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Estimation of drinking water quality parameters changes in response to land use changes

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Analyzing the relationship between land use and drinking water quality from rivers can be a solution to access clean water resources. In addition, it can reduce water treatment costs in the form of intended standards. Jajrood River is one of resources that provide Tehran's drinking water; therefore, stability of its quality is essential. Land use change in basin and the uncertainty of permitted limit of land use types change are issues that can cause stability or instability of water quality status in rivers. The aim of this study is to analyze the relationship between land use and Jajrood River's drinking water quality in order to give appropriate management solutions. For this reason, measured water quality parameters at four sampling stations in this basin for 15 years in temporal adaptation to available satellite images of study basin in three periods of time (between the years 2000 to 2015) using Geographical Information System (GIS) and temporal related data water quality of Jajrood River were analyzed for each of them. The results of the analysis of variance, correlation coefficient, and regression equation showed that land use change had significant effect on amounts of pH, Cl-, SO42- and NO3- in study sub-basins and total basin. The abovementioned results showed that; the water quality changes in a basin are a function of land use changes in their sub-basins.

Keywords: Water quality parameters; Jajrood River Basin; Land use change.

1.INTRODUCTION

Considering the challenges of water shortage in many parts of the world, finding clean water as drinking water is one of the major issues these days. Analyzing the relationship between land use and drinking water quality from rivers is one of the scientific and practical solutions to access clean water resources. Land use change in the basin and uncertainty of permitted limit of land use types change are issues that can lead to stability or instability of the status of water quality in rivers. The land use in the basin has important effects on the quality of river water, cf. Huang et al. [8]. The water quality of rivers is reduced by increasing human activities and change in land cover patterns in the basin [8,11,13]. Therefore, extensive researches have been carried out in the field of water quality management. However, there is a need to determine and quantify the effects of different types of land use on surface water quality [14]. The results of researches carried out in Iran and abroad show that, land use and periodic changes of their area for various purposes, such as drinking water have different effects on rivers water quality. The result of research carried out in Slovenia based on periodic land use maps shows that the location of historical land use reduces water quality in the basin [6]. In the Dongjiang River Basin, China, the effects change in land use patterns on water quality in base flow of the river, led to the development of experimental models on the change in land use patterns with water quality change in different parts of the study basin using multivariate statistical analysis. Accordingly, it has been found that the water quality of base flow is strongly influenced by location and extent of land use in the basin [2]. In Thailand's U-Tapao River Basin, assessment of the relationship between the riparian zone land use and water quality in rivers showed that increase in urban land use in riparian zone area resulted in water pollution [7].

Moreover, studying the relationship between river water quality with land use and land cover in the upstream of China's Han River basin showed that the urban land use with pH and Dissolved phosphorus (DP), agriculture with suspended particulate matter (SPM) and potassium permanganate index (I_{Mn}) and barren lands with leaf N concentration are significantly correlated (Li et al.

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2008). Findings of various researches showed that, depending on the spatial characteristics of basin and nature of different types of land use in each area, river water quality is affected. Thus, due to the specific characteristics of each basin, the results of these researches are related [1]. In Ireland Irish River, it was identified that urban, agriculture and pasture lands were the main factors affecting water quality of river [1, 3]. Moreover, studies on South Korea Basin showed that urbanization more than agricultural land use was the most important factor that reduces the river water quality [9]. In Ziyarat River basin, Golestan Province, change of forests area into agricultural lands, pasture, residential areas, bare land and roads is one of the key factors affecting water quality in the region [15]. Jajrood River is one of the resources which provide Tehran's drinking water, therefore stability of its quality is really essential and there is need for water quality management. Therefore, the aim of this research is to determine the relation between land use and river drinking water quality to provide appropriate management strategies.

2 MATERIALS AND METHODS

Study area

Jajrood River Basin is located at longitude 51.24 to 51.50 and latitude 35.46 to 36.30 with an area of approximately 453.909 km^2 (Fig .1). The maximum elevation of this basin is 4000 m above sea level and 1500 meter at the basin outlet. Annual average precipitation is 711 mm. The annual average temperature is 26°C with a minimum temperature of -8 and 32°C, recorded in January and July respectively. This river flows from north to south of the basin. Snow melting in northern mountains in the spring causes a marked increase in river flows [5,12]. Several villages and cities are located along the river with a population of approximately 200,000 inhabitants [12].

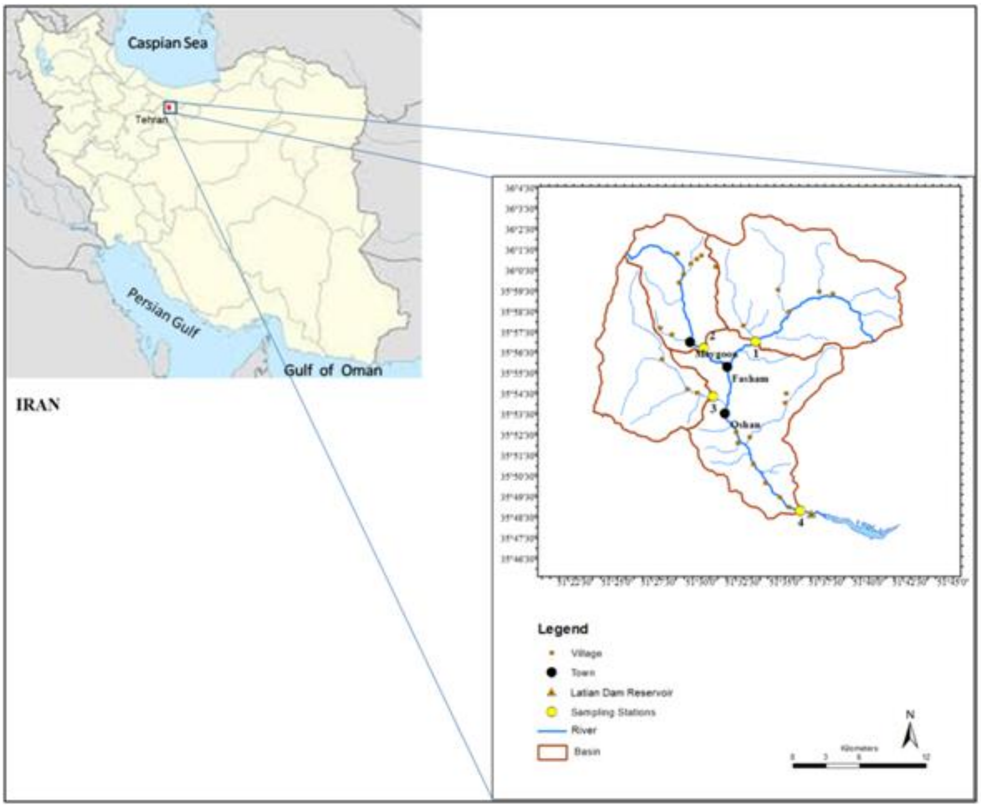

Fig. 1. Location of Jajrood River basin and water quality measurement stations: 1. Rooteh, 2. Meygoon, 3. Ahar, 4. Central Latian sub basin.

Water quality and land use data

In this study, the basin extent and different characteristics of each sub-basin led to the selection of four sub-basins with water quality sampling stations and the basin boundary and sub-basin boundaries determined by DEMs using Arc GIS. So, available average annual data of sampling water quality in four sampling stations and different types of land use concentrations in each station (Figure 1) based on the complete information of the results of measurements, average annual concentration data for three five year periods between 2000 and 2015 (Table 1) was determined from the Water Resources Research Organization (TMAB). In order to monitor water quality, these stations were located in High population centers and farming areas. Among the water quality parameters, pH, nitrate (NO_3^-), sulphate (SO_4^{2-}) and Cl^- were selected based on European Directive 75/440 / EEC [4] for surface water quality intended for the abstraction of drinking water and adequate available data. The data of land use state has been adjusted periodically utilizing remote sensing Land Sat satellite images of the basin for the same time and it was applied to assess land use changes. The changes were determined for three periods of time (2005, 2010 and 2015) processed by using Geographical Information System and Arc GIS 10.3 software in the format of 3 maps including orchards, pastures, residential areas and irrigated farming. The percentage of land use area was utilized in order to determine the relationship between land use and water quality parameters in each sub-basin and basin.

Analysis of data

In this paper, to analyze the characteristics of land use and water quality parameters, descriptive statistics were used. In order to test water quality parameters and land use variables, analysis of variance (ANOVA) was used. Pearson correlation analysis was used to examine the relationship between different types of land use and water quality variables at a significance level of 0.05 and 0.01. Thereafter, to determine the type of this relationship, multiple regression analysis was carried out, where the water quality was considered as dependent variable to the effect of land use changes in each sub-basin and the basin on it to be evaluated. In order to determine the best model for predicting each water quality variable, the regression equation was compared with R^2 value and it showed that the amount of change in the dependent variable are describable by change in the independent variables. All statistical analyses were performed using SPSS version 23 software.

RESULTS AND DISCUSSION

Water quality parameters of Jajrood River

Table 1 shows the summary of the mean and standard deviation of the measured parameters in three 5-year period from river water samples in four sub-basin stations separately, as well as in the whole Jajrood River basin. Moreover, permissible limits by European Directive 75/440/EEC on surface water quality were considered for drinking water. Average variable concentrations in defined interval, is less than the permissible limits suggested. This situation is due to the effect of factors such as direction and slope of the basin, type of land use and its distance from the river, waterways density, area precipitation, land cover density and morphology of rocks on the absorption and transportation rate of each variable with certain concentration into river water. It caused absorption and reduces its concentration in the river path to sampling stations. *Distribution of land use in Jajrood River basin and its sub-basin*

The land use of Jajrood River basin in three different periods shows that pasture lands were dominant land use type in the basin and four sub-basins (Fig. 2). In 2005, more than 90% of all sub-basins were pastured lands except the Central Latian sub-basin, but compared to other sub-basins, 10% of orchard lands were devoted in the Central Latian sub-basin. In 2010, the main land use were pastures in the sub-basins, but compared to 2005 in Meygoon sub-basin and compared to other sub-basins, the extent of pastures was reduced by 10% and correspondingly increased its orchards extent. In 2015, the main changes of land use were seen in Meygoon sub-basin, such that the extent of pastures land was approximately reduced by 12% during the third 5-year of study, and correspondingly increased the extent of orchards and residential areas. Land use changes in the basin from 2005 to 2015 showed that the extent of pastures was reduced by 4% and correspondingly increased its orchards extent. Moreover, there was not much change in irrigated farming and residential areas.

Linking land use and water quality parameters of river

The results showed that there was a significant relationship between sub-basins and study basin in terms of land use change by changing value of some parameters of drinking water quality, such as pH, Cl^-, SO_4^{2-} and NO_3^- , and the correlation coefficient between them varies from 1 to 0.994 (Table 2). The extent of change of pasturelands was significantly correlated with SO_4^{2-}, pH values and the extent of change of orchards with Cl^- values in the basin. While the extent of change of orchards and pastures was significantly correlated with SO_4^{2-} value, the extent of irrigated farming lands and residential areas was significantly correlated with pH value in the Central Latian sub-basin in dam. Moreover, "in the Ahar sub- basin; extent of change of orchards, pastures and residential areas has significant correlations with SO_4^{2-}, Cl^- and NO_3^- respectively. In Rooteh and Meygoon sub-basin, the extent of irrigated farming was significantly correlated with

Table 1. Descriptive statistics of water quality parameters sampling stations in three 5-year period

WQP	Permissible limits	Sampling Stations of each Sub-Basin								Total Drainage Basin of Jajrood River	
		Rooteh		Meygoon		Ahar		Central Latian			
		Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
pH	6.5-8.5	8.05	0.14	7.84	0.03	7.68	0.09	7.93	0.12	7.87	0.07
Cl^-(mg/L)	200	0.20	0.04	0.90	0.23	18.20	8.70	0.42	0.08	4.93	2.21
NO_3^- (mg/L)	25	4.17	0.33	4.35	0.31	3.81	0.55	4.21	0.99	4.14	0.42
SO_4^{2-} (mg/L)	150	0.59	0.03	1.64	0.29	27.31	9.92	0.81	0.07	7.59	2.51

pH value. To determine the land use effect on water quality, correlation analysis using regression model was obtained in Jajrood basin and sub-basins; thereafter, regression equations were estimated. For pH in the Rooteh, Meygoon and Central Latian sub-basins, orchards and residential areas were used as predictors. For Cl^- and NO_3^- in Ahar sub-basin irrigated farming, lands and residential areas were used as predictors. Moreover, in Central Latian sub-basins, orchards and residential areas were used as predictors. In Jajrood River basin, for pH, Cl^-, and SO_4^{2-}; irrigated farming lands and residential areas were used as predictors. The coefficient of determination in all predictions equals 1 ($R^2 = 1$) which shows that 100% changes in river water quality occurs due to orchards, residential areas and irrigated farming changes. In fact, results of regression analysis show that, among the existing land use, residential areas had the most important effect on drinking water quality, since it showed the sensitiveness on all four water quality parameters.

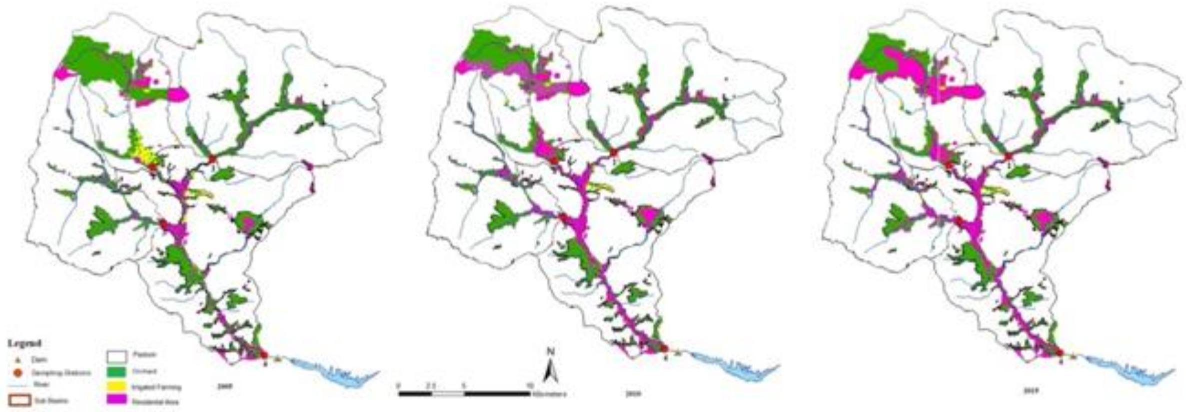

Fig. 2. Land use in the third period of 5 years 2005, 2010 and 2015(from 453.909 km^2 of the total extent of the study basin, 155.797 km^2 was devoted to Rooteh, 71.244 km^2 to Meygoon, 92.668 km^2 to Ahar and 134.201 km^2 to Central Latian sub-basin).

CONCLUSION

Study of different land use types in this basin showed, among the three types of land use, including irrigated farming, residential areas and orchards in the river basin and sub-basin located in Jajrood River riparian, that there is a significant relationship between drinking water quality parameters such as pH, Cl^-, SO_4^{2-} and NO_3^-. Residential areas have the greatest effect on river water quality. These findings are consistent with findings of Donohue et al. [3], Gyawali et al. [7] and Lee et al. [9], which showed that the urban land expansion in river riparian was affecting the water quality. Indeed, in each sub-basin, some factors such as land use distance from the river, land use area and their spatial distribution over the river, affect the river water quality. In the sub basin under study, residential areas, irrigated farming and orchards in riparian and relative increase of their extent, had a significant relationship with these parameters. On the other hand, in the Jajrood River basin, increasing the extent of irrigated farming, residential areas, and their position on the riparian had a significant relationship with the river water quality. Moreover, the studies of Glavan et al. [6] and Ding et al. [2] showed that location and extent of land use in the basin reduce water quality. Thus, taking into account this results and that of other studies in this field, it can be concluded that: in a basin, change in water quality is a function of land use change in their sub-basins, Moreover, "the effect of land use change on value and type of parameters are not the same and finally, the same relationship between land use change in the basin by changing the values and numbers of water quality parameters does not exist. Accordingly, to predict and understand the relationship between land use change processes and to achieve the best water quality parameters for water quality management solutions, especially providing drinking water from Jajrood River, it is necessary to determine the permitted limit of the type of land use change. Based on their effect in the change of water quality parameters in the basin and sub basin, and to separately manage drinking water quality in the river, it is necessary to determine the water quality buffer zone. Obviously, this can reduce water treatment costs in the form of intended standards.

Table 2. Pearson correlation coefficients between land use and drinking water quality parameters in Jajrood basin and sub-basins

Sub-basins	WQP	Pasture	Orchard	Irrigated farming	Residential area
Rooteh	pH	-.762	-.623	.997*	.768
	Cl^-	-.679	.756	.115	.672
	NO_3^-	-.177	-.978	.724	.186
	SO_4^{2-}	-.955	.327	.596	.952
Meygoon	pH	-.918	.832	-.988*	.686
	Cl^-	-.154	.913	-.658	-.250
	NO_3^-	-.679	.985	-.966	.332
	SO_4^{2-}	-.013	.846	-.545	-.385
Ahar	pH	-.302	-.002	.986	-.419
	Cl^-	1.000**	-.959	-.119	-.753
	NO_3^-	-.663	.859	-.649	.994*
	SO_4^{2-}	.935	-.999*	.220	-.930
Central Latian	**pH**	**-.968**	**.949**	**.999***	**.999***
	Cl^-	**-.672**	**.721**	**.500**	**.500**
	NO_3^-	-.621	.567	.773	.773
	SO_4^{2-}	-1.000**	.997*	.979	.979
Total Drainage Basin of Jajrood River	pH	-.998*	.970	.620	.919
	Cl^-	.969	-.998*	-.751	-.834
	NO_3^-	-.658	.394	-.249	.870
	SO_4^{2-}	.996*	-.921	-.492	-.969

Note: * $P< 0.05$; ** $P< 0.01$

Table 3. Regression equations

Sampling stations of each sub-basin	Dependent	Independent*	Equation	R^2
Rooteh	pH	OR/RA	pH = 9.758- 0.588 OR + 0.232 RA	1
Meygoon	pH	OR/RA	pH = 7.757+ 0.005 OR + 0.002 RA	1
Ahar	Cl^-	IF/RA	Cl = 30.582 - 7.065 IF - 15.709 RA	1
	NO_3^-	IF/RA	NO_3 = 3.447 - 0.073 IF + 0.764 RA	1
	SO_4^{2-}	IF/RA	SO_4 = 39.25 - 4.506 IF - 17.6 RA	1
Central Latian	pH	OR/RA	pH = 7.655- 0.005 OR + 0.245RA	1
	SO_4^{2-}	OR/RA	SO_4 = 0.595+ 0.015OR + 0.035 RA	1
Total drainage basin of Jajrood River	pH	IF/RA	pH = 7.785 + 0.174 IF + 0.026 RA	1
	Cl^-	IF/RA	Cl = 8.345 - 8.276 IF - 0.757 RA	1
	SO_4^{2-}	IF/RA	SO_4 = 10.52 - 4.2 IF - 1.133 RA	1

* Orchard (OR), Irrigated farming (IF), Residential area (RA)

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