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Pollution Load Assessment in the Soil and Water Resources: A Case Study in Karun River Drainage Basin, Southwest of Iran

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Abstract

Agricultural, industrial and urban waste discharges along with natural factors such as drought conditions are the main cause of decline in soil and water resources quality. Karun and Dez rivers, the largest drainage basin in the southwest region of Iran, are the important components in the climate system, and play a key role in human health and life of the study area. The issue has grown in importance in recent developments in sectors of agriculture, industry and urban that it has considerably affected water quality and increased contamination loads to the rivers. The aim of this paper is to determine and assess the contamination status and pollution loads to the studied rivers. The main issues addressed in this paper are pollution loads of: a) Agricultural drainage, b) urban wastewaters, and c) industrial wastewaters. A total of 284 samples consisted of 24 sources of agricultural drainages outlet, 9 sources of industrial wastewaters discharges, 38 sources of urban wastewaters discharges were collected during four times in 2013-14 in an attempt to make each season one sample. 15 physical and chemical parameters including flow rate, COD, PO_4, BOD, DO, NO_3, NH_3, TSS, pH, EC, TDS, Total Coliform, Fecal Coliform, Cl^{-1} and SO_4^{-2} were determined for each sample. Results showed that agricultural activities had the higher risk of degrading the quality of soil and water resources in Khuzestan Plain and Karun basin in salinity and increased load of soluble salts (TDS). The Agricultural drainages, with the capacity of $2{,}375\times10^6$ $m^3.yr^{-1}$, and a salt pollution load of $11{,}862\times10^3$ $kg.d^{-1}$ had the greatest contribution among pollutants. Dez River in Haft-Tapeh region with the 285×10^3 $kg.d^{-1}$ of organic pollution based on chemical oxygen demand (COD) being discharged by the sugarcane industries subsidiaries, such as KaghazPars and Harir, is considered sensitive and vulnerable regarding natural self-purification. Results show that Ahvaz, by discharging 400×10^3 $m^3.d^{-1}$ of urban wastewater to Karun River, from the gateway to the southern end of the city, is one of the major centers of organic pollution based on biochemical oxygen demand (BOD) and ammonia and microbial pollution loads.

Keywords: Karun and Dez rivers, contamination sources, pollution load, water and soil resources, Khuzestan Plain

Introduction

Soil and water are of crucial importance as the main elements in agricultural production. Therefore, any damage to them directly affects the quality and quantity of products and irreparably damages these resources (Hillel, 1997). The quality and quantity of these resources is associated with their exploitation and operation management (agricultural, urban, and industrial) (Jafarinejadi *et al*., 2010). Water consumers in agriculture sector are mainly the rural population, and due their economic and social characteristics which are based on traditional exploitation of resources, optimal water exploitation management has not progressed much in this section (Hosseini-Zare, 2004). Unfortunately, in non-agricultural purposes, the water resources exploitation system in industries and urban wastewater discharge is the same as it used to be in industrialized countries in the past

centuries (Hosseini-Zare, 2004). The pollution of soil and water resources has become a serious threat to human societies, environment, and natural ecosystems (Gyawali *et al.*, 2012). Fatouki *et al.* (2003) investigated the pollution in the Keiskamma River in South Africa. Their results showed that the discharge of wastewater of Keiskammahoek treatment plant was the most important point source of pollution load. The most important pollution loads of that river were related to salinity, nutrients, and oxygen-demanding compounds. Essien (2010) studied the pollution load of Ikpa River in Nigeria and reported that urban development of Uyo metropolitan was the major contributor to pollution of the river. It was concluded that pollution was mainly due to the discharge of leachate, urban runoff, and sewage into the river. Deng *et al.* (2010) studied the total pollution load on Yangtze River in China and examined the share of pollution load. The total pollution load of COD and ammonia nitrogen, inorganic nitrogen, and phosphate were estimated. Their results showed pollution load resulting from inorganic nitrogen and phosphate was higher than the refinement potential of the system. Mehrdadi *et al.* (2006) studied the pollutants of Tajan River in Mazandaran Province and concluded the Mazandaran Wood Industry, Paksar Dairy Industry, Antibiotic Production Industry of Sari, and Sari urban wastewater and agricultural activities were the most important pollution sources of Tajan River basin which seriously threatens water quality. Therefore, the increase of water needed in various sectors including agriculture activities and irrigation and drainage networks, shrimp and fish farms, industries, urban development, and water transfer can have huge impact on the water quality in Karun River in the future (Karamouz *et al.*, 2004). Karoon and Dez drainage basin, with an area of 21,500 square kilometers, accounts for 33.8% of the Khuzestan Province area. Suitable soil and water resources in the basin and the wide and potential range of natural resources, favorable climatic conditions, and rich oil and gas resources has led to growing development of agriculture, industry, aquaculture, population growth, and urbanization in the Karun and Dez riverbanks. This has caused various problems in most environmental aspects such as the impact on water and soil receiver resources, increased pollution, and reduced natural capacity of the environment in the studied region (Khuzestan Environmental Protection Agency, 2006). Great Karun river system consists of two major rivers of Dez and Karun and is the greatest surface water system in Iran with the average, maximum, and minimum annual discharges of 19,174, 38,323, and 7,915 MCM/year, respectively (Khuzestan Water and Power Organization, 2013). This study aimed at identifying and determining the pollution load of pollution sources in Karun and Dez basin which affect the quality of water and soil resources in Khuzestan region.

Materials and Methods

The study area included the Karun River basin from its entry point to Khuzestan plain (Gotvand) to Abadan and Khorramshahr and Dez River from its entry point to the Khuzestan plain (Dezful) to Bande-Ghir, where it joints Karun River and forms the great Karun River. Karun and Dez Rivers basin is the largest basin in the Khuzestan province in Iran located at geographical coordinates of 48° 10' to 52° 30' east longitude and 30° 20' to 34° 05' north latitude in the central Zagros Mountains. Karun basin has an area of 62,417km^2. Awareness of the present condition, determination of the main pollution sources, and specification of the hierarchical structure of qualitative variables were among the methods used in this study to determine the pollution load.

Then, the locations of the entry points of all pollutants including agricultural drainage, industrial wastewater, and urban wastewater to rivers were determined using Global Positioning System (GPS) and recorded in Excel software along with some other data. Twenty-four agricultural drainage systems, nine sources of industrial wastewater, and thirty-eight sources of urban wastewater located on routes of Karun and Dez rivers, including the cities of Dezful, Gotvand,

Shooshtar, Ahvaz, Khorramshahr, Abadan, Veis, and Mollasani, were identified. Sampling was conducted in the 2013-2014 water year. Figure 1 shows the sampling locations. Molinet (or volume measurement) was used for determining the discharge rate. Seventy-one samples were collected at each sampling amounting to 284 samples of pollution sources in four seasons. Samples were transported to the laboratory and were prepared. Qualitative variables, such as biochemical oxygen demand (BOD) and chemical oxygen demand (COD) were determined as an indicator parameters for pollution load of organic materials. Qualitative variables such as total dissolved solids (TDS), Cl^-, SO_4^{-2}, and TSS were determined as characteristics indicators of soluble and insoluble solids. The qualitative variables of nitrate (NO_3^-) and phosphate (PO_4^{-3}) were also determined as characteristics indicator of the pollution load of nutrients. Then, the indicator parameters of pollution load were measured. All steps including sampling, stabilization and transport of samples to the laboratory and the testing methods were all according to Standard Methods for the Examination of Water and Wastewater, 22nd Edition (2012). Contribution of pollution sources and prioritization of the various agricultural, urban, and industrial pollution sources in pollution load entering the river, was calculated by using SPSS20 and EXCELL based on the qualitative and quantitative obtained results of indicator parameters.

Results and Discussion

Results of descriptive statistics of parameters for using calculations of the pollution load for various pollution sources were determined (Table 1). The results of the pollution load and the degree of importance of soil and water pollution sources of Karun and Dez rivers basin in terms of pollution load by indicator parameters is shown in Table 2.

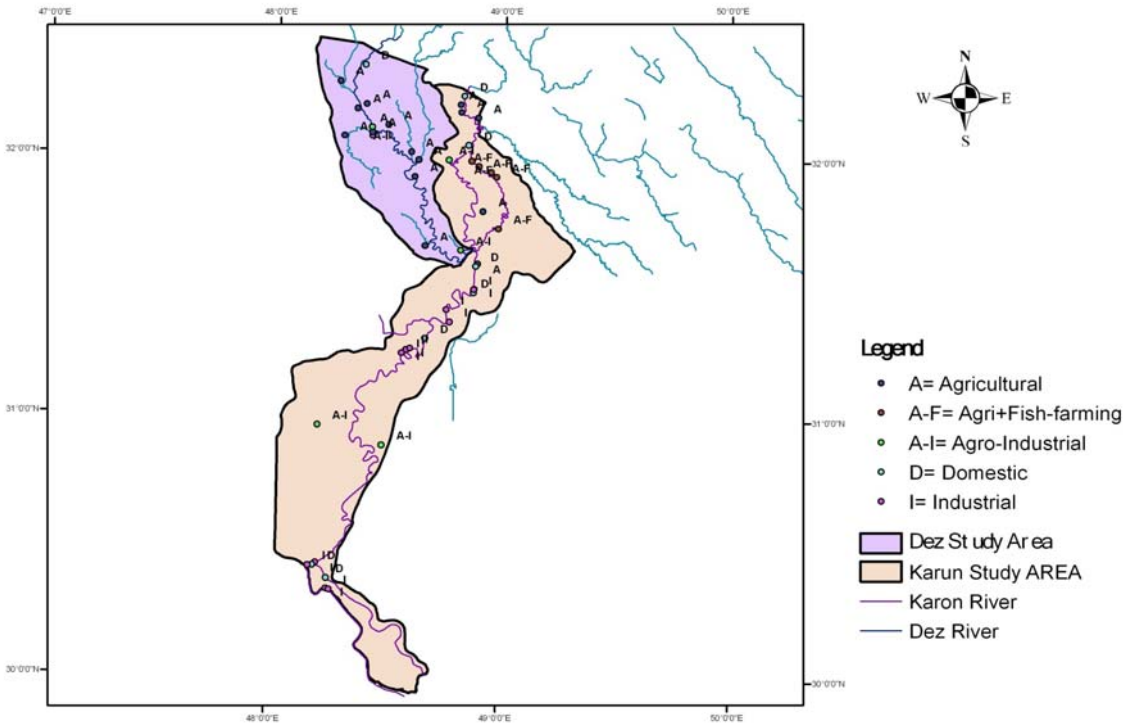

Figure 1. Location of the study area and pollution sources

Table 1. Statistical characteristics of pollution load indicators of pollution sources entering Karun and Dez rivers in four seasons of 2013-2014 water year

Pollution Sources		TDS	EC	pH	TSS	NO_3	PO_4	DO	BOD	COD	Total coliform	Fecal coliform	NH_3
		ppm	µmho/cm	-	ppm	ppm	ppm	ppm	ppm	ppm	NO/100 ml	NO/100 ml	ppm
Agricultural Drainage	Count	24	24	24	24	24	24	24	24	24	24	24	24
	Mean	2221	3263	7.7	59	7.6	0.05	6.8	5.19	32.04	43115	16079	0.73
	Min	451	711	7.3	20	1.27	0.005	3.6	2.14	14.7	8650	2200	0.25
	Max	4882	6540	8.1	180	16.05	0.41	10.2	21.2	115	110000	56150	2.5
	SD	1465	2050	0.19	42.8	3.47	0.085	1.88	3.93	19.33	31348	14746	0.46
Industrial Waste water	Count	9	9	9	9	9	9	9	9	9	9	9	9
	Mean	2169	3389	7.7	269	10.04	0.27	3.48	59.61	407	85222	31633	0.95
	Min	910	1297	6.9	40	3.47	0.01	0.20	21	68	15000	2000	0.25
	Max	3740	5750	8.5	1440	26.10	0.78	7.30	169	2200	110000	110000	1.5
	SD	850	1325	0.44	447	7.30	0.27	2.68	47.24	682	38228	33535	0.35
Urban Waste water	Count	36	36	36	36	36	36	36	36	36	36	36	36
	Mean	2107	3291	7.8	255	8	5.1	0	86	209	45×10^6	28×10^6	21.9
	Min	630	981	6.9	24	3.72	1.5	0	29	66	2×10^6	0.25×10^6	5
	Max	4090	6390	8.4	593	19.07	8.5	0	205	509	500×10^6	319×10^6	41.3
	SD	1011	1581	0.45	103	2.9	2.4	0	40	104	95×10^6	64×10^6	10.25

Table 2. Pollution load of pollution sources and their priority in polluting (discharge is in m^3/sec, and the indicators are in Tons/day)

Pollution Sources	Discharge Rate			TDS			BOD			COD			NO3			NH3		
	m^3/sec	%	Rank	Tons/day	%	Rank	Tons/day	%	Rank	Tons/day	%	Rank	Tons/day	%	Rank	Tons/day	%	Rank
Agricultural	75.3	87.3	1	11862	84.3	1	29.7	26.7	2	211	32.6	2	65.51	87	1	4.8	23.6	2
Urban	7.9	9.21	2	1638	11.6	2	53.51	48.2	1	130	20.1	3	5.08	6.75	2	15.25	75	1
Industrial	3.03	3.5	3	569	4	3	27.82	25	3	306.6	47.3	1	4.65	6.2	3	0.25	1.2	3
Total	86.23	100	-	14070	100	-	111	100	-	647.9	100	-	75.24	100	-	20.3	100	-

Table 2. (Continued) Pollution load of pollution sources and their priority in polluting (Discharge is in m^3/sec and the indicators are in Tons/day)

Pollution Sources	PO_4			Cl			TSS			SO_4		
	Tons/ day	%	Rank	Tons/ day	%	Rank	Tons/ day	%	Rank	Tons/ day	%	Rank
Agricultural	0.28	9.9	2	2654	80	1	342	47.5	1	4722	89.4	1
Urban	2.5	88.34	1	537.7	16.2	2	178	24.7	3	424	8	2
Industrial	0.05	1.76	3	123.4	3.72	3	199	27.7	2	134.5	2.55	3
Total	2.83	100	-	3315	100	-	719	100	-	5280	100	-

Assessment of Pollution Load of Agricultural Drainages

Results showed that from 86.23 m^3/sec pollutants discharge entering Great Karun system (Karun and Dez Rivers) before Ahvaz region, 75.3 m^3/sec (87.3 %) was related to agricultural drainages. Also, the results revealed that the most important problem of agricultural drainages was their salinity. The total pollution load entering Karun and Dez rivers due to different agricultural, industrial, and urban pollution sources is presented in Table 2. Accordingly, from a total of 14,070 tons/day minerals and inorganic compounds (TDS) pollution load discharged into water sources of Karun and Dez Rivers, 11862.5 tons/day (84.3 %) was due to agricultural drainages. According to calculations of the pollution load, agricultural pollutants accounted for 211.16 tons/day (32.6 %) of organic matter on the basis of COD (chemical oxygen demand) of the total of 647.92 tons/day entering Karun and Dez rivers. In this regard, agricultural pollutants ranked second after industries. Agricultural drainages accounted for 29.7 tons/day (26.75 %) of organic matter on the basis of BOD (biochemical oxygen demand) of the total of 111 tons/day entering Karun and Dez rivers. Agricultural drainages ranked second in this regard. With regards to of chlorides (2,654 tons/day), sulfates (4,722 tons/day) and nitrate (65.51 tons/day), agricultural drainages were the largest contributor of the pollution load entering the river, and since they have a significant discharge rate, pollution load due to agricultural drainages is very important. Afkhami (2004), Karamouz (2005), and Hosseini-Zare (2002) studied the pollution sources and their pollution load in Karun and Dez rivers basin and estimated that the contribution of agricultural drainages in pollution load of dissolved solids (TDS) and organic load based on BOD and COD as 70, 19 and 23.5 percent, respectively. Due to the significant development of agricultural and aquaculture activities and particularly the implementation and operation of the seven sugarcane industries development plans in northern and southern Ahvaz in the vicinity of Karun and Dez Rivers basin, the increased contribution and role of agricultural pollution sources in mineral and organic pollution load discharging into the river during this study compared to other is quite predictable.

Assessment of Pollution Load of Urban Wastewater

Results of inorganic and organic compounds pollution load and other indicators of urban wastewater pollution and their comparison with agricultural drainages is shown in Table 2. Results

showed that the discharge rate of urban wastewater was 7.90 cubic meters per second and constituted 9.2% of the total 86.23 cubic meters per second measured discharge rate. Urban wastewater ranked second after agricultural drainage in this regard. Table 2 also shows that from a total of 111 ton per day of organic pollution load in terms of biochemical oxygen demand (BOD) entering Karun and Dez Rivers, 53.51 ton per day (48.20 %) was due to urban wastewater. The share of agricultural drainages and industrial wastewaters was 29.7 and 27.82 ton per day of organic pollution based on BOD. Results also showed that from a total of 647.92 ton per day of pollution load based on COD, 130.14 ton per day (20 %) belonged to the urban wastewater. In the case of agricultural drainages and industrial wastewaters, 306 and 211 ton per day, respectively, were estimated based on COD. The pollution load of industrial organic compounds was mainly related to the sugarcane-related industries such as paper mill and Silk companies located in Haft-Tapeh region. Regarding the pollution load of dissolved salts, the total amount of dissolved solids (TDS) was calculated as 14,070 tons/day, and the share of urban wastewaters was calculated as 1638.5 tons/day (11.6 %). Another issue is the ammonia pollution load. From 20.3 tons/day ammonia pollution load, 15.25 tons/day (75 %) was due to urban wastewater. By comparing the results in Table 2, which is about to the final results of pollution load calculations, it was found that although the concentration of COD and nitrate was higher in urban wastewater compared to agricultural drainages, the pollution load discharges into the river by agricultural drainages was respectively 1.62 and 12.9 times higher than the urban wastewaters. This was due to very high discharge rate of agricultural drainages compared to urban wastewaters. Regarding organic compounds based on BOD, as shown in Table 2, the BOD levels of urban wastewaters was nearly twice the BOD levels of agricultural drainages. This indicates that microbial decomposition organic matter in urban wastewaters was higher compared to agricultural drainages, and if a considerable volume of urban wastewaters, such as urban wastewaters of Ahvaz, enters river, their oxygen demand would be much higher, which reduces water oxygen content more easily. Most organic materials in agricultural drainages are mainly byproducts of sugarcane industries and made of cellulose and are resistant to microbial decomposition (sugar cane wastes). These material can be transported to the extremes of river and be a source of organic material based on COD. Regarding control and prioritization of urban wastewater treatment, it can be said that according to the results, as Ahvaz is the capital of the province and is highly-populated, and with urban wastewater is directly discharged into the river by the rate of 400,000 cubic meters per day from the gateway of Ahvaz to the southern end of Ahvaz, Ahvaz was identified as a major centers of organic, microbial, ammonia material pollution load. The results of the present study is in agreement with studies conducted by the Environmental Department of Khuzestan (2002), Dezab Consulting Engineers (2001), and Hosseini-Zare (2002), which estimated 10.7%, 33%, and 14% share for TDS, BOD, and COD pollution load for urban wastewaters, respectively.

Assessment of Pollution Load of Industrial Wastewaters

Khuzestan is an agricultural production hub and is also considered an industrial hub due to existence of large oil, gas, steel, carbon, petrochemicals, and electronics as well as many small industries. Today's oil industry, with the development of the oil fields and discoveries and excavations, have affected international Shadegan and Hour-al-Azim wetlands, in addition to water resources and dam reservoirs and agricultural land of Karun and Dez rivers basin and the heart of the cities, by oil pollution caused by its activities. In recent decades, we have frequently witnessed failure and rupture in oil pipelines and oil spill pollution of soil and water resources in basin of Khuzestan Rivers. In addition to the aforementioned issues, a reality we have witnessed in recent

years is that due to numerous economical and labor-related problems, and particularly problems caused by sanctions, many industries are closed and other or semi-closed. According to authorities, many industries are operating with 40 % capacity, for instance, Khuzestan Pipe Co, Ahvaz Sepanta Co., Ahvaz Sugar Refinement, Ahvaz Khorramnoush, Pasargad Chemical, Abadan Dairy Co., Soap factory. Yas Khorramshahr Co., Khorramnoush Khorramshahr Co., Dezful Sugar Co. This issue has led to unemployment in Khuzestan province. Unemployment and the necessity to earn a living has caused many to turn to agricultural and aquaculture activities regardless of economic development capacity of Khuzestan. They have exploited water either by legal permits or illegally which make quality of water and soil resources face serious challenges in short-term and long-term. It has to be noted that sanctions and encouraging non-oil exports, including agricultural products with the goal of self-sufficiency and foreign exchange and overcoming sanctions have made additional pressure on water and soil resources, which has deteriorated the quality and increased soluble salts and pollution in the base resources. Results showed that industries related to the sugarcane industry, due to the cellulose nature of their materials, and related industries such as paper mill and Silk companies located in Haft-Tapeh area, with significant organic pollution load of BOD (21.9 tons/day) and COD (285 tons/day), had the greatest effect on the quality of water, and consequently, soil resources.

Conclusion

The important factors that destroy the quality of soil and water resources and increase the pollution load entering Karun and Dez rivers can be summarized as follows: Human factors including development in various aspects, such as increasing population, urbanization, development of economic sectors, including agriculture and aquaculture, industrial and issues of inter-basin water transfer, problems caused by the sanctions, including bankruptcy and closure of many industries and rising unemployment rate, and thus, many activities of unemployed people in agriculture and aquaculture, along with natural factors such as climate and climate change and reduced precipitation and consequently reduced runoffs and incidence of droughts. However, human factors, including soil and water resources management, are the most prominent causes of the current situation. Results showed that the major problem of soil and water resources in the Great Karun basin in Khuzestan Plain is caused by the minerals and soluble salts resulted from agricultural activities and the vast areas of cultivation. The discharge of drainage water to River systems is a common practice in Iran. This practice seriously decreases the quality of irrigation water to be used by the farmers at the lower reaches of the river system. Agricultural drainages belonging to the sugarcane industry located northern and southern Khuzestan is about 110,000 hectares. These Agricultural drainages with the Seasonal and high water consumption cultivation, such as the cultivation of paddy in Karun and Dez rivers basin, and the development of aquaculture were the main sources of water and soil pollution resources in the studied area. Dez River in the Haft-Tappeh region is a considered vulnerable and susceptible area regarding natural assimilative aspect due to organic pollution load discharged by sugarcane industries and the related industries, such as paper mill and Silk companies based on biochemical oxygen demand (BOD) and chemical oxygen demand (COD). Results also showed that Ahvaz, as a highly-populated capital of the province, due to discharge of urban wastewaters from the gateway of Ahvaz to the southern end of Ahvaz, is one of the major sources of organic pollution load based on biochemical oxygen demand (BOD) and microbial and ammonia pollution load. There was a clear trend of water quality deterioration as the water moved from upstream to downstream areas. The water quality at the upstream was found to be good with salinity levels in the range of 0.500 to 0.650 dsm^{-1}. The water quality gradually deteriorated in Khuzestan

Plain as a consequence of the confluence of pollution resources. The water quality at the lower reaches of the river system deteriorated to the extent that the salinity levels of river water reached between 2.5 to 6 dsm^{-1}. The water quality deterioration had a major effect on the development of salinity and sodicity in the irrigated land located in the lower reaches of the basin.

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