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Evaluation of Karun River Water Quality Scenarios Using Simulation Model Results

Mohammad Bagherian Marzouni [a*], Ali Mohammad Akhoundali[b], Hadi Moazed[c], Nematollah Jaafarzadeh[d,e], Javad Ahadian[f], Houshang Hasoonizadeh[g]

a Master Science of Civil & Environmental Eng, Faculty of Water Science Eng, Shahid Chamran University Of Ahwaz
b Alimohammad Akhoondali, Professor of Water Eng, Faculty of Water Science Eng, Shahid Chamran University Of Ahwaz
c Professor of Civil & Environmental Eng, Faculty of Water Science Eng, Shahid Chamran University Of Ahwaz
d Environmental Technology Research Center, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran
e School of Health, Ahvaz Jundishapur University of Medical Sciences, Ahvaz, Iran.
f Assistant Professor of Water Eng, Faculty of Water Science Eng, Shahid Chamran University Of Ahwaz
g Vice Basic Studies and Comprehensive Plans for Water Resources. Khuzestan Water and Power Authority.
[*]Corresponding author: *m-marzouni@mscstu.scu.ac.ir*

ABSTRACT

Karun River is the largest and most watery river in Iran. This river is the longest river which located just inside Iran and Ahvaz Metropolis drinking water supplied from Karun River as well (fa.alalam.ir). Karun River as the main source of water treatment plants in Ahvaz, like most surface waters affected by various contaminants which caused changes in water quality of the river (www.aww.co.ir). Causes such as constructing several dams at upstream river, withdrawal of water from the upstream to the needs of other regions of Iran, exposure of various industries along the river and discharge of industrial and urban sewage into the river, seen that today this river is deteriorating rapidly, qua today is the depth of river reach to 1 m with a high concentration of pollutants (www.tasnimnews.com). In this study, considering the quality parameters, by using the QUAL2K model and with regard to water quality standards of defined classification, we defined various scenarios. Then two parameters, BOD and DO were chosen as indicator parameters for assessing these scenarios. Model was calibrated to data from spring 2012 and validation was performed by winter and spring 2013. Then the model was used to take management decisions for critical situation. The results showed that by changing in location of entry pollutant in the river we achieved water environmental goals. This scenario is also useful for future that flow of river reduced.

Key words: Karun River, Management Scenario, QUAL2K Model, Water Quality, Simulation

1. Introduction

Environmental control costs rise constantly and environmental effects arising from errors in judgment is very widespread. Accordingly, environmental quality management, must be equipped with effective and powerful tools. These tools should be based on a true understanding of the features and determined by specifications of controlled environment. Catchment planning requires a range of analytical techniques that assess the current state of the environment and also provide estimation of various strategies to control contaminants. As part of environmental research on the occurrence, movement, transformation, impact and pollution control, Technology Development and Applications Branch in Environmental Protection Agency of United States developed management or engineering tools to control pollution and help to improve water quality goals (L. Bowie et al, 1985).

Effluent discharge into acceptor sources around the world, create a variety of environmental disasters and causing environmental protection organizations in the world to protect water quality and aquatic life, developed and implemented the standards for effluent discharge into acceptor resources.

Increase the amount of wastewater, improvement in treatment technology and environmental problems caused by the discharge of sewage into acceptor sources, caused that quality standards of acceptor sources were seriously considered. In these standards, the discharge of effluent should not reduce the quality of acceptor sources. To assess the effects of effluent discharge on acceptor sources, the assimilative capacity studies should be conducted. To determine the assimilative capacity, a series of these tools such as water quality models are needed to predict water quality in different situations.

The rational use of water resources has become a very important national policy issue in recent years and great efforts have been made to develop water environmental management strategies to ensure good water quality and sufficient water supply. In this respect, water quality modeling is increasingly recognized as an effective tool for water quality management decision-making (Zhang et al. 2012).

Mathematical models was so widely used to simulate ecological and water quality responses in the surface water resource, and simulation methods give us appropriate and effective policy to assess the methods of reducing pollution.

In recent decades, many water quality models have been developed for surface water bodies. For example, Zhang et al. (2012) investigated the quality of the Taihu Lake Basin using QUAL2K model and concluded that the water quality of this lake is caused by discharge of wastewater and effluent in Hongqi River that flows finally in Taihu Lake. Kannel et al. (2007) in the study, evaluated and explain the situation of Bagmati River and monitored those contaminants that reduce water quality and decrease in DO concentrations along its course. The Qual2k model was applied to simulate various water quality management strategies during critical period to maintain the targeted water quality criteria. Bottino et al. (2010) have study with the goal of evaluating the water quality of Canha River micro watershed. In this study five variables of water quality were analyzed in eight sampling stations from September, 2006 to July, 2007. Finally, they concluded watershed characteristics, as high slope, for example, were essential mainly to dissolved oxygen concentrations and even though QUAL2K has some limitations, its use is recommended for water resources management and future purposes. Camargo et al. (2010) used QUAL2Kw model in small Karstic watershed in Brazil to predict water quality. In this investigation, the model adequately represented the physical, chemical, and hydraulic aspects of the Fidalgo watershed [20]. Sakian D. (2006) in the study, investigate the role of Karun and Dez Dams on Karun river management. He used Qual2k model to calculate water need for dilution of pollutants to reach the water quality standard.

2. Material and Methods

2.1. Study Area

The Karun River basin is the largest river basin in Iran which is situated in south west of the country. Karun River originated from Zagros mountain ranges and passing through Khuzestan plain and finally reaches to the Persian Gulf. Several cities are situated along Karun River pass and the most important is Ahvaz, the center of Khuzestan province (Afkhami et al, 2007).

Karun River is one the largest rivers in Iran that collect and drain a huge amount of water of its catchment and transfer it in to the Persian Gulf. Karun River along its meandering path, in north of Gotvand and in 25 Km of north of Shushtar reaches Khuzestan plain. Karun River after joining to Dez River in the site called Bandqyr and through its Continuation path, passed Ahvaz city and passing about 190 km of its course, nearby Bahmanshir divides into two branches and eventually empties into the Persian Gulf.

In the past decades had witnessed that Karun River was the passage of the ships and river water quality and quantity was too high. But gradually, with the development of industry, agriculture, expanding urbanization around the river, discharge of various pollutants in the river, especially withdraw and intake of water in upstream of the river for drinking consumption in other cities and vivification and reclamation of other region by the water of this river, the depth and quality of water had been declined dramatically (www.farsnews.com). In recent years, with the pursuit of environmental protection authority, some industrial wastewater and effluent, changed their path and empty into some source except Karun River. Ahvaz slaughterhouse can be mentioned as one of these industries, but the situation of the river remains so dire and tragic. Ahwazi people when open the tap, faced muddy and sometimes fetid water with the smell of sewage, that is not only drinkable, but it is not usable too. According to health experts, in summer by warming the air and evaporation of river water, the smell of sewage into rivers doubled which endangers the health of citizens (www.mehrnews.com).

Karun River flow from 20 years ago reduced to fifth and there is no hope that the water level could be higher than what is seen today. In some areas, the river depth is 20 to 30 cm. Strong smell of sewage in some parts of the city makes living conditions for citizen so hard. It is expected that by continuing of dam construction in future, there will be only sewage in this river.

At This time that the author is engaged to preparation of this paper, Ahwaz citizens with the aim of supporting the preservation of the ecosystem of the river, have formed a human chain along the river (www.baharnews.ir).

Ahvaz, Abadan and Khorramshahr and Shushtar are the major sources of pollution of Karun River. In the meantime, Ahvaz metropolis due to having the largest and increasing population enter pollution into the river more than other cities that almost half of the incoming pollution is from Ahwaz metropolis, including domestic, urban and hospital sewage (www.entekhab.ir).

The study object included about 115 km of the Karun River that covers the city of Ahwaz (Capital of Khuzestan Province). Figure 1 shows the study area with water treatment plant and monitoring stations that administered by Khuzestan Water and Power Authority.

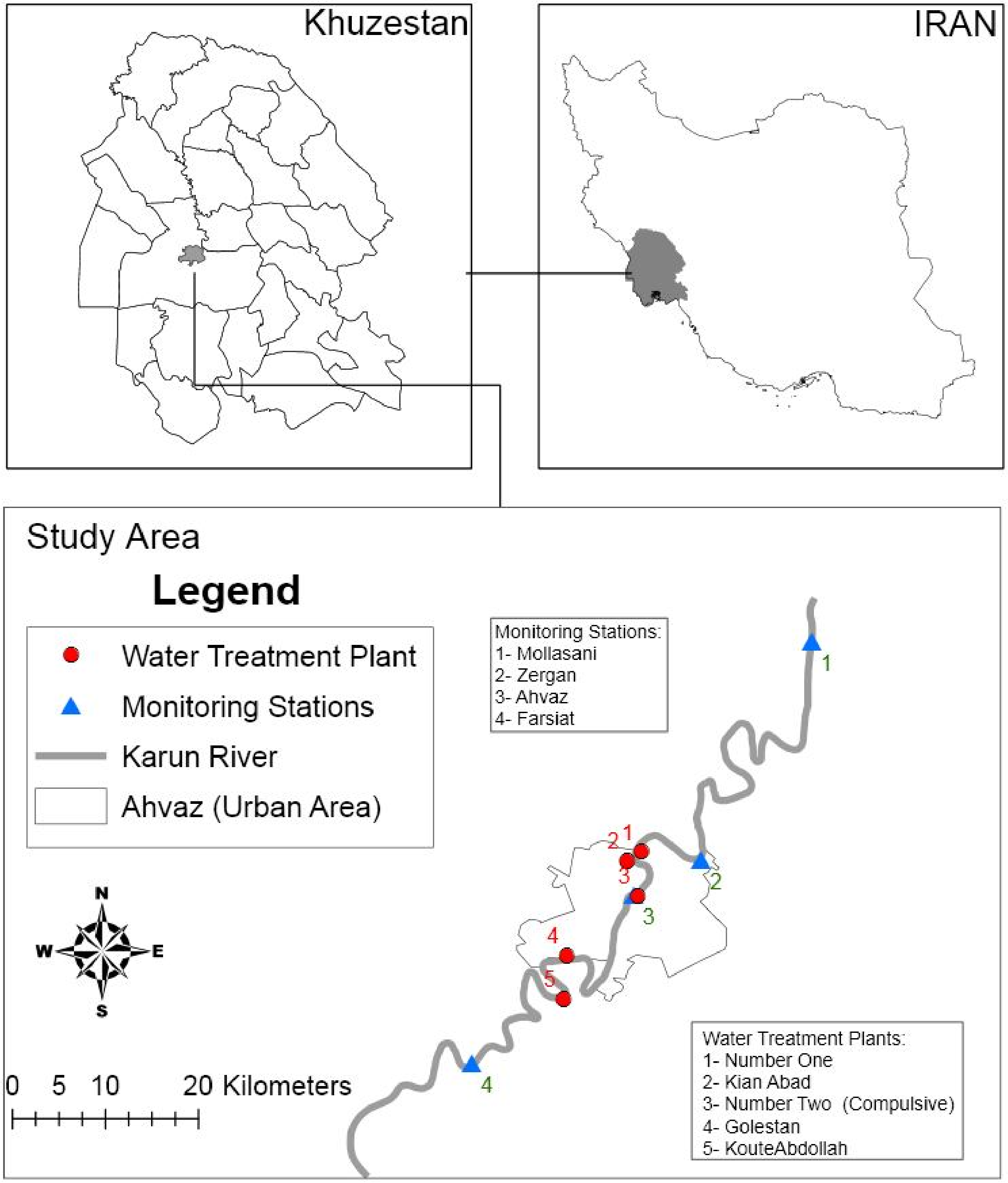

Figure 1. Study area, monitoring stations and water treatment plants.

2.2. Monitoring Sites and Data

In this paper we focus on particular region that include Ahvaz urban area. Ahvaz as a capital of Khuzestan province and one of important industrial and polluted city in Iran has always been noteworthy.

Among various sources of pollutants, the focus was on the pollutants from urban wastewater that directly empty to Karun River.

Table 1 shows Monitoring data that used for calibration and validation. Table 2 shows headwater flow. In this study the data from spring 2012 used for calibration and data from winter and spring 2013 used for first and second order validation. Water quality parameters which used in this study include: dissolved oxygen (DO), and 5 days biochemical oxygen demand (BOD).

Table 1. Karun River monitoring stations and water quality monitoring data.

Station	Mollasani	Zergan	Ahvaz	Farsiat
Distance (Km)	0	49	62	115
Date		3/20/2012		
BOD (mg/L)	2.14	3.74	3.58	3.4
DO (mg/L)	7.14	7.4	6.75	6.6
Date		4/29/2012		
BOD (mg/L)	2.86	3.32	3.5	3
DO (mg/L)	6.84	6.7	7.1	7.2
Date		5/22/2012		
BOD (mg/L)	4.32	3.72	3.76	3.42
DO (mg/L)	7.74	6.56	6.4	6.7
Date		2/23/2013		
BOD (mg/L)	4.06	3.66	4.6	3.62
DO (mg/L)	8.4	8	7.8	5.82
Date		5/28/2013		
BOD (mg/L)	3.38	2.8	4.2	1.9
DO (mg/L)	6.22	7.6	8.3	8.5

Table 2. Karun River headwater flow.

Date	3/20/2012	4/29/2012	5/22/2012	2/23/2013	5/28/2013
Flow	255	248	245	208	166

The monitoring stations (Fig. 1) taken for this study covered four stations (Mollasani, Zergan, Ahvaz, Farsiat respectively from upstream to downstream) along the river which monitored annually by Khuzestan Water and Power Authority. For DO and BOD permissible discharge in surface water are 2 mg/L, 50 mg/L, respectively according to “Environmental Criteria of Treated Waste Water and Return Flow Reuse, No. 535”. Table 3 shows point sources discharging in Karun River. These data provided from Khuzestan Water and Power Authority and Ahvaz Environmental Protection Agency laboratory, hospitals and industries self-reporting reports (self-expression reports) that reported monthly to Khuzestan Environmental Protection Agency.

Table 3. Flow and point sources pollution concentration

Name	Location (km)	Flow (m3/s)	DO (mg/L)	BOD (mg/L)
Mollasani	0.5	0.15	-	238.5
Ramin Power Plant (1)	6	0.43	5.4	29
Ramin Power Plant (2)	8.7	0.4	4.4	34
Veys	9.1	0.1	-	254.5
Loveymi	34.4	0.1	-	222.7
Loveymi (2)	38	0.5	-	150
Zergan Power Plant Effluent	43.6	0.24	-	7.6
Zergan WasteWater (1)	48.1	0.2	-	189.8
Zergan WasteWater (2)	48.5	0.065	-	284.1
Daghagheleh	53.1	0.05	-	57.6
Laleh Park	55.6	0.45	-	185.7
Abouzar Hospital	60.2	0.0058	-	70
Blach Bridge (1)	62	0.58	-	141.2
Blach Bridge (2)	62.3	0.35	-	183.8
Emam Hospital	62.6	0.0058	-	40
Mehr Hospital	62.6	0.0116	-	56
Mehr Avenue	62.8	0.52	-	94.5
8th Bridge	63	0.95	-	162.8
AlZahra Hospital	63.4	0.007	-	60
5th Bridge	64	0.45	-	166.1
Riparian Park - 9th Avenue	64.5	0.27	-	187
Riparian Park - 5th Avenue	65	0.23	-	173.3
Arvand Hospital	65.4	0.0058	-	32
Arya Hospital	65.4	0.0048	-	61
Golestan Hospital	66	0.03	-	33
Golestan Hospital (Shafa)	66.8	0.032	-	26
Boustan Hospital	67.2	0.0058	-	24
Sina Hospital	68.8	0.0116	-	41
Wastewater Treatment Plant	80.4	0.38	2.9	27
Ahwaz Rolling & Pipe Mills Co	82.5	0.15	1	69
Shahid Baghaei Hospital	82.5	0.007	-	24
Iran National Steel Industrial Group	82.5	0.12	5	52
Kaavian Steel Company	82.5	0.35	5	25

2.3. Surface Water Classification and Criteria

Surface Water Classifications are designations applied to surface water bodies, such as streams, rivers and lakes, which define the best uses to be protected within these waters (for example irrigation, drinking water supply, fishing, etc.) (http://portal.ncdenr.org/). Because Pakistan and Iran are neighbors and Iran has no surface water quality criteria, we used "National Surface Water Classification Criteria and Irrigation Water Quality Guidelines for Pakistan" for this study. This surface water classification that is proposed by WWF-Pakistan[1] has stringent criteria for drinking water class, compared to the same drinking water classes. WWF - Pakistan process for developing surface water classifications started with literature review and secondary research on surface water classification criteria & irrigation water quality guidelines that have been developed and are being followed throughout the world with a focus on developing/South Asian countries (National Surface Water Classification Criteria for Pakistan. 2007).

In this study our aim is to achieve “Class A” quality criteria. This class defined for sources of water supply that will require complete treatment (coagulation, sedimentation, filtration and disinfection etc.) for uses of water treatment plant as raw water. For DO we used class C criteria (Propagation of Fish and aquatic Life) to protect aquatic life simultaneously. The criterion for DO and BOD is 3 and 5 respectively.

2.4. QUAL2K Model

In recent decades, many water quality models have been developed for various types of water bodies (Zhang et al. 2012). Qual2k application is software for surface water quality modeling in order to find the optimal values of the coefficients and constants used in environmental projects. This model simulate river as one dimension non-uniform steady state flow and it can consider pollution loading as point and non-point source (Guideline Manual For Assimilative Capacity Studies in Rivers, No: 481. 2009).

QUAL2K is released by USEPA (United States Environmental Protection Agency, 2007) and freely available at (http://www.ecy.wa.gov/). QUAL2K has many advantages versus other models; it is useful in data limited conditions, is freely available and are not reserved for large rivers (i.e. deep and wide) (Bottino et al. 2010). Although Qual2k is one dimensional model, but use of this model for moderate management objective is useful.

In modeling activities, relations corresponding to the process are combined to determine relationship between the pollutants loading in the river and water quality changes. Therefore, in each model, factors that influencing the elimination or reduction of contaminants should be evaluated (Guideline Manual for Assimilative Capacity Studies in Rivers, No: 481. 2009). Water quality management strategy involves a series of complex interdisciplinary decisions based on reciprocation responses of water quality by changing controls (Kannel et al. 2007). So, according to the above-mentioned cases, processes that considered in the model, briefly described.

For all but the bottom algae variables, a general mass balance (figure 2) for a constituent in an element is written as (Chapra et al, 2008):

$$\frac{dc_i}{d_t} = \frac{Q_{i-1}}{V_i} c_{i-1} - \frac{Q_i}{V_i} c_i - \frac{Q_{out,i}}{V_i} c_i + \frac{E'_{i-1}}{V_i}(C_{i-1} - C_i) + \frac{E'_i}{V_i}(C_{i+1} - C_i) + \frac{W_i}{V_i} + S_i \qquad (1)$$

In the above formula, c_i, Q_i, V_i, E'_i, and W_i symbolize the component concentration of water quality, flow, volume, dispersion coefficient, and outer component load of reach i, respectively.

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[1]- WWF (World Wide Fund) is a global environmental conservation organization that aims to conserve nature and ecological processes by preserving genetic, species and ecosystem diversity, ensuring that the use of renewable natural resources is sustainable both now and in the longer term and promoting actions, to reduce pollution and wasteful exploitation and consumption of resources and energy.

S_i symbolizes the sinks and sources of the component due to a large number of transformation mechanisms and reactions in reach i. $Q_{out,i}$ symbolizes flow abstraction from reach i.

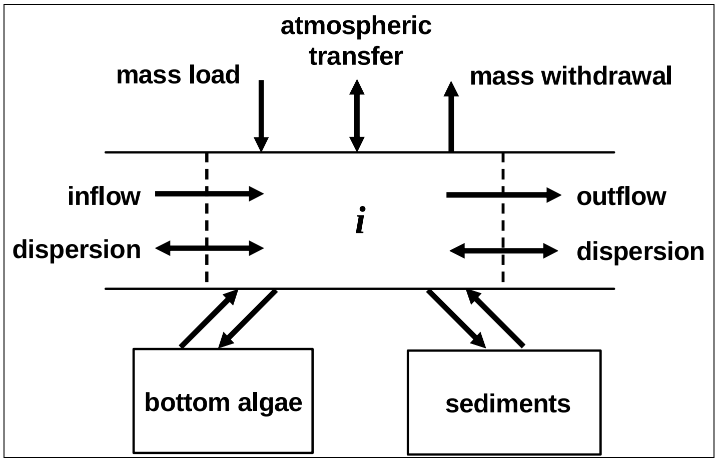

Figure 2. Mass balance for relevant components of the river system in reach i (Chapra et al, 2008).

The sources and sinks for the state variables are depicted in figure 3.

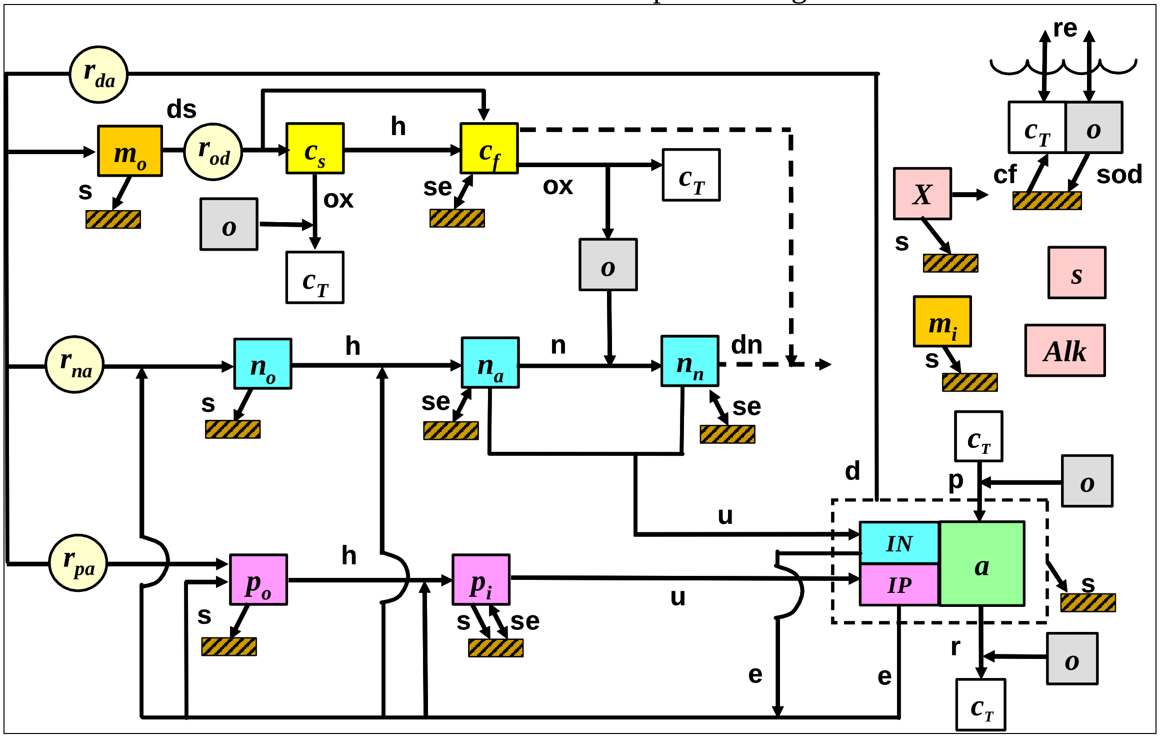

Figure 3. Model kinetics and mass transfer processes (Chapra et al, 2008).

The symbols that used in figure 3 are described as follows and the state variables are defined in Table 4. Note that for calibration and sensitivity analysis, understanding and realization of these mathematical formulas is required. These equations produced based on processes that occurred in the river ecosystem (figure 3). So, knowing these equations helps us to define strategies to improve water quality conditions. Kinetic and mass transfer processes listed in table 5 (Chapra et al, 2008).

Table 4. Model state variables (Chapra et al, 2008)

Variable	Symbol	Units	Variable	Symbol	Units
Conductivity	s	mmhos	Phytoplankton	a_p	mgA/L
Inorganic suspended solids	m_i	mgD/L	Phytoplankton nitrogen	IN_p	mgN/L
Dissolved oxygen	o	mgO_2/L	Phytoplankton phosphorus	IP_p	mgP/L
Slowly reacting CBOD	c_s	mgO_2/L	Detritus	m_o	mgD/L
Fast reacting CBOD	c_f	mgO_2/L	Pathogen	X	cfu/100 mL
Organic nitrogen	n_o	mgN/L	Alkalinity	Alk	$mgCaCO_3/L$
Ammonia nitrogen	n_a	mgN/L	Total inorganic carbon	c_T	mole/L
Nitrate nitrogen	n_n	mgN/L	Bottom algae biomass	a_b	mgA/m^2
Organic phosphorus	p_o	mgP/L	Bottom algae nitrogen	IN_b	mgN/m^2
Inorganic phosphorus	p_i	mgP/L	Bottom algae phosphorus	IP_b	mgP/m^2

Table 5. Kinetic and Mass transfer processes (Chapra et al, 2008)

Kinetic processes		Mass transfer processes	
Process	Symbol	Process	Symbol
Dissolution	ds	Reaeration	re
Hydrolysis	h		
Oxidation	ox	Settling	s
Nitrification	n		
Denitrification	dn	Sediment oxygen demand	SOD
Photosynthesis	p		
Respiration	r	Sediment exchange	se
Excretion	e		
Death	d	Sediment inorganic carbon flux	cf
Respiration/Excretion	rx		

2.5. Application and Implementation of QUAL2K to Simulate the Karun River

This is the data limited study with modest management objective, and hence QUAL2K was chosen as a framework of water quality modeling.

According to hydrological and hydraulic conditions, locations of water quality monitoring sites, and distributions of pollution sources, the 115 km length of the Karun River was divided into 115 reaches, with a same length. Each reach can be variable number of elements but in this study each reach is one element because of uniform conditions governing at each reach.

The input parameters involved in QUAL2K were dissolved oxygen and biochemical oxygen demand (BOD). According to field survey and hydraulic characteristics of the river, the bottom algae coverage were determined to be 18% and bottom SOD coverage was negligible. The internal calculation method was applied to calculate the re-aeration rate. The exponential model was selected for oxygen inhibition of CBOD oxidation and nitrification and also for oxygen enhancement of de-nitrification and bottom algae respiration (Zhang et al. 2012). Re-aeration wind effect was calculated by Banks-Herrera formula. Other rates and models, are summarized in table 7. The calculation step was set at 5.625 min to avoid instability in the model and to ensure the model was maintained in the steady-state. The solution of integration was done with Euler's method and Brent method for pH modeling (Kannel et al, 2007).

The extent of parameters that QUAL2K demanded were obtained from a large number of studies that collected in book titled "Rates, Constant and Kinetics Formulation in Surface Water Quality Modeling. 2nd ed. G. L. Bowie et al" and some other article that mentioned in references.

The parameters rates like CBOD oxidation rate (kdc), ammonium nitrification rate (kna) and nitrate de-nitrification rate (kdn), were obtained by trial and error. The model was run until the rates were appropriately adjusted and the reasonable agreement between model results and field measurements were achieved. These parameters are listed in table 7.

2.6. Simulation Method

Based on the method provided by Guideline Manual For Assimilative Capacity Studies in Rivers No. 481 and with the data obtained from the Khuzestan Water and Power Authority and Khuzestan Environmental Protection Agency and using mathematical equations presented in the model, the pollutants emissions were calculated.

The monitoring data from spring 2012 were applied for calibration. For Validation of the model, model was run with another completely different data set that monitored in winter and spring 2013, which was set with a little change of the calibrated rates that was negligible, so that by this approach, the validation of the calibrated model under different situation was tested. Thus, the model was prepared for the future simulation that is simulating water quality during the critical period.

Note that the calibration results of the QUAL2K model were in accordance with the monitoring values, with a few inconsistencies. The calibrated parameters are shown in Table 7. The model calibration results were in well agreement with the measured data, with some exceptions. Some errors are inevitable in this modeling, with the objective of modest management goal. As the model predictions are in the daily average, the observed data may be different depending upon the time of samplings[2].

After calibration and validation, the model is ready to simulate defined scenario in critical time period (June). The simulation steps are as follows (Zhang et al, 2012.):

(1) The water quality objectives must be determined based on the water environmental management requirements of the Karun River. In this study, the points of water treatment plants which placed next to the river bank are control points for BOD and for DO the whole points of river are control points.

(2) Simulate the defined scenario and scrutiny of various options.

3. Results and Discussion

In spite of some errors, the modeling results were quite acceptable to achieve modest management goals for such a data limited condition. A sensitivity analysis was performed to identify the parameters of the river water quality model that have the most influence on the model outputs. It was found that the model was highly sensitive to COD oxidation rate (kdc), nitrate de-

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[2]- For example at daytime, DO increases because of the higher rates of photosynthesis of the plants and at night, it decrease because of algal respiration.

nitrification rate (kdn), Basal Respiration rate (kr1b) as example. In this study, data taken in the spring of 2012 were used for calibration and results are shown in figure 4, 5 and 6. As seen in figures 4, 5 and 6, the simulated values correspond well with the monitoring data with some negligible exception. For first and second order validation, used data in winter 2012 and spring 2013 and results are shown in figure 7 and 8. Simulated values for the validation are also correspond well, with monitoring data. Calibrated parameters and models are showed in table 7.

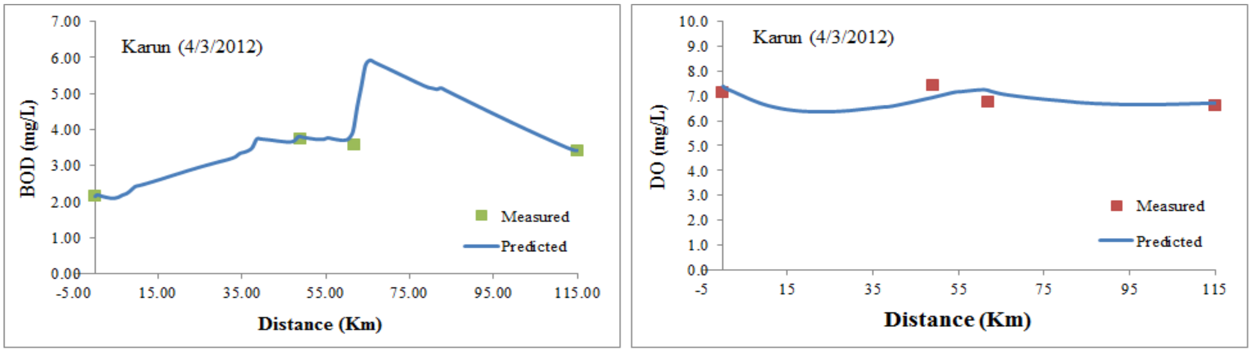

Figure 4. Water quality calibration results for the Karun River (April 3, 2012).

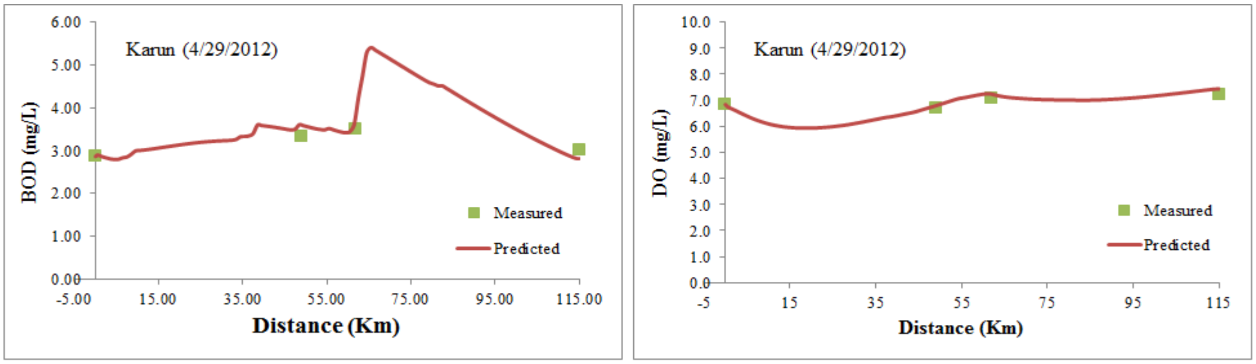

Figure 5. Water quality calibration results for the Karun River (April 29, 2012).

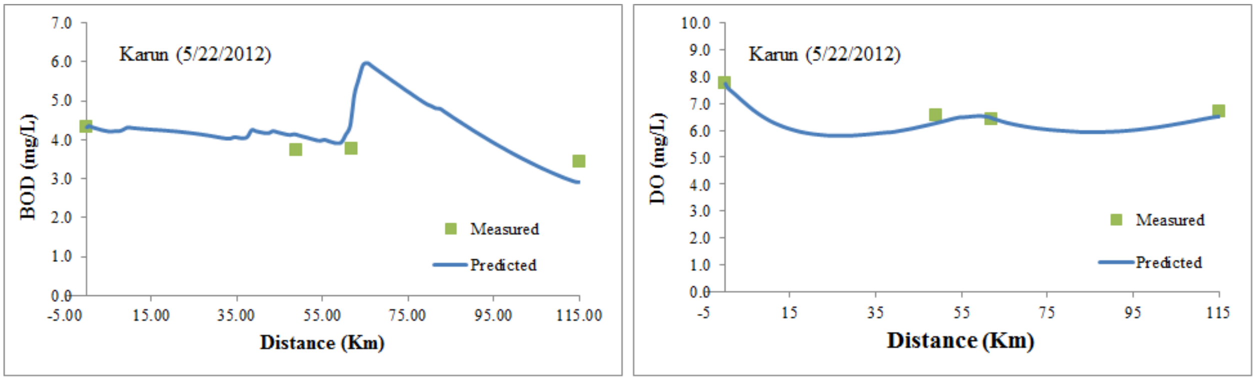

Figure 6. Water quality calibration results for the Karun River (May 22, 2012).

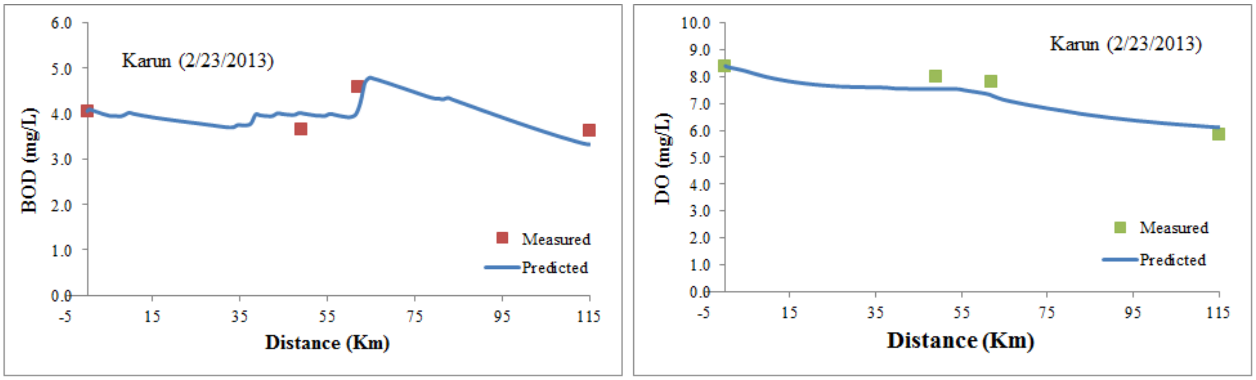

Figure 7. Water quality validation results for the Karun River (February 23, 2013).

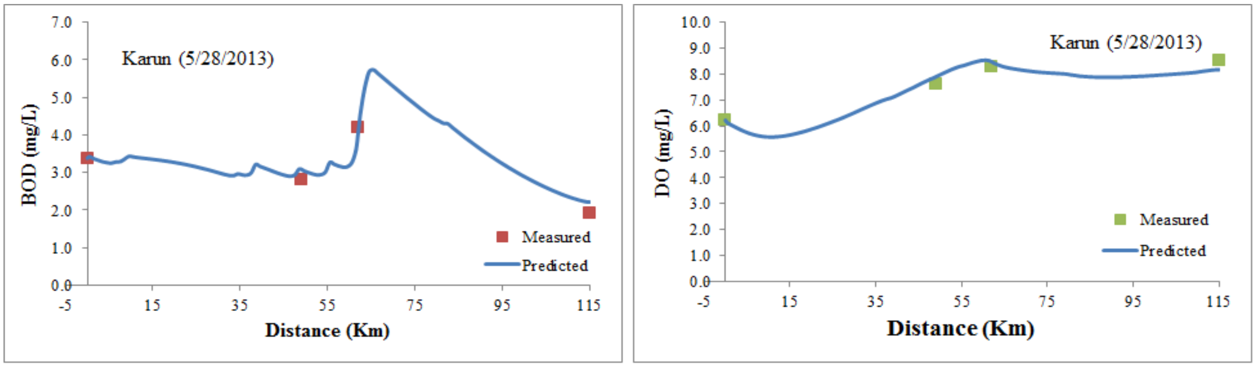

Figure 8. Water quality validation results for the Karun River (May 28, 2013).

Table 7. Calibrated parameters for simulating Karun River water quality.

Parameter	Value	Units	Symbol	Min value	Max value
Stoichiometry:					
Carbon	40	gC	gC	30	50
Nitrogen	7.2	gN	gN	3	9
Phosphorus	1	gP	gP	0.4	2
Dry weight	100	gD	gD	100	100
Chlorophyll	1	gA	gA	0.4	2
Oxygen:					
Reaeration model	Internal				
Reaeration wind effect	Banks-Herrera				
Oxygen inhib model CBOD oxidation	Exponential				
Oxygen inhib parameter CBOD oxidation	0.60	L/mgO2	K_{socf}	0.00	1.00
Oxygen inhib model nitrification	Exponential				
Oxygen inhib parameter nitrification	0.60	L/mgO2	K_{sona}	0.00	1.00
Oxygen enhance model denitrification	Exponential				
Oxygen enhance parameter denitrification	0.10	L/mgO2	K_{sodn}	0.00	1.00
Oxygen inhib model phyto resp	Exponential				
Oxygen inhib parameter phyto resp	0.60	L/mgO2	K_{sop}	0.00	1.00
Oxygen enhance model bot alg resp	Exponential				
Oxygen enhance parameter bot alg resp	1.00	L/mgO2	K_{sob}	0.00	1.00
Phytoplankton:					
Max Growth rate	2.9	/d	k_{gp}	1.5	3
Respiration rate	0.6	/d	k_{rp}	0	1
Nitrogen half sat constant	65.9	ugN/L	k_{sPp}	0	150
Phosphorus half sat constant	2	ugP/L	k_{sNp}	0	50
Inorganic carbon half sat constant	1.29E-04	moles/L	k_{sCp}	1.30E-06	1.30E-04
Light model	Half saturation				
Light constant	83.8	langleys/d	K_{Lp}	28.8	115.2
Bottom Plant:					
Growth model	First-order				
Max Growth rate	13.5	gD/m^2/d or /d	C_{gb}	0	100
First-order model carrying capacity	138	gD/m^2	$a_{b,max}$	50	200
Basal respiration rate	0.2	/d	k_{r1b}	0	0.3
Photo-respiration rate parameter	0.5	unitless	k_{r2b}	0	0.6
Inorganic carbon half sat constant	1.95E-05	moles/L	k_{sCb}	1.30E-06	1.30E-04
Light model	Half saturation				
Light constant	1	langleys/d	K_{Lb}	1	100
Subsistence quota for nitrogen	15	mgN/gD	q_{0N}	0.072	72
Subsistence quota for phosphorus	5	mgP/gD	q_{0P}	0.01	10
Detritus Dissolution rate	4.2	/d	k_{dt}	0	5
Slow CBOD Hydrolysis rate	3.5	/d	k_{hc}	0	5
Fast CBOD Oxidation rate	0.5	/d	k_{dc}	0	5
Ammonium Nitrification	0.75	/d	k_{na}	0	10
Nitrate Denitrification	0.24	/d	k_{dn}	0	2

As can be seen in figures 4, 5 and 6, BOD and DO change are almost constant in these months. The average increase of BOD in 55th km to 65th km, is 2 mg/L that is for direct discharge of untreated sewage of city in this area. But at 80th to 83th kilometer, despite the congestion of polluting resources, river water reaction is not sensible that is because of observance of effluent discharge standards by these industrial centers.

As you can see in the above figures, despite the river's response to the localized depletion and increasing in BOD level, there is no sensible decrease in DO level that is for high flow of river. It is not unnatural that this high flow has a considerable amount of oxygen. DO level after decreasing trend after 15 kilometer (that is for direct depletion of Mollasani and Veys city center), from 15th to 55th kilometer increased which is for mechanisms that are in river to compensate the lack of dissolved oxygen. But after 55 kilometer course of the river, because of direct discharge of sewage in Ahvaz, DO level decreased or at least remain constant. As seen in figures 4 to 8, Ahvaz sewage has greatest impact on increasing BOD and Mllasani, Loveymi and Weys has less impact on the increases of BOD in river. At 80th kilometer in which Ahwaz West wastewater treatment plant is located, despite high flow of this pollution source, significant rise in the amount of BOD is not observed, which indicates the importance of treatment before disposal. In figures 4 and 5 before entering to the urban area, gradually increase in the amount of BOD is observed that is for the impact of non-point sources (agricultural areas). But the next figures, this effect is far less due to the various amount of agricultural drainage during different seasons. There are also agricultural land after urban area, but it's agricultural drainage transmitted away from study area. Although Dehkhoda drainage is in the study area, but it depleted to another source, however not too long ago it discharged to Karun River.

After calibration and validation of model, we simulate defined scenario in critical time period (June). First scenario examines the movement the point of pollutants entering to the river and water quality changes (Fig. 9). In the second scenario, the impact of reducing flow in first scenario is evaluated (Fig. 10). In the third scenario, the impact of increasing flow to the BOD and DO concentration is investigated (Fig. 11). In the fourth scenario, reduction of pollution load to water quality has been investigated (Fig. 12). In the fifth scenario, displacement of entering points of pollutants in addition to reducing 30 percent of pollution load has been studied and finally compared with a further reduction of pollutant loads (Fig. 13). In the sixth scenario, effluent discharge standard in urban and whole study area was applied and compared (Fig. 14).

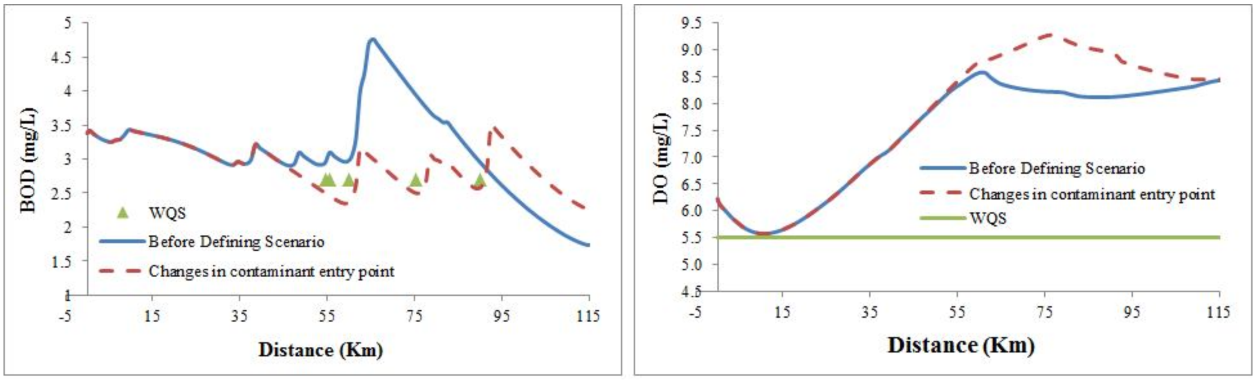

Figure 9. First scenario: movement the point of pollutants

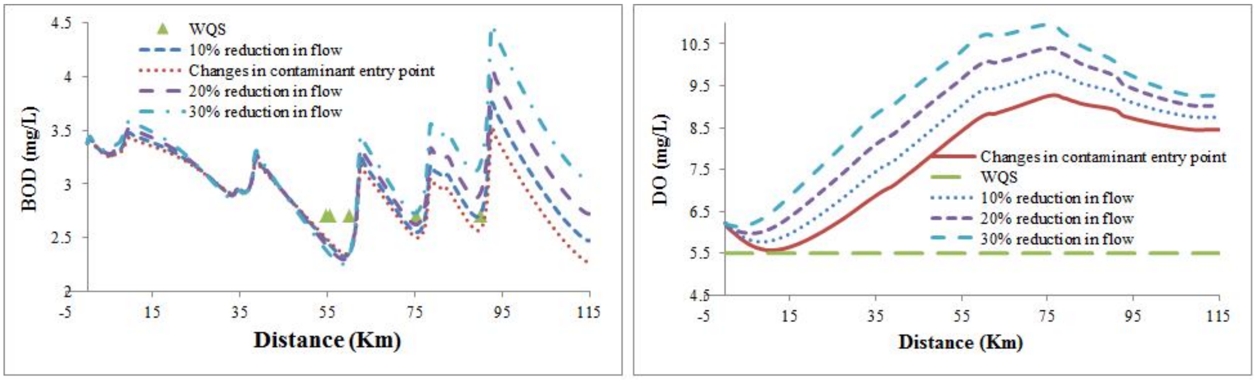

Figure 10. Second scenario: impact of reducing flow in first scenario

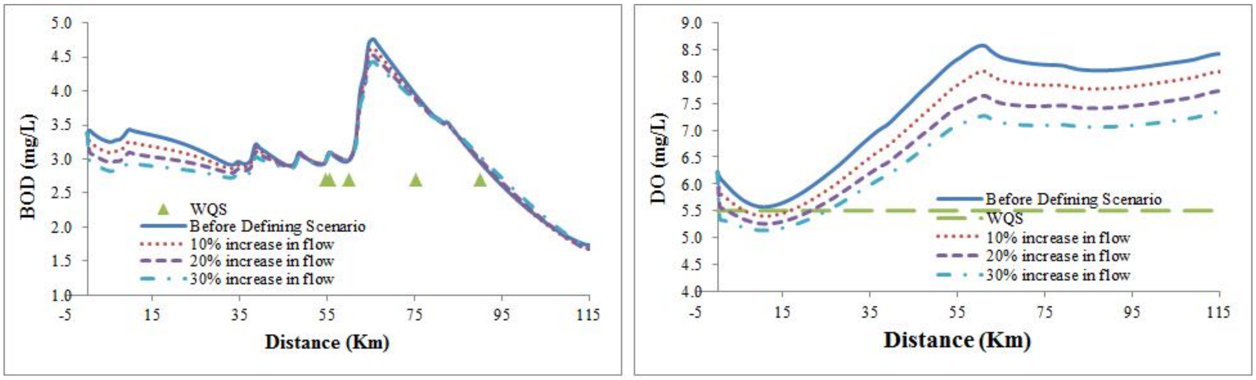

Figure 11. Third scenario: the impact of increasing flow to the BOD and DO concentration

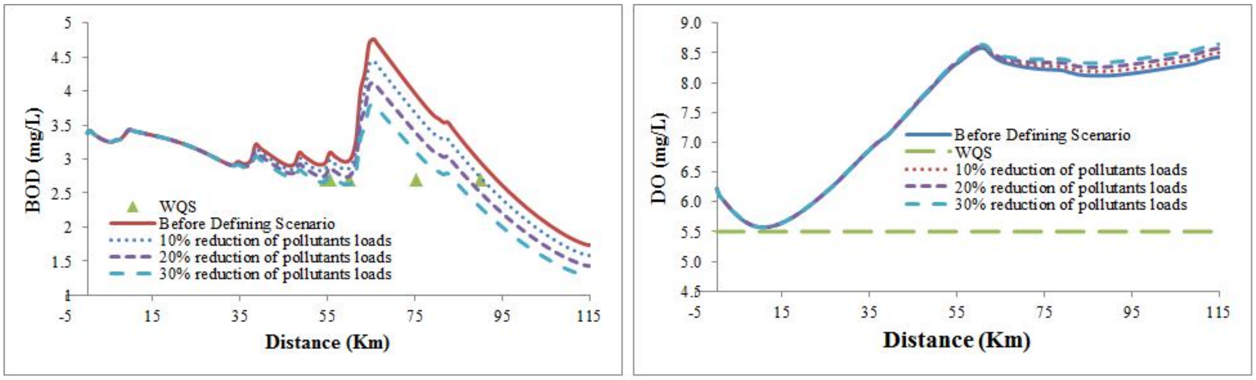

Figure 12. Fourth scenario: reduction of pollution load to water

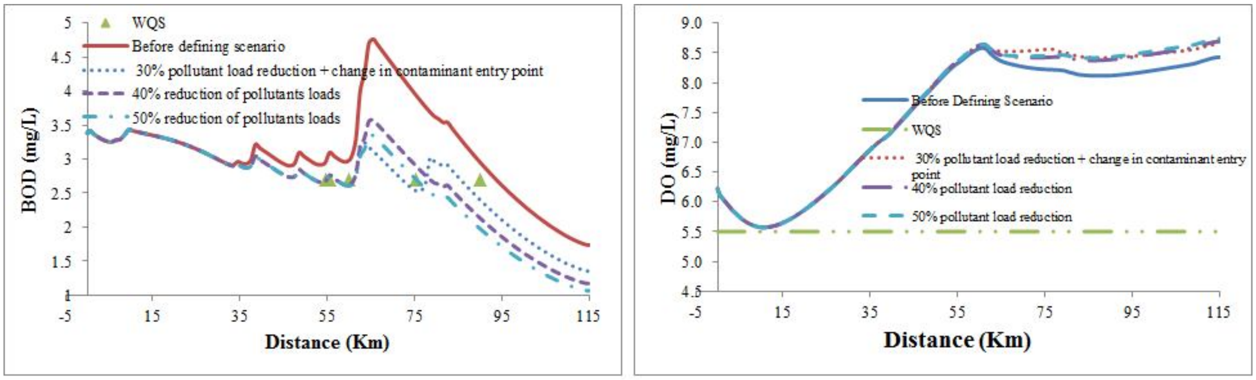

Figure 13. Fifth scenario: displacement of entering points of pollutants in plus reducing 30% of pollution load and further reduction of pollutant loads.

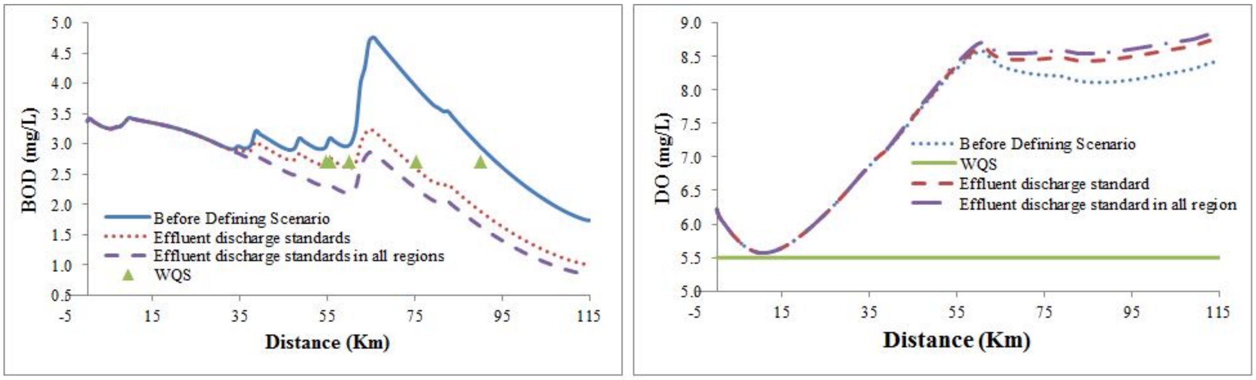

Figure 14. Sixth scenario: effluent discharge standard in urban and whole study area.

In first scenario, the significant pollution load transmitted to another point of river course (Zergan, Daghagheleh and Laleh Park transmitted to 62th kilometer of river course, black bridge sewage transmitted to 78th kilometer and 8th bridge, 5th bridge, riparian park transmitted to 92th kilometer of river course after water treatment plant). As seen in figure 9, water quality objective was achieved by defining this scenario and BOD level before water treatment plants withdrawal points were below “class A” BOD criteria. Increasing in DO after this pollutant depletion point displacements is clearly evident (Fig. 9). Although DO concentration in the river is always higher than standard. In the second scenario we evaluate the flow reduction (which could be occured in future) to the concentration of BOD and DO of first scenario (Raj Kannel et al. 2007). As seen in figure 10 although DO level increased (that is due to decreased depth of water and increase of re-aeration rate (Chapra et al. 2008)) by flow reduction but BOD at last water treatment plant station exceed the “class A” criteria. It seems that by transmitting black bridge sewage to 92th kilometer of river course, water quality goal could be accessible. Third scenario shows that flow augmentation in river (although because the current trend of reducing flow by construction of several dams is not accessible) is not useful. Because only in first courses of the river reduction in BOD level was seen and in the other course of river there is no sensible change in BOD level. DO level is also reduced due to increase in the depth of river and low concentration of increased flow (Chapra et al. 2008). Fourth scenario shows pollution reduction options and its performance in water quality management. As seen in figure 12 by 30% reducing in pollution load we don’t achieved water quality goal. Option one in fifth scenario evaluate the 30%

pollution load reduction plus change in depletion point of significant pollution source. Indeed this option is the combination of first and third scenarios but only 5th bridge and riparian park sewage transmitted to 92th kilometer of river course. The remained options in fifth scenario simulated the 40% and 50% reduction in pollution load. As seen, in 50% pollution reduction we achieved water quality goal for preparing raw water for water treatment plant. DO level is improved a little bit.

In sixth scenario we applied effluent discharge standard at Ahvaz urban area and whole area. As seen in figure 14 we achieved water quality goal in both option although utilization of effluent discharge standard at urban area is enough.

4. Conclusion

The objectives of this study were to ensuring the maintenance of water quality classification criteria for DO and BOD. The one-dimensional stream water quality model QUAL2K was calibrated and confirmed using the data in 2012 and 2013. The model represented the field data quite well with some exceptions and modeling results were quite acceptable to achieve modest management goals for such a data limited condition. Simulation results showed that Ahvaz urban area is critical area for water quality management. The model was applied to simulate water quality during the critical period to maintain stated water quality criteria. Six scenarios was defined and different states were evaluated. Among the results we can mentioned that (1)- flow augmentation is not useful for river pollution reduction, (2)- Significant pollution source displacement is useful for now and future which flow reduction expected. (3)- Effluent discharge standards cause conservation of our water bodies. (4)- we can achieved water environmental goal by 50% treatment and further refining cause additional costs.

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