International Journal of Earth, Energy and Environmental Sciences
ISSN: 2517-942X
Vol:5, No:4, 2011

Necessity of Risk Management of Various Industry-Associated Pollutants

(Case Study of Gavkhoni Wetland Ecosystem)

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Abstract**—**Since the beginning of human history, human activities have caused many changes in the environment. 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 designing water quality control systems. Thus, using different methods such as flow duration curves, discharge-pollution load model and frequency analysis by HYFA software package, risk of various industrial pollutants in international and ecologically important Gavkhoni wetland is analyzed. In this study, a station located at Varzaneh City is used as the last station on Zayanderud River, from where the river water is discharged into the wetland. Results showed that elements' concentrations often exceeded the allowed level and river water can endanger regional ecosystem. In addition, if the river discharge is managed on Q25 basis, this basis can lower concentrations of elements, keeping them within the normal level.

Keywords**—**Pollutants Risk, Industry, Flow Discharge, Management, Gavkhoni Wetland

I. INTRODUCTION

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 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 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 solve the problem.

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Majnunian et al [1] state that Gavkhoni wetland with its living species and even the human communities living adjacent to it form an integrated system whose life and survival is dependent on the river. Clark [2] 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 slows 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. Ranjbar (1982) states that in general, very low amounts of heavy metals are naturally found in living ecosystems. Heavy metals are among very stable pollutants and can not get decomposed biologically. Anderson et al [14] conduct an experiment on absorption of metals in sediments of an artificial pond in Sacramento during the years 1998-1994. In their study, Dastjerdi et al [3] state 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 [9] 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 & Menhinik richness index, Simpson & Shannon diversity index, EPT/C ratio, and Hilsenhof familial biologic indicator, water quality in these stations was investigated. Lowe et al (2000) investigated sediment pollution of Mayi-Po coastal wetland (Hong Kong). They collected samples from six stations along the wetland in February and measured several parameters of various types of heavy metals. Aminiranjbar et al [8] 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, Cr) in Anzali wetland. Manshouri [6] and Crites and Techobanoglus (1998) maintain that heavy metals are among pollutants present in the wastewater of industries, mines and factories as well as municipal and agricultural runoff. 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 [4] 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. This study aims to analyze risks associated with industrial pollutants in protected Gavkhoni wetland.

II. Material and Methods

Introducing the Study Area

Gavkhoni wetland ($15^{'}32^{o} - 22^{'}32^{o}\,N$ and $45^{'}52^{o} - 59^{'}52^{o}\,E$) is 140 kilometers southeast of Isfahan and 30 kilometers away from Varzaneh City (nearest town to the wetland) (Figure 1). It is 1,470 meters above the sea level. Its maximum width is about 50 km and its maximum length is 25 km. The water depth in most parts of 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 considerably decreases in summer due to lower inflow as well as higher evaporation rate.

Gavkhoni wetland is considered 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 degrees Celsius throughout the year, and minimum and maximum average temperature of the wetland is -6.6 and 37.4 degrees Celsius, respectively. Its temperature in 5 months of the year is above 20 degrees Celsius and in another 5 months is below 10 degrees Celsius. According to data provided by the same organization for 1987-1995 period, average annual rainfall is about 83 mm, whereas annual evaporation rate in the area is estimated at 3000 to 3200 mm.

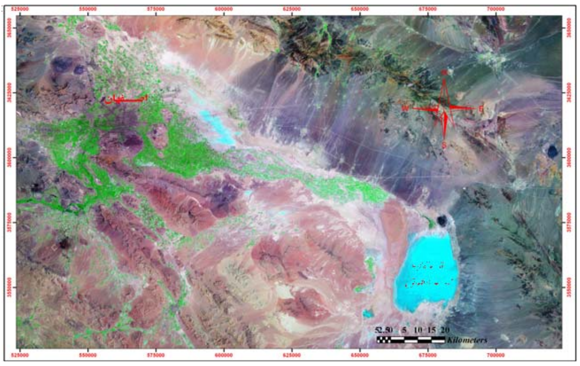

Fig. 1 Geographical location of the study area

TABLE I
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

TABLE II
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
1-1	Mineral W. M.	Acid and Alkaline	*		*	*		*	*	*	*		
1-2		Cyanide W. M.				*							
1-3		Solution and mud of heavy metals				*	*	*	*	*			
1-4		Asbestos W. M.					*	*					
1-5		Unknown solid W. M.				*		*	*				
2	Oil W. M.									*			
3-1	Organic W. M.	Consumed halogen solution						*	*	*			*
3-2		Non halogenic solution	*					*	*	*	*		
3-3		Color and resin W. M.						*	*	*	*		
3-4		Anti life W. M.	*				*	*	*	*	*		
3-5		Chemical organic matter			*	*		*					
4	Corruptible organic matter		*					*		*			
5	W. M. with high volume and low risk			*	*			*					
6-1	Miscellaneous w. m.	Infectious W. M.	*									*	
6-2		Lab W. M.						*				*	
6-3		Explicable W. M.							*				

W. M. = Waste Matter

III. Method of the Study

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, i.e. 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 1973-2006. 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

ISSN: 2517-942X
Vol:5, No:4, 2011

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 2).

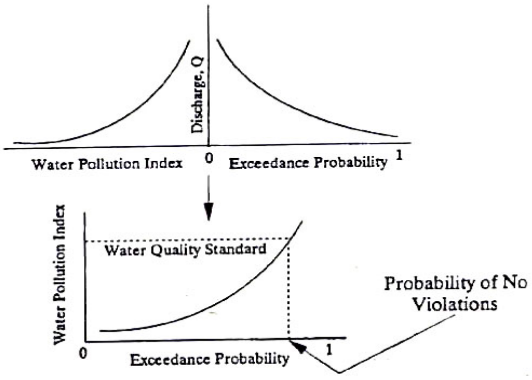

Fig. 2 Flow Duration Curve and Analyzing of Exceeding Probability and Water Quality

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.

IV. Results and Findings

In this study, Varzaneh station as 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 H1, H2 and H3 statistics. The results show that their value (H1: -0.40, H2: 0.02, H3: -0.09), especially H1 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 summarized in Table. Moreover, correlation charts of above values are shown Figures 3-7.

TABLE III
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	$Mg = -4.978Q + 143.36$

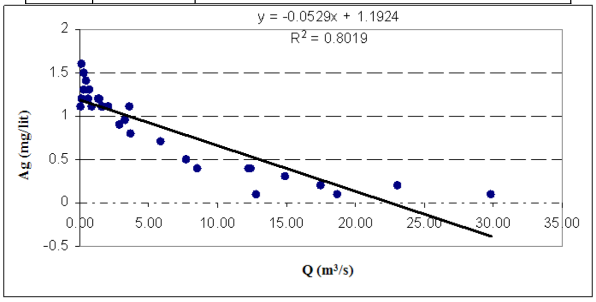

Fig. 3 Correlation Graph for Discharge-Ag Values in Varzaneh Station

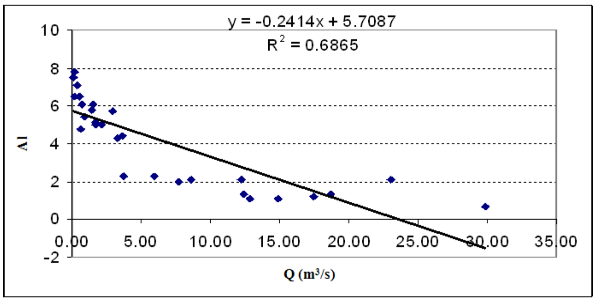

Fig. 4 Correlation Graph for Discharge-Al Values in Varzaneh Station

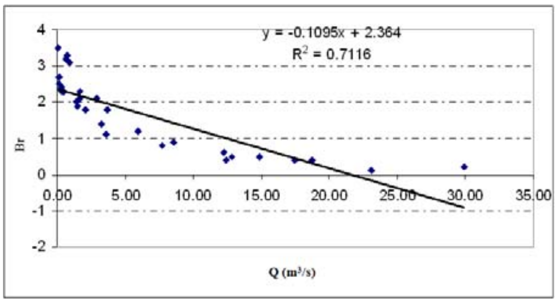

Fig. 5 Correlation Graph for Discharge-Br Values in Varzaneh Station

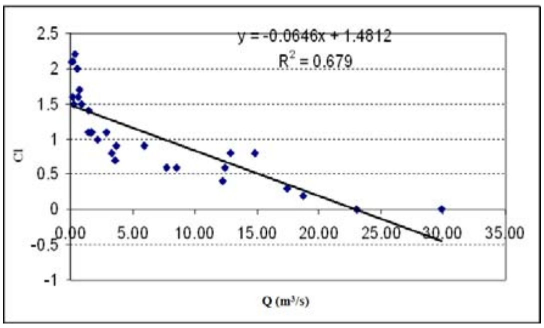

Fig. 6 Correlation Graph for Discharge-Cl Values in Varzaneh Station

International Journal of Earth, Energy and Environmental Sciences
ISSN: 2517-942X
Vol:5, No:4, 2011

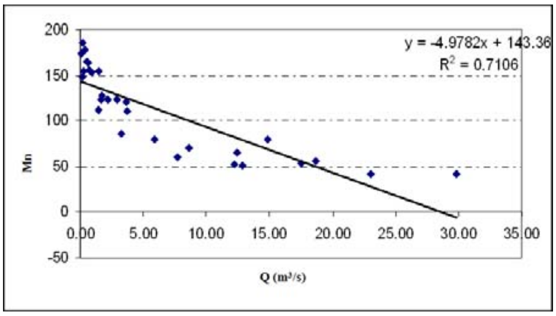

Fig. 6 Correlation Graph for Discharge-Mn Values in Varzaneh Station

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 (Figure 8). Finally, using relevant plots, $Q_{25}, Q_{50}, Q_{75}, Q_{90}$ were calculated to analyze pollutants' risks (Table IV).

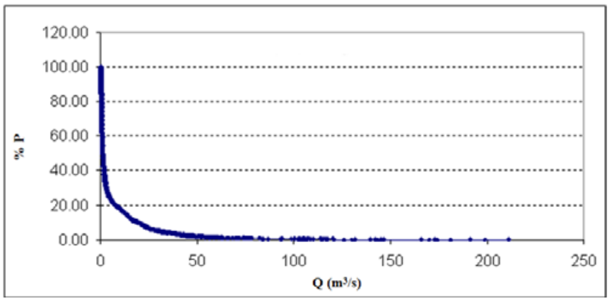

Fig. 8 Flow Duration Curve for Varzaneh Station

TABLE IV
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	

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

TABLE V
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

Finally, obtained values were compared with the standards 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 decrease. However, in Q50, Q75 and Q90, their amount exceeded standard level, 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 developed for this situation.

In order to estimate minimum flow in the region, we used the data gathered in Varzaneh station. Using 7-day mobile average and choosing minimum average level in HYFA software package, minimum flow level was determined for various return periods (Table 6).

TABLE VI
MINIMUM FLOW FOR VARIOUS RETURN PERIODS ESTIMATED USING HYFA SOFTWARE PACKAGE

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

Given that a 10 year return periods is used to choose minimum flow level in the region, 0.023 cubic meters per second was chosen as the minimum flow levele of the region. Using flow duration curve, probability percentage of exceeding was estimated at above 0.99. 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.

V. DISCUSSION AND CONCLUSION

The results show that the risk analysis of water quality in the region is of particular importance. Given the industrial areas surrounding the river, this should be considered more seriously. According to the above study, it becomes clear that 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 (i.e. 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 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 won't 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 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.

Acknowledgements

The authors would like to thank financial supports from Islamic Azad University, Ardestan branch.

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