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RESEARCH PAPER

Modeling DO and BOD_5 Changes in the Dez River by Using QUAL2Kw

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ABSTRACT

The present study evaluates the water quality of Dez River, a river 23 km long, via QUAL2Kw model, based on simulation of DO and BOD5 p98arameters, through considering water quality standards during six months in three stations of Kashefieh, Pole-Panjom, and Hamidabad. To determine the model's validity and compare the observational data, the paper uses the square mean square error (RMES) and the squared mean square error coefficient (CV). The achieved results of the model largely indicate the actual conditions of the river, which represent the ability of QUAL2Kw model to simulate qualitative parameters. The main contamination of Dez River comes from municipal wastewater, either directly imported by river residents or collected by urban canals. It, then, enters the river at a certain point. Based on the simulation and observational results of DO at two stations of 5th and Hamidabad Bridge in all months of sampling, it is below 5 mg/L, regarded a threat to aquatic life. In addition, BOD5 parameter goes beyond 6 mg/L in Hamidabad station, being a threatening factor for aquatic life in this station. Critical conditions of Dez River, low discharge, and high loading of pollutants have increased the concentration of water quality parameters. Given the results of RMSE and CV parameters, the model has had the best conformity for DO parameter, followed by BOD5.

Keywords: Dissolved Oxygen, Self-purification, Dez River, BOD5, QUAL2Kw

INTRODUCTION

Rivers are the main sources of surface water for domestic, industrial and agricultural purposes and often carry large municipal wastewater, industrial wastewater and seasonal runoff from agricultural lands to downstream areas. Water quality is the ratio of measuring status of water resources to the needs of living species and human needs. Water quality depends on local geology and ecosystem, and human activities can have a negative impact on water quality (Curtisand MorningRoth 2013; Huang et al. 2014). The river is a part of the surface water resource which is vital for living. The quality of river water is greatly influenced by the land use and human activities in the catchment area (Rachmansyah et al., 2021). The discharge of different urban, industrial, and agricultural pollution, more than the river self-purification capacity, leads to the deterioration of the river ecosystem and the increase of water treatment price in lower bounds. In allocating pollution loading to different pollutant sources, it is necessary to take environmental standards as well as treatment costs into consideration. In common models of river water quality management, the permitted wastewater discharge rate for each pollutant source is determined based on minimization of treatment costs by

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considering downstream water quality limitation as a constraint, or by minimizing the water quality violation from the standard by considering a treatment budget limitation as the constraint (Niksokhan et al. 2009; Ghosh & Mujumdar 2010; Barati 2011; Nikoo et al. 2012, 2013; Barati 2013; Huashan et al. 2013; Barati et al. 2014; Liu et al. 2014; Joonwoo et al. 2015; Tavakoli et al. 2015; Hosseini et al. 2016; Jie et al. 2016; Shakibaeina et al. 2016; Wang et al. 2016; Alizadeh et al. 2017; Chounlamany et al. 2017; Saberi & Niksokhan 2017; Zeferino et al. 2017; Moridi Ali. 2019; Farjoudi et al. 2021).

The parameters involved in the river ecosystem encompass a wide range, and since the rate of removal, reduction and increase of pollutants and factors affecting them is different, and there are some commonalities in some cases, it is not possible to address all the characteristics and quality parameters of water. Therefore, in order to evaluate the characteristics of river quality, it is necessary to consider the parameters which have the greatest impact on the river's self-refining process, considering the time and place constraints and modeling methods which express the other characteristics of water quality parameters (Vanaei et al., 2018). Streeter and Phelps were among the first to model the river's water quality and discussed measuring BOD (Biochemical Oxygen Demand) and DO (Dissolve Oxygen) parameters (Streeter and Phelps, 1925).

BOD is the amount of oxygen required by aerobic microorganisms in the water sample for oxidation of organic matter, which, according to the international standards, is measured at 20°C, and its measurement lasts 5 days (Liu et al., 2011). BOD is a term for the amount of oxygen needed for the biological decomposition of an organic matter in a water sample. Therefore, BOD measurement is the basis for detecting biodegradable organic matter in water. Common methods used to determine BOD are often very difficult along with measurement errors. The basis of these methods is to determine complex factors such as the oxygen microorganisms needed to breathe in a sample and oxidation of ammonia (Kunwar et al., 2009). However, since many variables affect water quality parameters, and there exists a nonlinear and complex relationship between them, common methods cannot solve the water resources quality management problem well (Xiang et al., 2006; Wu et al., 2000).

Choosing the right model usually depends on the objectives of the study, the simplicity of the model, its applicability and the available facilities. Nowadays, QUAL2Kw model is considered to be one of the best tools for simulating water quality due to its flexibility, user-friendliness and availability (Hanfeng et al., 2013). QUAL2K is a comprehensive integrated one-dimensional water quality model which affects DO through nitrogen circulation, algae growth, and sediment oxidation process. This model is a hydrological model and integrates the temperature model (Allam et al., 2016; Chi et al., 2009). Thus, it is widely used around the world. In addition, Gupta et al. (2013) showed that in stimulating DO and BOD in India's Kashkpira River QUAL2Kw model, after calibration and validation, performs well and can be used as a reliable management tool. Bagheri-Marzouni et al. (2014) used QUAL2Kw model to simulate DO and BOD of Karun River in Iran. First, this model was calibrated and validated with data taken from this river, and then it was employed to make management decisions using different scenarios. The results of this study showed that their environmental impacts can be reduced by changing the location of pollutants entering the river. Further, Stackelberg and Nileson (2014) used the QUAL2Kw model to study the water quality of the Jardan River in Utah. For this purpose, they examined 83 km of river length and used four sampling periods for calibration and validation of the model. Furthermore, they focused on the causes of low oxygen content and, finally, found that one of the primary causes of oxygen soluble oxygen deficiency in river water was the degradation of organic matter and poor aeration of the river. Ismail and Robescu (2015) investigated the capability of QUAL2Kw model to simulate water quality of the Great Danube

River. The model was calibrated using data in April 2008. Then, it was validated in September 2008. The output of the model showed that the calibration and validation results were consistent with the observed values with some exceptional cases. Although QUAL2Kw is a one-dimensional fixed model, it can be used as a suitable tool to simulate water quality in large rivers (Hadipour Niktarash et al., 2019).

In addition, to investigate the effects of pollution discharge in Taleghan River, QUAL2Kw model was used to simulate and investigate seasonal changes in river water quality. The results indicated that the amount of dissolved oxygen in September would change from 4.5 to 6.52 mg/L, while its amount would change from 4.8 to 5.3 in February. The amount of oxygen reduction in the high-water season was related to drainage and the washing of agricultural lands around the river. In addition, BOD values in high-water season change from 6 to 31 mg/L and in low water season from 10 to 26 mg/L, which is due to dilution of river flow in high-water season. Zallaghi and Afrous (2019) used a QUAL2Kw qualitative model to simulate quality parameters NO-3 and PO4-3 in seven stations on Dez River with the length of 15 km. The values of river quality parameters and other information obtained from field studies were used for calibrating and predicting the model. Further, MAE (Mean Absolute Error) and CV (Coefficient Variation) were used to determine the validity of the model and to compare the observational data. The results of the model indicate the actual conditions of the river which itself shows the ability of QUAL2Kw model to simulate qualitative parameters. The main contamination of Dez River is from municipal wastewater. Based on the results of PO4-3 parameter in the study period in the area of sewage entering the Dez River, it is considered to be a threat to aquatic life. Low rate of discharge in downstream of Dez River and high loading of pollutants have increased the concentration of water quality parameters.

In order to simulate Ardak River in Khorasan-e-Razavi, Nikakhtar et al. (2020) used dynamic model of QUAL2Kw. To calibrate, the data from November 2014 in Khorasan-e-Razavi’s Regional Water Company were used, and to validate, various water quality parameters of May 2016 were used. The results showed that the model was suitably valid for NO, and COD, pH, DO parameters, and is able to simulate the water quality parameters in both branches of Ardak river. Also, river water in Abghad branch has higher quality because of the population’s stability and the low pollutant sources. Water quality in both branches is under the effects of agricultural and horticultural pollutants and the disposal of villages’ sewages as well. Ranjith et al. (2020) used QUAL2Kw model of water quality to predict water quality in some parts of Tungabhadra River in Karnataka, India. By means of the data coming from field and laboratory measurements of the model for the parameters of oxygen solution, the demands for biochemical oxygen and nitrogen of the whole calibration were validated. The statistic methods used to measure the function of the model were SE (Standard Errors) and MME (Mean Multiplicative Error). The model showed an appropriate proportion with the field data; however, there were some minor exceptions. Although the simulated data are different from some measurement parameters, the results of calibration and validation are still reliable. This kind of result can be applied especially in developing countries where enough investment is not paid for the repeated observational activities.

BOD (Biochemical Oxygen Demand) has strong affinity with DO, and this indicates the need of oxygen for the decomposition of organic materials living in the waters. BOD turns to be an important factor in assessing the amount of organic materials’ pollution in the river (Siwiec et al., 2001). Deoxygenating rate is the process of reduction of the amount of oxygen which occurs within the aquatics’ bodies, because they use oxygen through microorganisms to decompose the pollutants (Kumarasamy, 2015). The process of deoxygenating rate is an important process in the river’s attempt in self-purification which means to destroy the pollutant organisms that are biologically decomposable to re-purify the water. Deoxygenating rate affects and, sooner or later, self-purification occurs. If a region had different temperatures, the amount of deoxygenating rate could be special. The amount of deoxygenating rate is also an important factor in Streeter-Phelps equation which is always used for modeling of the river's water quality. Furthermore, river's quality, the existence of substance and pollutants in the river, affects the amount of deoxygenating rate. The researches on deoxygenating rate of Dez River are too low in number. The lack of optimization in decomposition of microorganisms is also one factor which influences the river's self-purification. Therefore, in this study, the situation of decomposing microorganisms is regarded as one of the characteristics to be studied. Being aware of the change process and the prediction of Dez River's water quality, the present study tries to investigate the amount of wastewater entering the river and to give some solutions for making the quality better and reducing the effects of pollutants. The purpose of this research is simulating the quality changes of the river's water with the help of QUAL2Kw software, and also analyzing the self-purification of the river from Kashefiyeh to the lower part of it in HamidAbad. It is worth mentioning that no research has been conducted using this model in Dez River. Therefore, the results of this study can be used in developing a pollutant loading control program for Dez River in order to ensure the health of river water quality for aquatic animals, providing favorable biological conditions of index species and similar uses in related organizations.

MATERIALS AND METHODS

Dez River originates from the southwest highlands of Arak, Boroujerd, Aligudarz and Bakhtiari mountains such as Zardkuh, Estroankuh, and Ghalikooh. This river is one of the most permanent watery rivers in Iran. It is composed of two main branches: Caesar and Bakhtiari. Dezful is one of the cities of Khuzestan province in southwestern Iran, located by the Dez River and its coordinates include the geographical latitude of 16°, the geographical length of 25° and the height of 137 meters above the sea level. This study's area is a part of Dez River in watershed in Dezful city, between Kashefieh station and downstream of Dez River in Hamidabad station with a length of 23 km (Fig 1).

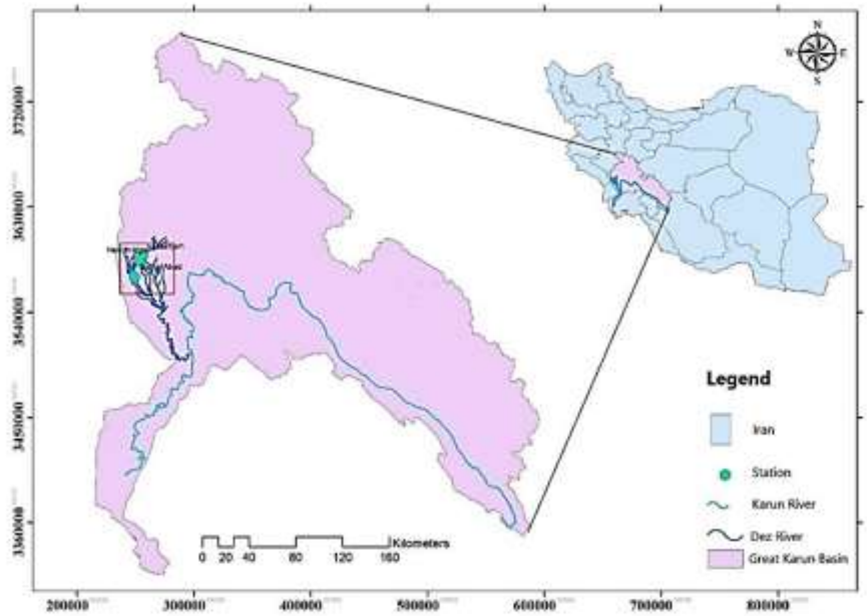

Fig 1. Location of sampling stations on Dez river map in Khuzestan province and Iran

In terms of climatic conditions, this region has a warm climate with a Mediterranean weather; therefore, moderate rain is expected in this region. The average amount is 348 mm based on the statistics of the past 14 years. The warmest month is August with an absolute maximum of 53 degrees Celsius and an average of 36 degrees Celsius and the coldest month is January with an absolute minimum of -0.9 and an average temperature of 11.3.

The main reasons for decreasing the quality of surface water are the entry of municipal and domestic wastewaters, agricultural and industrial wastes and runoff (organic, inorganic and heat) and solid and semi-solid wastes. The outlet wastewater of the army garrison in front of Rudband, urban wastewater in the downstream east coast of the Pol-e-Panjom and in the area of the old bridge as non-points from the west coast, the wastewater from the water and wastewater treatment plant of Dezful city, as well as the wastewater of the Village of Gavmishabad downstream of the river were the points used for sampling. The sample volume of wastewater and effluent collected for the above experiments was 2 liters, which was used in sterile containers. In addition, the samples were collected to measure BOD5 and DO parameters in Dezful water and wastewater laboratory. Then, the achieved results out of measurement were simulated by means of QUAL2Kw.

After conducting research and library study, the selection criteria of sampling stations were identified. Then, the points of sewage entering the Dez River between the studied intervals were selected as point and non-point in order to indicate the trend of water quality in the upstream of each interval. Then, the hydrological and topographic conditions, number and distribution of pollutants in rivers, concentration and load of pollution discharged in each part of the river were investigated. Then, by obtaining general knowledge, the river was divided into several different hydraulic ranges, physical characteristics (river slope, river cross section, roughness, discharge, etc.) and reaction coefficient (such as aeration and air entertainment), so that it could be measured at the beginning of each interval station.

Table1. Flow measured at Dezful hydrometric station

(Measurement month)	**November 2019**	**December 2019**	**January 2020**	**February 2020**	**March 2020**	**April 2020**
Flow (m^3/s)	116	35	45	47	53	67

In this study, the effects of changes in physical and chemical parameters of Dez River were evaluated. For this purpose, the qualitative parameters of BOD5 and DO were evaluated for six months from November 2017 to April 2018 between Dezful (Kashefieh) and Hamidabad stations with a distance of 23 km in two ranges of 5 and 18 km, as shown in Table 2. Sampling was conducted in the direction of Dez river from upstream of Kashefieh, Pol-e-Panjom and Hamidabad (Figure 1). The samples were transferred to water engineering laboratory of Islamic Azad University of Dezful for BOD5 and DO measurements. The tests were carried out by DO HQ30d measuring machine manufactured by HACH company and BOD measuring device model OXITOP IS 6 manufactured in WTW Company, Germany (Figures 2A&B). The measurement results are listed in Table 3 and the results of the measurement were, then, simulated using QUAL2Kw software.

Table 2. Geographical coordinates of stations

Station	Longitude (utm)	Latitude (utm)	Height from sea level (meter)	Distance from downstream (Km)	Bed width (m)
Kashfiyeh	3587614	255614	142	23	120
New bridge	3584805	253628	116	18	494
HamidAbad	3570267	249019	75	0	594

Fig 2B. Device for measuring BOD

Fig 2A. Device for measuring Dissolved oxygen

Table 3. Parameters Measured Input to Model

(Station)	(Sampling month)	BOD5 (mg/l)	DO (mg/l)
Kashfiyeh	November 2019	5	5
	December 2019	4	5.1
	January 2020	5	4.9
	February 2020	5	5.1
	March 2020	4	5.1
	April 2020	6	5
	January 2021	3	5
New bridge	November 2019	6	4.9
	December 2019	5	4.8
	January 2020	6	4.8
	February 2020	6	4.9
	March 2020	5	4.8
	April 2020	8	4.9
	January 2021	5	5
HamidAbad	November 2019	10	4.6
	December 2019	8	4.4
	January 2020	7	4.6
	February 2020	10	4.6
	March 2020	8	4.4
	April 2020	12	4.6
	January 2021	6	4.6

Fig 3. General View of river

QUAL2Kw model divides the river into different ranges, each of which has the same hydraulic conditions (longitude, floor width, wall slope, etc.). Intervals are numbered ascending from the upstream of the mainstream of the river to the downstream, respectively, and point or non-point sources can enter or exit any part of the river. In addition, the model can divide each interval into an arbitrary number of elements with a control volume (the basic computational unit of the model) in which the elements of each interval have the same length, and the length of the elements can vary from interval to interval (Fig 4). The QUAL2Kw model simulates each sub-branch as the main branch of the river and draws separate diagrams for each of them. Nowadays, this model is widely used in waste load determination studies and is generally accepted by experts (Chapra and Pelletire, 2003; AsheghMalla et al., 2016).

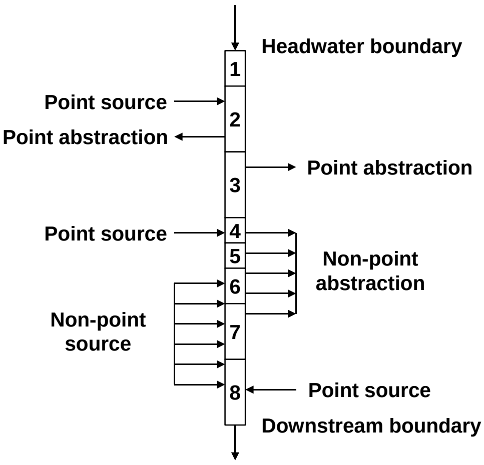

Fig 4. QUAL2Kw model subdivision for river without branches

Balance relations used in the QUAL2Kw model include the flow balance for the N range of the river in the QUAL2Kw model based on Figure 5 as defined below (Chapra et al., 2006).

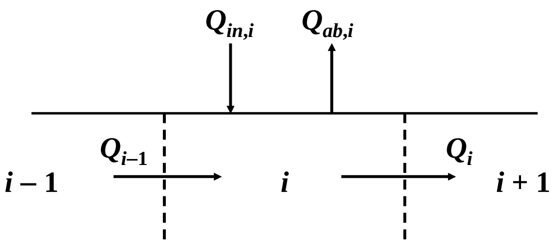

Fig 5. Flow Balance for the N range of the

$$Q_i = Q_{i-1} + Q_{in,i} - Q_{out} \quad (1)$$

In equation (1), Qi is the output current from interval i to i+1 (m3/d), Qi-1 shows the output current from the interval i-1 (m3/d), Qin,i represents the total input current from point sources and non-points to the interval i (m3/d), and Qout,i is considered as the total output from point and non-point sources to the interval i (m3/d).

Qual2kw model simulates inputs or outputs of non-points linearly. Figure 6 shows the beginning and ends of these resources and is weighed according to the input load to each interval. Therefore, the length of input or output sources must be known as non-points (Chapra et al., 2006).

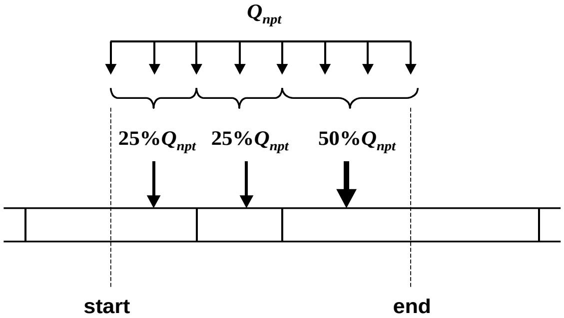

Fig 6. Way of considering non-point input sources to an element in the QUAL2Kw

The purpose of calibration is to minimize the difference between predicted and observed outputs, which can be done by accurate measurement of parameters or by optimization methods. In general, there is a special relationship between the general shape of the model and the physical system studied earlier. Through the model parameters, which determines the accuracy of the parameters values for the appropriate action, between the model output and the recorded output? Ideally, the model should reflect reality as much as possible.

After collecting all the information needed in calibration stage, the model was performed during November, December and January of 2020. Then, the simulated amounts were compared to the observed amounts which had been recorded in hydrometric stations. The low degree of difference between them shows that simulation has been nearer to the reality and, as a result, is acceptable. The change of coefficients and model parameters in permitted periods in a way that the difference between the observed data and the simulated ones is minimized is called calibration (Pelletier and Chapra, 2008b). In QUAL2Kw software, calibration is performed in two ways: manual and automatic (Pelletier and Chapra, 2008a; 2008b). In automatic way which is based on genetic algorithm, calibration is done by introducing a function, named fitness, in a software's page with the same title (Pelletier and Chapra, 2008b; Pelletier et al, 2006). The amount of this function defines the conformity of observed and simulated data. The software alters the coefficients through the amount of this function and other options related to genetic algorithm (Pelletier and Chapra, 2008b; Pelletier et al, 2006). Before calibration, water flow should be calibrated, and this is done through manning coefficient so that with the alteration of this coefficient, the observed data related to the chart, would have most conformity with simulated data in Travel Time parameter. After calibration, the model was validated automatically with the help of data from February, March and April 2020 in a way that it considered the achieved coefficients of the previous stage fixed. The model is evaluated based on the new observed data and the conformity of observed and simulated data. To evaluate the accuracy, RMSE error square mean score and CV error square mean coefficient were used as equations (2) and (3). If the different amount of this indicator in validating stage with the calibration stage is 20 percent, the results of validating stage and, consequently, the model will be accepted; otherwise, the model does not present the reality.

Where RMSE is square mean square error, Oi is considered as observational data, Pi shows simulated data by model, N means number of observations (stations), and CV indicates square change coefficient of square mean error.

RESULTS AND DISCUSSION

The purpose of the simulation of river water quality is to estimate the changes in the quality parameters of the river water as accurately as possible so that the model can give similar results to the actual results in the river. For this purpose, sampling was done from three points of the river and evaluated in the simulation results. Simulation results should be as consistent as possible with the data obtained from rivers. Calibration is required to match the results of the model. Calibration means adjusting the rates and parameters involved in the equations to simulate water quality parameters so that their results are consistent with the river quality data. For calibration, the data of November, December and January 2019 were used, and the kinetic coefficients were utilized in modeling, as shown in Table 4.

Table 4. Calibration parameters table with values

Parameter	Value	Units	Symbol
Stoichiometry:			
Carbon	40	gC	gC
Nitrogen	7.2	gN	gN
Phosphorus	1	gP	gP
Dry weight	100	gD	gD
Chlorophyll	1	gA	gA
Inorganic suspended solids:			
Settling velocity	0.06128	m/d	v_i
Oxygen:			
Reaeration model	Internal		
Temp correction	1.024		θ_a
Reaeration wind effect	Banks-Herrera		
O2 for carbon oxidation	2.59	gO_2/gC	r_{oc}
O2 for NH4 nitrification	4.57	gO_2/gN	r_{on}
Oxygen inhib model CBOD oxidation	Exponential		
Oxygen inhib parameter CBOD oxidation	0.60	L/mgO2	K_{socf}
Oxygen inhib model nitrification	Exponential		
Oxygen inhib parameter nitrification	0.60	L/mgO2	K_{sona}
Oxygen enhance model denitrification	Exponential		
Oxygen enhance parameter denitrification	0.60	L/mgO2	K_{sodn}
Oxygen inhib model phyto resp	Exponential		
Oxygen inhib parameter phyto resp	0.60	L/mgO2	K_{sop}
Oxygen enhance model bot alg resp	Exponential		
Oxygen enhance parameter bot alg resp	0.60	L/mgO2	K_{sob}
Slow CBOD:			
Hydrolysis rate	3.5	/d	k_{hc}
Temp correction	1.047		θ_{hc}
Oxidation rate	1.18385	/d	k_{dcs}
Temp correction	1.047		θ_{dcs}
Fast CBOD:			
Oxidation rate	0.5	/d	k_{dc}
Temp correction	1.047		θ_{dc}

After calibrating the model with the measured information, it can be validated using the rest of the measured information. In other words, without changing the calibration parameters, the model is executed with the new conditions. Then, by comparing the results obtained from the model and the measured values, it is possible to check the performance of the model for the new conditions and estimate the reliability of the calibrated model (Islamic Republic of Iran Vice presidency for Strategic Planning and Supervision, 2012). The data for February, March and April 2019 were used for validation. Kinetic coefficients used in modeling are seen in the table below Table 4. After calibrating the model with given data, it can be validated using the remained data. It means that without changing calibration parameters, the model will be applied. Then, comparing the achieved results and the measured amounts, the validity of the model's function can be estimated for the new conditions and also the reliability of the calibrated model (Islamic Republic of Iran Vice Presidency Planning and Supervision, 2012). In addition, water quality standard was used to evaluate the river conditions. And, RMSE square mean error and CV error square mean coefficient percent were used for the accuracy of each of the simulated parameters, the results of which are shown in Table 5.

Table 5. Root Mean Square Error Root Mean Square Error RMSE and coefficient of variation CV

Parameter / Month	BOD5		DO	
	CV	RMSE	CV	RMSE
November 2019	0.10	0.74	0.04	0.21
December 2019	0.07	0.44	0.03	0.16
January 2020	0.03	0.17	0.01	0.069
February 2020	0.11	0.76	0.02	0.103
March 2020	0.02	0.09	0.02	0.11
April 2020	0.06	0.54	0.02	0.102
Mean	0.06	0.46	0.026	0.12

DO increases by photosynthesis of plants, and decreases due to chemical oxygen oxidation, nitrification and transpiration of plants. Depending on whether the water is supersaturated or under-saturated, it gains or losses oxygen during the re-aeration process (Pelletier and Chapra, 2008). DO is an important indicator, representing the state of biological growth and water pollution level. Oxygenation is effective in improving water soluble DO. Mixing treated wastewater is essential for increasing local flow and oxygenation in order to achieve acceptable levels of water quality (Kannel et al., 2007). The amount of DO in rivers depends on several factors such as water temperature, re-aeration, available organic load or inlet to the river. The self-purification capacity of river is considered as the function of time and place factors, intensity of incoming pollutants and environmental conditions of the river bed. In fact, the evaluation of river's self-purification is to determine the amount of DO based on this capacity. Further, it is possible to get the river in terms of pollution, where there is a critical situation of soluble oxygen deficiency (Ansaripour et al., 2013). The low amount of excreting oxygen causes the low speed of organisms' pollution to improve. Seasons are not important factors in the amount of deoxidizing rate. In general, there is no fundamental process which distinguishes between dry and rainy seasons (Yustiani, 2021).

The normal range of the amount of deoxidizing rate to the surface water is 0.1-0.23 mg/L (Peavy et al., 1985). To have a comparison, the rivers' daily amount of oxygenation excretion out of Iran, in a normal range like Ravi river in Pakistan, is 0.14-0.23 mg/L (Haider and Ali, 2010) and in Gomti river in India it is 0.45 mg/L daily (Singh and Jha, 2008). The low amount of deoxygenating rate usually comes from clean water without microorganisms and organic materials. The reason of low amount of deoxygenating rate can also be the chaotic condition of the river's stream (Karnaningroem and Hendriarianti, 2015). The minimum and maximum DO levels in Dez River in the study area were 4.4 mg/L for Hamidabad station in December and March 2017 and 5.1 mg/L for Kashfieh station in December, February, and March 2017, respectively. As displayed in Figure 7, the lowest and highest amount of soluble oxygen measurement in November is 4.6 mg/L in Hamidabad station and 5 mg/L in Kashefieh station, respectively. In addition, the lowest and highest amounts of oxygen in the simulated solution in November are 5 mg/L in Kashefiyeh station and 5.24 mg/L/km 21, respectively. DO increased from the beginning of the range up to 21 km after discharging army garrison wastewater, urban wastewater from the west coast of the old bridge to Pol-e-Panjom, Gavmish-abad wastewater and Dezful water and wastewater treatment plant, as well as the existence of parks and coastal parks with a gentle slope to the end of the range continued. In the downstream of Hamidabad station, the amount of DO simulation is too high, which can be noted due to measurement errors, unfired inlet wastewater in the area and simulation errors. In downstream of Hamidabad station, the amount of simulation is more than that of measurement, which can be related to measurement error, unknown sewage in the area, and simulation errors.

In addition, the simulated oxygen solution has an increasing trend from the beginning of the interval to 20.9 km and then from this kilometer onwards to 4 km in December, January, February, and March (Figures 8-11). Figure 8 had a decreasing trend and then continued with a constant slope until the end of the interval with a constant value. As shown in Figure 12, the model simulated the process of DO in a decreasing way in April due to an increase in seasonal runoff and loading pollutant sources on a daily basis, increasing the concentration of pollutants and decreased significantly in this month due to the nourishing of the DO in river. The amount of DO in the water has a direct relationship with the discharge so that it increases by increasing the amount of oxygen in the solution. One of the most important factors influencing the amount of oxygen in the complex is the existence of organic matter, which increases the biological and chemical oxygenation and reduces the amount of DO. Accordingly, the most important factor in reducing dissolved oxygen in Pol-e-Panjom and Hamidabad bridge stations is the entrance of wastewater containing municipal organic matter to the river, the existence of a floating bridge about 18.9 km which acts as a barrier and reduces the velocity of water flow.

In addition, the excessive use of Dez irrigation network of the diversion dam for agriculture is another factor. Due to a decrease in the base flow of the river and loading the pollutant sources on a daily basis, this component increased the concentration and lower contact length of this component in the river. Because of loading the pollutants in the river, the amount of phosphate increased dramatically this month, which is in line with the results of Zallaghi and Afrous (2019). According to river water quality standard (EPA), the amount of DO in water is at least 5 mg based on Figures 7-12. Thus, the amount of this parameter in Kashefieh station is at the standard level, but it is lower than the permissible limit in Pol-e-Panjom and Hamidabad bridge stations. The mean square parameters of RMSE error square and square change coefficient of CV error square mean for this component are better than 0.12 and 0.026. According to the RMSE parameter and CV, the model had the best simulation in January, April, February, March, December, and November.

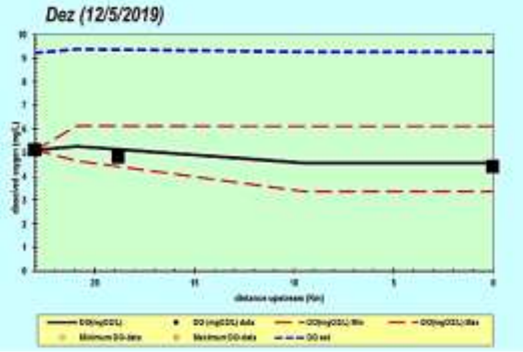

Fig 8. Simulation of DO in Dez River December 2019

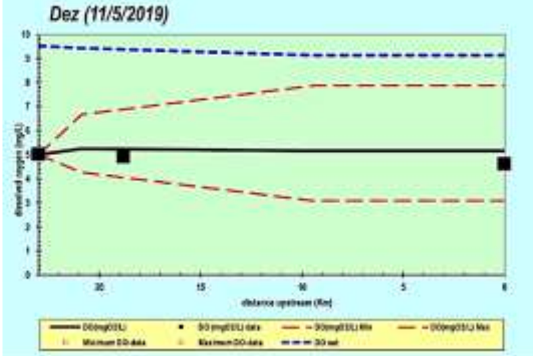

Fig 7. Simulation of DO in Dez River November 2019

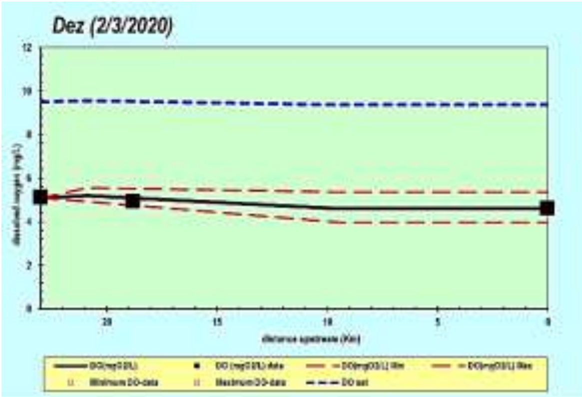

Fig 10. Simulation of DO in Dez River February 2020

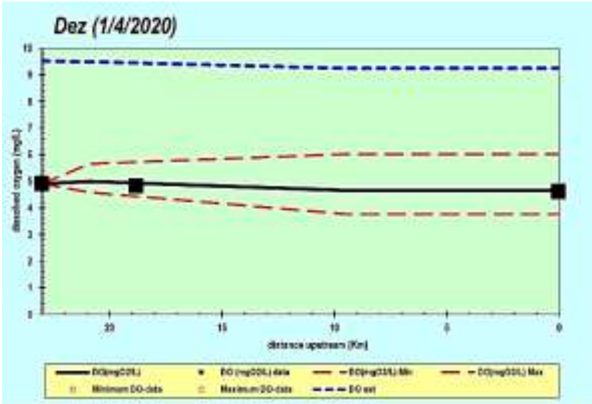

Fig 9. Simulation of DO in Dez River January 2020

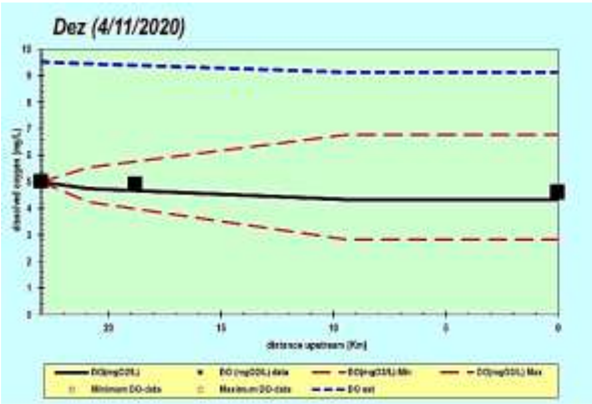

Fig 12. Simulation of DO in Dez River April 2020

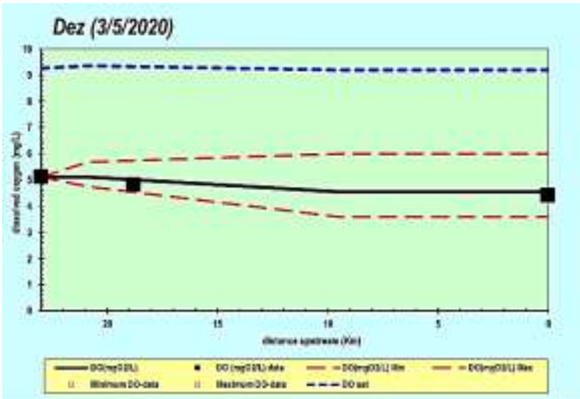

Fig 11. Simulation of DO in Dez River March 2020

BOD has a strong relationship with DO because it indicates the need for oxygen to decompose organic matter in water. BOD becomes an important factor for evaluating the contamination of organic matter in the river (Siwiec et al., 2011). Oxygen Clearance rate is the process of reducing the amount of oxygen that occurs due to the use of oxygen by microorganisms to break down pollutants in the aquatic body (Kumarasamy, 2015). Figures (13-18) show the changes in slow biological oxygenation (BOD5) simulated by QUAL2Kw model in November, December, January, February and March 2020 and April 2020 on Dez River. BOD5 has high fluctuations in the studied period in all months due to the entrance of urban and rural wastewaters and agricultural runoff. In addition, water quality in downstream of the river decreases to the mediator of the entry of point and wide sources of pollutants. The existence of municipal wastewater and waste water on the riverbank (riverside villages, parks and coastal restaurants) is one of the main causes of water pollution in all months and its effect is increasing the concentration of nutrients in the river. Diagrams of Figures 13-18 in all months with a steep slope have an increasing trend of changes. The average of the minimum quality parameter of BOD5 measured and simulated is equal to 4.83 and 4.8 mg/L, respectively, for the upstream discovery station. Further, the average of the highest quality parameter of BOD5 measured and simulated is equal to 9.1 and 7.9 mg/L, respectively, related to Hamidabad station downstream. The highest amount of BOD5 was measured and simulated in April, which was 12 and 10.44 mg/L in Hamidabad station, 8 and 7.52 mg/L in Pol-e-Panjom station, and 6 mg/L in Kashefiyeh station, respectively. The higher the oxygen biological demand in the river, the more oxygen is needed to remove BOD. Due to the effect of BOD5 parameter on the amount of dissolved oxygen, DO is lower in Pol-e-Panjom and

Hamidabad stations where BOD5 is more than Kashefieh station. The graphs obtained from the simulation in all the studied months have an increasing trend from the beginning of the interval to km 9, and then continue from 9 km to the end of the route with a fixed slope. The output diagram of the model is in accordance with the input data to the model in two stations of Kashefieh and Pol-e-Panjom, but the simulation is less than the measurement data in Hamidabad station except for January and April in other months. The errors during sampling, measurement, as well as the simulation of unknown pollutants entering the river downstream are considered to be the main reasons for this difference, which is consistent with similar results on the Karun River using the QUAL2e and QUAL2Kw models. Hoseini and Hoseini (2017) and Jafarzadeh et al. (2001) found the COD and BOD values measured at similar stations were higher than the simulation values obtained from the model. Further, the results of qualitative evaluation of Zarrinehrood River using QUAL2Kw model indicated that both reaction and transfer process affect the concentration changes of quality parameters during dry seasons, while the transmission process is dominant and effective in wet season. Subsequently, the analysis of pollutant sources shows that vast sources such as waste and waste accumulated on the riverbank have the highest share in water pollution (nutrients) (Biglari, et al., 2019). The results corresponded with the Ghorbani et al. (2020) showed that with a discharge of 190 m3/s, the BOD value would be critical in 40 km of the Dez Regulating Dam. The EC value exceeded the permissible value with a discharge of 50 CMS at Bamdaj station that poses a serious threat to the environment. The mean squared parameters are the mean squared error RMSE and the squared variance of the mean squared error CV for this component is 0.46 and 0.06, respectively. According to RMSE and CV parameter, the model had the best simulation for March, January, December, April, November and February.

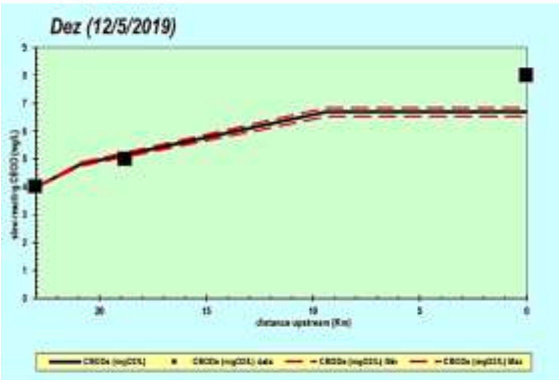

Fig 14. Simulation of BOD5 in Dez River December 2019

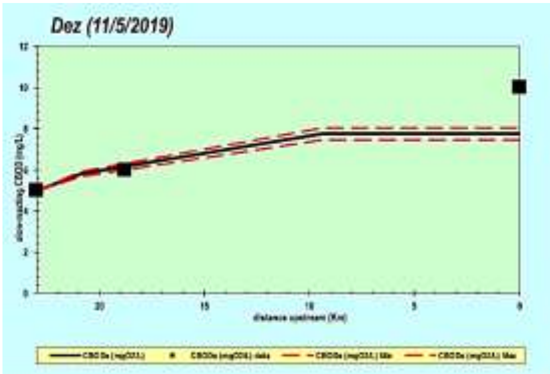

Fig 13. Simulation of BOD_5 in Dez River November 2019

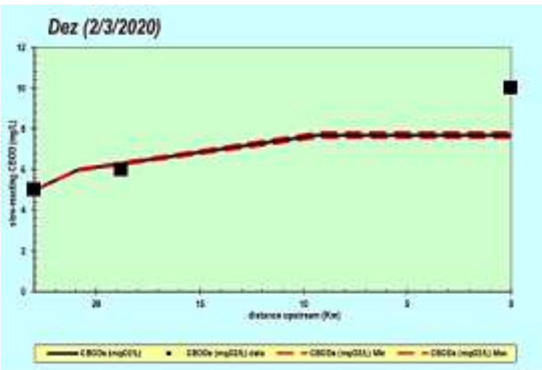

Fig 16. Simulation of BOD5 in Dez River February 2020

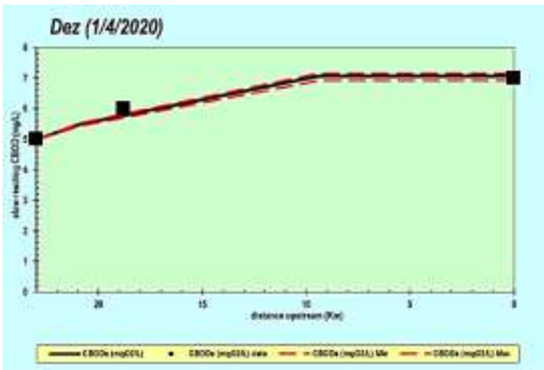

Fig 15. Simulation of BOD_5 in Dez River January 2020

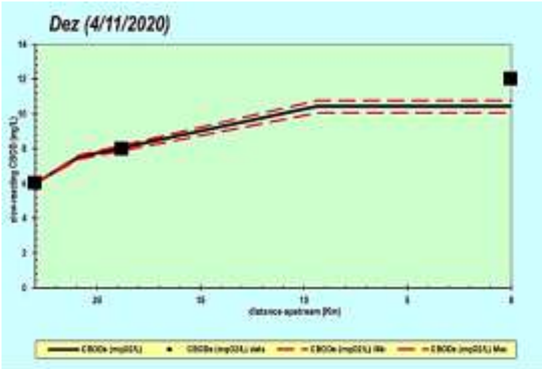

Fig 18. Simulation of BOD_5 in Dez River April 2020

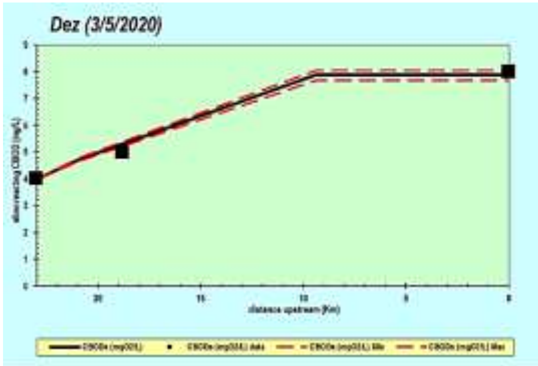

Fig 17. Simulation of BOD_5 in Dez River March 2020

The analysis of model's sensitivity is usually done before, or during, the final calibration to help one have an appropriate understanding of each parameter's change (calibration amounts) in relation to the rates' change. It sometimes happens when a change in the amount of a rate might have opposite results in different parameters, i.e. it might cause the increase in the amount of one parameter and the decrease of another (Rivers' Capability of Self-purification Studies, journal 481). However, we do the simulation (calibration, validation, and verification) and then will deal with the model's sensitivity in relation to the rates of Hydrolyze BOD (khc) figure (19), oxidation BOD figure (20), and the base rate of algae breathing (krlb) figure (21) in order to help the reader have a better understanding of the change in the results of simulation related to the change in the rates. Each rate has specific period so that the user is obliged to ultimately choose a rate within this certain period. Data from December 2020 were used to analyze model's sensitivity. First, the model was performed with minimum rate and its results were compared with the rate used in calibration and validation and with maximum rate. As seen in the figure, with the increase of hydrolyze rate of BOD5, the amount of BOD5 parameter reduces. Regarding the figure (19), the results of BOD5 parameter simulation show a high sensitivity to its change because the results of BOD5 parameter simulation exhibit deep changes against this rate's change. About BOD5 oxidation rate, the results of BOD5 parameter simulation show noticeable changes in oxidation rate, i.e. with a change in BOD5 oxidation rate; many noticeable changes would have been done in simulation results. (fig. 20). For the basic rate of algae breathing, BOD has some minor changes (fig. 21). This kind of analysis on simulation results, known as sensitivity analysis, paves the way for the user to define the most suitable rates for the whole parameters. To achieve the best rate composition, the best way is to define all the rates with high sensitivity to one parameter and the ones with low sensitivity to another, and, first of all, define the amounts of all these rates.

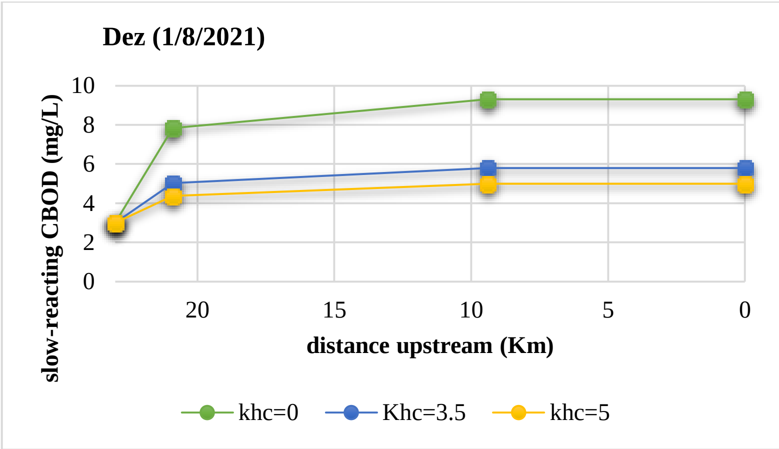

Fig 19. Investigation of changes in BOD simulation by changing the value of BOD hydrolysis rate

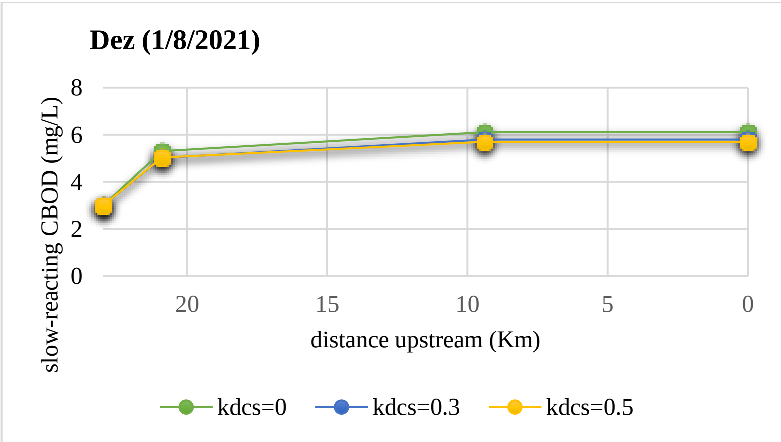

Fig 20. Investigation of changes in BOD simulation by changing the value of BOD oxidation rate

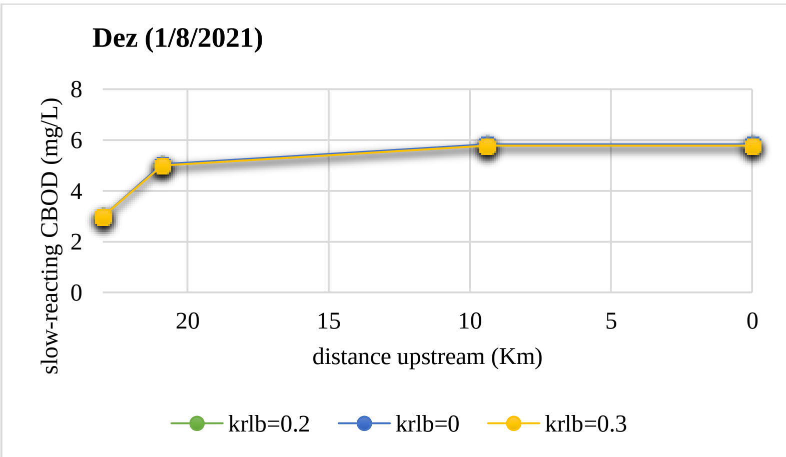

Fig 21. Investigation of changes in BOD simulation changes by changing the basal rate of algal respiration

CONCLUSION

This study was conducted to determine the trend of changes and water quality prediction of Dez River using QUAL2Kw software. The results of research can be summarized as follow. The DO parameter in Kashefiyeh station in all months except January is 5 mg/L and in January 4.9 mg/L is less than river water quality standard (EPA), but in two stations of Pol-e-

Pnjom and Hamidabad Bridge in all months of sampling it is less than 5 mg/L. It is regarded as a threat to aquatic life. BOD5 parameter based on EC/44/2006 EU standard in Hamidabad station is more than 6 mg/L, which is regarded as a threatening factor for aquatic life in this station, but it is less than 6 mg/L in two other stations in all months except April at Pol-e-Panjom station. The amount of DO along the river decreased in all months so that in Pol-e-Panjom and Hamidabad stations it decreased to less than 5 mg/L. Bod5 parameter has an increasing trend along Dez River so that the downstream of Dez River in April 2020 reached the highest value of 12 mg/L in Hamidabad station. The BOD5 rate increases at the beginning of the low interval due to the influx of wastewater since the base discharge is low, and the bed width is high and sensitive to pollutants. River water always flows and its quality fluctuates from upstream to downstream, and this makes the analyzing of pollution load capacity a complicated process (Aliffia and Karnaningroem., 2019; Saliy and Setiawan., 2021). The trend of changes along the river in April 2016 has an increasing trend which can be related to the critical conditions of the river, low basin discharge in this month, the entry of municipal sewage, floating bridges and high water abstraction. By decreasing the discharge, the velocity decreases, the contact length decreases, and the concentration of pollutants increases. Untreated municipal wastewater entering the river raw is one of the factors influencing this parameter. According to the square mean squares of RMSE error, the model had the best conformity for soluble oxygen parameter and, consequently, biological oxygen demand. The results show that this model is more sensitive than river flow, rapid rate of BOD oxidation and nitrification rate compared to other input parameters of the model. QUAL2Kw has the potential to assess water quality along the river and can be used as a valuable tool for Dez River management strategies. Likewise, the implementation of QUAL2Kw should be considered according to the techniques of optimization and evaluation of accuracy in different situations. The total municipal wastewater of Dezful and the villages along the river (except for the refinery of Dezful city) which have a volume of approximately 250 liters per day and contain a variety of microbes and detergents enter the river directly without any refining and purification. They are the most important polluting sources for the Dez River, especially the riverbank. Discharge of sewage in the river path by the municipality due to the construction of the Pol-e-Panjom station, the installation of floating bridges and concrete dams, as well as the construction of parks and tree planting in the river bed resulted in reducing the speed of water. The entrance of domestic wastewater leads to a high concentration of BOD5. This means that oxygen required for biological oxidation of organic matter in wastewater within 5 days is one of the important pollutants of wastewater. Moreover, agricultural effluents entering the river from upstream are considered to be the main reasons for the growth of aquatic plants in the Dez River. This simulation uses a trial and error method on point source and non-point sources in the form of domestic waste from households and hotels. It can be seen that water quality increases and decreases, and several parameters such as Phosphate and BOD, which have great potential to pollute water bodies, exceed water quality standards. The types of pollutants lot go on this simulation, which comes from the Hospital, the Market, and domestic waste. This should, accordingly, be considered because it affects the quality of water in a river downstream (Vichotama et al., 2021). Another reason for the growth of aquatic plants and algae is that widening the river by concrete dam reduces the depth of water and, therefore, sunlight easily penetrates the river floor, leading to rapid growth of these algae. The lack of dredging the river in recent years has caused the growth of algae and moss in a large part of the river so that the flow of water has severely decreased and moss has become the place of accumulation of waste and waste in the downstream of the old bridge and the sides of the floating bridge as well as around the Pol-e-Pnjom. The floating bridge alone has also helped these algae to grow a lot. Among the environmental strategies for maintaining the water quality of Dez River along the way are organizing Gavmish Abad wastewater, directing urban wastewater to Dezful municipal sewage network, clearing and dredging critical areas of algae growth, collecting or urgent measures for reconstruction of floating bridge, releasing the outlet discharge in accordance with the right of Dez River water by Water and Power Organization. Based on the studies and reviews, the most important sources and centers polluting the Dez River include: sewage from the villages by the path, municipal and agricultural wastewater in the upstream. The results are consistent with the results of Nakhaei and Shahidi studies (2010) on the zayandehrud River, Vasudevn et al., (2011) on the Yamana river Delhi, Stackelberg and Neilson (2014) on the Jordan River in the US state of Utah, Bagherianmarzouni et al. (2014) on the Karun river, Mehrasbi and FarahmandKia (2015) on the Karun river, Hoseini and Hoseini (2017) on the Karun river, Biglari et al., (2019) on the Zarine River, and Zallaghi and Afrous (2019) on the Dez River, Nikakhtar et al., (2020) on Khorasan-e-Razavi's Ardak river, Ranjith et al. (2020) on Tungabhadra river in India, Melo et al. on Inhindava river in the north-east of Rio grande Do sul, Hardyanti et al. (2020) on Klampook river.

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CONFLICT OF INTEREST

The author declares that there is not any conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancy has been completely observed by the author.

LIFE SCIENCE REPORTING

No life science threat was practiced in this research.

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