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Full Length Research Paper

Effect of industrial and agricultural pollutants on the sustainability of Gavkhuni lagoon wetland ecosystem

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It is necessary to apply suitable management of water resources because of the increasing trend in pollution. Nowadays, industrial regions are major pollution resources of environment, and as such, management of these regions has an important role to play in pollution combat. Correct and scientific utility of all resources can make the most suitable consumption for us. It is important that humans understand the cumulative negative effects of development on rivers, and to develop a program for controlling this serious risk. In this study, quality statistics of Zayanderud river and its corresponding discharge in Varzaneh gauge station was used. Using dependency relationship between flow discharge and water pollutants concentration, the concentration of each pollutant in relation to industry with different probability levels was determined. Results showed that there is a high concentration of toxic elements often times, so river water can have destructive effects on the ecosystem of a region. If river base discharge will be considered on the basis of Q25, then it can reduce elements concentration in normal level, in other words, management programs for industrial regions should be based on the discharge of river because in drought periods, importing element concentration to lagoon will be increased and this has high level of destruction. However, factories waste water and other industrial regions must be changed on the basis of river discharge in drought and wet years. In addition, it is necessary to develop suitable management of industrial regions.

Key words: Sustainable management, risk, factories, heavy metals, Gavkhuni lagoon.

INTRODUCTION

Since the beginning of human history, human activities have caused many changes in the environment. Uncontrolled human settlement and industrial development have exerted extreme pressure on the wetland drainage systems, (Mbabazi et al., 2010). Today, a particular attention should be paid to gaining knowledge about water quality of wetlands which are pristine natural environments rich in genetic reserves. If qualitative conditions of industrial areas (in terms of both physicochemical and biological conditions) are not addressed properly, they could cause disruption in natural ecosystems, especially, in rivers. With regards to the quality of water resources, determination of pollutant sources plays a pivotal role in engineering projects as well as the designing of water quality control systems. Water is considered as an important factor in the arid and semi-arid areas because water shortage affects the agricultural production, (Al-Mefleh and Tadros, 2010). Zayanderud river has several thousands of years of history in Iranian civilization and has been the origin of major developments in the area. With the expansion of urban area in the region, a better part of agricultural lands that used to play an essential role in the production and livelihood of regional inhabitants has been destroyed and devoted to other uses such as industrial and residential applications. Therefore, a special attention should be

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paid to the risk of various industry-associated pollutants in Zayanderud ecosystem and management of that risk. Today, a major problem of many domestic wetlands is the significant increase in pollution which is mostly associated with agricultural and industrial pollutions. In fact, agricultural and industrial wastewater is discharged into wetlands, which endangers ecologic environment of the region and reduces biodiversity of the area. Among the two abovementioned sources of pollution, industrial pollution discharged from industrial centers and factories into the aquatic environments is of a considerable importance. If the rate of industrial contamination continues to rise in the coming years, it can have a very detrimental effect which might be impossible to rectify. Therefore, management of such areas in terms of the rate of water inflow to the wetland and industrial wastewater can greatly contribute to solving the problem.

Majnunian et al. (1998) stated that Gavkhoni wetland with its living species and even the human communities living adjacent to it forms an integrated system whose life and survival is dependent on the river. Clark (2000) argues that heavy metals are one of the most important pollutants that are either naturally present in the water or get into the water through municipal, industrial and agricultural discharges. Since the flow of water slow down in the wetland, heavy metals accumulate in soil, plants and aquatic species, thus, finding their way into human food chain. This process ultimately endangers both human health and the environment and, in the long run, can reduce population size and diversity of plans and animals. Heavy metals are among very stable pollutants and cannot get be decomposed biologically. Anderson et al. (2000) conducted an experiment on the absorption of metals in sediments of an artificial pond in Sacramento during the years 1998 to 1994. In their study, Dastjerdi et al. (2001) stated that in some cases, these metals in very low concentrations can have not only an adverse effect on cellular activities, but they can also cause reproductive problems, muscular/nervous disorders, egg infection and infection in egg-laying animals which may even lead to their deaths. In a study, Mirzajani et al. (2008) considered benthos communities in the wetland and some organic properties of water in 12 rivers leading to Anzali wetland. They designated 21 stations in various points of the wetland watershed, including upstream locations (near cities) and near the entrance to the wetland. Using Margalof and Menhinik richness index, Simpson and Shannon diversity index, EPT/C ratio, and Hilsenhoff familial biologic indicator, water quality in these designated 21 stations was tested.

The main transport routes to wetlands include run-off from the catchment area and direct deposition on the wetland surface (Lindstrom, 2001). Stations were investigated. Wetlands can significantly affect the concentration, speciation, and transport of Hg (Paterson et al., 1998; Wang et al., 2002; Liu and Ding, 2007).

Heavy metal pollution is an environmental problem of worldwide concern because most of them such as cadmium and lead can be toxic, even at low concentrations (Bahadir et al., 2007). For example, lead and cadmium are heavy metal pollutants released by vehicles which are propagated into the urban environment by traffic flow (Taebi et al., 2007). Heavy metals are considered as dangerous environmental pollutants that enter the food chain and pose serious health threats to humans, plants, as well as, other animals (Mirghafari, 2005). Metals discharged into coastal areas of marine environments are likely to be scavenged by particles and removed to the sediments (Pari and Lakhan, 2007). Aminiranjbar et al. (2000) investigated and measured heavy metals concentration (Zn, Cr, Cd, Cu) and studied their relationship with A chlorophyll concentration in leaves of three species of aquatic plants of Anzali wetland including Hydrocotil and Trapap (floating species) and Tifa (marginal species). These species play a considerable role in food chain and ecosystem of the wetland. Sartaj et al. (2005) investigated the emission and accumulation of industrial heavy metals (Pb, Zn, Cd, Cu, Ni and Cr) in Anzali wetland. Manshouri (1999) and Crites and Techo-banoglus (1998) maintained that heavy metals are among pollutants present in wastewater of industries, mines and factories as well as, municipal and agricultural run-off. Heavy metals get into the soil and water in solution form and cause pollution of surface and ground water as well as, soil and disrupt ecosystems in which they enter. In his study, Osat (2003) tried to suggest a regression model to explain the relationship between discharge level of river flow duration and its causes. He used these models to estimate river flow duration curves of rivers in regions for which comprehensive statistics was not available. In Iran, many researches have been done on water management in the agro-business sector. They have looked at the problems and suggested possible solutions to improve the situation (Ommani, 2011). This study aims to analyze the risks associated with industrial pollutants in protecting Gavkhoni wetland.

MATERIALS AND METHODS

Study area

Zayandrud basin is located between 50° 20′ to 53° 20′ E and 31° 15′ to 33° 45′ N with the area of 41503 km^2 of which 16649 km^2 is in mountainous area and 24854 km^2 in the foothills and plains (Figures 1 to 3). The basin is a part of Esfahan and Sirjan catchment in the Iran's central plateau according to the Iran's hydrology classification. Gavkhoni wetland $(15^{'}32^{o}-22^{'}32^{o}N$ and $45^{'}52^{o}-59^{'}52^{o}E)$ is 140 km Southeast of Isfahan and 30 km away from Varzaneh City (nearest town to the wetland) (Figure 1). It is 1,470 m above the sea level. Its maximum width is about 50 km and its maximum length is 25 km. The water depth in most parts is about one meter which varies with water input throughout the year. Its area is about 47,000 ha which also varies with water input to the wetland, so that its area increases in wet and humid seasons and

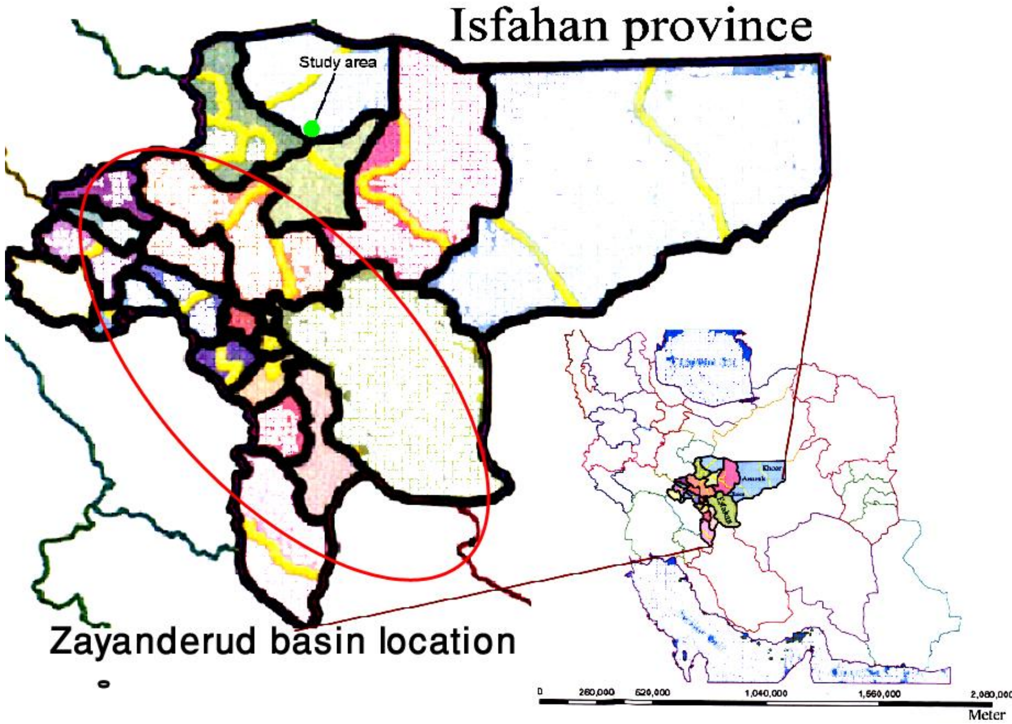

Figure 1. Location of Zayanderud basin in Iran.

considerably decreases in summer due to lower inflow as well as, higher evaporation rate.

Gavkhoni wetland is considered as one of the hot and desert areas of Iran with its temperature varying significantly throughout the year. According to Weather Forecast Organization reports, mean day temperature of the wetland varies from 1.83 to 28.9°C throughout the year, and minimum and maximum average temperature of the wetland is -6.6 and 37.4°C, respectively. Its temperature in 5 months of the year is above 20°C and in another 5 months is below 10°C. According to data provided by the same organization for 1987 to 1995 period, average annual rainfall is about 83 mm, whereas, annual evaporation rate in the area is estimated at 3000 to 3200 mm.

To determine the risk of pollutants especially, in times of drought, and evaluate its effect on quality of water sources for pollutant concentration adjustment as well as, its effects on wetland Gavkhoni ecosystem, we use water quality and corresponding discharge data in upstream wetland, that is, Varzaneh station. Hence, using the flow duration curve, we estimated discharge-pollution load relationship for pollutants such as Cl, B, Al, Ag and Mg in various probabilities for the period of 1973 to 2006. Then, using linear momentum method and H statistics, we examined homogeneity of the data.

Discharge-pollution load relationship

The relationship between pollutant concentration (C) and flow discharge (Q) is the most important relationship for predicting the amount of pollution concentration in situations for which statistics are not available. Most practical equation is the linear relationship between the logarithm of pollutant concentration and flow discharge. This relationship is as follows:

$$c = \alpha + \beta q + \varepsilon \qquad (1)$$

Where $c = \ln(C)$, $q = \ln(Q)$, α and β are model parameters, and ε is model remainder which has a normal distribution (Figure 4).

Once the best model is determined, pollutant concentration is determined by assigning various probability levels to discharge rate. Comparing resulting values with standard levels, we can calculate risk associated with the increase in surface water pollutant concentration. These results can be used to better manage the system to guarantee the survival of wetland ecosystem.

RESULTS AND DISCUSSION

Linear moment relation curve introduced by Hosking (1990) showed the relationship between $L-\tau_4$ and $L-\tau_3$ (or $L-\tau$ and $L-\tau_3$). In the $L-\tau_4$ curve versus $L-\tau_3$, all three distribution parameters are shown by the curve. A curve shows adaptability of several distributions although, no statistical test is defined in the relationship with this curve in order to distribute selection, but it can be used at point distance from the curve as a basis to select a suitable distribution (Hosking, 1986).

In this study, Varzaneh station as the closest station to Gavkhoni wetland was used to analyze quality risk. Then, in order to examine homogeneity of daily discharge rates of Varzaneh station, we calculated H_1, H_2 and H_3

Figure 2. Zayanderud Basin and Gavkhooni swamp location.

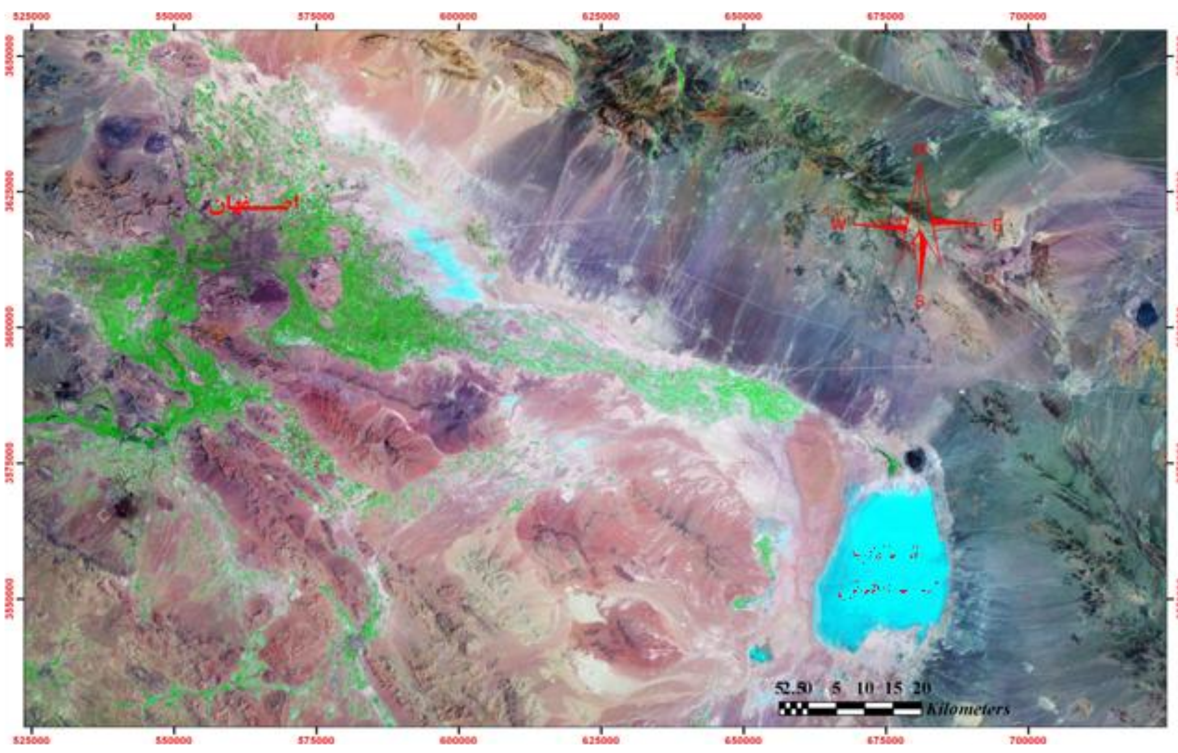

Figure 3. Geographical location of the study area.

statistics. The results showed that their value (H_1: -0.40, H_2: 0.02, H_3: -0.09), especially, H_1 value, were less than 1. Therefore, daily discharge series of the region are homogeneous. Using corresponding discharge and pollution load values, we estimated discharge-pollution load relationship as well as, coefficients, which are

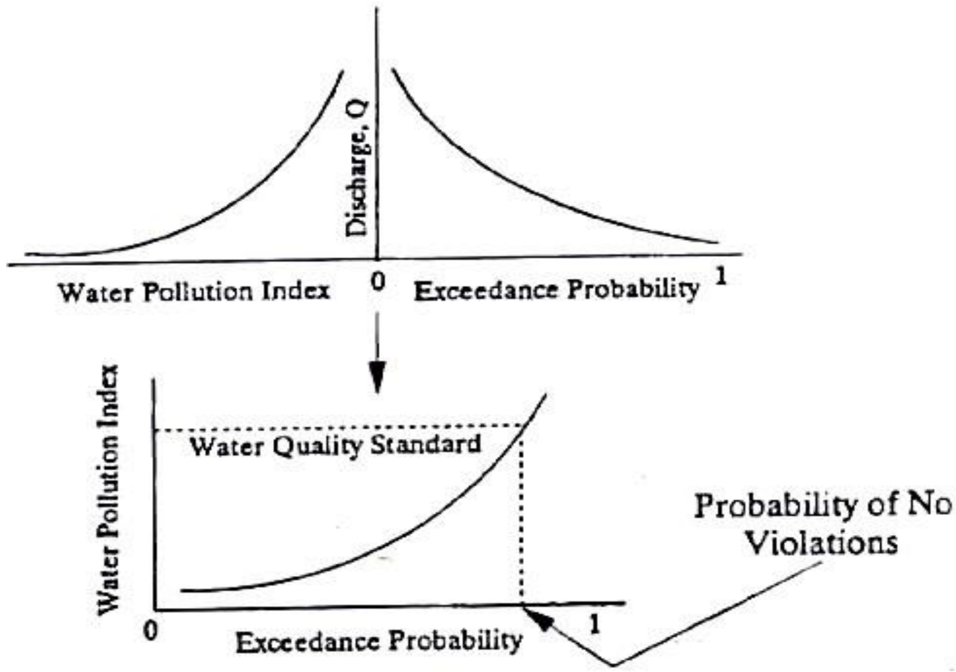

Figure 4. Flow duration curve and analyzing of exceeding probability and water.

Table 1. Area and facilities of some of the industrial towns of Isfahan province.

Town name	Total area (ha)	Operational phase (ha)	Assigned area (ha)	Assignable area (ha)
Esfidvajan	253	253	165	176
Oshtorjan	366	366	214	216
Rangsazan	1400	314	260	350
Sepehrabade Shahreza	55	45	34	36
Sepid-dasht (Hasanabade Jarghuye)	52	33	19	34
Segzi	500	500	432	433
Serahe Mobarake	277	277	246	254
Kuhpaye	500	150	111	123
Mohamadabade Margh	13	13	11	12
Harand	50	50	18	35
Varzaneh	50	50	5	32

summarized in Table 3. Moreover, correlation charts of the aforementioned values are shown Figures 5 to 9.

Flow duration curve

Using daily discharge values in the period of 1973-2004, flow duration curve was plotted. In doing so, we first sorted the data in descending order. Then, using the Weibull relationship, probability percentage of exceeding was estimated for discharge values. Then, discharge rate and probability percentage of exceeding were plotted correspondingly (Figures 10 to 11). Finally, using relevant plots $Q_{25}, Q_{50}, Q_{75}, Q_{90}$ were calculated to analyze pollutants' risks (Table 4).

Then, using discharge rates and relationships shown in Table 3, amount of elements in various probability levels were calculated (Table 5).

Finally, obtained values were compared with the standard set for elements. Results showed that the amount of Ag, Al and B in Q25 were not above the standard level. In other words, with a high rate of discharge, elements' concentrations decreased. However, in Q50, Q75 and Q90, their amount exceeded the standard level, thus, making a toxic condition for living population of the regional ecosystem.

As for Cl and Mg, their amounts were always more than the standard level. Therefore, a solution needs be

Table 2. Waste materials produced by various groups of industries.

No.	Waste material		Food and agricultural production	Mining	Energy production	Production of metals	Production of organic materials	Chemical industries and associated fields	Machinery, equipment and metal tools	Clothing, leather and textile	Paper and printing	Health and medical services	Business and Trade Services
1-Jan	Mineral W. M.	Acid and Alkaline	*		*	*		*	*	*	*		
2-Jan		Cyanide W. M.				*							
3-Jan		Solution and mud of heavy metals				*	*	*	*	*			
4-Jan		Asbestos W. M.					*	*					
5-Jan		Unknown solid W. M.				*		*	*				
2	Oil W. M.									*			
1-Mar	Organic W. M.	Consumed halogen solution						*	*	*			*
2-Mar		Non halogenic solution	*					*	*	*	*		
3-Mar		Color and resin W. M.						*	*	*	*		
4-Mar		Anti life W. M.	*				*	*	*	*	*		
5-Mar		Chemical organic matter			*	*		*					
4	Corruptible organic matter		*					*		*			
5	W. M. with high volume and low risk			*	*			*					
1-Jun	Miscellaneous w. m.	Infectious W. M.	*									*	
2-Jun		Lab W. M.						*				*	
3-Jun		Explicable W. M.							*				

W. M. = Waste matter.

Table 3. Derived models for discharge- pollution load relationship for various metals.

No.	Metal	Derived model
1	Ag	$Ag = -0.0529Q + 1.192$
2	Al	$Al = -0.2414Q + 5.7$
3	B	$B = -0.1095Q + 2.36$
4	Cl	$Cl = -0.0646Q + 1.489$
5	Mg	$Mg = -4.978Q + 143.36$

developed for this situation.

In order to estimate minimum flow in the region, we used the data gathered in Varzaneh station. Using a 7-day mobile average and choosing minimum average level in HYFA software package, minimum flow level was determined for various return periods (Table 6). Given that a 10 year return periods is used to choose minimum flow level in the region, 0.023 cubic meters per

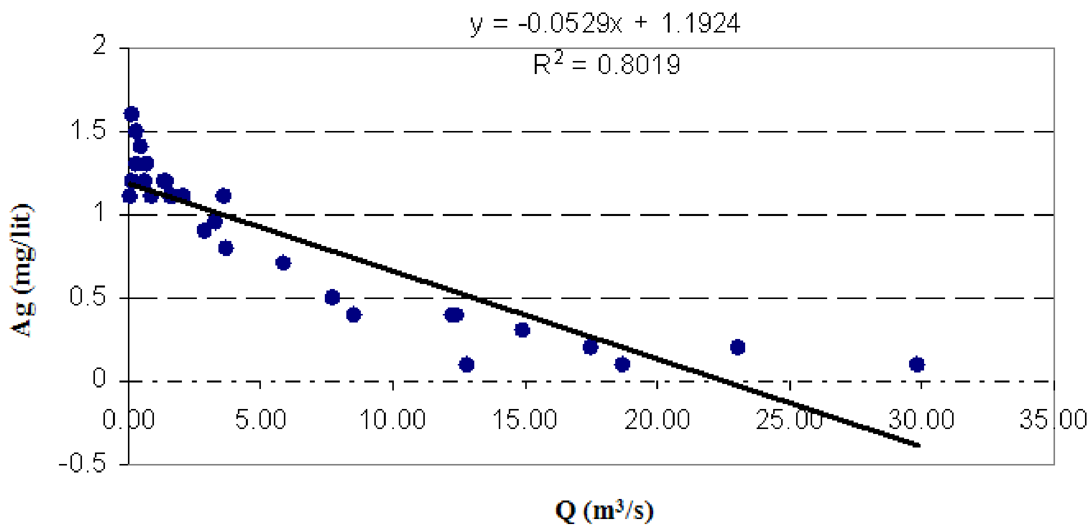

Figure 5. Correlation graph for discharge-Ag values in Varzaneh station.

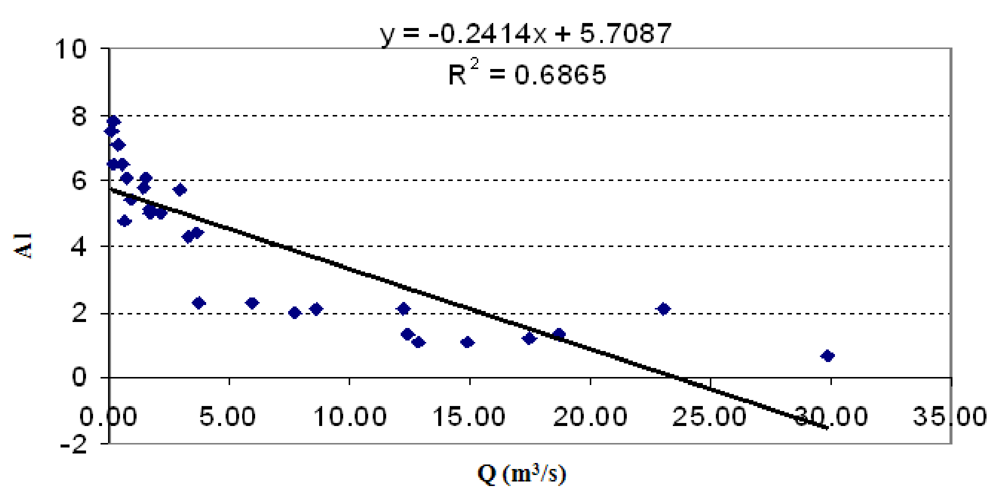

Figure 6. Correlation graph for discharge-Al values in Varzaneh station.

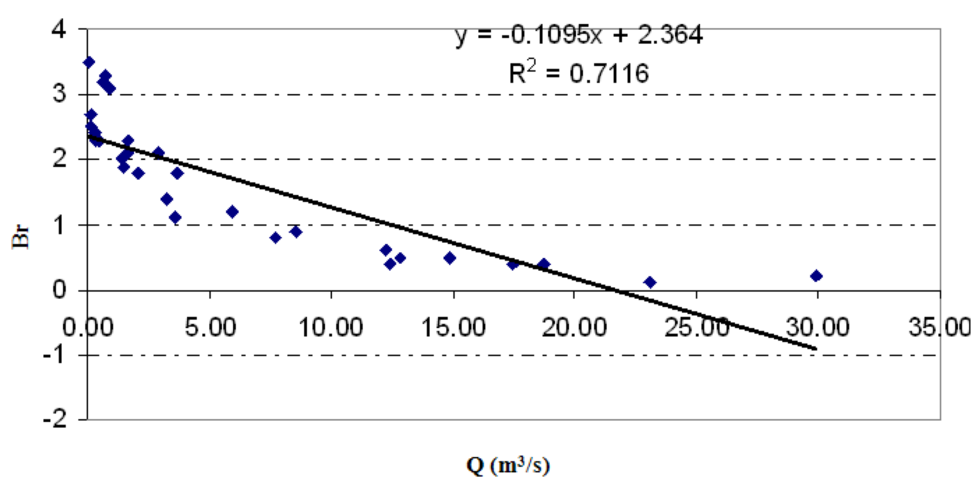

Figure 7. Correlation graph for discharge-Br values in Varzaneh station.

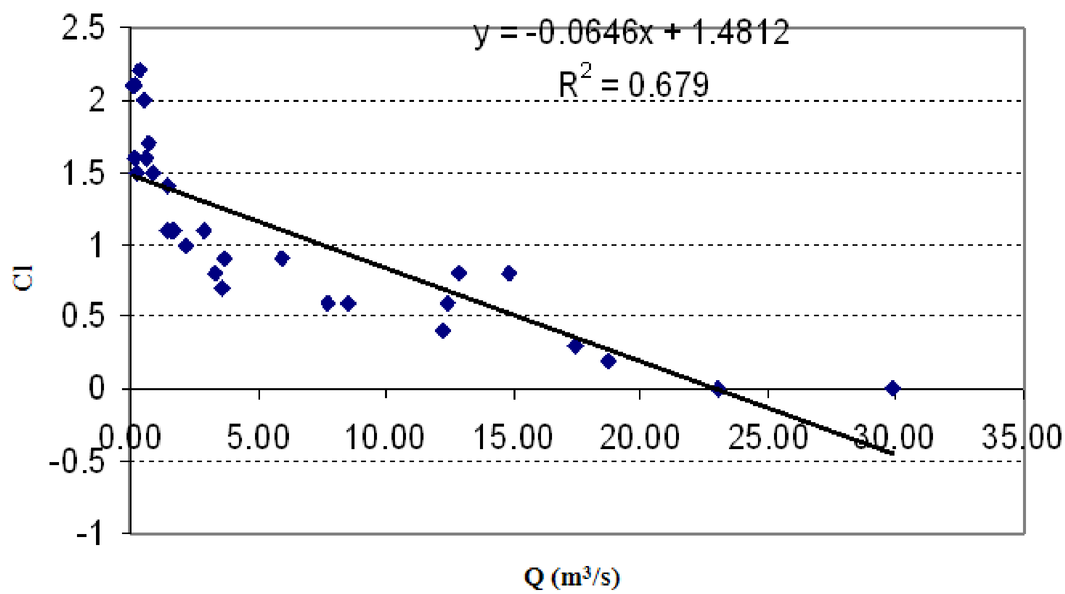

Figure 8. Correlation graph for discharge-Cl values in Varzaneh station.

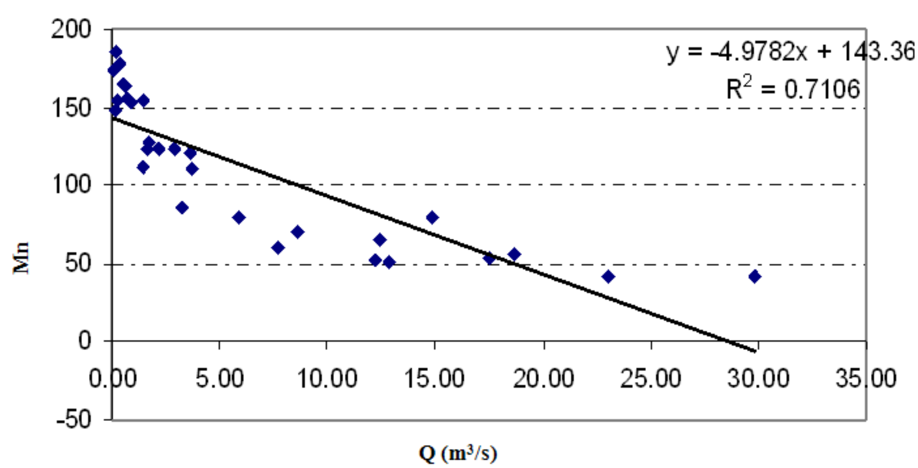

Figure 9. Correlation graph for discharge-Mn values in Varzaneh station.

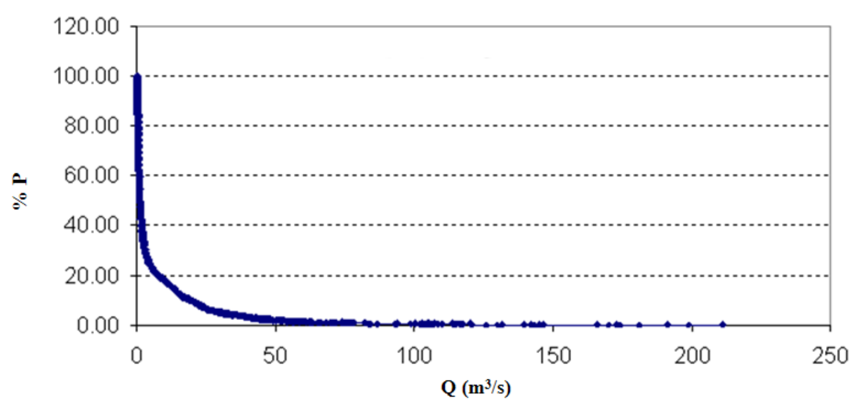

Figure 10. Flow duration curve for Varzaneh station.

Table 4. Estimation of Chandak values using flow duration curves.

No.	Chandak values
1	$Q_{25} = 4.25 m^3/s$
2	$Q_{50} = 1 m^3/s$
3	$Q_{75} = 0.35 m^3/s$
4	$Q_{90} = 0.109 m^3/s$

Q25: in 25% of times, discharge rate is more than the values associated with Q25.

Table 5. Amount of elements at various probability levels.

Chandak	Ag	Al	B	Cl	Mg
Q_{25}	0.967	4.67	1.89	1.21	122.2
Q_{50}	1.139	5.45	2.25	1.42	138.3
Q_{75}	1.174	5.61	2.32	1.46	141.6
Q_{90}	1.186	5.67	2.34	1.48	142.8

Table 6. Minimum Flow for various return periods, estimated using HYFA software package.

	Return period					
Variable	2	5	10	20	50	100
Minimum flow	0.413	0.068	0.023	0.009	0.004	0.001

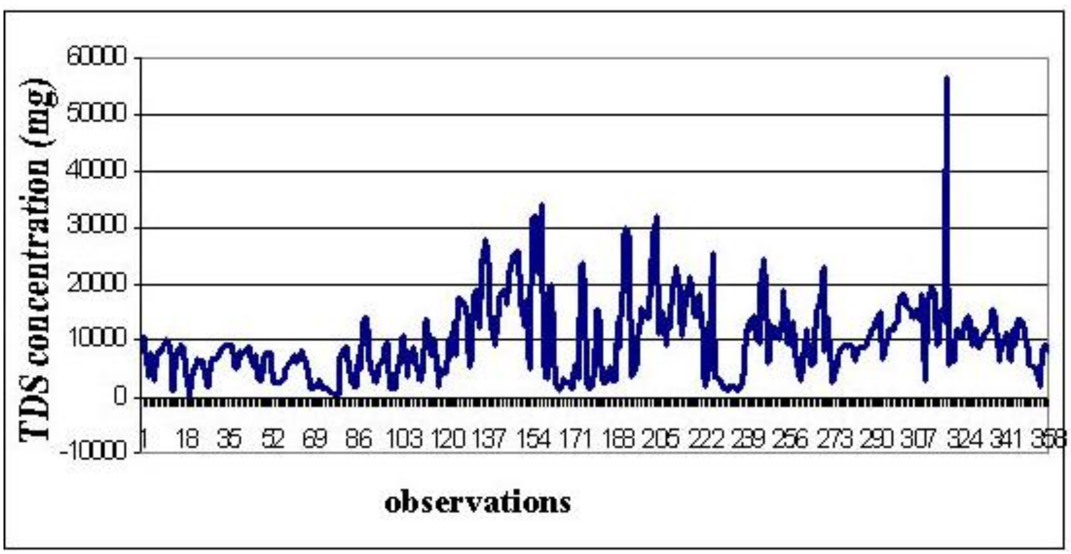

Figure 11. TDS changes in statistical period.

second was chosen as the minimum flow level of the region. Using flow duration curve, probability percentage of exceeding above 0.99 was estimated. According to this result, all metals have a high concentration in this rate of discharge. Therefore, in minimum discharge level, river water can be seriously detrimental to the environment and wetland ecosystem.

Conclusion

The results showed that the risk analysis of water quality in the region is of a particular importance. Given the industrial areas surrounding the river, this should be considered more seriously. According to the ongoing study, it becomes clear that the discharge rate has a significant effect on regional pollution and can prevent metals' concentrations from increasing. However, regional condition becomes very severe in times of drought and industrial factories should stop discharging their wastewater into the Zayanderud river. Minimum level of discharge rate of the river brings about a high concentration of heavy metals. This situation causes unrecoverable damages to the ecosystem of Gavkhoni wetland. Several activities carried out by the industry as well as, river water management sector can keep elements' concentration within the standard level. In doing so, when the wetland inflow decreases (that is, river water discharge decreases), industrial factories and centers should discharge lower amounts of wastewater into the river; and in wet years, more amount of water should be directed toward the wetland. In this way, heavy metals concentration can be decreased to the standard level. In this regard, Q25 can be used as an index for the increase in regional discharge. In order to resolve problems and bottlenecks created in the process of industrial development and achieving long-term goals in terms of resource productivity, many measures have been thought of. A practical way for proper spatial organization of industries is creating towns and industrial complexes within the framework of National Strategy of Industries' Development, putting them in places designated in skeletal development plans. This action focuses not only on industrial activities, but also helps in integrated management of them and makes it easier to achieve environmental goals. With the development of such towns, various industrial groups get integrated in the same place. This action allows for balanced physical development of industrial areas, coordination of various industries. Moreover, while this action helps decision-makers to earmark proper lands for industrial applications, it will not allow industrial plans to destruct valuable agricultural lands.

Creating and developing industrial towns can prevent industrial factories from careless expansion in residential areas of cities, thus, reducing the adverse effects of this well-known phenomenon. Furthermore, this action can help us make the most of financial, natural and human resources and capabilities. Therefore, development and expansion of industrial towns and even moving isolated industrial plants to such towns can significantly contribute to maintaining balance in various environmental sectors, keep industrial pollution from spreading in the environment, and finally help top managers in developing practical plans.

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