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Determining the best water quality model for the rivers in north of Iran (case study: Pasikhan River)

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Abstract

The aim of this paper is to study the popular models used for the simulation of major elements of a water quality system. The present study compares results of the CE-QUAL-W2 model with the WASP5 and MIKE11 models to assess the water quality of Pasikhan River. The contaminant loadings of Nitrate and Phosphate are utilized in the CE-QUAL-W2, WASP5 and MIKE11 simulations. This study is the first report of the innovative use of three commonly used numerical models for selecting a suitable tool to simulate the rivers water quality. All three models simulated measured data reasonably well. The sensitivity analysis for CE-QUAL-W2 model shows that the model is highly sensitive to the Manning coefficient and point source flow rate. The calibrated model responses are in good agreement with the field data and can be used as scenario generators in a general strategy to conserve or improve the water quality. During the period of intense stratification, predictions from CE-QUAL-W2 are inconsistent better to the measured data than those from Mike11 and WASP5 due to the improved transport scheme used in CE-QUAL-W2. In general, CE-QUAL-W2 offers significant advantages over Mike11 and WASP5 in simulations of water quality in the Pasikhan River.

Keyword: Numerical modeling; Water quality modeling; CE-QUAL-W2; MIKE11, WASP5; Pasikhan River.

1. Introduction

The surface water quality is a matter of serious concern today. Rivers due to their role in carrying off the municipal and industrial wastewater and run-off from agricultural land in their vast drainage basins are among the most vulnerable water bodies to pollution. The surface water quality in a region is largely determined both by the natural processes (precipitation rate, weathering processes and soil erosion) and the anthropogenic influences

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like urban, industrial and agricultural activities and increasing exploitation of water resources [1,2].

Since, rivers constitute the main inland water resources for domestic, industrial and irrigation purposes, it is imperative to prevent and control the rivers pollution and have reliable information on the quality of water for effective management. In view of the spatial and temporal variations in the hydrochemistry of rivers, regular monitoring programs are required for reliable estimates of water quality. This results in a huge and complex data matrix comprised of a large number of physico-chemical parameters, which are often difficult to interpret and draw meaningful conclusions [3]. Further, for effective pollution control and water resource management, it is required to identify the pollution sources and their quantitative contributions. Water quality question in water bodies have been extensively studied using various numerical models in the past decades. Two principal concerns that arise in such situations are the mean fixed level of water quality and the impact of temporal variability of types and levels of pollution on water quality. One of the major factors of effective control is the ability to relate causes (inputs) to effects (outputs) and to predict the effects of control actions and changes to pollution sources. Numerical modeling is an ideal tool for simulating physical, chemical, and biological changes in aquatic systems. Numerical modeling allows rapid and varied evaluation of causes and effects, and its principal advantage is that it enables an analysis of even long-term actions over a short time with limited investment costs. Few examples of a successful application of such programs cause lack of confidence among potential users. Another barrier is the cost dealing with the purchase of commercial simulation programs. Fortunately, it is possible to avoid this by using "public-domain" programs. Currently, several well established one and two dimensional models, such as WASP5 [4], CE-QUAL-W2 [5] and MIKE11 [6] have been used to simulate water quality in river, lake and estuary.

The aim of this paper is to study the results of WASP5, CE-QUAL-W2 and MIKE11 simulations relevant to the specific region in order to select a suitable model needed for the simulation of Nitrate and Phosphate parameters of the shallow rivers. The Pasikhan River was selected as a case study to demonstrate the applicability of the proposed method. The river is located in Guilan province, north of Iran. The selected study area is mostly comprised of agricultural lands and the use of fertilizers and pesticides are common practices. Nitrate and Phosphate are common parameters in fertilizers. The most important environmental problems of Phosphate and Nitrate are the following:

These two parameters are important and essential elements for plant and animal nutrition. High levels of Phosphate and Nitrate can lead to increased eutrophication in lakes and rivers. Furthermore, Nitrate pollution in lakes and rivers can lead to declines in amphibian population.

In order to test the selected models and proposed methodology, Pasikhan River was selected. This river flows through the agricultural lands and is subjected to contamination, therefore, it is a good example for this study and its objectives. Two parameters that are selected to evaluate the simulation results are Nitrate and Phosphate. These parameters have been selected due to their high amounts in agricultural wastewater which is the major source of pollution in the region.

2. Material and methods

2.1. Software water quality models

Three types of model configurations exist in hydrodynamic and water quality modeling of water bodies: one, two and three dimensional models. There are probably as many numerical methods available to solve river water quality problems but each model, separately is useful for a specific project.

2.1.1. One-dimensional models

One-dimensional models are most commonly used in rivers, but can also be used in special cases in estuaries and lakes with large length-to-width ratios. Common one dimensional models are QUAL2E [7], HSPF [8], SWMM [9], DYRESM-WQ [10], CE-QUAL-RIV1 [11], ATV [12] and Mike11. In this study the MIKE11 model was used for simulation. MIKE11 software was developed by Danish Hydraulic Institute (DHI) water and environment, and it is a fully dynamic, one dimensional modeling program which can be used for simulating steady and unsteady flows, water levels, sediment transport and water quality in both simple and complex river and channel systems. The implicit, finite difference scheme is employed in the computation to model the interaction of the fluvial flow and tide through solving the Saint-Venant equation [13]. This software did not take wind effects into account.

2.1.2. Two- and three-dimensional models

Two- and three-dimensional models are typically used in reservoirs, lakes, and estuaries. They are almost exclusively finite element, finite volume, or finite difference. Because large water bodies are generally stratified, they must simulate buoyancy effects; thus, the hydrodynamic and transport equations are coupled, because the buoyancy effects are a major complication in these models. Common two dimensional models are CORMIX [14], WASP5, POM [15], ECOM [16-17] and CE-QUAL-W2. In this study the WASP5 and CE-QUAL-W2 models were used for simulation.

2.1.2.1. CE-QUAL-W2

The CE-QUAL-W2 model uses a numerical scheme for a direct coupling between hydrodynamic and water quality simulations. Also, the model uses the same time step and spatial grid for concurrent hydrodynamic and simulations. Model simulations can be made over seasonal, annual, or multi-year cycles [18-24]. CE-QUAL-W2 model is based on the assumption that flow and transport phenomena in river with a distinct flow direction and a regular bathymetry can be computed from the laterally integrated Navier–Stokes equations [25-26].

In this study the CE-QUAL-W2 model was selected for simulation of Nitrate and Phosphate in Pasikhan River based on available field measurements from Guilan regional water company (2002). The results of this simulation were compared with those of the Mike11 model and WASP5 model. The CE-QUAL-W2 model is based on a finite-difference approximation to the laterally averaged equations of fluid motion including: (1) the free surface wave equation; (2) hydrostatic pressure; (3) horizontal momentum; (4) continuity; (5) constituent transport; and (6) equation of state. The model quantifies the free surface elevation, pressure, density, horizontal and vertical velocities, and constituent concentrations. By solving implicitly the free surface elevation, the restriction of the Courant surface gravity wave stability criterion is lifted, thereby allowing longer time steps for efficient computations. Explicit numerical schemes are also used to compute velocities, which affect the transport of energy and biological/chemical constituents. In CE-QUAL-W2 model applications, the hydrodynamic runs provide real-time simulations of velocities, temperature, and a conservative tracer such as salinity prior to the water quality calculations. Its water quality module can simulate 21 constituents ranging from a conservative tracer, suspended soils, coliform bacteria, total dissolved solids (or salinity), labile and refractory dissolved oxygen matter, algae, detritus, ortho Phosphate or total Phosphorus, ammonia, nitrite/nitrate, dissolved oxygen, sediment, total inorganic carbon, alkalinity, PH, carbon dioxide, bicarbonate, carbonate, iron, and carbonaceous biochemical oxygen demand (CBOD). Users have the option to select a subset of interrelated constituents in the simulation. A predominant feature of the model is its ability to compute the two-dimensional velocity field for narrow systems that stratify. Flow and the distribution of water quality parameters in stratified rivers are governed mainly by a dynamic balance between the adjective transport in the longitudinal (and to some extent vertical) direction and the turbulent (diffusive) transport in the vertical direction. Accordingly, CE-QUAL-W2 uses the laterally averaged equations of continuity, momentum and transport. The main formulations involve a vertically varying, longitudinal momentum balance, vertical momentum in the form of the hydrostatic approximation and local continuity, and longitudinal and vertical transport of the different constituents.

2.1.2.2. WASP5

The WASP5 (Water quality Analysis Simulation Program) system is a generalized framework for modeling contaminant fate and transport in surface waters. The model does not solve a set of multi-dimensional dynamical equations, but rather is based on the flexible compartment modeling approach. WASP5 can be applied in one, two, or three dimensions. Problems that have been studied using the WASP5 framework include biochemical oxygen demand and dissolved oxygen dynamics, nutrients and eutrophication, bacterial contamination, and organic chemical and heavy metal contamination. The hydrodynamic module of WASP5 is based on the conventional Saint-Venant equations that describe one-dimensional unsteady flow in an open channel. Using the principle of mass conservation, the equation of continuity has the following form

$$\frac{\partial H}{\partial t} + D\frac{\partial U}{\partial x} = 0 \qquad (1)$$

where H is the water surface elevation (head) (m), D is the water depth (m), U is the longitudinal velocity (m/s), t is the time (s), and x is the longitudinal distance (m). The equation of motion can be derived from the principle of conservation of energy, or momentum. Taking into consideration the actions of gravity and the force of friction exerted by the bed, the equation of motion is given by

$$\frac{\partial U}{\partial t} + U\frac{\partial U}{\partial x} = -g\frac{\partial H}{\partial x} - g\frac{n^2}{R^{4/3}}U|U| \qquad (2)$$

where g is the acceleration of gravity m/s^2 , n is the Manning roughness coefficient (s/m^3) and R is the hydraulic radius (m) [27].

2.2. Study area

The Pasikhan River is one of the main rivers in the central of Guilan province and after passing from Pasikhan valley, it reaches to Anzali lagoon. Pasikhan is the most polluted river that reaches Anzali lagoon. The average of river annual discharge is about 736 MCM per years. The river length and basin is about 75 km and total area of approximately 665 Km^2 respectively [28]. The river originated from heights with 2800m level. The top branches of the rivers are: Siyah Mezgi, Emamzade Ebrahim and Chenar roudkhan. The Pasikhan River system is an important source of water supply, tourism and recreation and irrigation for farming. The condition of the Pasikhan River and its branches have degraded with agriculture and human activity waste water discharge over the years in term of water pollution, river environment and ecosystem. The study area is from Emamzade Ebrahim hydrometric station to Nokhaleh hydrometric station. The quality parameters in these two stations and 4 other stations between them were measured and analyzed. The river and the selected stations are shown in figure 1.

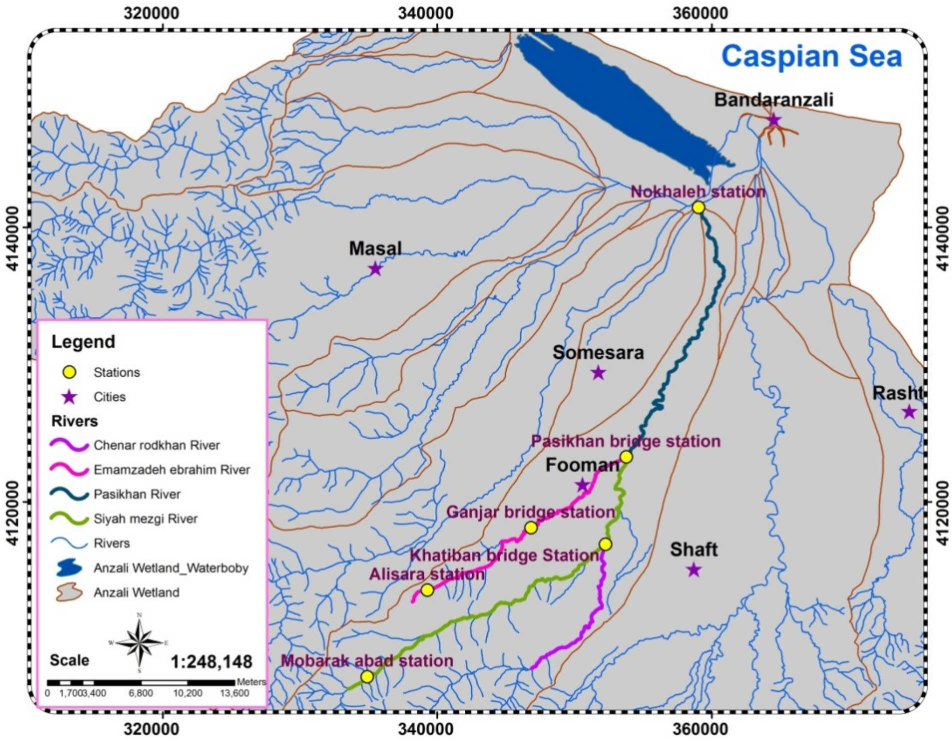

Figure 1.The location of quality stations on Pasikhan River.

The Guilan Provincial Water Company has carried out water quality monitoring programs of the Pasikhan River in Guilan since 2004-2005 through a network of six stations. The monitoring of water quality at the 6 stations was performed for six times; three times in 2004 (27 Jul, 27 Aug and 27 Oct) and four times in 2005 (25 Jan, 25 Apr, 26 May and 26 Jan) For the purpose of establishing the water quality of the river, water quality monitoring stations were selected, covering upper and lower regions of Pasikhan River. During each sampling, measurements of temperature and water flow were taken using relevant field meters. The samplings nitrate and Phosphate analysis have been done at the Guilan regional water company Laboratory. To initiate the process of modeling all the identified streams of the study area, details of the main catchment of Pasikhan River, physical characteristics of the river such as cross sectional levels and dimensions, longitudinal bed profiles and slopes, meteorological and hydrological data such as rainfall for Pasikhan region, parameters and coefficients of the affected water quality components and pollution inputs in term of pollutant concentration was compiled and analyzed. Tables 1 and 2 illustrate the characteristics of the samples in Pasikhan River. The degradation of water quality is the direct impact of pollution due mainly to the changes in the land use pattern such as urbanization, infrastructure development, deforestation, tourism, agricultural activities and waste dumping. The region of Pasikhan River catchment with the high level of agriculture activities and settlements close to the river banks was most highly affected. The results of water quality tests show that Phosphate and Nitrate exit the region with high rate.

Table 1. Nitrate values in field data mg/l

	27.7.2004	27.8.2004	27.10.2004	25.1.2005	25.4.2005	26.5.2005	26.6.2005
Mobarak abad	3	5.3	4.2	6.21	2.91	3.05	0.28
Khatiban bridge	2	0	1.01	0.4	2.64	2.7	0
Pasikhan bridge	4.6	0	0.04	6.01	3.49	2.98	0.3
Nokhaleh	0	0	0	6.45	3.01	2.33	0.28
Alisara	1.2	1.7	2.4	1.31	4.39	4.51	4.35
Ganjar bridge	1.5	3.2	1.81	2.14	3.69	2.82	1.53

Table 2. Phosphate values in field data mg/l

	27.7.2004	27.8.2004	27.10.2004	25.1.2005	25.4.2005	26.5.2005	26.6.2005
Mobarak abad	1.14	0	0	0	0	0	0
Khatiban bridge	1.5	0.09	0	0	0	0.14	0.02
Pasikhan bridge	0.16	0.36	0	0.62	0.36	0.24	0.12
Nokhaleh	0.18	0.16	0.26	1.09	0.72	0.12	0.04
Alisara	1.82	0	0	0	0	0.04	0.04
Ganjar bridge	1.88	0	0	0	0	0	0.04

2.3. Statistical Criteria

2.3.1. Required data for modeling

To simulate the river with CE-QUAL-W2 model, information from the ecological conditions, topography of the district and also simulation duration are required which are as follows:

Duration of simulation: The first day of sampling selected as the simulation initial time. According to CE-QUAL-W2 model manual, the data must enter in terms of the days past from the 1th January. Therefore the first day of simulation is 207.5th day of 2004 and the simulations have been done in days of 238.5, 299.5, 389.5, 479.5, 510.5 and 541.5. After running the model the first 5 data were used for the calibration purposes and data of the next 2 days were used for validation.

River geometry: The first file to model is river geometry. In this file firstly the river divided to some segments and each this segments become smaller the accuracy of modeling increase but the running time of model increase too. To increase the accuracy of the modeling in outlet points the segments are between 30 to 50 m and in the others parts between 500 to 1000 m. On this regard Siyah Mezgi branch was divided to 34 segments and Pasikhan and Emamzadeh Ebrahim branches to 108 segments totally. The river was divided to 3 layers in the vertical dimension in which each layer is equal to 2m. The first and the last layers and segments are taken as the boundary conditions.

Meteorological data and Physiology of the case study: The date that specify in meteorological file includes: air temperature, dew point, wind speed and cloud cover during the modeling days. For shading coefficient, according to software manual the coefficient equals to 0.5 was selected for all segments.

Boundary conditions: The data of Nitrate and Phosphate values, water temperature and water discharge in the upstream and in a separate file enters to the model as the boundary conditions. In this research the boundary conditions in Alisara station (upstream of Siyah Mezgi River) and Mobarak Abad station (upstream of Emamzadeh Ebrahim and Pasikhan Rivers) are used for modeling.

River draining and pumping: Water pumping from various regions of the river and drainage water entering into the river can cause point source changes in loads of pollutants. This information which includes flow rate, temperature and concentration of the qualitative parameters in the water are given in the form of tributary data files to the model.

2.3.2. Calibration and validation the model

While modeling formulation is more related to science, calibration has aspects more related to art [29]. Good calibrations are more than curve fitting exercises that simply align model simulations with observed constituent behavior. The most preferable calibration approach among modelers and researchers is the manual user guided calibration. In this study for hydrodynamic calibration, measured levels at Mobarak Abad and Alisara stations were used as the upstream and Pasikhan bridge and Nokhaleh stations were used as the downstream boundary conditions. For calibration and validation the data (data obtained during 7 months) divided to two groups. First 5 months (about 70 percent of data) used for calibration and the next two months used for validation. In this research, Nitrate and Phosphate transport and processing kinetic coefficients were estimated using model guideline recommendations and river conditions. After calibration and validation, to analyze the accuracy of each simulated parameters correlation coefficient, mean of absolute Error (3) and performance coefficient (4) are computed. It must be mentioned that with higher amount of performance coefficient and near zero value for the mean of absolute error and correlation coefficient, the model results are more accurate.

$$MAE = \frac{1}{N} \sum_{i=1}^{N} \left| (x_p - x_o)_i \right| \tag{3}$$

$$C_p = \frac{\sum_{i=1}^{N} (x_p - x_o)^2}{\sum_{i=1}^{N} (x_o - \overline{x}_{ave})^2} \tag{4}$$

where x_p, x_e, $\overline{x}_{ave}$ and N are simulated data, field data, average field and number of data, respectively.

2.3.3. Sensitivity analysis and Calibration of CE-QUAL-W2

Sensitivity analyses were done involving a number of input parameters that can be separated into three categories. The first category comprises parameters that were not measured but would potentially be involved in the calibration process, including the thermal conductivity of the stream bed and evaporation coefficients. A second category included meteorological parameters measured at a single location and assumed spatially uniform over the study area. Although these parameters were not adjusted during calibration it was desirable to assess their influence on model output. A third category included discharge, stream width, riparian vegetation height, and shade factor, which is a product of the vegetation density and contiguousness. These parameters would be directly affected by potential management practices; therefore, the sensitivity of the models to these parameters was very important. In this part, first, sensibility analyses have been done to find the parameters that model depends more to them and then the simulation data for calibration obtained. One parameter with high sensibility in the model is the Manning coefficient with which a little variation can change the results significantly. Therefore the Manning coefficient in Mobarak Abad and Nokhaleh stations are specifically used for calibration. After running the model, 0.033 was selected as the Manning coefficient in Pasikhan River. Variation of input drainage water to the river and pumping from the river are the other parameters used for calibration. Considering the fact that data related to drainage water and the pumping were not of high accuracy, the model showed high sensitivity to their changes. Therefore, in order to calibrate the model, changes between 20-30% were applied in these data. The results of sensibility analyses in Pasikhan and Ganjar bridges are shown in figures 2 and 3.

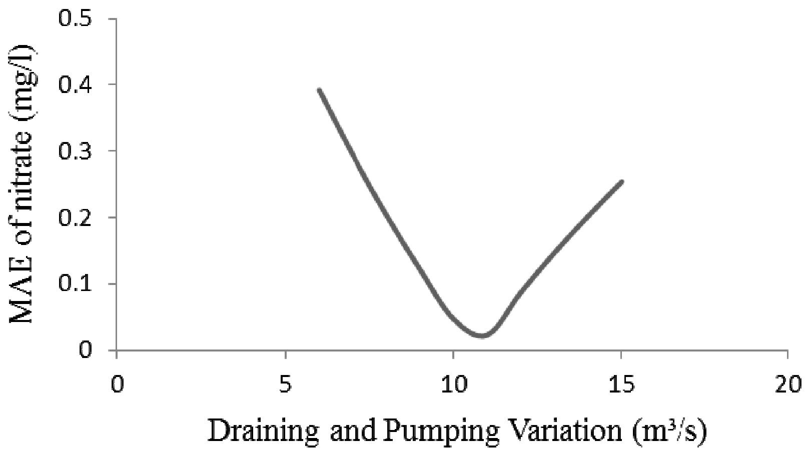

Figure 2. MAE of Nitrate value versus to draining and pumping in Pasikhan Bridge station.

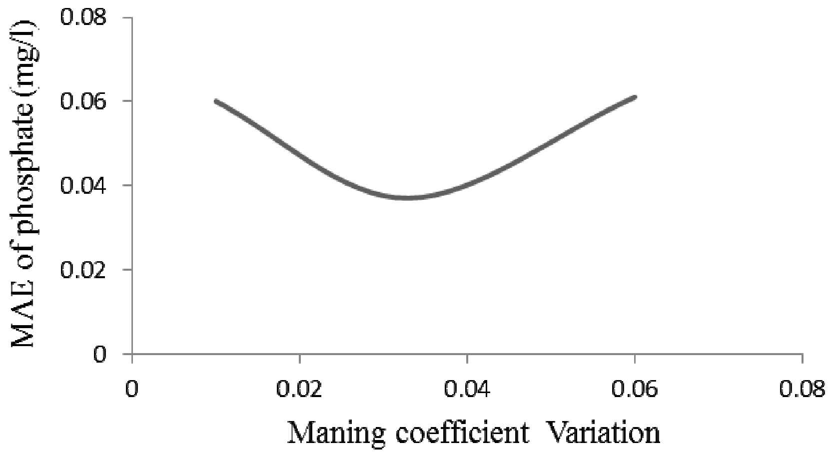

Figure 3. MAE of Phosphate value versus Manning coefficient in Ganjar Bridge station.

The results show the quality parameters in different parts of the river have decreasing or increasing trend that depends on agricultural activities and drainage in the area. Therefore the Nitrate values increase in Emamzadeh Ebrahim and Pasikhan branches in Mobarak Abad and Pasikhan bridge stations. Furthermore the results show that the Nitrate values in all stations increased during the cultivation season. The Phosphate values in the river are trace except in two regions of Emamzadeh Ebrahim and Pasikhan branches. The statistical analyses and the mean of absolute error and performance coefficient are computed in the calibration stage and are shown in Tables 3 and 4.

Table 3. R^2 values of Nitrate and Phosphate in calibration stage.

Parameter	Mobarak abad	Khatiban bridge	Pasikhan bridge	Nokhaleh	Alisara	Ganjar bridge
Po_4 $\left(mg/l\right)$	99%	92%	79%	94%	99%	99%
No_3 $\left(mg/l\right)$	85%	95%	99%	99%	96%	97%

Table 4. C_p and *MAE* values in calibration stage.

River name	parameter	C_p	MAE
Emamzade Ebrahim	No_3 $\left(mg/l\right)$	0.035	0.24
	Po_4 $\left(mg/l\right)$	0.29	0.16
Siyah Mezgi	No_3 $\left(mg/l\right)$	0.03	0.189
	Po_4 $\left(mg/l\right)$	0.0854	0.084

2.3.4. Validation of CE-QUAL-W2

After calibration, the validation of the model has been done with field data in six stations. Then the results of simulation were compared with the field data to find the efficiency of the model. After the validation of data with analytical analysis, the mean of absolute error (*MAE*) and performance coefficient (C_p) are computed for Nitrate and Phosphate separately in each branch. The results show that the minimum (C_p) and (*MAE*) values in validation stage belong to Nitrate in Siyah Mezgi branch. The Nitrate value in Emamzadeh Ebrahim and Pasikhan branches range from 1.015 to 3.891 (mg/l) during June. The maximum amount observed in Siyah Mezgi River at Alisara station due to the main drain discharges in upstream of the station. The Phosphate value in June reaches to 0.24(mg/l) and reaches to 0.12(mg/l) in July in Pasikhan bridge. The Phosphate values in the other parts of the river were traced. The validation data of Nitrate and Phosphate and the statistical analyses are shown in Tables 5 and 6 respectively.

Table 5. C_p and *MAE* values after validation stage.

River name	Parameter	C_p	MAE
Emamzade Ebrahim	No_3 $\left(mg/l\right)$	0.128	0.262
	Po_4 $\left(mg/l\right)$	0.245	0.026
Siyah Mezgi	No_3 $\left(mg/l\right)$	0.018	0.12
	Po_4 $\left(mg/l\right)$	0.17	0.024

Table 6. The results of CE-QUAL-W2 model in validation stage for Nitrate and Phosphate.

Station name	Date of simulation	No_3 $\left(mg/l\right)$		Po_4 $\left(mg/l\right)$	
		Field data	Simulated data	Field data	Simulated data
Mobarak abad	26.05.2005	3.051	3.891	0	0
	26.06.2005	0.28	1.276	0	0
Khatiban bridge	26.05.2005	2.7	2.615	0.14	0.208
	26.06.2005	0	0.073	0.02	0.28
Pasikhan bridge	26.05.2005	2.98	3.048	0.24	0.131
	26.06.2005	0.3	0.321	0.12	0.018
Nokhaleh	26.05.2005	2.33	2.334	0.12	0.011
	26.06.2005	0.28	0.291	0.04	0.197
Alisara	26.05.2005	4.51	4.779	0.04	0.095
	26.06.2005	4.35	4.764	0.04	0.091
Ganjar bridge	26.05.2005	2.82	2.834	0	0.055
	26.06.2005	1.53	1.555	0.04	0.027

3. Results and Discussion

3.1. Comparing the results of CE-QUAL-W2 with WASP5 and Mike11

Maleki [30] simulated the Nitrate and Phosphate in Pasikhan River by using Mike11 and WASP5. The results between Mike11, WASP5 and CE-QUAL-W2 compared with each other and are shown in Tables 7, 8 and 9. The simulated and field data in four stations include: Khatiban bridge station, Pasikhan bridge station, Nokhaleh station and Ganjar station on: 2005/05/26 and 2005/06/26. The mean of absolute error (MAE) and performance coefficient (C_p) were computed for simulated data to compare the results of three models and are shown in Table 9. As it can be seen in the abovementioned tables (MAE) and (C_p) are the minimum in CE-QUAL-W2 model that shows good agreement of the model in shallow rivers to simulate the selected parameters. The assumptions made in CE-QUAL-W2 could be one reason for these results.

Table 7. Results of simulation of Nitrate and Phosphate by WASP5 with field data.

Station name	Date of simulation	No_3 $\left(mg/l\right)$		Po_4 $\left(mg/l\right)$	
		Field data	Simulated data	Field data	Simulated data
Khatiban bridge	26.05.2005	2.7	2	0.14	0.2
	26.06.2005	0	0.053	0.02	0.016
Pasikhan bridge	26.05.2005	2.98	3.6	0.24	0.16
	26.06.2005	0.3	1	0.12	0.09
Nokhaleh	26.05.2005	2.33	1.4	0.12	0.18
	26.06.2005	0.28	0.5	0.04	0.031
Ganjar	26.05.2005	2.82	1.5	0	0.01
	26.06.2005	1.53	2	0.04	0.033

Table 8. Results of simulation of Nitrate and Phosphate by MIKE 11 with field data.

Station name	Date of simulation	No_3 $\left(\frac{mg}{l}\right)$		Po_4 $\left(\frac{mg}{l}\right)$	
		Field data	Simulated data	Field data	Simulated data
Khatiban bridge	26.05.2005	2.7	2.184	0.14	0.021
	26.06.2005	0	0.02	0.02	0.029
Pasikhan bridge	26.05.2005	2.98	1.21	0.24	0.021
	26.06.2005	0.3	0.8	0.12	0.028
Nokhaleh	26.05.2005	2.33	1.473	0.12	0.02
	26.06.2005	0.28	0.311	0.04	0.027
Ganjar	26.05.2005	2.82	3.19	0	0.037
	26.06.2005	1.53	2.7	0.04	0.037

Table 9. *MAE* and C_p values for CE-QUAL-W2, WASP5 and MIKE11 compare.

Parameter	Statistical Parameters	CE-QUAL-W2	WASP5	MIKE11
NO3	MAE	0.037	0.627	0.654
	C_p	0.001	0.206	0.529
PO4	MAE	0.031	0.032	0.074
	C_p	0.239	0.329	1.831

4. Conclusion

The results of this study have shown that predictive tools based on CE-QUAL-W2 model offer reliable results if compared with those of WASP5 and MIKE11 models. The CE-QUAL-W2 is a suitable model for analyzing the quality parameters in shallow river. The best simulation belongs to the Phosphate parameter. According to the results CE-QUAL-W2 is more compatible with the field data comparing with Mike11. Because the Nitrate is unstable, the trend of Nitrate during the months is not the same as Phosphate. The results also show that the effects of discharging drain water and wastewater in the river are quite noticeable and affect the river water quality. This wastewater has effects on the downstream of the rivers too. Therefore the drain water and wastewater must be controlled and treated before discharges directly to the rivers. In addition, application of water quality models is an established tool in water resources management.

References

[1] S.R. Carpenter, N.F. Carao, R.W. Correll, R.W. Howarth, A.N. Sharpley and V.H. Smith, Nonpoint pollution of surface waters with phosphorus and nitrogen. Ecological Applications, *Journal of Ecological Applications*, Vol. 8, (1998) 559-568.

[2] H.P. Jarvie, B.A. Whitton and C. Neal, Nitrogen and phosphorus in east - coast UK rivers: speciation, sources and biological significance. *Sci. Total Environ*, 210-211, (1998) 79-109.

[3] W. Dixon, B. Chiswell, Review of aquatic monitoring program design, *Water Research, Water Res*, 30, (1996) 1935–1948.

[4] R.B. Ambrose, T.A. Wool, J.L. Martin, *WASP5.x, A Hydrodynamic and Water Quality Model–Model Theory*, *User's Manual*, and Programmer's Guide, USEPA, USA, 1993.

[5] T. Cole, E. Buchak, *CE-QUAL-W2: A Two-dimensional, Laterally Averaged, Hydrodynamic and Water Quality Model,* Version 2.0, Instruction Report EL-95-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 1995.

[6] *DHI, MIKE11 User Manual*, DHI Software, 2005.

[7] L.C. Brown, T.O. Barnwell, *The Enhanced Stream Water Quality Models QUAL2E and QUAL2E-UNCAS: Documentation and User Manual*, USEPA/6003-87/007. USEPA, USA, 1987.

[8] *ATV, Allgemein verfuegbares Gewaesserguetemodell. Projektabschlussbericht*, *02 WA9104/4, ATV,* Hennef, Germany, 1996.

[9] M. Inc, E. Inc, *Storm Water Management Model Volume I – Final Report*, U.S. Environmental Protection Agency, 11024DOC07/71, 1971.

[10] D. Hamilton, S. Schladow, Prediction of water quality in lakes and reservoirs. Part 1 - Model description, *Ecological Modelling,* Vol. 96, (1997) 91–110.

[11] Environmental Laboratory, *CE-QUAL-RIV1: A Dynamic, One-dimensional (longitudinal) Water Quality Model for Streams: User's manual,* Instruction Report EL-95-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS, 1995.

[12] B.R. Bicknell, J.C. Imhoff; J.L.Jr. Kittle, T.H. Jobes; A.S.Jr. Donigian, *Hydrologic Simulation Program – Fortran, User's Manual*, in cooperation with USGS and USEPA, 2001.

[13] M.B. Abbott, *Computational Hydraulics: Elements of the Theory of Free Surface Flows*, Pitman, London, 1979.

[14] G.H.Jirka, R.L.Doneker, S.W.Hinton, *User's manual for CORMIX: A Hydrodynamic Mixing Zone Model and Decision Support System for Pollutant Discharges into Surface Waters*, Prepared for USEPA Office of Science and Technology, Cooperative Agreement No. CX824847-01-0, 1996.

[15] A.F. Blumberg, G.L. Mellor, *Three-Dimensional Coastal Ocean Models*, edited by N.S. Heaps (American Geophysical Union, Washington, DC), 1987.

[16] A.F. Blumberg, G.L. Mellor, A coastal ocean numerical model in Mathematical Modelling of Estuarine Physics, *Proceedings of an International Symposium*, Hamburg, August 24-26, 1978, edited by J. Sundermann and K.P. Holz, pp. 202-219, Springer-Verlag, New York, (1980).

[17] A.F. Blumberg, G.L. Mellor, A description of a three-dimensional coastal ocean circulation model in Tree-Dimensional Coastal Ocean Models, *Coastal Estuarine Stud*, Vol. 4, edited by N. Heaps, pp. 1-16, AGU, Washington, D.C., 1987.

[18] E.J. Garvey, E. Tobiason, M. Hayes, E. Wolfram, D.A. Reckhow, J.W. Male, Coliform transport in Pristine Reservoir: modeling and field studies, *Water Science and Technology*, Vol. 37, 2 (1998) 137-144.

[19] O. Gunduz, S. Soyupak, C. Yurteri, Development of water quality management strategies for the proposed Isikli Reservoir, *Water Science and Technology*, Vol. 37, 2 (1998) 369-376.

[20] R.G. Kurup, D.P. Hamilton, R.L. Phillips, Comparison of two-dimensional laterally averaged hydrodynamic model application to the Swan River Estuary, *Mathematics and Computers in Simulation*, Vol. 51, (2000) 627-638.

[21] J.T. Kuo, W.C. Liu, R.T. Lin, W.S. Lung, M.D. Yang, C.P. Yang, S.C. Chu, Water quality modeling for the Feitsui Reservoir in northern Taiwan, *Journal of the American Water Resources Association*, Vol. 39, 3 (2003) 671-687.

[22] W.S. Lung, S. Bai, A water quality for the Patuxent Estuary: current conditions and predictions under changing land-use scenarios, *Estuaries*, Vol. 26, 2A (2003) 267-279.

[23] J.L. Martin, Application of two-dimensional water quality model, *Journal of Environmental Engineering, ASCE*, 114 (1988) 317-336.

[24] C.P. Mc Kee, E.L. Thackston, R.E. Speece, D.J. Wilson, R.J. Cardozo, *Modeling of Water Quality in Cheatham Lake*, *Technical Report No.42*, Environmental and Water Resources Engineering, Vanderbilt University, Nashville, 1992.

[25] S. Bloss, R. Lehfeldt, J.C. Patterson, Modelling turbulent transport in stratified estuary, *Journal of the Hydr. Eng, ASCE*, 114 (1988) 1115–1133.

[26] E.M. Buchak, J.E. Edinger, *Longitudinal–vertical Hydrodynamics and Transport: Development, Programming and Applications,* Prepared for U.S. army corps of engineers waterways experiment station, Contract No. DACW39-84-M-1636, Vicksburg, MS, 1984.

[27] V. Vuksanovic, F. De Smedt, S. Van Meerbeeck, Transport of polychlorinated biphenyls (PCB) in the Scheldt Estuary simulated with the water quality model WASP5, *Journal of Hydrology*, Vol. 174, (1996) 1-18.

[28] B. Razdar, K. Mohammadi, J.M.V Samani, Simulation of Nitrate and Phosphate Parameters in Pasikhan River using CE-QUAL-W2 Model and the results compare with Mike11 model, *4th National Congress on Civil Engineering*, Tehran, Iran, (May 7-9, 2008).

[29] R. Whittemore, Editorial: is the time right for consensus on model calibration guidance?, *Journal of Environmental Engineering, ASCE*, 127 (2001) 95–96.

[30] R. Maleki, Comparing of Mike11 and WASP5 Models in Simulation of river water quality, Case study: Foomanat Region, *M.Sc. Dissertation*, Submitted to the Department of Agriculture Engineering, Tarbiat Modarres University, 2005.