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# Simulation of Water Pollution Load Reduction in the Zayandehrood River, Isfahan, Iran Using Qual2kw Model

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## Abstract

Today, due to the usage of rivers for transferring urban and industrial wastewaters as well as agricultural drainage water, they are exposed to different sources of pollution. Therefore, knowing the trend of qualitative changes of rivers is effective for controlling pollution sources. In this study, the water quality of Zayandehrood River was investigated and for simulation of qualitative data, Qual2kw model was used. The information used includes qualitative information of the river water and hydrometric, meteorological and contaminants information. The investigated parameters were BOD, DO, and nitrate which were taken from 12 stations. Simulation of qualitative data by Qual2kw model for BOD and DO parameters suggests that there is a suitable match between the measured and simulated data, but simulation for nitrate parameter was not performed well. The results of model indicated that due to withdrawal of water for agricultural uses, the river water's flow rate was very low at terminal stations. Furthermore, dissolved oxygen concentration in these stations was very low, while the chemical oxygen demand concentration was very high due to entry of industrial and human wastewater. For this reason, the river is no longer able to receive organic load and does not have self-purification capability.

## 1. Introduction

Water is one of the primary natural sources for consumption, fish breeding, entertainment, etc. Therefore, traditionally, humans have always been trying to use water resources [1]. Surface water, especially across large cities, is exposed to discharge of numerous contamination sources. These contaminants are able to alter the balance of the ecosystems [2]. Due to rapid development and urbanization, water scarcity and pollution have significantly affected the availability and quality of water resources [3].

Furthermore, the growth of the population together with rapid industrialization, urbanization, and increased agricultural production have brought about contamination in waters and diminished quality of water ecosystems, especially in urban creeks and rivers in developing countries [4]. Most rivers in Iran, such as the Zayandehrood and the Karoon, are reported to be polluted because of an inflow of liquid and solid wastes [5].

Rivers have self-purification properties and do it through chemical processes such as oxidation, hydrolysis, and photochemical reactions, physical processes such as sedimentation, evaporation, and aeration, and biological processes [6].

To solve environmental problems, managers should select suitable programs for mitigation of pollution [4]. To achieve this target, water quality planning and management are needed along an entire river to ensure that the assimilative capacity remains sufficient along the entire river. To address this, the complex relationships between waste loads from different sources and the resulting water quality of the receiving waters need to be studied. Mathematical models describe these relationships [7].

In recent decades, various models have been developed for simulation and investigation of water quality. Among these methods are WASP7, TOMCAT, SIMCAT [8,9], along with artificial intelligence methods, especially artificial neural network [10] Another series of models is called Qual2k models, designed by American Environmental Protection Agency [11]. It is one of the most well-known instruments for simulation of water quality, with flexibility, free access, and convenient usage being the main features of this model [12].

Qual2k model have the potential for the simulation of different water quality parameters in wet and dry seasons as well as long and short rivers, and can also run with low amounts of data [10]. QUAL2Kw can simulate a number of water quality parameters including temperature, pH, carbonaceous biochemical demand, sediment oxygen demand, dissolved oxygen, organic nitrogen, ammonia nitrogen, nitrite and nitrate nitrogen, organic phosphorus, inorganic phosphorus, total nitrogen and phosphorus [13]. Zhang et al. (2012) studied the quality of the Taihu Lake Basin using QUAL2K model and concluded that the water quality of this lake was the result of wastewater and effluent discharge in Hongqi River which flows in Taihu Lake [14]. Giraldo et al. (2015) modeled the 50km of the Aburra-Medellin River using the Qual2kw model. A calibrated model with 3 scenarios (short, medium, and long term) was investigated. The results showed positive effects of Bello's sewage treatment on the balance of BOD, dissolved oxygen and nitrogen [15].

## 2. Material and Methods

### *2.1. Study area*

Zayandehrood originates from Zardkouh mountain chain in Zagros area. After passing over the main Zagros fault, it enters Sanandaj-Sirjan area and eventually pours down into the Gavkhuni swamp, which is located in the boundary of Sanandaj-Sirjan [10]. Zayandehrood water basin is located in the middle of the Iranian central plateau, at coordinates of 50°02' to 53°24' of eastern longitude and 31°11' to 33°42' of northern latitude. The area of this basin is around 41550 km2 and its average altitude 2514 m [16].

Zayandehrood River is the only permanent river of this water basin, originating from the eastern ranges of Zardkouh Bakhtiari in the middle Zagros and flows in the direction of southwest to northeast reaches the Zayandehrood dam. From this point onwards, the river changes its direction towards southeast and follows a distance of around 435 km and after passing from north of Chaharmahal and Bakhtiari province and Isfahan plain, it pours into Gavkhuni swamp, around 20 km away from Varzaneh village [17].

### *2.2. Data*

To employ Qual2kw model for simulation of rivers, a series of input information should be determined for the model. This information includes qualitative information of the river water, hydrometric information, information about the river's cross sections, meteorological information, and information about the input contaminants in the region of interest. The utilized qualitative data was collected through sampling in both dry and wet seasons. The qualitative parameters used for simulation of the water quality of Zayandehrood river included concentration of dissolved oxygen, biological oxygen demand, and nitrate.

The hydrometric information and the information of the river's cross sections were obtained from hygrometry stations of the regional water company of Isfahan province. The number of stations of interest is 9, with the information obtained included water discharge, water flow rate, and water depth. Information about input contaminants in the study area include the most important point contaminants of the Zayandehrood river including Isfahan steel plant, Mobarakeh Steel factory, slaughterhouses, livestock facilities, treatment plant in the south of Isfahan, etc. Nonpoint contaminants include agricultural drainages and runoffs.

The most essential meteorological data required by Qual2kw software include air temperature, dew point temperature, cloud coverage, and wind speed. This information was obtained from the meteorological organization of Isfahan province. The information was collected from synoptic stations established around the river.

### *2.2. Qual2kw software*

Qual2kw model can solve equations associated with the river under both permanent and pseudo-dynamic conditions. The QUAL2K framework, developed by the US Environmental Protection Agency, can simulate the migration and transformation of conventional pollutants. This program is able to simulate parameters including dissolved oxygen, biochemical oxygen demand, temperature, chemical oxygen demand, total nitrogen, and suspended solids, etc.

Using Qual2kw model, simulation of the Zayandehrood river water in both wet and dry seasons in 2017 was done and following the model calibration, simulation of the qualitative parameters including dissolved oxygen, biochemical oxygen demand, and nitrate was performed.

### *2.3. Method*

The first stage is River discretization, for which and to determine the sampling stations, GIS maps and Google Earth software were used. River discretization is conducted based on a dramatic change in the river discharge or its quality including the site of discharge of urban or industrial wastewater or the site of entry of peripheral branches of the river or in sections where change occurs in hydraulic conditions of the river. The second stage is sampling and data collection for the Qual2kw software. Meteorological and hydraulic information of the river was taken from relevant organizations and sampling was performed in February 2014 and July 2016. The samples were then transferred to a laboratory in order to be analyzed according to standard methods. The parameters measured at each station included water temperature, pH, biochemical oxygen demand (BOD), dissolved oxygen (DO) and nitrate.

The third stage is incorporation of the collected data in the specific worksheet of each data, which includes qualitative properties of the river upstream, air temperature, dew point temperature, cloud cover, and data of the samples taken from the sampling stations. Once the data was introduced, the output model could be extracted. The last stage of simulation is model calibration. In this research, the model was calibrated through trial and error. After entering different data in the relevant worksheets, output was obtained. Then, for greater match between the diagram of observational data and simulation data, calibration was performed manually.

## 3. Results and discussion

*3.1. Analysis of qualitative data*

*Dissolved oxygen (wet season)*

The diagram of changes in the measured and simulated dissolved oxygen in December 2014 and January 2015 is presented in Figure 1. As can be observed, the value of dissolved oxygen gradually increases from beginning of the range, and after a while, it diminishes, such that the DO value reaches zero from around the second half of the river.

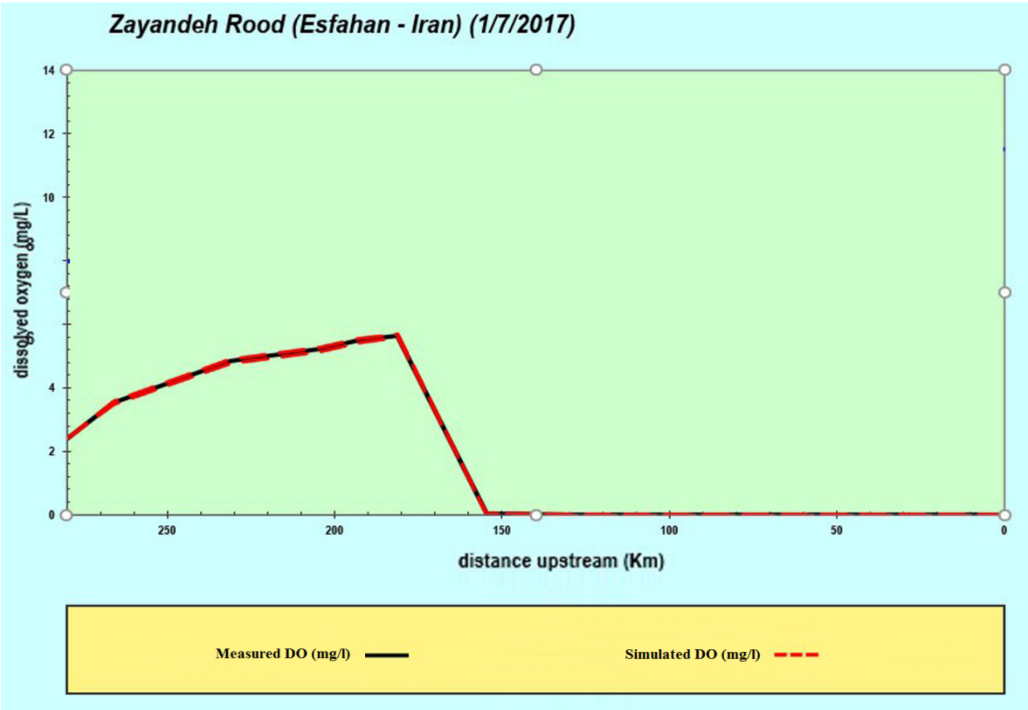


**Figure 1:** Simulated DO (mg/L) in wet season of the year

*Dissolved oxygen (dry season)*

The output diagram of DO in the dry season of the year is shown in Fig. 2. As can be observed, the diagrams of measured and simulated data have suitable match, suggesting proper simulation of this parameter by Q2kw model. The extent of DO in water is very trivial in dry seasons of the year and from the second half of the river, it reaches zero.

*Biochemical oxygen demand (wet season)*

According to Figure 3, representing changes in measured and simulated CBOD of the river, no difference was observed between the diagram of observational data and simulation data.

Considering the CBOD diagram, the extent of this parameter is very trivial in initial stations. However, as the wastewaters of different industries enter the river, CBOD value increases and becomes constant at terminal stations.

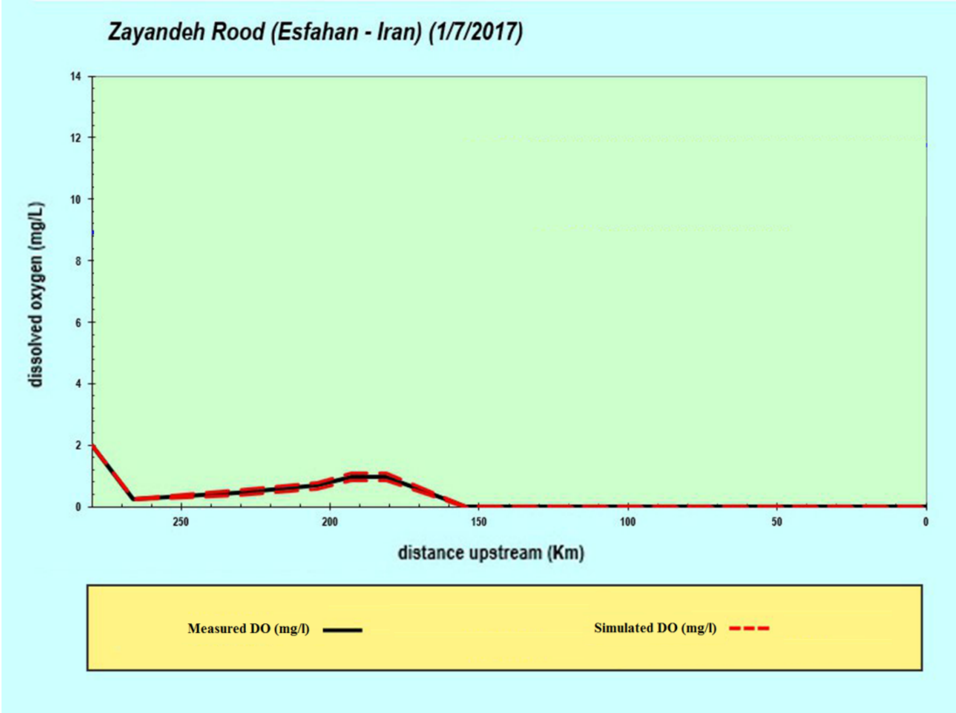


**Figure 2**: The diagram of simulated DO (mg/L) in dry season

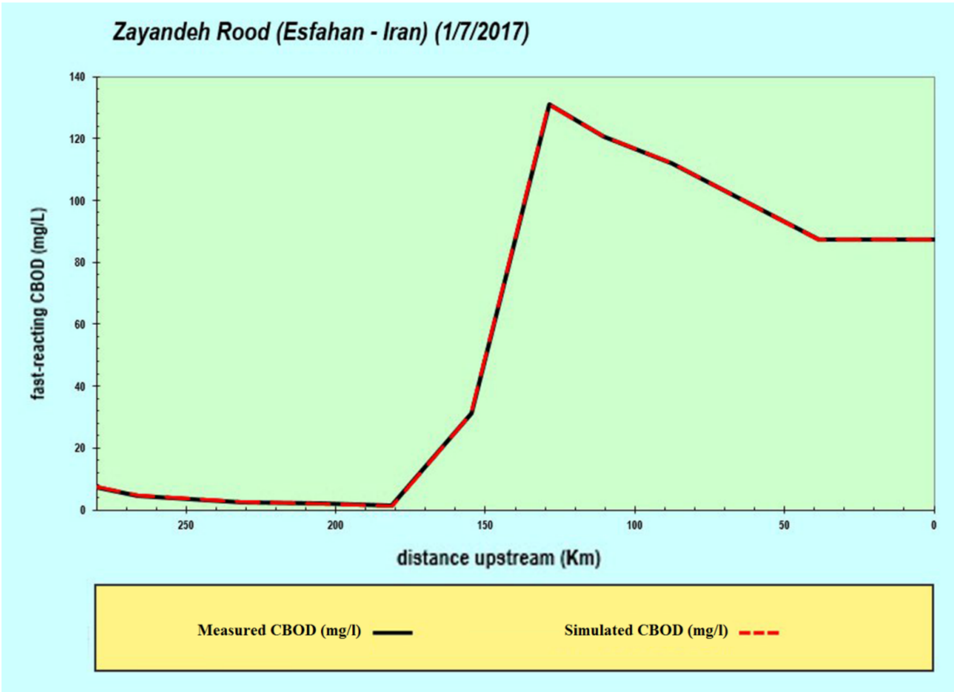


**Figure 3:** Simulated CBOD (mg/L) in the wet season of the year

*Biochemical oxygen demand (dry season)*

Based on Fig. 4, a complete match between observed that observational and measured data have been observed The extent of simulated CBOD at initial stations is not considerable, but gradually from 130 to 180 km, it increases dramatically, and then diminishes gradually again.

*Nitrate (wet season)*

The diagram of changes in the nitrate in the river for the measured and simulated data is provided in Figure 5. As can be seen, at the beginning of the output diagram, no match point has been observed between the measured and simulated data. However, at the 150 kilometer-mark, these two types of data have found match with each other.

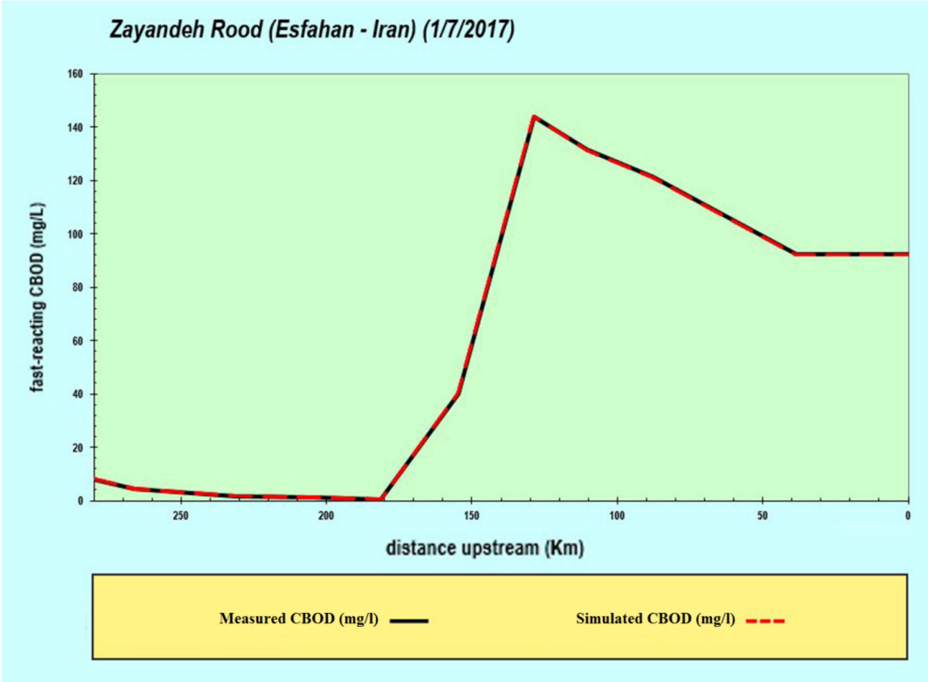


**Figure 4:** The diagram of simulated CBOD (mg/L) in dry season

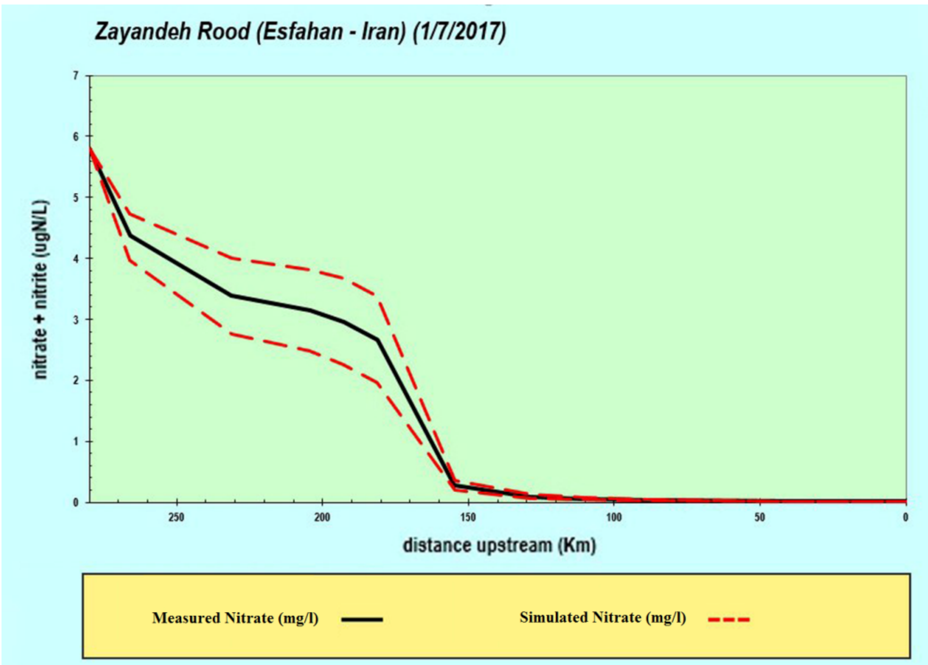


**Figure 5:** Simulated Nitrate (mg/L) in the wet season

*Nitrate (dry season)*
The diagram of changes in the measured and simulated nitrate in June and July 2016 is shown in Fig. 6. The output diagram of the simulated nitrate at the beginning of the river is around 10.5 mg/L, but at 270 kilometers, it diminishes dramatically and then reaches zero. However, the measured nitrate has followed an opposite trend and from 270 kilometers to the end of the river, it increases gradually.

*3.2. Discussion*
*Dissolved oxygen (wet season)*
As can be observed in the diagram of dissolved oxygen simulated in the wet season of the year, the value of DO in headwater is 2.4 mg/L, which increases gradually up to 170 kilometers from headwater. This is due to the fact that from Cham Heydar to Cham Aseman station, there are no considerable point and nonpoint contaminant sources.

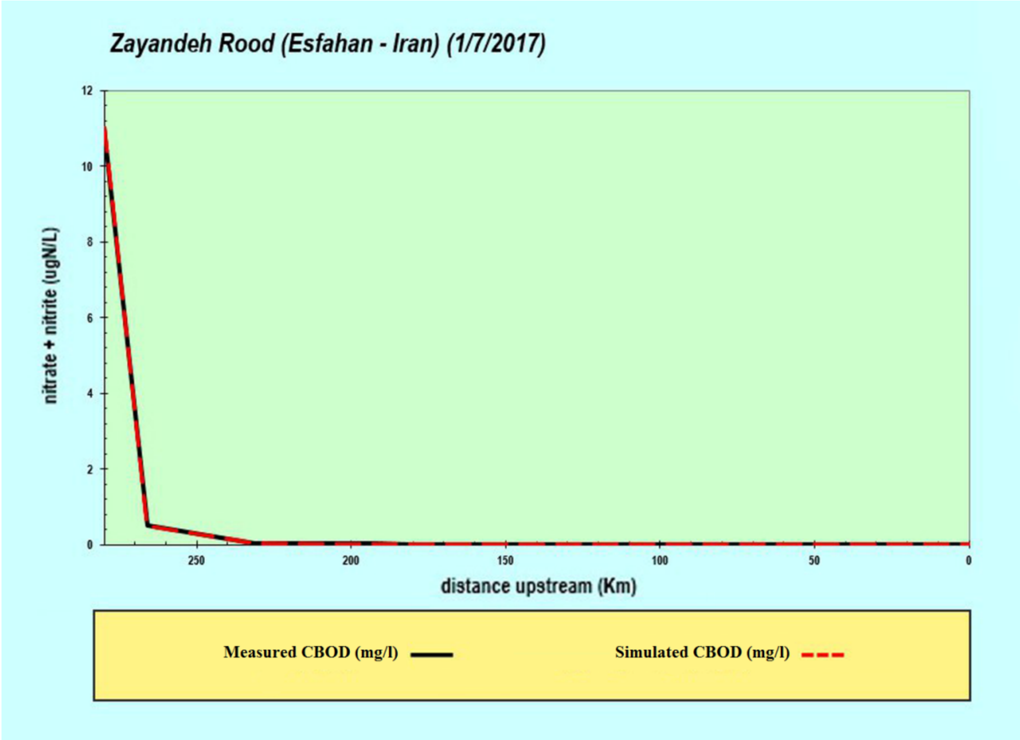


**Figure 6:** The diagram of simulated nitrate (mg/L) in dry season

From the 170 km, a dramatic decrease in DO is observed, such that its value reaches 1 mg/L in this part of the river, which is due to entry of untreated wastewater from slaughterhouses, livestock facilities. This causes elevation of the organic load of the river and reduction of its dissolved oxygen. In the last stage, once the river leaves Isfahan city and urban and rural wastewaters enter the river, DO consumption for oxidation of organic compounds in the water reaches around 0.2 mg/L. Eventually, DO value of the water that pours into the Gavkhuni swamp is 0.1 mg/L.

Overall, based on the output results obtained from the simulation, it was observed that the trend of changes in the dissolved oxygen along the river was descending which can be due to entry of various pollution sources along the river as well as hydraulic conditions of the river including diminished flow rate of the river and water discharge. These result in diminished extent of river aeration and a falling trend of dissolved oxygen in the river. Hadgo et al. (2014) also concluded that the release of different pollution sources into the river caused the reduction of dissolved oxygen along the Ndarugu River in Kenya [18].

According to the research carried out by Magagoyev et al. (1393) and Hadgo et al. (2014), in general, according to the results of simulation results, the process of changes in dissolved oxygen along the river is decreasing due to It can be noted that several sources of pollutants along the river, as well as the hydraulic conditions of the river, such as the reduction of river flow and the reduction of water flow, can be reported, which leads to a decrease in the aeration rate of the river and the decreasing trend of dissolved oxygen in the river.

*Dissolved oxygen (dry season)*

Considering the DO diagram simulated in the dry season, DO concentration measured at the upstream station of the river was 2 mg/L. At subsequent stations, the trend is the same up to kilometer 190 onward where there is a gradual decrease in DO, reaching 0.1 mg/L in the last station.

The output diagram obtained from simulated data also indicates this, but only at 260 kilometers, DO level dropped dramatically and reached 0.2 mg/L, and then increased again gradually to Morkan station. The cause of the dramatic decrease in DO may be the lack of enough information in this part of the river.

The gradual decrease in DO from 130 kilometer onwards was also due to discharge of wastewater of different industries including slaughterhouses, tallow water drilling, ossification powder, etc.

The critical status of DO in June and July 2016 in comparison with December 2015 and January 2016 is due to the considerable decrease in the river's discharge, elevation of air temperature and increased metabolic activity in water, decreased cloudiness, and diminished precipitation.

*Biological oxygen demand (wet season)*

The value of the measured BOD in the headwater of river was below 5 mg/L, which followed the same trend up to 180 kilometers. However, from 130 to 180 km, due to entry of wastewater from industries, tallow water drilling, drains, and livestock water, etc., which have a high BOD percentage, the BOD value went up dramatically to 130 mg/L.

From 130 km onwards, BOD value was decreasing gradually, yet its value was still high. This was because it passed through Isfahan city. BOD value at terminal stations and downstream of the river reached 83 mg/L, and did not grow significantly reaching the Gavkhuni swap.

Based on comparison of the results obtained from the output of the measured and simulated data in this research, it can be concluded that the river is not able to receive high organic load as well as wastewaters. This is due to usage of the water along the river. Furthermore, before reaching Isfahan city, the river water was utilized for agriculture and water flow rate and discharge of the river came down after Isfahan city. Giraldo et al. (2015) also mentioned the similar results in their study [2].

*Biological oxygen demand (dry season)*

As it can be observed in the simulated BOD in the dry season, BOD concentration of the river was low at the first stations. However, from 130 to 180 km, with the entry of organic contaminants which enter the river from point and nonpoint sources, BOD level increased dramatically from 5 to 140 mg/L. This was due to entry of wastewater including the wastewater of animal husbandries, household wastewater from villagers, wastewater produced by slaughterhouses, etc. From 50 to 130 km, BOD of water diminished gradually, reaching 100 mg/L at the end of the river route.

According to the output diagram of the simulated data, it is observed that the output diagram has a large distance with the measured BOD value in some points. This is due to entry of untreated urban and rural wastewater from poultry breeding industries, etc. Furthermore, the cause of increased BOD level in summer compared with winter is elevation of water temperature in summer, fall in dissolved oxygen in water, decreased precipitation, etc.

*Nitrate (wet season)*

Considering the diagram of simulated nitrate in the wet season, which indicates the output results of nitrate for the river in December and January, the output of the model has no match point with the measured data. In the upstream of this river, at Chamheydar station, the level of nitrate was measured to be 5.8 mg/L, but along the path due to diminishing water discharge and entry of contaminants resulting from agricultural drainage, its concentration gradually increased. The maximum nitrate concentration was found in Varzaneh station, at 11 mg/L. The main reason for this is wastewater resulting from animal husbandry activities. These activities produce large amounts of nitrogen and phosphorus, and the wastewater resulting from these centers is usually not treated. As most of these centers are close to Varzaneh station, elevated nitrate levels have been observed in this region.

In the output diagram resulting from simulated data, the opposite has occurred, whereby the nitrate-concentration diagram is descending, such that it reaches zero by the last station. Considering the obtained output diagram, it can be found that Q2kw model does not have a good potential for nitrate simulation.

*Nitrate (dry season)*

Considering the diagram of nitrate simulated in the dry season, it was observed that the maximum nitrate concentration usually occurred in late winter and early spring, which can be due to nitrate leaching in response to precipitation in winter and beginning of cultivation season. The nitrate measured at the upstream station of the river was 10.5 mg/L, which gradually increased up to the 180 kilometer-mark. This was due to entry of agricultural drainages in the region into the river water. However, from 180 kilometers to the last station, it is observed the diminished nitrate level in the river, which reached 6 mg/L in the last station.

However, the output diagram of the simulated data shows the opposite. According to the diagram obtained from the simulation data, from the first station, nitrate level experienced a dramatic decrease near the 270 km point and reached 0.5 from 11 mg/L. Then, from 270 km onwards to the end of the river, nitrate level fell gradually reaching zero in the last station.

As mentioned previously, the output diagram obtained from the simulation of nitrate parameter suggests that Qual2kw model does not have a suitable performance for simulation of this parameter and simulation has not been performed correctly.

## Conclusion

Based on available data and the values of simulated DO which is within the standard quality criteria of DO above 4 mg/L along Zayandehrood River, water quality was acceptable at upstream stations of the river. However, at active downstream stations, the water quality has deteriorated. The concentration of dissolved oxygen along the river had a decreasing trend, which could be due to entry of various pollution sources along the river as well as the hydraulic conditions of the river including diminished flow rate of the river and water discharge, resulting in lowered extent of river aeration, thereby decreasing dissolved oxygen in the river. Due to excess water usage from the river for agricultural uses, the river became dry after reaching Varzaneh station. The extent of biochemical oxygen demand increased along the river and was due to the release of contaminants containing organic compounds into the river, thereby causing a fall in dissolved oxygen of the river. Concentration of nitrate increased from upstream station to the last sampling station, which was due to the release of wastewater resulting from agricultural activities, causing entry of nitrogen and phosphorus into the river. In this study, it was found that the extent of dissolved oxygen in the river was very low, especially at downstream stations and the river was not able to receive organic load any further. Shortage of water dissolved oxygen caused slower oxidation of organic compounds, and the river lost its self-purification potential gradually. The simulation of water quality data by the Qual2kw model for the BOD and DO parameters shows that there is a good match between the measured and simulated data and it proved the potential of Qual2k model.

## References


1. S. Prajithkumar, S. Verma, B. Mahajan, *IJERGS*, 3(2015) 652-658.
2. B.L. Giraldo, C. Palacio, R. Molina, R. Agudelo, *DYNA*. 82(2015) 195-202.
3. L. Zhang , M.R. Hipsey, G.X. Zhang, B. Busch, H.Y. Li, Water *Sci Technol,* (2017) in press.
4. W. Zhu, Q. Niu, R. Zhang, R. Ye, X. Qian, Y. Qian, *Int. J. Environ. Res. Public Health*, 12(2015) 2215-2229.
5. M. R. Mehrasbi, Z. Farahmand Kia, *J. Hum. Environ. Health Promot*., 1(2015) 1-11.
6. Fisenko, How Does the Niagara Whirlpool Get Involved in Niagara River Self-Purification. (2013) https://www.researchgate.net/publication.
7. M. Rafiee, A. M. Akhond, H. Moazed, S. W. Lyon, N. Jaafarzadeh, B. Zahraie*, JHS,* 1(2013) 10-22.
8. E. Elsayed, *JNRD,* 4(2014) 54-63.
9. M. Azimi, A. Ghavasieh, H. Hashemi, S. Barekatein, S. Jafari Gol, *National water Congress with clean water approach, water and power industry University*, (2012) 1-2 march.
10. M.A. Hossain, I. Sujaul, M. Nasly, *RJRS*, 3(2014) 6-14.
11. The United States Environmental Protection Agency. *Stream Water Quality model (Qual2k)*. http://www.epa.gov/Athens/wwqtsc/index.html
12. Davoodi, *Advanced Applied geology*, 16(2015) 60-71.
13. P. R. Kannel, S. Lee, Y. S. Lee, S. R. Kanel, G. J. Pelletier, *Ecol. Model.* 202 (2007) 503-517.
14. R. Zhang, X. Qian, X. Yuan, R. Ye, B. Xia, Y. Wang, *Int J Environ Res Public Health* 9(2012) 4504-4521.
15. L. R. Giraldo, C. Palacio, R. Molina, R. Agudelo, *Dyna* 82(2015) 195-202.
16. S. Modaberi, R. Harami, A. Alizadeh, A. Mahbubi*, The 12th Congress of Iranian Geology Association* (2008), Ahwaz.
17. R. Jafari, *Sari natural resources and agricultural Sciences University*, water engineering group, (2010) 7-8 December.
18. L. Hadgu, M. Nyadawa, J. Mwangi, P. Kibetu, B. Mehari, *CWEEE* 3 (2014) 162-169.


(2018) ; http://www.jmaterenvironsci.com