple parameters due to trend variations.

2. Materials and Methods

2.1. Study Area

This paper focuses on the southern part of the Golestan province, in Ziarat jungle. This area located in the northern mountainside of the Alborz Mountains is regarded as having the most important nutrients of Golestan province and especially the Qareh Sou catchment and Suteh peat swamp forest region. Almost 18% of Golestan Province (20,367 km^2) is covered by forests (400,000 hectares). It also has the third-largest cereal yield amongst the 31 provinces of Iran. Water scarcity and salinity are major problems [12].

The altitude of the region is approximately 950 m from sea level. There are no specific topographical and geological features except hills and valley in the Ziarat. Two stratigraphic units, the Precambrian and Mesozoic sediments, play a major role in the lithology of the Ziarat. Precambrian sediments mainly consist of dark green metamorphic schist (mica schist, chlorite schist, quartzite, marble and slate) and the bright green Gorgan green schist. Mesozoic sediments consist mainly of limestone and dolostone with layers of marl in the upper Jurassic. In some places there are loose sandy Quaternary sediments. According to the Emberger climate diagram, climatic conditions of this region are temperate and semi-arid. Annual rainfall is approximately 520 mm and the annual mean temperature is approximately 18 °C. Fig. 1 shows the location of Suteh PSF (No. 1) and the Ziarat spring (No. 2).

2.2. Sampling and Analysis

In order to study the physiochemical parameters of groundwater quality, the nearest spring, Ziarat spring, has been selected. To examine the trend analysis, physiochemical parameters were analyzed from 1998 to 2015, in different seasons. Overall, 37 samples were analyzed from Ziarat Spring. TDS, pH and EC were measured by a water checker portable hatch model HQ40D53000000. The bicarbonate (HCO_3^-) had been measured by the Alkalinity measurements method. K^+, Na^+, Cl^-, Mg^{2+}, Ca^{2+}, and SO_4^{2-} were measured by furnace 4100 atomic absorption using standard methods [13].

To examine the water quality parameters condition, trend analysis and sensitivity analysis of various parameters, Minitab software (V. 16.2.2) has been used. To determine trends, time series decomposition analysis and for sensitivity analysis of multiple parameters, response analysis of factorial analysis and Pareto charts have been used. Trend analysis examines whether the selected parameters of a water increase or decrease during the observation period.

3. Results and Discussion

Major ions in groundwater are variable by nature which may be due to geographical conditions, geological aspects, and climatic conditions [14]. The statistical analysis of the physiochemical parameters are presented in Table 1. Abundances of major ions in this study (based on mean concentration) are in the following order HCO_3> Cl> Na> SO_4> Ca> Mg> K.

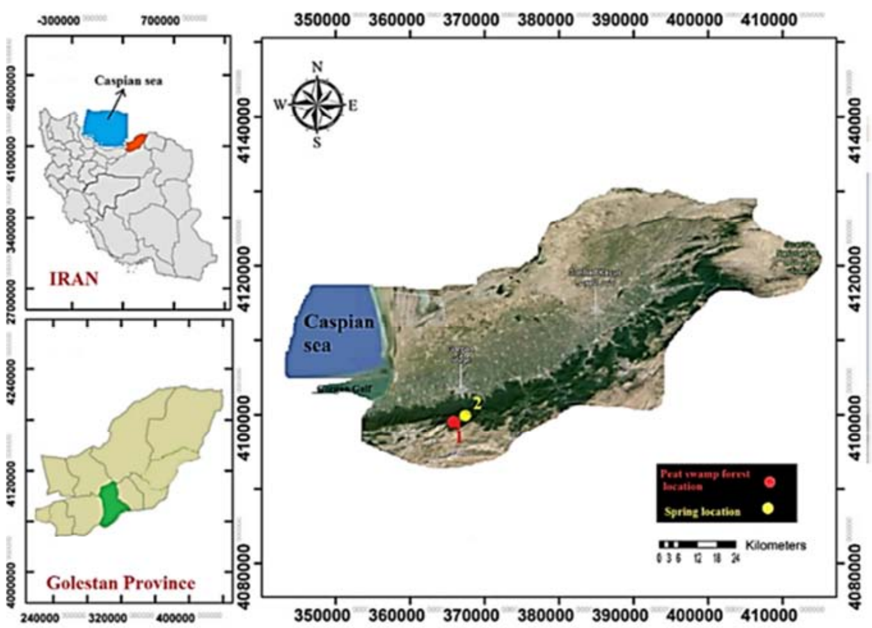

Figure 1. *Study area and sampling location; (1) Suteh PSF and (2) Ziarat Spring.*

Table 1. *Summary statistics of physiochemical parameters, Ziarat spring, during 1998-2015.*

Variable	Number	Mean	StDev	Minimum	Q1	Q3	Maximum
EC	37	1939.6	106	1651	1875	2021.5	2133
T.D.S	37	1213.4	78.9	1035	1169.5	1275	1371
PH	37	7.193	0.3877	5.8	7	7.45	7.8
Ca^{2+}	37	122.59	25.91	70	103	146	160
Mg^{2+}	37	42.42	11.45	18	34.8	50.4	66
Na^{+}	37	221.53	25.64	164.68	201.02	241.73	266.8
K^{+}	37	21.81	7.13	3.12	15.99	26.33	41.06
HCO_3^{-}	37	347.37	49.97	231.8	317.2	381.25	420.9
Cl^{-}	37	346.36	15.17	312.4	337.25	356.77	369.2
SO_4^{2-}	37	210.93	40.77	139.2	186	236.4	352.8

3.1. Trend Analysis

The pH is one of the most important variables in water quality assessment. In this study, pH ranges from 5.8 to 7.8. The trend analysis of the pH value versus years from 1998 to 2015 demonstrates a decreasing trend over time for pH (Fig. 2). The electrical conductivity is directly related to the ions. In this study, the EC values range from 1651 to 2133 µS/cm. Fig. 3 shows the trend analysis of EC in this area. The EC trend shows an increasing trend. Based on approximate values that have been presented by the American Public Health Association [15], the samples of this spring are located in a fresh water stream (Fig. 4).

Total dissolved solids are an essential feature of water quality [14]. In wastewater and contaminated regions, TDS can consist of organic matter dissolved [16]. In this study, the TDS values range from 1035 to 1371 mg/liter. The most important sources for TDS in water may be industrial sources, soil pollution, agricultural and local runoff. Fig. 5 shows the changes of yearly quantity of TDS during the observation period that is a rising trend from 1998 to 2015.

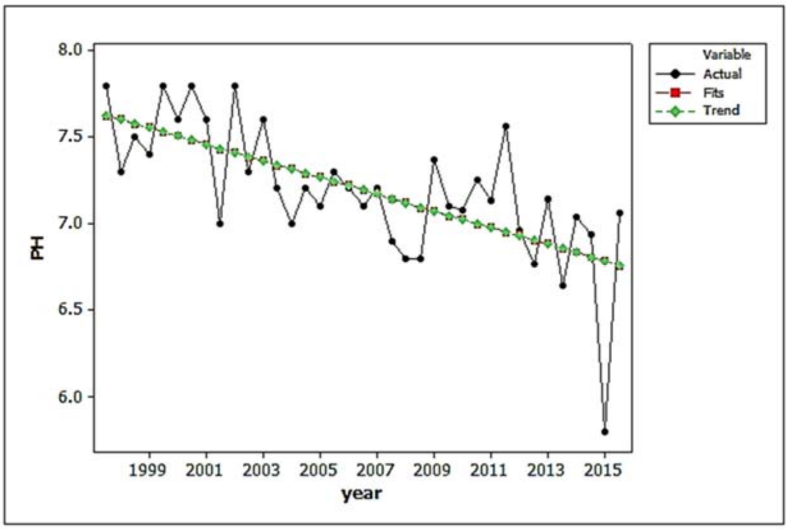

Figure 2. *Time series analysis of pH versus year that shows the trend of pH.*

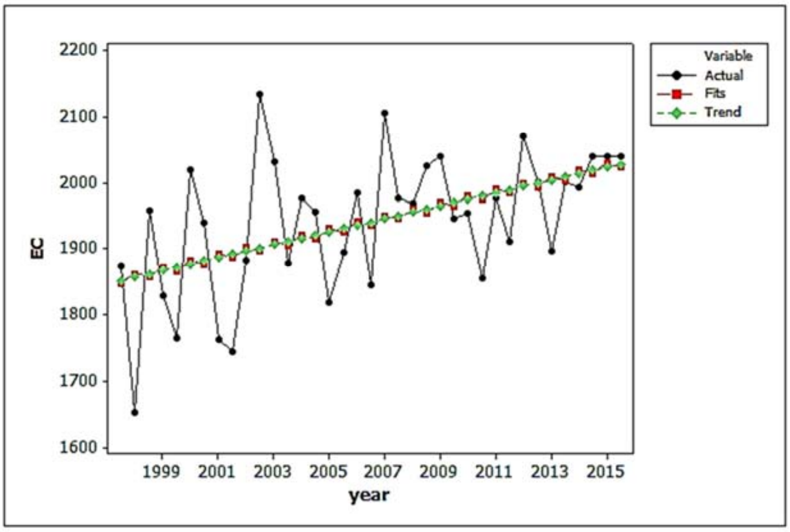

Figure 3. *Time series analysis of EC versus year that shows the trend of EC.*

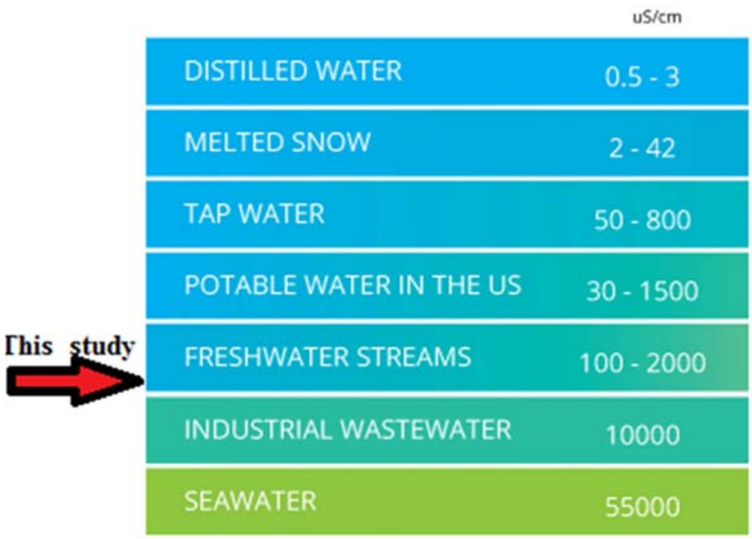

Figure 4. *Water classification based on EC [15].*

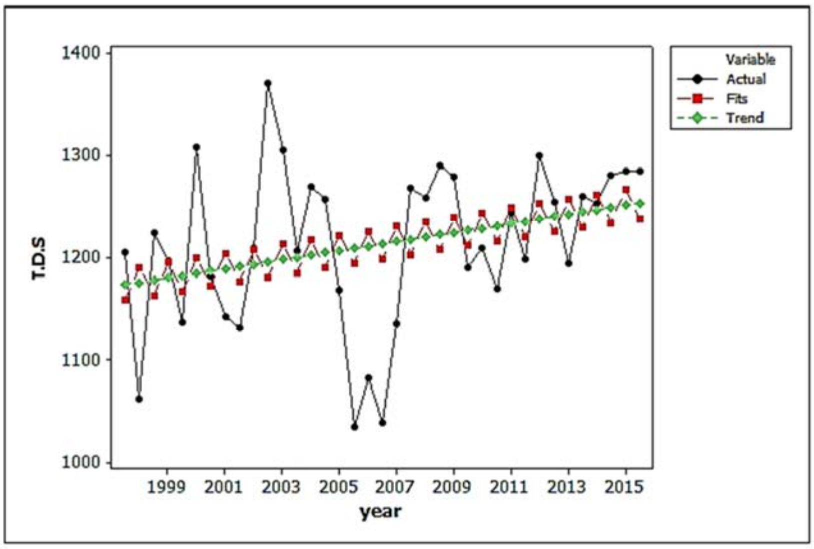

Figure 5. *Time series analysis of TDS versus year that shows the trend of TDS.*

3.2. Sensitivity Analysis

In order to determine the sensitivity of pH, EC and TDS, the factors which affect each parameter have been determined and then the variation of the index based on changes for each parameter used by the Pareto chart (One of the Seven Basic Tools of Quality) has been carried out. In this method, the effects of each parameter are examined separately, and then effects of each pair of parameters are combined and finally possible combinations of all parameters are examined. Therefore, the most sensitive parameter (factor) is determined [17].

In order to study the sensitivity of pH, major ions, as singularity and in combination, have been considered as seven factors. Due to the count up parameter combination, only the 30 largest effects have been shown in the charts. The Pareto chart of the pH is shown in Fig. 6. Based on the chart, the most important factor for pH is Na×HCO_3 and after that a combination of Ca, Mg and HCO_3 will play an important role. If we want to consider single factors, calcium will be the determinant parameter and after that bicarbonate will be important. Determinative ions in this study (based on sensitivity analysis pH) are in the following order Ca > HCO_3> Mg> SO_4> K> Na > Cl.

Similar to pH, to examine the sensitivity of EC, major ions, as singularity and in combination, have been considered as factors. The Pareto chart of the EC has been shown in Fig. 7. As can be seen from the chart, the major important factor for EC is Calcium and after that the K×SO_4 factor will have the main impression. If we want to consider single factors, calcium will be the determinant factor and after that magnesium will be determinative. Determinant ions in this area (based on sensitivity analysis of EC) are in the following order Ca > Mg> SO_4> HCO_3> Na >K> Cl.

In order to investigate the sensitivity of TDS, major ions as singularity and in combination have been chosen as components. The Pareto chart of the TDS has been shown in Fig. 8. According to the chart, the most important factor for TDS is K × SO_4 and after that the K × Ca factor will play the main role. If we want to consider single factors, Potassium will be determinant factor and after that Chloride will be determinative. Determinant ions in this area (based on sensitivity analysis of TDS) are in the following order K> Cl > HCO_3> Ca > Mg> SO_4> Na.

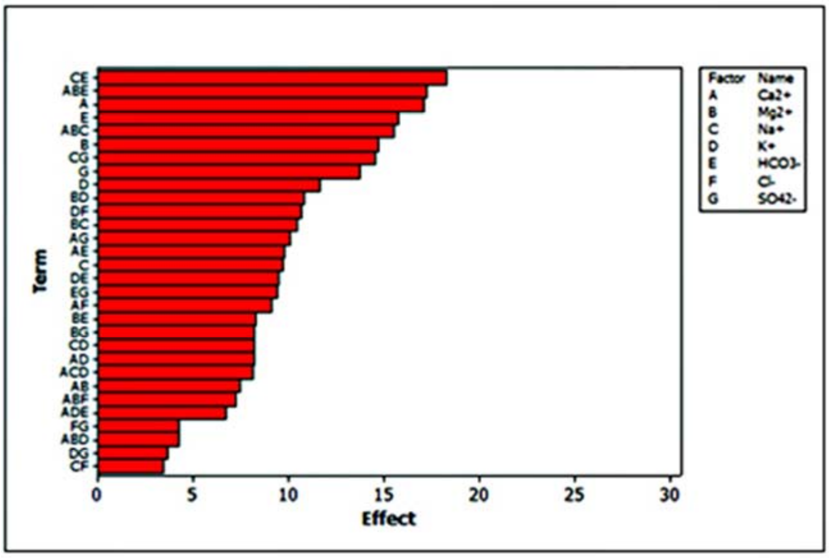

Figure 6. *Pareto chart of pH based on major ions in Ziarat spring.*

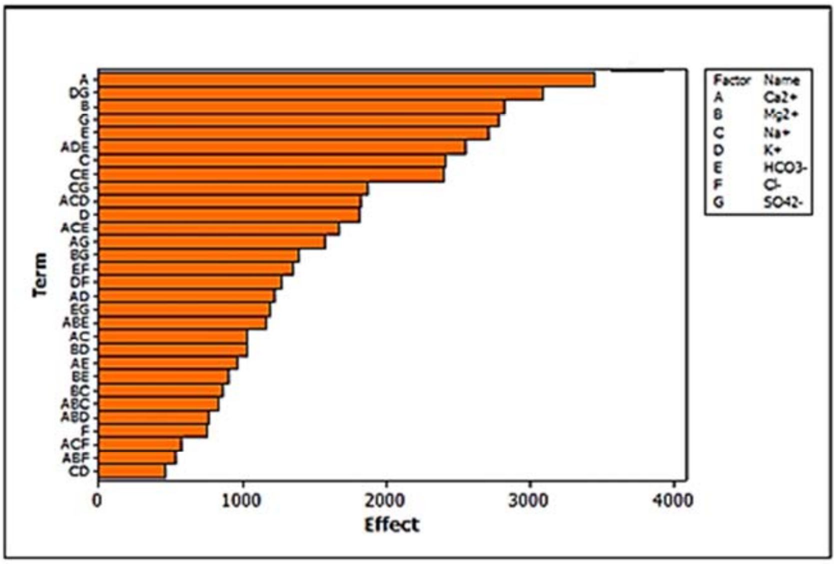

Figure 7. *Pareto chart of EC based on major ions in Ziarat spring.*

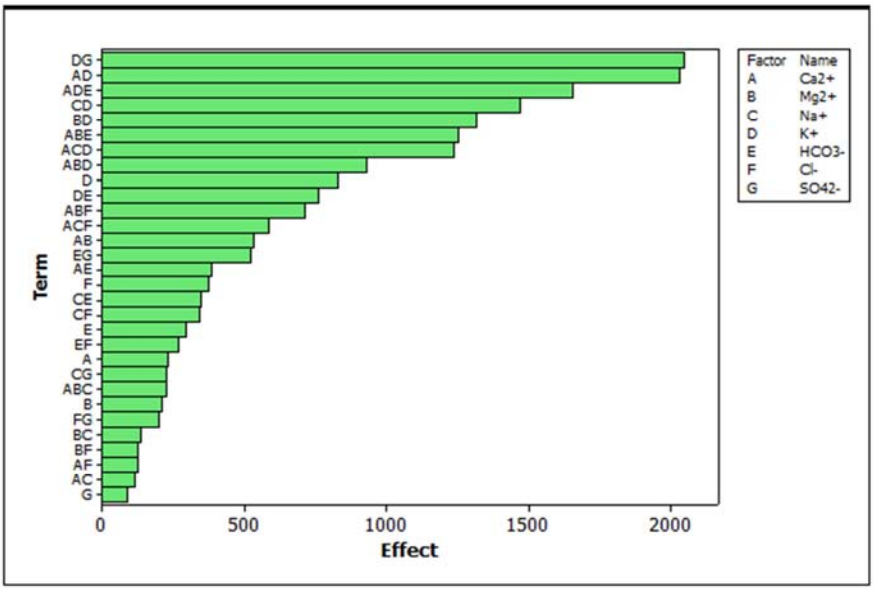

Figure 8. *Pareto chart of TDS based on major ions in Ziarat spring.*

4. Conclusion

Evaluation of long-term water quality trend is a challenging issue [18]. In this article, an endeavor has been made to examine the trend analysis of physiochemical parameters of groundwater in the Ziarat spring in order to assess the groundwater quality changes of Suteh PSF. To achieve this purpose, 37 groundwater samples were collected and analyzed from 1998 to 2015. The order of abundance of ions are HCO_3> Cl> Na> SO_4> Ca> Mg> K.

In order to investigate the trend of parameters, the time series decomposition analysis model was used. Trend analysis of pH from 1998 to 2015 demonstrates a decreasing trend (from alkaline to acidic) but EC and TDS trends show an increasing trend. In addition, in order to scrutinize the study, sensitivity analyses for pH, TDS and EC were used. According to the sensitivity of pH based on major ions, the most important factor was Na×HCO_3 and then a combination of Ca, Mg and HCO_3. Determinative ions in this study (based on singular sensitivity analysis pH) are in the following order Ca > HCO_3> Mg> SO_4> K> Na > Cl. According to the sensitivity of EC based on major ions, the most important factor was calcium and then the K×SO_4 factor. Determinant ions in the studied area (based on singular sensitivity analysis of EC) are in the following order Ca > Mg> SO_4> HCO_3> Na >K> Cl. Finally, according to the sensitivity of TDS based on major ions, the most important factor was K × SO_4 and then the K × Ca factor. Also, determinant ions in this area (based on singular sensitivity analysis of TDS) are in the following order K> Cl > HCO_3> Ca > Mg> SO_4> Na.

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