Biosci. Biotech. Res. Comm. Special Issue No 1:87-93 (2017)

BBRC
Bioscience Biotechnology
Research Communications

Statistical evaluation of chemical and biological contamination in Yamchi Dam basin water

Romina Rasuli Asl and Hossein Saadati*

Department of Natural Resourses, Ardabil Branch, Islamic Azad University, Ardabil, Iran

ABSTRACT

Rivers are the most vulnerable water resources due to carry urban and industrial wastewater and agricultural wastes. In this study, the trend of changes of water quality of main branches of Yamchi Dam and water of dam reservoir during the time series were evaluated according to the Spatiality changes and the most sensitive branch was identified due to produce contamination as well as the time and location of changes (amounts) of water quality parameters to Yamchi Dam were evaluated. According to the statistical results in 2001 to 2015 related to the stations studied, it can be concluded that Nir River among all the variables studied is as the most pollutant river from the three main rivers of the upstream region of Yamchi Dam. According to the results, the river's water quality parameters from 2001 onwards has been increasing process, variables of fecal coliform, bicarbonate, DO, BOD and sodium respectively, as main factors have the greatest impact on water quality survey of the main branches of Yamchi Dam. Three main branches of Yamchi Dam are different in terms of rate and amount of variables mentioned and have had significant effect on water quality of Yamchi Dam. Variables studied except DO in all stations are considered pollutant in terms of the drinking water standard

KEY WORDS: YAMCHI DAM, WATER QUALITY, STATISTICAL INDICATORS

INTRODUCTION

Today, surface water quality is one of the major concerns and considers a health index for community (Charu and Verma, 2008). Data that describes temporal and spatial variations of water quality in river can be used to identify the relative importance of natural and human effects (Ramazani and Hashemi, 2011). Over the past decade, monitoring the water quality of the river has increased by measuring water quality parameters (Bu *et al*, 2010). Therefore, evaluating water quality is very important because it directly affects public health and life of aquatic ecosystem (Dixon and Chysol, 1996). P. *et al* (2009) used multivariate regression analysis including principal component analysis (PCA) and cluster (CA) to study the spatial and seasonal variations of surface

ARTICLE INFORMATION:

**Corresponding Author: Ah.saadati@iauardabil.ac.ir*
Received 27th Nov, 2016
Accepted after revision 20th March, 2017
BBRC Print ISSN: 0974-6455
Online ISSN: 2321-4007
Thomson Reuters ISI ESC and Crossref Indexed Journal
NAAS Journal Score 2017: 4.31 Cosmos IF : 4.006

Online Contents Available at: http//www.bbrc.in/

water quality of Haraz Watershed in Iran (during the summer and fall 2007 and winter and spring 2008). To assess the temporal and spatial variations of water of Jajrud River in Iran, they investigated water samples in a three-year period for each month in the 18 stations with PCA and CA statistical analysis. CA and PCA led to similar results, box plots show that PCA can show the temporal and spatial variations approximately (Razmkhah *et al* 2010).

Vega and colleagues in evaluating the seasonal changes and pollutants effects of river water quality of Pisuerga Spain using statistical analysis investigated variables of physicochemical of water during 2.5 years from 3 stations. The PCA showed that the mineral amount, human pollution and the temperature has dropped. (Bardvaj *et al* 2010) In investigating water quality of Kali Gandaki River in India using PCA, they analyzed factors such as shelves, poor drainage, ion exchange, intensity of use of nutrients and household pollutions. The results of this study showed that in some areas, due to increase of alkalinity, water becomes hard and is not suitable for drinking and irrigation purposes. To assess water quality of upstream basin of Yamchi Dam, first the quality parameters related to the main branch of Nir, Lai and Jurab were collected from the Department of environment and regional water organization of Ardabil province from 2001-2002 to 2014-2015 which contains concentrations of salts (TDS), acidity (pH), dissolved oxygen (DO), biological oxygen demand (BOD), chemical oxygen demand (COD) and total hardness (TH).

MATERIAL AND METHODS

THE STUDY AREA

Yamchi Dam basin with area of 709.18 square kilometers is placed in the geographic area 28" 46' 47 ° to 57" 05' 48 ° east longitude and 24" 01' 38 ° to 15" 09' 38 ° north that limits from north with Meshkinshahr, from North-East with Ardebil, from west and south to Eastern Azarbaijan and from southeast to the basin of Ghuri Chay. Yamchi Dam main branches included Nirchay, Laichay and Lamchay that after connecting to each other make a great river that is called up Balqelychay that is one of the important branches of Aras River in the North West of Iran that flows in South North and collects the waters of the main branches of Yamchi Dam from East and South of the area. YamchiDam main branches because of flowing from important residential areas such as Nir and villages in the region and also placing some industrial and resort centers near the river and because of the drinking and agriculture water supply of area is one of the major dams of Azerbaijan region. On the other hand, the area because of the ruling of the above conditions and serious threats caused by wastewater of industry and domestic sewage is constantly threatened by pollution. Therefore, such a situation increases the vulnerability of the study area to the issue of pollution. Figure 1 shows Yamchi Dam position in the North West of Iran, West of Ardebil and also the position of hydrometric stations studied.

RESEARCH METHODOLOGY

Compliance with statistical principles to prevent from wasting time and increasing the accuracy, first the variables studied were minimized. Since the number of parameters mentioned above is large and it is not possible to check all of them in the form of a master's thesis therefore, it was acted to minimize the variables using principal component analysis (PCA). After determining the main variables of all three stations (Nir, Lai and Jurab) by adopting a common statistical base, shared variables were selected from three stations. After

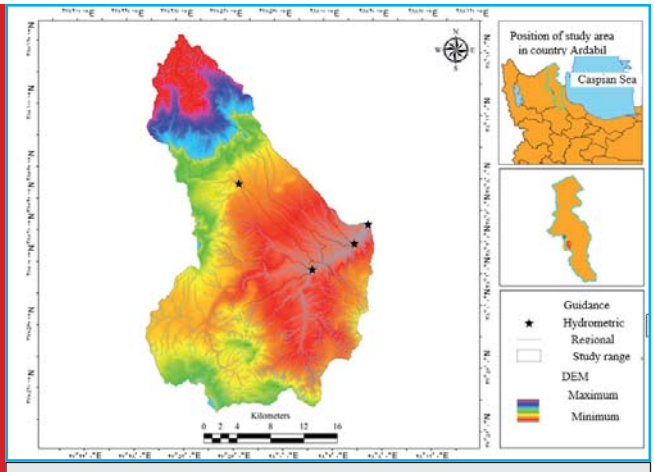

FIGURE 1. Position of the study area

selecting the common parameters at the later stage, it was acted to group comparisons based on common variables. So that it was acted to investigate the presence or absence of significant difference between the three main branches of Yamchi Dam ie Nir, Lai and Jurab using multivariate analysis of variance, at this stage the presence or absence of difference between the three stations is determined. After this stage, it was acted to group averages of the variables among three stations and it became clear which of the variables of these three groups are different. In the next step, it was acted to compare the amount of shared variables with standard value using One Sample T-test; the purpose of this step is to identify the most polluted river of the main branches of Yamchi Dam. In this study, a sample T-test hypotheses are: 1. The null hypothesis: The value of investigated variables is in permitted range. 2. Hypothesis: The value of investigated variables is not in permitted range. Finally, to determine the trend of changes of data and identify the type and time of it, it was acted to analyze the trend of time series using Mann-Kendall non-parametric test, and the presence or absence of changes was specified.

Kolmogorov-Smirnov test was used to assess the normality of variables. Determining the appropriateness of data was performed using the KMO index and Bartlett test, in components analysis, maximum equity (Eigenvalue) belongs to the first component (Pc1) and gradually by increasing class of components, this amount decreases. It should be noted in this method, each component is independent of other components (Yao *et al*., 2013). Each component is a linear combination of variables that its equation can be shown as equation 3-1 (Jolliffe, 1986).

$$PC_1=a_{11}X_1+a_{12}X_2+\ldots+a_{ij}X_j$$

In this equation, PC is the main component, is the coefficient or special vector (Eigen Vector) and is variable considered (Jolliffe, 1986). In order to select the number of effective components, components were selected that their Eigenvalue was more than one. To interpret the effective features in a component that controls the most changes, selection criteria was used (Doran and Parkin, 1994).

$$SC=\frac{0.5}{(PCeigenvalue)^{0.5}}$$

In this equation, SC is selection criteria, PC is the main component and Eigenvalue is the special value (Doran and Parkin, 1994). After identifying the most influential variables in each station by considering the common base among the main station variables, variables that were present in all three stations were selected as the major variables in qualitative studies of upstream water of Yamchi Dam. All statistical analyzes were conducted in SPSS v.20 software.

In this study, the method of multivariate analysis of variance was used to investigate the significant difference between the variables of factor analysis (including five variables of bicarbonate, sodium, DO, BOD and fecal coliform) in three main branches of Yamchi Dam (Nir, Lai and Jurab).

Among the groups after the significant difference among the main branches of Yamchi Dam was approved then, using Duncan method from grouping methods of averages, it was acted to identify the different variables in the three branches.

In order to understand the trend of changes of data and identify the type and time of it, it was acted to analyze the time series using the Mann-Kendall non-parametric test and the presence or absence of changes was specified. In this study, the graphical method of Mann - Kendall test was used. About the graphical method, mentioning points about the statistic U and U 'is necessary. If the sequence U and U ' based on i is drawn as a graph, in the significance mode of the trend, two graphs at the starting point of phenomena outside the scope intersect each other and will move in opposite direction of each other, this point of collision is called mutation. While if there isn't trend, two sequences U and U 'move almost in parallel or will act in several times of collision, so that does not lead to change direction. U graph to the year (axis X) is drawn and for that significance of trend and point of its mutation to be achieved, the sequence U 'is defined.

RESULTS AND DISCUSSION

Principal components analysis (PCA) was used in order to determine the minimum effective variables in investigating qualitative changes of upstream water of Yamchi Dam (main branches of Nir, Lay and Jurabchay). First KMO factor was used in determining the suitability of the data for principal components analysis to achieve this goal. The value of this factor is always variable between zero and one. If the value of this ratio is less than 0.5, the data will not be suitable for factor analysis and if its value is between 0.5 to 0.69, it can be analyzed main components more carefully. If KMO coefficient is larger than 0.7, principal components analysis in the decrease of data will be effective (Jolliffe, 1986). As well as to ensure correlation between input variables or independent, Bartlett's test was used. Based on the results, KMO coefficients in three main branches of Nir, Lai and Jurabchay was obtained 0.769, 0.782 and 0.724 respectively that the amount confirms the correlation between input variables for principal components analysis. Bar-

Table 1. Investigate KMO and Bartlett tests to detect changes in upstream water quality of Yamchi Dam

Significant level	Bartlett test	Test KMO	Station
0.000	86.774	0.769	Nir
0.000	89.345	0.782	Lai
0.000	82.761	0.724	Jurab bridge

tlett's test was significant for all three rivers in 0.01 so the data are suitable for PCA.

The main components analysis was used to assess the water quality changes of main branches of Yamchi Dam. Therefore, variables that at least one of the coefficients of them is used to form the component have relatively high amount. According to Table 2, Nir, Lai and Jurab stations had 4, 5 and 4 main components and in total according to the considered criteria, it was specified among 10 variables, Nir, Lai and Jurab stations have respectively 9, 3 and 5 main variable. Because of the variety in number and type of main variables in each station, considering common base between main variables related to each of the three stations, three variable of DO, BOD and fecal coliform were selected as the main variables (effective factors). So the variables of fecal coliform and DO and BOD as the main factors have the greatest impact and other variables have the least impact in investigating water quality of the main branches of Yamchi Dam.

According to the results of analysis of variance, there is a significant difference between the three main branches. Values Sig. that for stations studied is less than 0.05, and then by 95% confidence level, there is a significant difference between the main branches of Yamchi Dam based on five variables (bicarbonate, sodium, DO, BOD and fecal coliform). In other words, three main branches of Yamchi Dam in terms of amount of variables mentioned are different with each other and have significant effect on water quality of Yamchi Dam.

It was specified in the results of multivariate analysis of variance that there is a significant difference between three main branches, but it is not clear which of the variables (bicarbonate, sodium, DO, BOD and fecal coliform) are different. Comparisons of the average of variables in groups surveyed by Duncan method showed bicarbonate amount in rivers of all three with Sig. equal one in each three main branches are different, sodium amount among two branches of Nir and Jurab with Sig. equal to 0.763, there is no significant difference but the amount of sodium in the Lai branch with sodium in two branches of Nir and Jurab is quite different. The number of fecal coliform in the water of branches of Lai and Jurab is very similar but the number of fecal coliform

Table 2. Number of main components,: EV (Eigenvalue),: SC (selection index) and: Cu (cumulative variance) in assessing the changes of water quality of the main branches of Yamchi Dam

Fifth main component		Fourth main component		Third main component		Second main component		First main component		Station
-	EV	2.017	EV	2.538	EV	6.898	EV	8.746	EV	Nir
-	SC	0.352	SC	0.313	SC	0.19	SC	0.169	SC	
-	Cu	96.184	Cu	6.581	Cu	74.495	Cu	41.648	Cu	
1.228	EV	2.109	EV	4.33	EV	5.365	EV	6.967	EV	Lai
0.451	SC	0.344	SC	0.24	SC	0.215	SC	0.189	SC	
100	Cu	93.358	Cu	83.313	Cu	61.664	Cu	34.837	Cu	
-	EV	1.966	EV	2.314	EV	3.702	EV	11.078	EV	Jurab
-	SC	0.356	SC	0.328	SC	0.259	SC	0.15	SC	
-	Cu	95.304	Cu	85.473	Cu	77.901	Cu	55.391	Cu	

Table 3. The results of multivariate analysis of variance

Source	Dependent Variable	Type III Sum of Square	df	Mean Square	F	Sig.
Three froups of Nir, Lai, Jurab	Bicarbonate	59233.637	2	29616.818	180.443	.000
	Sodium	1921.608	2	960.804	69.644	.000
	DO	1.264	2	4.632	1.509	.000
	BOD	5.621	2	2.810	8.002	.000
	Fecal coliform	5411.641	2	2705.820	4.072	.000

Table 4. A sample t test results with constant value of main three branches variables

One-Sample Test							
Station	Common variables	T	Degree of freedom	Sig.	Difference of average	Confidence level 95%	
						Less	More
Nir	Sodium	-98.84	8	0.000	-175.11	-179.2	-171.03
	bicarbonate	-14.31	8	0.000	-84.46	-98.07	-70.85
	fecal coliform	4.8	8	0.000	47.61	24.75	70.47
	DO	-3.05	8	0.02	-0.46	-0.81	-0.11
	BOD	-51.93	8	0.000	-12.67	-13.24	-12.11
Lai	Sodium	-2618.4	8	0.000	-193.26	-193.4	-193.09
	bicarbonate	-132.2	8	0.000	-155.68	-158.4	-152.9
	fecal coliform	3.907	8	0.05	24.39	9.9	38.7
	DO	0.206	8	0.862	0.056	-0.568	0.68
	BOD	-69.4	8	0.000	-13.015	-13.447	-12.582
Jurab	Sodium	-145.6	8	0.000	-175.64	-178.4	-172.8
	bicarbonate	-9.809	8	0.000	-42.18	-52.097	-32.26
	fecal coliform	6.353	8	0.000	58.31	37.146	79.48
	DO	-0.467	8	0.653	-0.098	-0.579	0.384
	BOD	-79.762	8	0.000	-11.92	-12.267	-11.57

in Nir branch is different with two other branches (Table 4).The amount of BOD in water, branches of Lai and Jurab not have much difference with each other but the amount of this variable in Nir branch is very different from the other two branches. DO variable situation is similar to variable BOD.

According to the results of a sample t test, the significance level (Sig) is larger than 0.05, then, the null hypothesis is confirmed with confidence of 95 percent. As the value of Sig of one sample t-test in all parameters except DO is less than 0.05 so the variables considered in all stations except DO in terms of the standard of the drinking water are considered pollutant. DO variable in two stations of Lai and Jurab is equal to the threshold of pollution and is not considered statistically pollutant.

According to the results of Mann - Kendall non-parametric test, all stations follow the process of changing the station of Nir that is why only the results of Station Nir is provided. In the graph of the annual average DO of station, a significant mutation with positive trend in

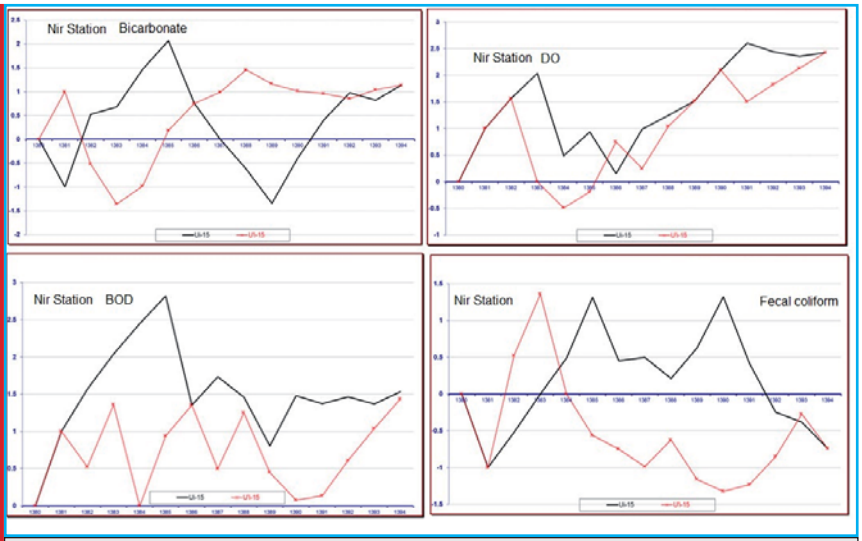

FIGURE 2. Mann - Kendall non-parametric test, Nir Station

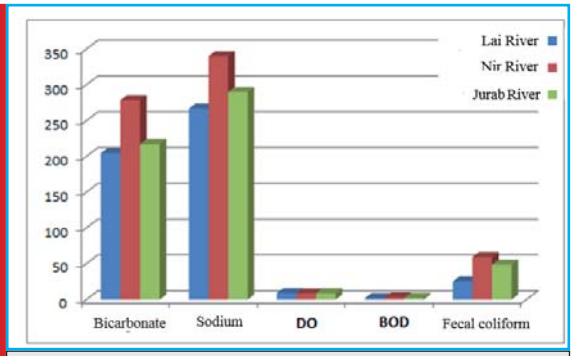

FIGURE 3. Graph of average of variables investigated in the main branches of Yamchi Dam

2007 can be seen that is presented as graph. In the graph of annual average bicarbonate of station Nir, two significant mutations with positive and negative trend in 2003 and 2007 can be seen as in 2007 has undergone a sudden change and governance of its trend is negative. It is concluded from investigating the behavior of changes U and U 'related to annual average BOD of station Nir that, without significant change and mutation has experienced the normal process of maximum Sodium. In the graph of average annual fecal coliform of station Nir, a significant mutation with the positive trend in years 2005 is seen. As in 2007, it has experienced a mutation and its trend is declining.

According to the results of the previous sections and referring to the multi-year average related to the stations studied (Fig. 3), it can be concluded that Nir river in all the variables studied is as the most pollutant river among the three main rivers of the upstream region of Yamchi Dam.

CONCLUSION

According to the results of this study, it can be said evaluating water quality conducted in this study has integrated and comprehensive expertise knowledge. As it can be acted to better understanding, manage and reduce its pollution by the selection of the main factors in water quality. Based on the results obtained, features such as fecal coliform, bicarbonate, DO, BOD and sodium were selected as effective factors, which are a combination of chemical and biological parameters of water. Research about selecting effective factors, determining the minimum or the most optimal effective characteristics on water quality in different regions can be guidance for proper assessment of water quality by spending a minimum cost and time. Reviews related to multivariate analysis of variance indicate high accuracy and ability to detect the presence or absence of difference between study stations.

The use of this method in the analysis of different groups with different variables is very effective and provides significant results. About the identification of variables that shows significant difference among the stations studied, the Duncan method due to advantages compared to other methods such as LSD, Dunnett and can be compared groups (Nir, Lai and Jurab stations) mutually and to be ensured the significant difference between the variables of the stations. So it is concluded Duncan method has a highly accurate in identifying different variables between stations. A sample T test as a standard method to examine the value of variables with standard value of them has a high efficiency and the results obtained of it indicate pollution of parameters investigated in available stations. As Nir station has the highest pollution among the stations studied. The reason for this is the flowing Nir River through urban area of Nir and adjacent villages as well as industries in the region, which always production waste in these industries and urban sewage directly enter the river and is a serious threat to aquatic and Yamchi Dam that is as producer reservoir of drinking water for Ardabil. Of the results obtained of time series of Mann-Kendall can be clearly observed that parameters investigated during 13 years, have maintained its upward trend and are rising. This implies the increase of human-produced pollutants that without attention to the rights of posterity and due to mismanagement is destroying environment.

RECOMMENDATIONS

Due to the sensitive situation of the region and the expansion of residential and industrial areas adjacent to rivers in the region, it is recommended to be used drainage system suitable for agricultural lands overlooking the river. In order to prevent the entry of industrial wastewater and domestic sewage to the rivers of area, sewage system is reconstructed in area and in sections that is deprived of sewage, proper system of sewage to be implemented. Lands use changes, especially deforestation and gardens and convert them to residential areas in riverbanks to be prevented and in accordance with the river privacy to be prevented the entry of more pollution to groundwater and surface water sources.

It is suggested to be achieved necessary information from potential of land for various uses before use the land in the area, with land capability assessment for different uses. According to the capabilities of GIS in land planning, it is suggested to be implemented the logistic plan in the region by taking advantage of the capabilities of this system. It is suggested to be investigated the effect of other parameters such as the amount of soil

erosion, rainfall and flooding also with more details on the amount of dissolution time.

REFERENCES

Bardwaj, V., D.S. Singh and A.K. Singh. (2010). Water quality of the Chhoti Gandak River using principal component analysis, Ganga Plain, India. Journal of Earth System Science, 119: 117-127.

Bu, H., Tan, X., Li, S. and Zhang, Q. (2010). Temporal and spatial variations of water quality in the Jinshui River of the South Qinling Mts, China. Ecotoxicology and Environmental Safety. 73: 907-913 pp.

Charu, P. and Verma, N. (2008). Mulitivariate analysis of drinking water quality in Bhopal, India. Envirionmental Monitoring and Assessment. 140: 119-122 pp.

Dixon, W. and Chiswell, B. (2012). Review of aquatic monitoring program design. Water Research. 30:1935-1984 pp.

Doran, J. W., and Parkin, T. B. (1986). Defining and assessing soil quality. Journal of Soil Sciences Pages 3-21

Jolliffe, I. T. (1986) Principal Component Analysis Springer-Verlag, NewYork.

Pezhman, A.H., Nabi Bidhendi, G.R., Karbasi, A.R., Mehradadi, N., Esmaeili Bidhendi, M.(2009). Evaluation of spatial and seasonal variations in surface water quality using multivariate statistical techniques. International Journal of Environmental Science and Technology (IJEST). 6:467-476 pp.

Ramezani, S. and Hashemi, H. (2011). Analysis of water quality of Zarrine Rud River with statistical technique of main component analysis of Fourth Conference on Water Resources Management in Iran. Amirkabir University of Technology, Tehran.

Razmkhah, H., Abrishamchi, A. and Torkian, A. (2010). Evaluation of spatial and temporal variation in water quality by pattern recognition techniques: A case study on Jajrood River (Tehran, Iran). Journal of Environmental Management. 91: 852-860 pp.

W. Doran and P Parkin (1996) (eds.) Defining soil quality for a sustainable environment. il Science Society of America Special Publication no. 35, Madison, WI.

Yao, H., Thornton, B., Paterson, E., (2012). Incorporation of 13C-labelled rice rhizodeposition carbon into soil microbial communities under different water status. Soil Biology & Biochemistry 53, 72e77.