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ORIGINAL RESEARCH PAPER

Investigation of Daily Waste Load Allocation in Zarrineh-Rud River for Environmental Management of Cold-Water Fish Species

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ABSTRACT

A critical aspect of qualitative management of water resources is the optimal waste load allocation in a river system. Zarrineh Rud is one of the crucial, permanent, water-rich rivers in West Azerbaijan province in the northwest of Iran and the Urmia lake basin. The present study investigates the effects of daily waste load on environmental management of cold-water fish species in a portion of Zarrineh Rud with a length of 57.5 km using the QUAL2K simulation model. The selective parameters of the model were flow rate, dissolved oxygen (DO), biochemical oxygen demand (BOD). Simulations were conducted for May 2019. The model was calibrated by determining the oxidation coefficient of carbonic materials and the reaeration coefficient of the river, based on the root-mean-square-error (RMSE) measure. To determine the susceptible and critical points in Zarrineh Rud, the dissolved oxygen (DO) was considered the most critical indicator based on standards associated with cold-water fish farming and maintaining the aquatic life in the river ecosystem. Results showed that the concentration of dissolved oxygen in the river is variable between 7-8 mg/L, which exceeds the maximum standard value required for aquatic life. The output data of the simulation model revealed that the maximum allowable value of dissolved oxygen deficit is 2 mg/L based on cold-water fish species standard and 1.35 mg/L based on aquatic life preservation standard. The station S5 at the river downstream with 3.53 mg/L dissolved oxygen deficit was the most critical point for cold-water fish farming, and the 26th kilometer of the river with a dissolved oxygen deficit of 2.05mg/L was the most critical point for maintaining the aquatic life; therefore, some scenario must be developed for waste load reduction at this station.

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1. Background

Since ancient times, human being has been seeking water resources along with their control and management. Currently, regarding the ever-increasing demand for drinking water, agriculture and industry on the one hand, and climatic changes and water scarcity from others, require to deploy advanced methods for water resources management. As one of the vital surface water resources and valuable ecologic resources, rivers have multiple roles and functions like drinking water supply, water transportation, industry and urban demands, water transportation, fishing, fisheries, visual and aesthetic values (Jalilzadeh yengejeh et al., 2014; Roomiani, 2016;Amin Fard et al., 2019;Jalili, 2020;). Understanding the causal relationship between river water quality and waste loading is the first action to determine the self-purification capacity of a river. This relationship is affected by different physical factors such as flow rate, flow velocity, depth of water, movement time, temperature, and chemical biochemical properties like sediment oxygen demand (SOD), photosynthesis, algae respiration, and nitrification. Besides these features, the rate of different reactions should be considered in studying this relationship (Sajjadi et al., 2019). For identifying the expected reaction of the river against the pollutant discharges, different mathematical models should be developed. These models not only allow the prediction of future loading effects but also estimate the water quality in response to the conditions not monitored in the past (e.g., a critical condition in low flow rate) (Fataei et al., 2011; Nazari et al., 2020). Rivers are valuable water resources, and their health condition and preservation survive the life of all creatures used them. The sustainable application of each function must be based on protective principles and sustainable deployment from the river, and oversight to the river capacity can lead to water pollution and threaten the ecosystem's life (Hakimpour, 2005). The ever-increasing development of agricultural and industrial activities and impressive volume of urban sewage cause the pollution of water resources, especially rivers. Rivers' pollution is one of the crucial problems of water resources and relates to the economic development and life quality in many countries worldwide (Chapra et al., 2008; Nikpour et al., 2020;Azarm et al., 2020;Ahari et al., 2021;Nikpour et al., 2021). Controlling, monitoring, and predicting the variation of qualitative parameters in quality management of rivers demonstrate that involved people and analysts inevitably need approaches, techniques, and models that are close to the nature of the problem as far as possible and are in more conformance with the environment. The qualitative method for simulating rivers, owing to their features, can provide suitable and fruitful procedures to recognize and analyze river pollution in as detail as possible, followed by arguments, controls, and correct decisions about qualitative management of water (Tajrishi., 2011;Orooji et al.,2021). The qualitative modeling allows us to acquire a clear understanding of the reaction of a water body against tensions arising from the waste load and can help us plan and make decisions in the framework of qualitative guidelines (Oliveira et al., 2013;Ghanavat Amani, 2021). Qual2kw model has also been used for simulating the seasonal changes of self-purification in the Karun River. In this study, a region of length 113 km was selected in the river, and BOD, DO, nitrate, and chloroform contents were examined to simulate the water quality of the river considering different scenarios by decreasing and increasing the flow rate of river and pollutant sources (Moghimi Nezhad et al., 2017). Also, another study has been conducted on the Dez river to investigate its self-purification capacity showing its 98% self-purification capacity (Ebadati, 2017). Qual2kw simulation model was used to examine the self-purification capacity of Divandarreh river; also, AME and root-mean-square-error were applied to evaluate and validate the model's results (Babakhani, 2019). In another study conducted on the Jajar river (Indonesia), results indicated no natural purification process in this river. In other words, the experiments on water samples in each inlet section show the waste existence, which is verified by unacceptable results for DO and BOD concentration parameters (Nugraha, 2020). It should be noted that the leakage from the river to groundwater is one of the critical phenomena required to be evaluated in rivers and is a necessary tool for pollutant elimination (Semenov, 2019).

In another study, a water quality modeling system was developed for the Gaoping river basin in Taiwan. Results showed that suspended solids play an essential role in calculating the water quality index (WQI) of the river, and they were a critical factor for calculating WQI, especially at the upstream part of the basin in water-abundant seasons. This was because soil erosion leads to an increase in the concentration of suspended solids in the water after floods that occur in water-abundant seasons, and the high flow rate of the river causes the discharge of pollutants from non-point sources ammoniacal nitrogen at the upper parts of the river. Also, results showed that an integrated approach could directly link a river's flow velocity, water quality, and pollution index (Lai, 2013). The self-purification capacity has been implied as to the main factor in predicting the Bhavani river health in India. A river of length 215 km was considered in this study, and oxygen was introduced as the most influential factor in the self-purification capacity of rive (Kartigha, 2017). A combined program of modeling and WASP qualitative simulation was utilized for evaluating the effects of plants in the Reedy River in South Carolina on eliminating the effluents discharged from sewage treatment plants both qualitatively and quantitatively. All variables used in TMDL were applied in the first simulation, and in the second simulation, the model included the complete elimination of effluents of sewage treatment plants discharged into the river. Results showed that eliminating effluents cause the removal of 70% of waste load by upstream plants and a 66% removal of waste load downstream. Based on the daily flow rate values, it was predicted that all nitrogen, phosphorous, and mass loads would be reduced on average in seven years (Privette et al., 2017). Huang used the SWAT model to evaluate the effect of land cover and land use on the water resources of the northern river basin in China. Results demonstrated a good agreement between simulated and observed data both daily and monthly and the monthly amount of phosphorous and ammoniacal nitrogen loads (Huang et al., 2013). Another research was conducted to identify the pollution sources and evaluate their effects on the Galing river in Malesia using numerical simulation models, results showed that Galing river has low-quality water due to the discharge of domestic and industrial wastewater, which is categorized as class 4 in terms of river water quality. The prediction model revealed that an 80% decrease in the river waste load could enhance river water quality to class 2 (Lee et al., 2017). In another study, the QUAL2Kw model is applied to evaluate the reaction of the Sertima river in Portugal to different waste loads such as nitrogen and phosphorous. The comparison between the measured and simulated flowrates indicated that it is necessary to decrease the actual load of phosphorous and nitrogen by 5-10 times to enhance the class of rive from eutrophic to mesotrophic (Oliveira et al., 2012).

In evaluating self-purification capacity in Juma River, China, the self-purification capacity was introduced as one of the critical factors affecting river health (Tian et al., 2011). Measurements performed for examining the self-purification capacity showed that biological sampling could complete the physio-chemical analysis of water quality (Gonzales et al., 2014). Different types of qualitative models have been evolved for simulating rivers, reservoirs, bays, and groundwater. QUAL2K is among the models mainly used for simulating river systems. In recent decades, different simulation models have been employed for the qualitative management of rivers. In these methods, the river is divided into some segments, and this can be done where an abrupt change occurs in river flowrate or its water quality, such as the points at which wastewaters are discharged, or secondary branches of river are joined. Accordingly, the intended parameters of governing equations are calculated in each segment and assumed to be constant in the river's length. QUAL2K is extensively applied for simulating the water quality in rivers. This model can consider the river systems branch-wise or with its secondary branches; also, it can simulate river in 1D with the non-uniform steady-state flow and take into account both the point and nonpoint loading effects. QUAL2K can also simulate variation daily with lower than 1-hour time steps (Kerachian, 2012).

Since Zarrineh Rud river is among the essential arteries of water supply for Urmia lake in northwestern Iran and catches different pollutant streams in its path, the present study aims to evaluate the daily waste load of this river for environmental management of cold-water fish species using QUAL2K model.

2. Materials and Methods

2.1. Study Region Introduction

This river is located at geographical coordinates of 45° 45' - 47° 24' N and 35° 40'-37° 28' E. Different point and nonpoint sources of pollution such as Miandoab sugar factory wastewater, effluent flowed out of Miandoab wastewater treatment plant, slaughterhouse wastewater, and agricultural effluents and urban wastewaters of nearby villages are discharged into the river and decrease its water quality. In the present study, a subsection of the river between the Nourozlu diversion dam and the river discharge into Urmia lake, about 57.5 km in length, was selected for evaluating the water quality of Zarrineh Rud using the QUAL2K model. Qualitative specifications of sampling site in May and August 2019 are presented in Tables 1 and 2. The evaluation of model output results (model calibration) was performed by varying the oxidation coefficient of BOD and reaeration coefficient applying RMSE measure; then, coefficients with the lowest RMSE were selected as the best parameters for the model calibration.

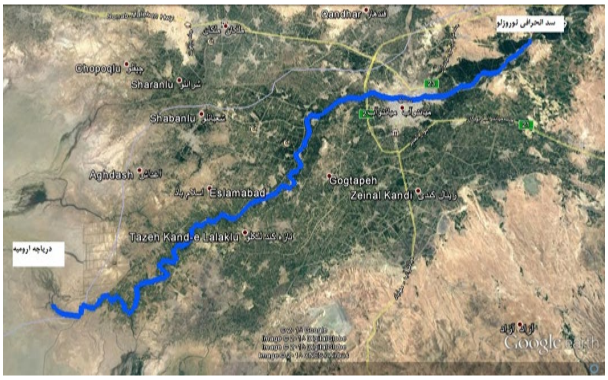

Figure 1. Study area of Zarrineh-rud river

Table 1. Quality characteristics of Zarrineh-rud sampling site in May 2019

No	S-Psition(Km)	BOD	Do	EC	Ph	T
S1	57.5	3.8	7.2	454	7.8	25
S2	49.5	3	5.6	537	7.9	21
S3	40.14	5.1	6.0	562	7.6	12
S4	23.08	3.9	5.5	655	7.85	18
S5	0.2	3.7	5.2	983	7.7	19

Table 2. Quality characteristics of Zarrineh-rud sampling site in August 2019

No	S-Psition(Km)	BOD	Do	EC	Ph	T
S1	57.5	5.0	5.6	400	7.6	25
S2	49.5	4	5.5	520	7.6	21
S3	40.14	9.5	5.0	550	7.7	12
S4	23.08	10.5	4.0	576	7.8	18
S5	0.2	6.5	3.5	650	7.9	19

QUAL2K model divides a segment of the river into several numerical elements and conducts the hydrologic balance in terms of flow rate (m3/s), thermal balance in terms of temperature (°C), and mass balance in terms of concentration (mg/L) for each element.

3.Result

The evaluation results of the qualitative simulation model (model calibration) of Zarrineh River in spring based on the square root mean square error (RMSE) method between the simulation data and the observational data are presented in Table 3. As mentioned above, the most proper coefficient for model calibration is selected based on the lowest RMSE. Therefore, the best oxidation coefficient of BOD was obtained with RMSE of 0.14, and the best reaeration coefficient of the river was determined as 8.5 with RMSE of 0.24, and then both of them were applied to model calibration.

Table 3. Results of quantitative comparison between QUAL2K model and observational data for Zarrineh-rud river in spring

No	Reaeration coefficient of DO (observational data)				Oxidation coefficient of BOD (observational data)			
	8.5	15	22	33	2	3	4	5
RMSE	0.24	0.87	1.01	1.15	0.99	0.43	0.14	0.51

The trend of variation in parameters of electrical conductivity (EC), Nitrate (NO3), and Ph in sampling stations of Zarineh-Roud river was evaluated in the spring and summer seasons of 2019 in comparison with FAO standards for irrigation of agricultural products. According to conducted investigations, the results of electrical conductivity parameter is less than 700 µohms/cm in all sites except the S5 site in the spring season. Therefore, the quality of Zarineh-Roud river water for agricultural irrigation usage is without any limitation according to FAO standards. Also, the Ph variation graph for Zarineh-roud river water is in the range of 6.5-8.5 (the allowable limit for agricultural irrigation) in all stations in both spring and summer seasons of 2019. The nitrate variation graph of the Zarineh-roud river is in the range of the maximum allowable limit for consumption in agricultural irrigation in all sites in the spring and summer seasons of 2019. With this description, it can be concluded that the quality of Zarineh-roud river water regarding under investigation parameters is suitable for irrigation of agricultural products.

3.1. Analysis of inorganic suspended solids

The graph of simulation of inorganic suspended solids (ISS) for Zarineh-roud river in spring and summer seasons of 2019 is presented in figures 2 and 3. As it can be seen, there is a good correlation in all stations in the spring season except S4 and S5 stations. The value of the concentration of inorganic suspended solids of Zarineh-roud river is 125, 152 milligrams per liter in site S1 in spring and summer in order. The concentration of this parameter has been increased a little in both seasons by the entrance of agricultural drain water. The maximum increase has happened in 46-kilometer distance point by the entrance of sugar factory wastewater. This parameter value at the mentioned point has reached 150 and 174 milligrams per liter in spring and summer in order. There has not been any important occurrence in the deposition of these materials in the remaining parts of the river considering the density of suspended material and flow rate of the river. The concentration of these materials has been stable approximately down to the end of the river and has been reached 151 and 173 milligrams per liter in station S5 in spring and summer in order.

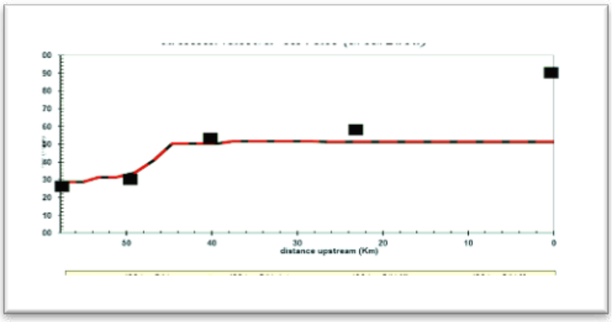

Figure 2. Simulation graph of suspended solids in Zarineh-roud river in May 2019

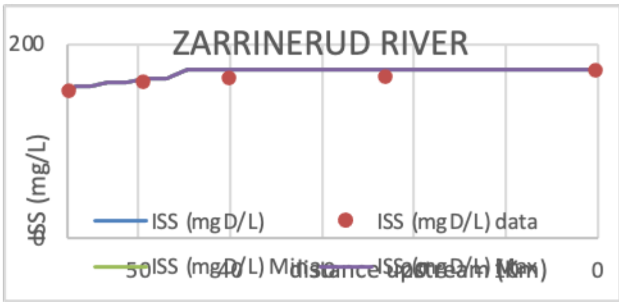

Figure 3. Simulation graph of suspended solids in Zarineh-roud river in August 2019

3.2. Analysis of water acidity (pH)

The graph of observed data and output data for the simulation model of Zarineh-Roud river from the outlet of Norouzlu regulating dam down to Uromia lake has been shown for the parameter of pH in figures 4 and 5. It should be explained that Ph is an important parameter in water and it impacts most of the chemical and biological reactions of water. In other words, the reactions in water happen in a special range of pH. Also, different utilizations of water including drinking, agricultural, aquaculture consumptions are applicable in the standard range of 6.5-8.5. Usually, the pH of sewages and agricultural drained water is in the range of alkalinity and therefore decreases the pH of accepting water a little. As it can be seen, observed data have a good correlation with model simulation graph in both spring and summer seasons of 2019. The model simulation graph shows in the spring and summer seasons the pH variation of the Zarineh-roud river has a stable trend approximately and does not show noticeable changes. Only in the spring season, it shows a small increase in pH at locations close to the entrance of agricultural drained water. By looking at the graphs, it can be seen that the pH value of the Zarineh-roud river is at the standard level.

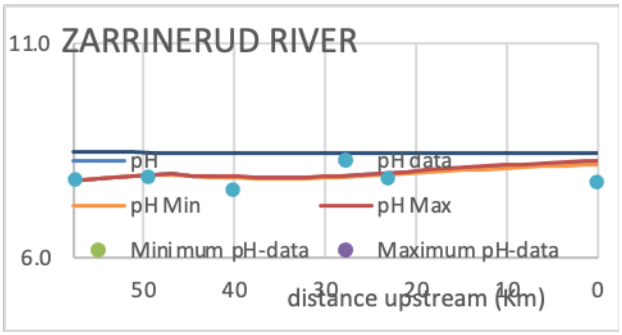

Figure 4. pH simulation graph of Zarineh-roud river in May 2019

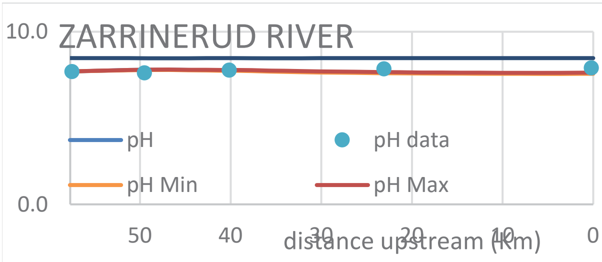

Figure 5. pH simulation graph of Zarineh-roud river in August 2019

3.3. Analysis of Nitrate

The factors of increasing the nitrate amount in water resources are mainly human wastewater and agricultural drain water and it is defined as a middle form of nitrogen. Nitrate changes to (N2) form during a process entitled denitrification and exits the water in the gas form. Despite the nitrification process which is done in presence of oxygen and the aeration coefficient of the river has a positive impact on the reduction of ammonium, the denitrification process happens without the presence of oxygen, and aeration of the river does not have an impact on its conversion. Therefore, the denitrification process usually is very slow and occurs rarely in the rivers that are flowing and always taking up oxygen by natural aeration. As it can be seen, there is a good correlation between observed data and model simulation graph in all stations except station S5 in the spring and summer seasons. As it was mentioned before, the existence of no correlation between the S5 station and output graph of the simulation model can be due to the entrance of a contamination source or sources in this distance which increases the nitrate of the river (Figure 6 and 7).

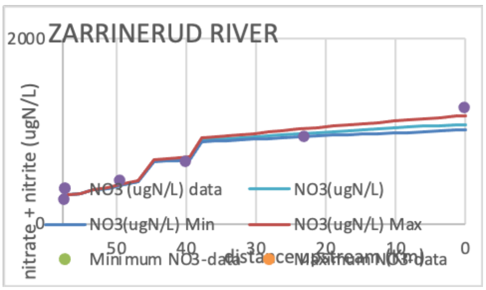

Figure 6. Simulation graph of nitrate in Zarineh-roud river in May 2019

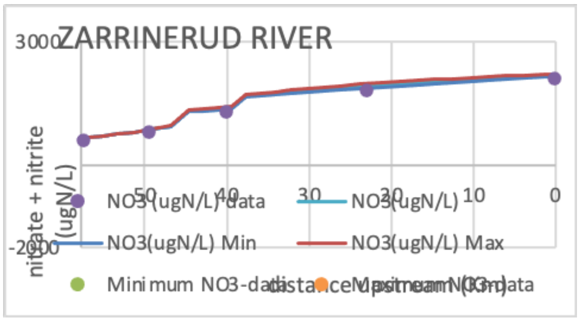

Figure 7. Simulation graph of nitrate in Zarineh-roud river in August 2019

3.4. Analysis of Ammonium

The ammonium ion is the primary form of nitrogen in the aquatic environment. The presence of ammonium in water is related to human and agricultural pollutions such as urban and rural sewage and agricultural drain water. Ammonium in the presence of dissolved oxygen transforms to nitrite and then nitrate during the nitrification process. Therefore, the reduction of ammonium amount is accompanied by the increase of nitrate concentration in the rivers. This process is done more quickly in the case that the aeration coefficient of the river is high. The simulation graph of the variation in ammonium concentration shows a decreasing trend in the spring season and its value has reached from 510 µgr/l in the headwater of the river before the discharge of municipal wastewater of Miandoab city in 39 Kilometers distance point to the value of 480 µgr/l. The discharge of municipal wastewater of Miandoab city has increased the value of this parameter to 511 µgr/l again. The decreasing trend of ammonium due to the high flow rate and also high aeration coefficient of the river in the spring season has been continued down to the end of the river and has reached to value of 351 µgr/l. The concentration graph of ammonium simulation graph variation is different in the summer season relative to the spring season. The evaluation of hydraulic details of output simulation's current of Zarineh-roud river in the summer season shows that the aeration coefficient of this river is relatively lower in the summer. One of its important reasons is the low flow rate. Therefore, the river in the distance between river headwater (Norouzlu dam outlet) up to point in the kilometer of 39 does not have appropriate self-purification due to discharge of agricultural and urban pollutants and hence it can not do quick nitrification. The concentration of ammonium increased from 746 µgr/l to 960 µgr/l. This increase is more severe and quicker in the point of 39 kilometers distance, and at the point of 37 kilometers distance increases to 1222 µgr/l. Again, from the point of 37 kilometers distance the decreasing trend of ammonium is started which is due to the nitrification process and decreasing of concentration of pollutants in the downstream of Miandoab, and it reaches 660 µgr/l at the end of the river (Figures 8 and 9).

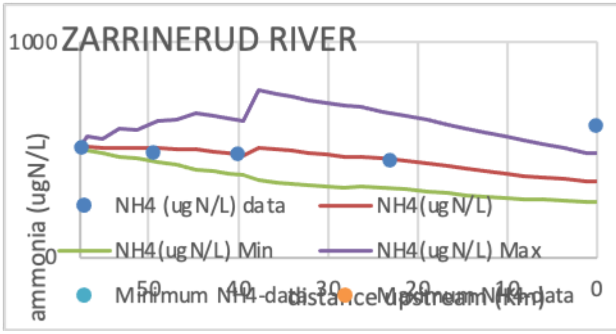

Figure 8. Ammonium simulation graph for Zarineh-roud river in May of 2019

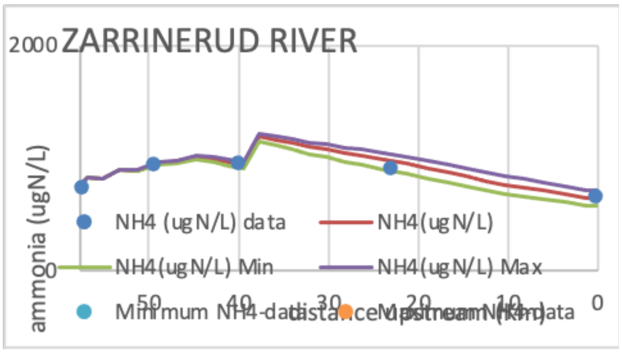

Figure 9. Ammonium simulation graph for Zarineh-roud river in August of 2019

3.5. Analysis of Electrical Conductivity

The graphs of the simulation model of electrical conductivity (EC) for the Zarineh-roud river in the spring and summer seasons of 2019 have been shown in figures 10 and 11. As it can be seen, there is a good correlation between the graph of observed data and the model simulation graph up to 38 kilometers distance. But, after the point of 38 kilometers distance, the observed data in the summer season (stations number 4 and 5) does not correlate with the graph of the model's output and passes over it. Its reason can be the discharge of pollutant sources that have not been detected and applied in the model. It should be explained that the most important factor for electrical conductivity in surface waters is agricultural drain water. Other pollutant sources such as residential sewage have lower electrical conductivity compared to agricultural drain water and only if the discharge rate of mentioned sewages would be high, they can influence the electrical conductivity of the river. Hence, it is probable that by the development of irrigation and draining network of Miandoab plain especially in lower parts of the city, the agricultural drain water for adjacent lands to the river is discharged in non-centralized form and increases the mentioned parameter leading to non-correlation status with model simulation graph in this area. The value of electrical conductivity of Zarineh-Roud in the river headwater (outlet of Norouzlu regulating dam) in the spring and summer seasons were 400 and 454 µohms/cm in order. This value has a rising trend up to the 38 kilometers distance point where most of the influential pollutants on electrical conductivity such as drain water from agricultural activities, livestock slaughterhouse, sugar factory, and municipal sewage are discharged into the river. But, from this point afterward, the model simulation graph in both spring and summer seasons is not increased which is due to the reduction of the concentration of entering pollutants. The concentration amount of that stays constant down to the end of the river (station S5) and in the spring and summer is equal to 571 and 602 µohms/cm in order. In general, the value of electrical conductivity of the Zarineh-roud river is in the natural limit and is in the standard range that is required for agricultural, aquacultural needs and is in the standard range for preserving the life of aquatic ecosystem creatures.

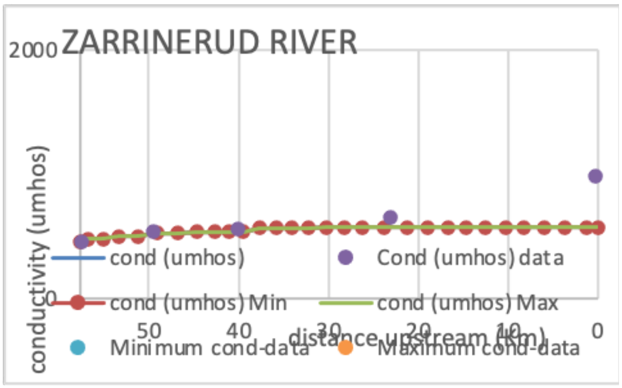

Figure 10. Electrical conductivity simulation graph for Zarineh-roud river in May 2019

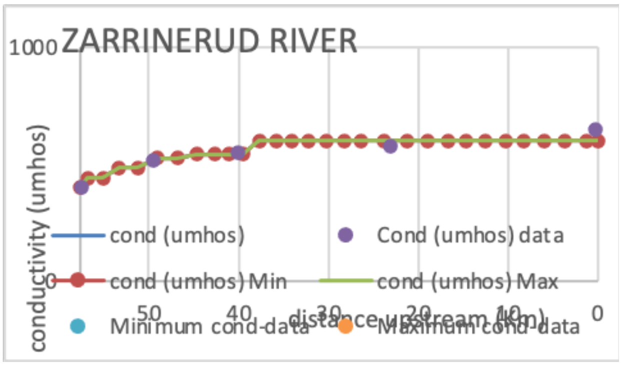

Figure 11. Electrical conductivity simulation graph for Zarineh-roud river in August 2019

3.6. Analysis of Dissolved Oxygen

Simulation graphs for variation trend of dissolved oxygen (DO) for Zarineh-Roud river in spring (May) and summer (August) of 2019 have been presented in figures 12 and 13. As it can be seen, observed data except station 5 in the spring gets correlated with the model simulation graph with a little difference. As it was mentioned before, in the recent case, the probability of the existence of undetected centralized and non-centralized pollutant sources which increases the consumption of dissolved oxygen in this range has led to a little difference in simulation model results. The amount of dissolved oxygen in river headwater (outlet of Norouzlu regulating dam) in the spring and summer seasons were 7.2 and 5.68 mg/l in order. In both graphs, the trend of variation of dissolved oxygen is a decreasing trend which is due to entrance of pollutant sources such as drain water from agricultural activities, livestock slaughterhouse, sugar factory and wastewater from Miandoab city and its municipal sewage-treatment plant and also wastewater from neighboring villages. Despite the entrance of different pollutant sources to the river, the value of dissolved oxygen has been decreased relatively. But, the aeration coefficient of the river and self-purification capacity of the river has been at a level that these pollutants were not able to decrease the dissolved oxygen value more. The minimum environmental standard of the river for dissolved oxygen is equal to 5 milligrams per liter. Therefore, the results of the simulation model show higher values for dissolved oxygen.

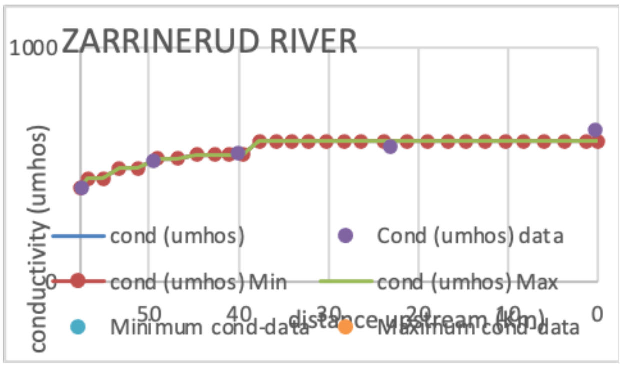

Figure 12. The graph of dissolved oxygen simulation for Zarineh-roud river in May 2019

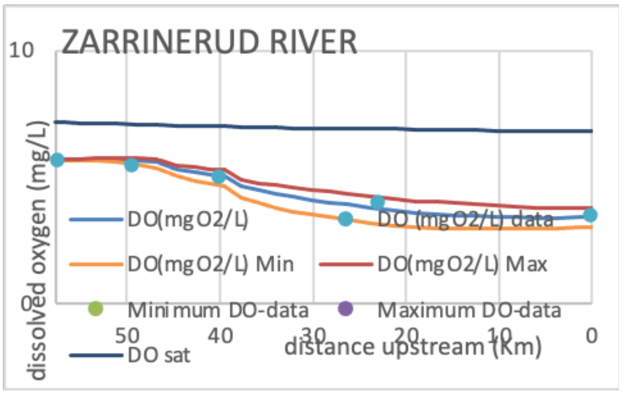

Figure 13. The graph of dissolved oxygen simulation for Zarineh-roud river in August 2019

3.7. Analysis of biochemical oxygen demand

The graph of biochemical oxygen demand simulation (BOD) and observed data in the spring and summer seasons of 2019 have been presented in Figures 14 and 15. As it can be seen, there is a good correlation between observed data and model simulation graph in all stations except station S5 in the spring season. The main reason for rising BOD in rivers is humans sewage, food processing wastewater, and animals excreta. The agricultural drain water usually has a very lower BOD. BOD of Zarineh-Roud in river headwater in the spring and summer seasons are 3.8 and 5 mg/l in order. Up to the point with 46 kilometers distance in the river, there is no other specific pollutant source except agricultural drain water that can influence the increase of the BOD value of the river. Therefore, this parameter has been decreased due to the self-purification of the river and the oxidation of organic materials, especially in the spring. We can see two cases of quick and severe increase of BOD of Zarineh-Roud river in the simulation graph. The first case is related to the discharge location of sugar factory wastewater in the 46 kilometers point, in which the graph in the spring season has been increased from 3 to 6.2 mg/l and in the summer season from 4 to 10.76 mg/l. The second case is related to the location of wastewater of Miandoab sewage treatment-plant in 38 kilometers point, in which the BOD of Zarineh-Roud river has been increased from 5.1 to 6.84 mg/l in the spring season and from 9.5 to 13.35 mg/l in the summer season. In the distance between 46 kilometers point to 38 kilometers point, the graph has decreasing trend due to non-existence of an important pollutant source with high BOD and also self-purification of the river because of increase in aeration coefficient. In the continuation of the river, we are observing the decrease in BOD of the river which is due to very good raeration of the river and high self-purification capacity despite the entrance of different pollutant sources such as raw sewage water of villages adjacent to the river, and non-centralized agricultural drain water in lands around the river. The BOD value at the end of the river in spring reaches 2 mg/l and in summer it reaches 6.5 mg/l. The maximum environmental standard value of BOD for a river is 5 mg/l. It can be seen that from 46 kilometers distance point up to 38 kilometers point in the river, BOD value has surpassed the environmental standard limit.

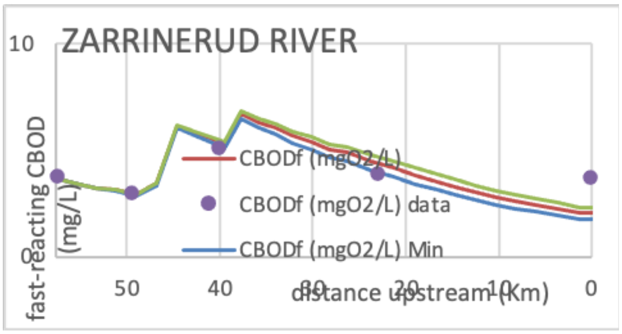

Figure 14. BOD simulation graph for Zarineh-roud river in May 2019

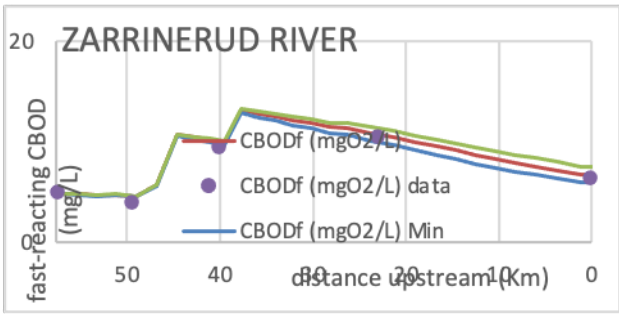

Figure 15. BOD simulation graph for Zarineh-roud river in August 2019

3.8. Analysis of inorganic phosphor

The obtained graph from the phosphate simulation model and observed data graph of Zarineh-Roud river in spring and summer seasons of 2019 have been presented in Figures 17 and 18. As it can be seen, observed data have a good correlation with model simulation graph. Non-correlated cases are related to the S5 station in the spring season and the S4 station in the summer season in which the phosphate concentration of observed data is more than its value in the modeling graph. Its reason can be due to a pollutant source that enters into the river in that area, but it was not detected in this research and it was not applied in the model. The mentioned pollutant source is probably a momentary source. The phosphate value in the spring and summer seasons in the river headwater was 67 and 108 µg/l in order. By entering the pollutant sources up to the point at 38 kilometers distance of the river, the phosphate amount shows a gradually increasing trend, and its value before discharging of Miandoab city municipal wastewater in the spring and summer has reached 40 and 315 µg/l in order. The maximum value of phosphate rise is located at the Miandaob city municipal wastewater discharge location and its value reaches suddenly to 492 and 805 µg/l in spring and summer in order close to the point at 38 kilometers distance. By considering this point that the most important sources of phosphate in surface water resources are agricultural drain water which contains chemical fertilizers and human origin sewages, it can be seen that noticeable changes of phosphate have occurred in the simulated graph at the 38 kilometers distance point by entering sewage of Miandoab city into the river. It should be explained that despite some quality parameters whose concentration reduction is a function of river aeration coefficient, the most important factor of phosphate reduction in water is related to its deposition speed.

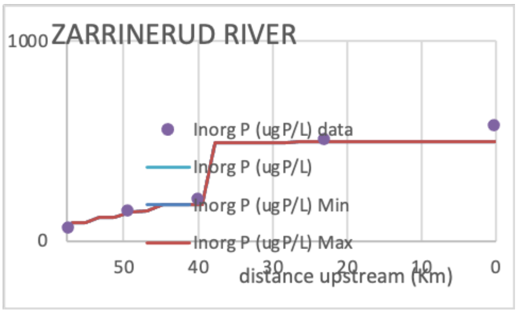

Figure 16. Inorganic phosphor simulation graph of Zarineh-roud river in May 2019

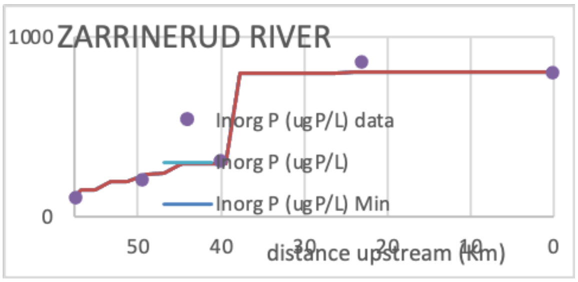

Figure 17. Inorganic phosphor simulation graph of Zarineh-roud river in August 2019

4. Discussion

Computer-aided simulation models are a powerful tool for analyzing and predicting the quality of water resources and determining critical points with the aim of quality management of surface water resources. So far, various models have been developed for simulating the river's water quality, of which the QULA2K model is applied to simulate the water resources owing to its enormous capabilities qualitatively.

Results obtained from the model calibration using the correction of reaeration coefficients and oxidation coefficients of BOD indicated that simulation results and observational data are in good agreement from the outlet of Norouzlu dam up to Urmia lake, and the applied coefficient is of high reliability.

By evaluating the simulation results for DO concentration parameters along Zarrineh Rud river, it is observed that the river had an appropriate aeration capacity and, although many pollution sources such as Miandoab's sugar factory, slaughterhouse, effluents from Miandoab's wastewater treatment plant, sewage from villages surrounding the river, and streams from Miandoab's plain drainages are discharged into the river, high reaeration capacity of the river keeps the oxygen volume in the standard level. Generally, the Zarrineh Rud River has a remarkable reaeration capacity, and its DO content is in good condition.

Results of allocating the TMDL from point and nonpoint sources of pollution that can be discharged into Zarrineh Rud river to satisfy the minimum standard of cold-water fish farming at the withdrawal site of Fesendoz complex showed that 60% of BOD waste load in spring and 41% in summer could daily be discharged from upstream point and nonpoint sources of pollution in addition to the present condition of the river; at the same time, the cold-water fish farming standard is also met. For satisfying the cold-water fish farming standard, the NH4 waste load from point and nonpoint sources of pollution should be reduced by 98% in spring and 88% in summer. It is also necessary to increase nitrate waste load by 10% in spring and decrease it by 88% in summer to meet cold-water fish farming standards. For phosphate content, a 75% and 90% decrease in the waste load of point and nonpoint sources at river upstream is required in spring and summer, respectively, to provide the cold-water fish farming standard at the point where water is harvested by Fesendoz fish farming complex.

In general, qualitative evaluation of the Zarrineh Rud River using QUAL2K qualitative modeling indicates that the river's water quality is mitigated in the study period due to the discharge of pollutants like agricultural drainages and wastewaters of population-focused urban and rural areas. By examining the variation trend of qualitative parameters in the Zarrineh Rud River in sampling stations, it is observed that the electrical conductivity of the river is suitable for protecting the aquatic life in both seasons. DO concentration of the river is in allowable range in all stations in the spring season, and at S4 and S5 stations in the summer season, it exceeds the limit determined by the standard of the department of environment for preserving the aquatic life. Station S1 has a phosphate content in the allowable range for preserving aquatic life in both spring and summer, and in other stations, this parameter is more than the maximum acceptable level for preserving aquatic life in both seasons. Also, the concentrations of BOD, ammonium, and nitrate are within the standard range for aquatic life preservation in both seasons for all stations, and they exceed the standard acceptable level for aquatic life preservation in the river ecosystem.

Results obtained from optimal allocation of TMDL in Zarrineh Rud river aiming to meet minimum requirements of standards for the aquatic life preservation in the river ecosystem at the critical point (26th kilometer) showed that the BOD waste load discharge from upstream point and nonpoint sources of pollution can be increased by 16% in spring and must be decreased by 70% in summer to meet the requirements of warm-water fish species standard. Also, for optimally allocating the waste load related to NH4 from point and nonpoint sources of pollution at the river upstream, a 68% increase and 57% decrease in NH4 waste is essential in spring and summer seasons, respectively, to meet the standard of warm-water species of the river.

The studies conducted by other researchers suggested that the water quality of rivers in the summer and winter seasons has the poor condition in terms of some simulated parameters such as BOD, NO3, ammoniacal nitrogen compared to other seasons. Also, by examining the water quality improvement programs in the Taihu lake basin in china, they suggested that the mentioned model can be used as an effective tool in water quality improvement programs [22]. Generally, the river's water quality was good in Sarab; however, by moving in the river's length, its quality reduced due to the discharge of pollution sources like agricultural drainages and sewages of urban and rural areas, and this was hold in this study too. Nevertheless, because of the high self-purification capacity of the Zarrineh Rud River, pollution sources could not significantly reduce the water quality except in some specific cases. By examining the pollutant acceptance capacity of the Qara Aghaj River using QUAL2K software, Miri concluded that the oxygen concentration of the river is in the standard level according to simulations and actual results, which shows the proper self-purification capacity of the river (Mirii et al., 2010). Najafi examined the water quality of the Qarasu River in Kermanshah using QUAL2K software and concluded that the DO concentration of the river is lower than the acceptable level generally. The most critical point is located after Kermanshah city affected by the discharge of effluents and urban wastewater into the river (Babakhani et al., 2019). The qualitative study on the water quality of the Zarrineh Rud river using the QUAL2K model for environmental management of cold-water fish species indicates that the river's water quality in the study period is reduced due to the discharge of pollution resources such as agricultural drainages and rural and urban wastewaters. As Chang and Carney have suggested, increased human activities have contributed to the increase in the share of sub-basins from the river's output waste load; however, the river's self-purification speed increases rapidly because of the flow intensity and the high self-purification capacity under the effect of reaeration and river depth reduction along the river. Hashemi's findings indicate the effects of residential, agricultural, and livestock husbandry land use on the water quality in the Karaj river.

Due to the limited qualitative data of this study, other parameters such as algae, phytoplankton, and parameters affecting the model like river bed sedimentation are not examined.

The ever-increasing development of agricultural and industrial activities and impressive volume of urban sewage cause the pollution of water resources, especially rivers (Haghnazar et al., 2021). The factors of increasing the nitrate amount in water resources are mainly human wastewater and agricultural drain water and and it is defined a middle from of nitrogen (Haghnazar et al., 2021).

5. Conclusion

Generally, the river's water quality was good in Sarab; however, by moving in the river's length, its quality reduced due to the discharge of pollution sources like agricultural drainages and sewages of urban and rural areas, and this was hold in this study too. Nevertheless, because of the high self-purification capacity of the Zarrineh Rud River, pollution sources could not significantly reduce the water quality for cold-water fishes except in some specific cases.

Since the main reasons for pollution of Zarrineh Rud river are the discharge of raw urban and rural wastewaters, sewages of the slaughterhouse, Sugar factory wastewater, and agricultural drainage water of Miandoab's plain through drainages, the recommended approaches that can be applied to allocate the daily waste load in Zarrineh Rud river for environmental management of agricultural irrigation species are as follows:

A- Establishment of the wastewater treatment plant for villages surrounding the Zarriveh Rud river downstream of Miandoab's plain.

B- Standard wastewater discharge from Miandoab's wastewater treatment plant by province water and Wastewater Company.

C- Controlling the agricultural fertilizer and pesticides consumption in the Zarrineh Rud basin according to existed standards by supervision of agricultural Jihad organization in the province

D- Establishment of the wastewater treatment plant for treating the wastewaters from the sugar factory and slaughterhouse of Miandoab and their discharge according to the standards of the department of environment.

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