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**ORIGINAL ARTICLE**

# Modeling of BOD and Ammonia in Karkheh River using WASP6

**Alireza Aliverdi [1], Hossein Eslami [2]**
[1] - Msc student of Department of Water Engineering, Shoushtar Branch, Islamic Azad University, Shoushtar, Iran
[2]- Department of Water Engineering, Shoushtar Branch, Islamic Azad University, Shoushtar, Iran
Corresponding Author email: eslamyho@gmail.com

**ABSTRACT**
*Drought in recent years, the importance of the conservation and utilization of surface water resources are made more visible. Although Iran is the world's arid regions, attention and protection of surface water quality in many cases, have been ignored or considered too low. River water as the main artery in sustained chain has always been considered to be Excesses of human, population growth and the increasing need for variety, quantity and quality of water have transformed and human share in the enjoyment of the blessings God has continually declined. Discharging pollutants from agricultural, industrial and municipal waste streams make this tract are as a focal point of environmental contamination are critical. In this study, simulation of water quality parameters in the range of Karkheh River Paypol - Alhayy was performed by the WASP6 model. The results indicate that the biological oxygen demand (BOD) is optimal in the range studied. Ammonia is at a disadvantage in the desired range.*
***Keywords***: *Modeling, BOD, Ammonia, Kharkheh, WASP6*

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## INTRODUCTION

With the passage of time and the development of science, water quality, was also considered. Water is the most abundant substances found in the environment and almost 75% of the Earth's surface is covered. But the use of water resources, limitations such as salt restriction, 97% of it (which exist in the ocean), the lack of more than 2 percent (the glacier and soil and atmosphere humidity), and the result is the amount of water for drinking and other uses, less than 1 percent. Various sources of pollution in the water around it are inserted in the hydrological cycle. These pollutants can be natural or synthetic.

Transfer of a contaminant in water, only water flow (mass flow) are not riding on it, but depending on the concentration of these contaminants in this water mass movement and the processes of diffusion and longitudinal dispersion in water player is also dispersed.

To the mass flow of a contaminant mixed with water, moving along with the flow of water. Diffusion process is divided into two types: Molecular diffusion and turbulent diffusion. Today, a qualitative simulation model is widely used in river management policy, planning and simulation of river systems.

In this paper, the mathematical model WASP6 is used, which has the ability to describe the spatiotemporal variation of the most important quality parameters of an aquatic body. Razzagh Manesh [1] WASP model used to simulate water quality Kor River, Iran. Maleki [2] Study on Pasikhan River, to simulate parameters of nitrate, phosphate, ammonium and nitrogen using the Mike11 and WASP6. Zheng et al. [3] using a three-dimensional physical model and mathematical model WASP5, Satilla River in Georgia spans quality parameters simulated. The study by Artioli et al. [4] cargo capacities, the model used WASP6 on a river PO in Italy. The model was used in Karkheh River for a period between 2012 and 2013, for which there were available data of BOD and NH4. Karkheh River was chosen because of its great importance as a water resource and also, because of the very serious problems that it faces during the last few years, due to the pollution from nearby industries and intense agricultural activities. Karkheh River suffers from continuous pollution, due to point (municipal and industrial wastes) and non-point sources (fertilizers from nearby crops in the river basin, etc.). The purpose of this study is to simulate the Karkheh river quality parameters of Ammonia and BOD using WASP6.

## MATERIAL AND METHODS

Karkheh River Basin area (south west Iran) is 42,239 square kilometers in the site of Paypol station. The average annual volume of flow in Paypol is over 5916 million cubic meters and annual long-term average discharge of 188 cubic meters per second is equivalent to this station. More than 64% of the total annual runoff occurs in February to May [5].
Selected reachs including Itervals between hydrometric stations of Paypol, Shahid Najian, Abdolkhan and Alhayy. Quality parameters measured in these stations is done, the data collected can be classified into four groups:
A - Qualitative information about contaminants and input lateral flow into Karkheh river
B - Information on the surveyed sections from the river
C - The daily flow data of hydrometric stations located on the Karkheh River, and
D - Information about the Karkheh river monitoring stations.
There are 47 stations on the Karkheh River and its main tributaries. The temperature in the area varies from -25 ° to 50 ° C maximum. Annual average rainfall in the basin varies from 300 to 800 mm per year.
The weather Karkheh Basin belongs to the Mediterranean climate and the relative humidity is 45.5% annually [5]. Interval studied include hydrometric stations of Paypol, Shahid najian, Abdolkhan and Alhayy and quality parameters will be measured at this station, In this study, 2012-2013 data has been used for verification and calibration of water quality parameters.
Water parameters such as biological oxygen and ammonia in the study area on Paypol- alhayy reach of Karkheh River simulated by mathematical WASP6 model.

### Structure of WASP model

WASP (Water Quality Analysis Simulation Program) is a mathematical model that analyses water quality issues in one-, two- and three-dimensional aquatic systems [6,7], such as rivers, ponds, streams, lakes, reservoirs, estuaries and coastal waters. The model describes the mass transfer and transformation of typical and toxic pollutants in water and sediments of the mentioned aquatic bodies. The quality parameters that the model describes are: DO, CBOD, Chl-a, Organic–N, NH3-N, NO2-N, Organic–P and OPO4. The essential input data can be: a) meteorological (temperature, wind speed and direction); b) hydraulic (Manning coefficient, cross sections and slope); c) qualitative parameters (DO, BOD and heat); d) initial and boundary conditions for all variables; e) time series of inflows of quality parameters; and f) coefficients of reaeration, deoxygenating etc.
The hydrodynamic model WASP system consists of two stand-alone computer programs, DYNHYD5 and WASP7, which can be run in conjunction or separately. The hydrodynamics
Program, DYNHYD5, simulates the movement of water while the water quality program, WASP, simulates the movement and interaction of pollutants within the water. WASP is supplied with two kinetic sub models to simulate two of the major classes of water quality problems: conventional pollution (involving dissolved oxygen, biochemical oxygen demand, nutrients and eutrophication) and toxic pollution (involving organic chemicals, metals, and sediment). The linkage of either sub model with the WASP7 program gives the models EUTRO and TOXI, respectively. It is noted that EUTRO and TOXI cannot be run separately, but in conjunction with WASP and DYNHYD5. The basic principle of both the hydrodynamics and water quality program is the conservation of mass. The water volume and water quality constituent masses being studied are tracked and accounted for over time and space using a series of mass balancing equations. The hydrodynamics program also conserves momentum, or energy, throughout time and space.
In this paper, WASP model structure to form the desired route must first be segmented. For simplicity, the distance between the stations was considered as a unit. The Karkheh River was divided into 4 segments. Calculate the volume of each segment, average velocity and average depth of water, the next step in the calculation. Discharges recorded from each station are current composed function that was introduced as the Flow Function to the system. After completing the input data, simulation work was performed.

### Model calibration and verification processes.

The purpose of calibration is adjustment of parameters such that the model results with observations (at an optimum) to match. Definition, it must determine the best match. Observed data from the study area were collected within a period of 12 months. Observed data for calibration and verification of the models were divided into two categories: the first 6 months to calibrate and the second 6 month was used for verification. To evaluate the accuracy of the model, the correlation coefficient, mean absolute error (MAE) and the coefficient of performance (Cp) was calculated according to the model equations. Values in terms of cubic meters of water for each segment must be given to the model. Can be used for mean scale of period and mean cross-section area Calculation of between two consecutive segments, each segment can be calculated water volume [8].

**Velocity and water depth calculation**

WASP6 model for steady and unsteady conditions is applicable. Velocity and depth values used in the model for each of the different conditions are different. For steady conditions, velocity and depth of the model is fixed and specified quantities. But for unsteady conditions to be achieved velocity and depth values as functions of the form aQb where the flow rate Q and the coefficients of a and b are the values in the model. According to the data collected, no values for the rate of studied reach, to obtain the relationship between the discharge- velocity and the discharge- depth, Can be repeated execution of a simulation model of hydraulic characteristics of the river, Calculate the rate of speed and depth values for the coefficients of the relations obtained above (Table 1). Coefficients mentioned in Table 1 have been estimated in a way that best match with the measured concentration changes of qualitative variables are qualitatively River.

Table 1- hydraulic coefficient values for the discharge proportional to the speed Depth in the reach [5]

| B | | A | |
|---|---|---|---|
| $vel - Q_{exp}$ | 0.2 | $vel - Q_{coeff}$ | 0.65 |
| $D - Q_{exp}$ | 0.2 | $D - Q_{coeff}$ | 2.7 |

**Initial conditions**

The purpose of the initial conditions is introduction of first pollutant concentrations at the start of the model in the range under study. Concentration parameters BOD, ammonia was determined at the start of the simulation in Table 2 are presented.

Table 2- values used for the initial conditions

| station | The start of period simulation | BOD | Ammonia |
|---|---|---|---|
| Paypol | May 2012 | 3.12 | 0.92 |
| Shahid najian | May 2012 | 3.48 | 1 |
| Abdolkhan | May 2012 | 3.13 | 1.1 |
| Alhayy | May 2012 | 2.44 | 0.85 |

**Constants and Rates used for the simulation software WASP6**

In this study, selecting n = 0.03 outputs of the software were calibrated model of the river. Reliability coefficients calculation for each of the quality parameters, the main focus of this research was to create a simulation that is the most important step closer to fact. The following constants and rates for the entire software WASP6 are expressed. Many factors affect the rate of nitrification. These factors include PH, temperature, concentrations of ammonia and nitrite, dissolved oxygen, suspended solids, organic compounds, and mine. In turn, the temperature effect on nitrification models only considered [9].

Become a revived form of nitrogen oxide (Nitrification), oxygen is consumed. Nitrification process has two stages, a first stage of the oxidation of ammonia to nitrite [10].

$$NH_4^+ + 1.5O_2 \longrightarrow NO_2^- + H_2O + 2H^+$$

The second stage of nitrification, bacteria can oxidize nitrite to nitrate.

$$NO_2^- + 0.5O_2 \longrightarrow NO_3^-$$

Rate of nitrification of Nitrate reduction to $N_2$ is under anaerobic conditions. Decay rate in the WASP model is based on modified dissolved oxygen saturation relationships and more CBOD water quality models with first-order kinetic equation are given. Rate coefficients of Oxygen demand and determination methods have been obtained by USEPA and various Researches. Known several factors affect the CBOD removal from water column that water temperature is the most important factor, usual half saturation coefficient amount for oxygen consumption is 0.5 mg / lit [11].

**Diagrams of WASP6 model in calibration phase**

 

Model calibration used data from observations of four stations in six months April, May, June, July, August and September of 2012. According to available data and simulated parameters, calibration was done at the end of each period. Coefficients were calculated for each parameter along the river. The result of model calibration is presented in Figures 1 to 8 and statistical analysis is given in Tables 3 to 6.

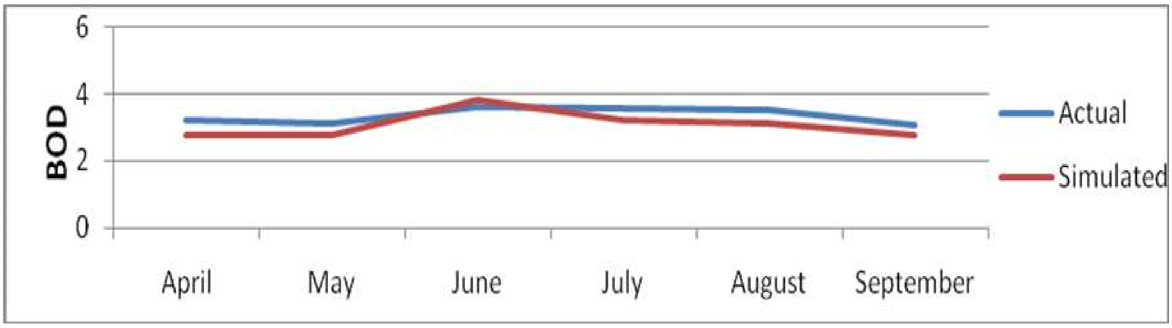


**Figure (1) the amount of *Biological Oxygen Demand (BOD)* in the calibration of model for the Paypol station**

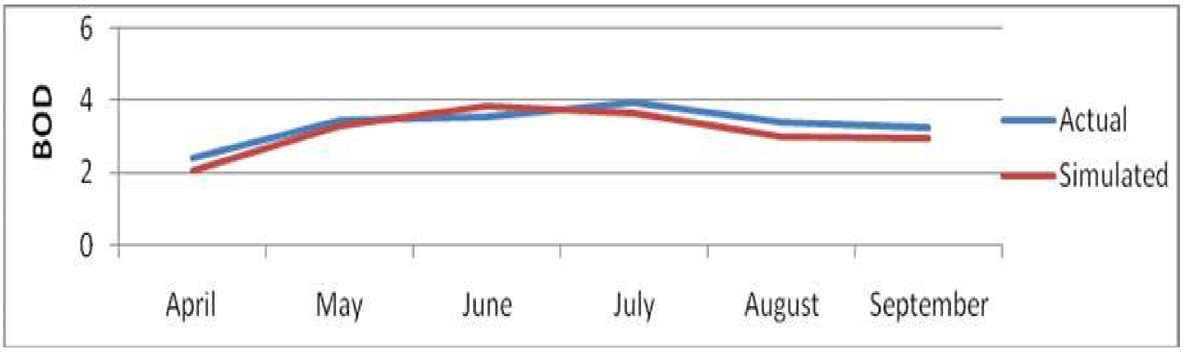


**Figure (2) the amount of *Biological Oxygen Demand (BOD)* in the calibration of model for the Shahid najian station**

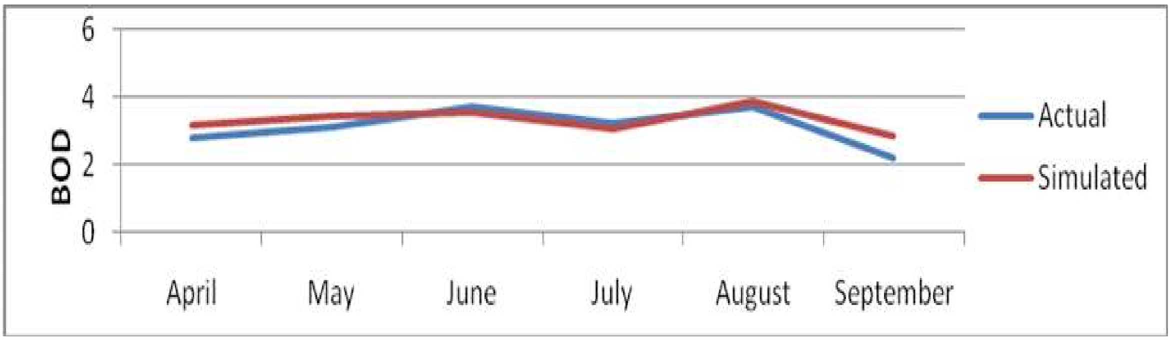


**Figure (3) the amount of *Biological Oxygen Demand (BOD)* in the calibration of model for the Abdolkhan station**

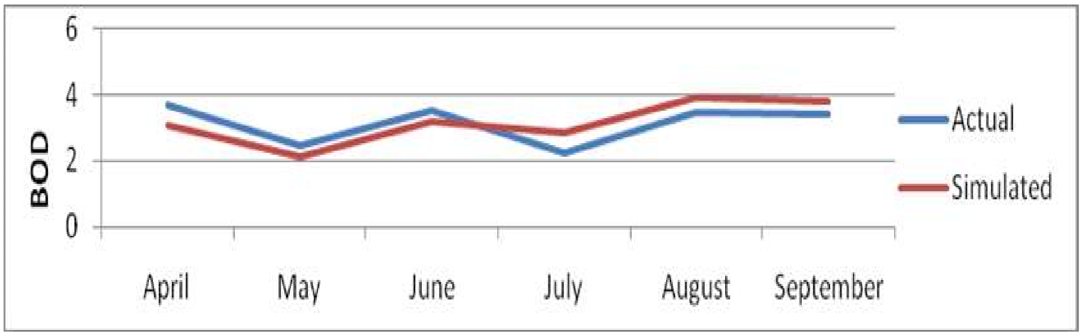


**Figure (4) the amount of *Biological Oxygen Demand (BOD)* in the calibration of model for the Alhayy station**

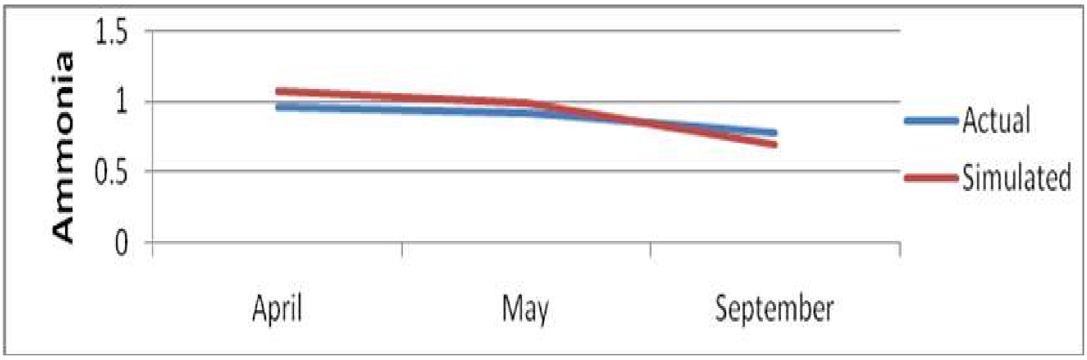


**Figure (5) the amount of Ammonia in the calibration of model for the Paypol station**

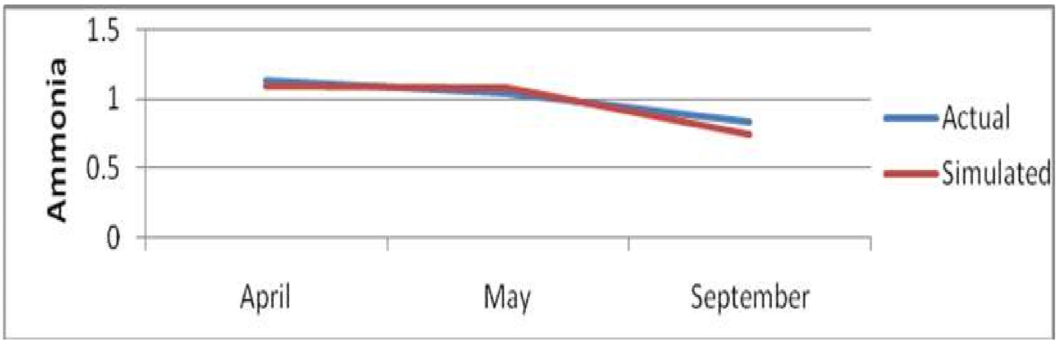


**Figure (6) the amount of Ammonia in the calibration of model for the Shahid najian station**

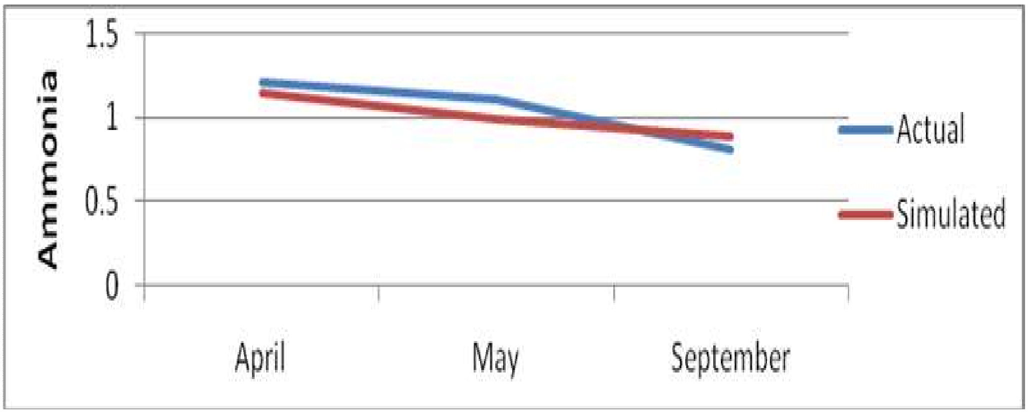


**Figure (7) the amount of Ammonia in the calibration of model for the Abdolkhan station**

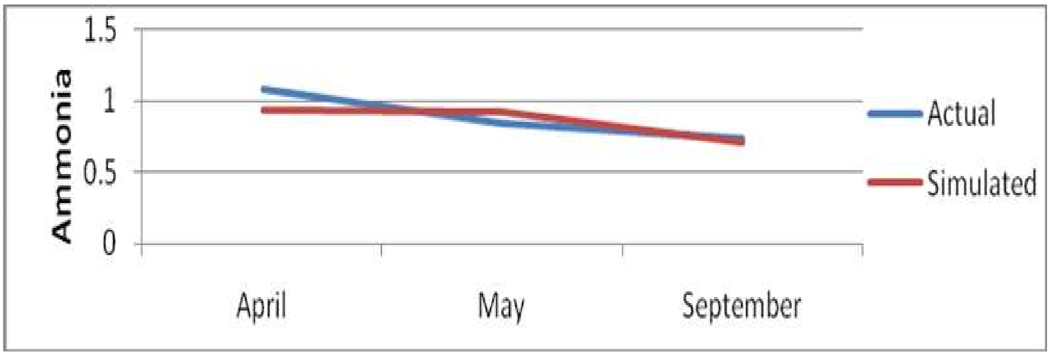


**Figure (8) the amount of Ammonia in the calibration of model for the Alhayy station**

**WASP6 model verification phase diagrams**

After calibration model WASP6, verification was performed with 4 station data from months of October, November, December, January, February and March of 2012. The following charts (9-16) compare the model results with observational data to determine performance quality parameters in the simulation model. Statistical analysis is given in Tables 7 to 10.

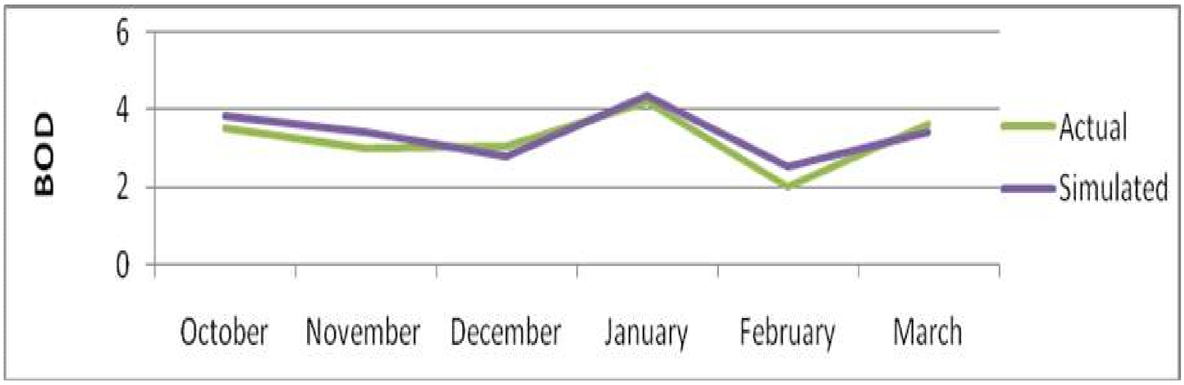


**Figure (9) amounts of *Biological Oxygen Demand (BOD)* at the stage of verification for the Paypol station**

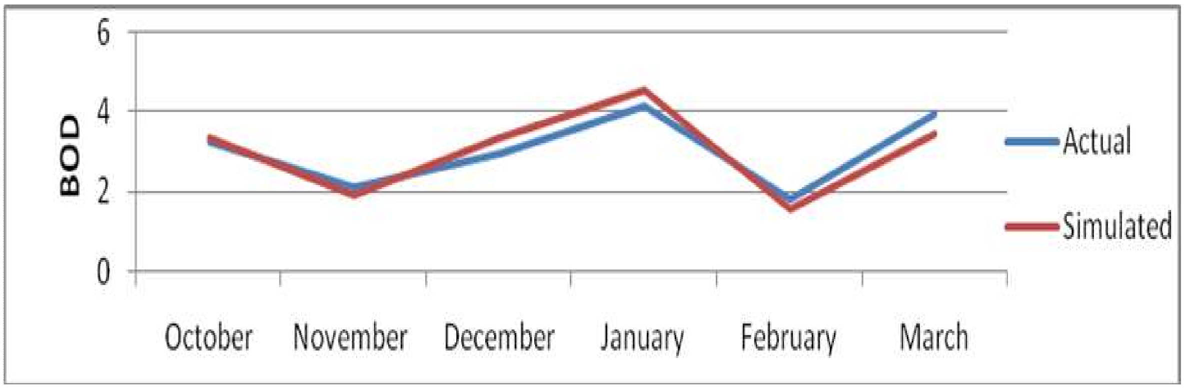


**Figure (10) amounts of *Biological Oxygen Demand (BOD)* at the stage of verification for the Shahid najian station**

 

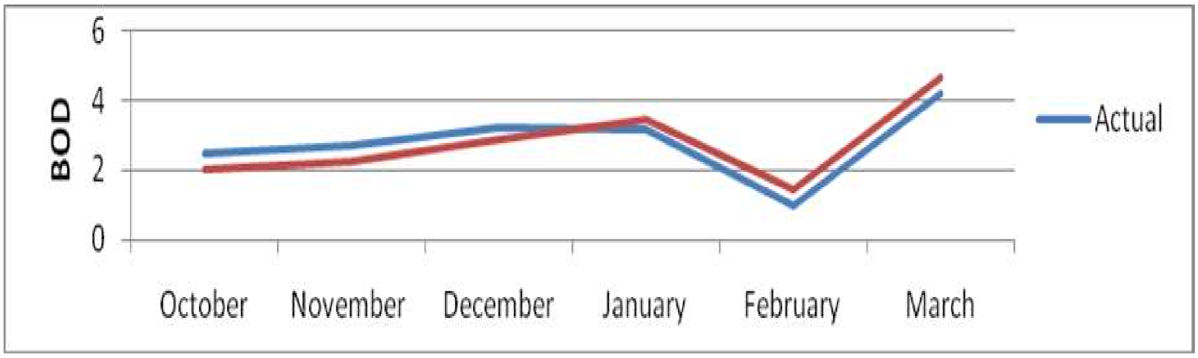


**Figure (11) amounts of *Biological Oxygen Demand (BOD)* at the stage of verification for the Abdolkhan station**

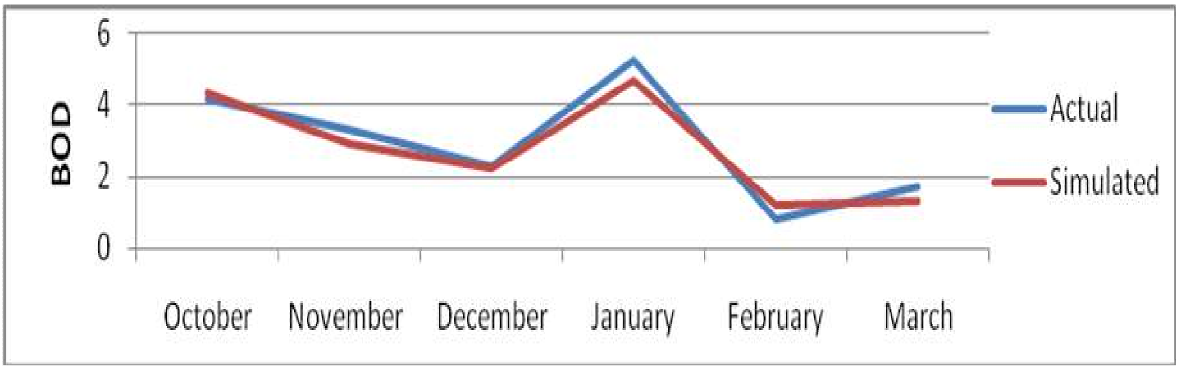


**Figure (12) amounts of *Biological Oxygen Demand (BOD)* at the stage of verification for the Alhayy station**

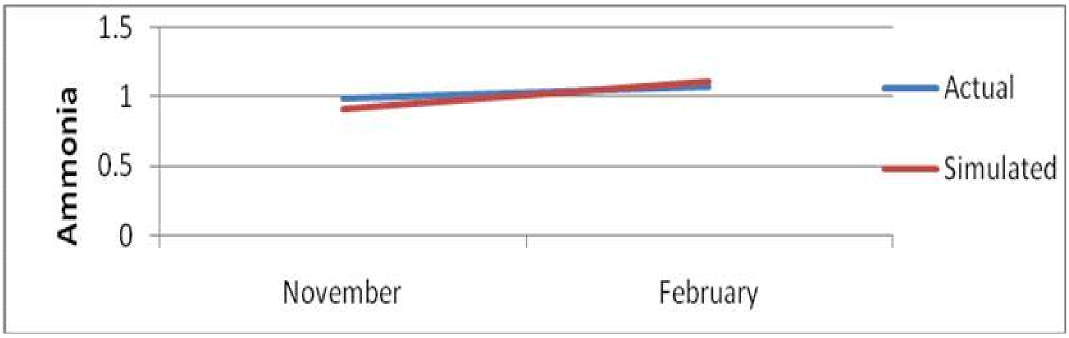


**Figure (13) amounts of Ammonia at the stage of verification for the Paypol station**

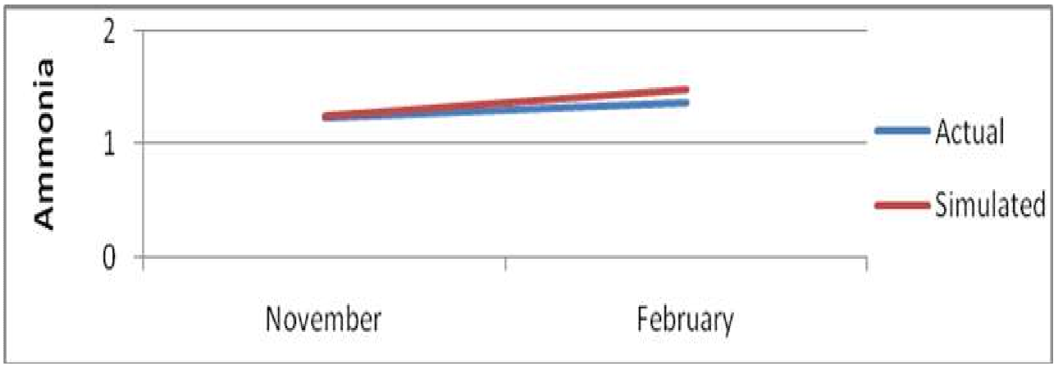


**Figure (14) amounts of Ammonia at the stage of verification for the Shahid najian station**

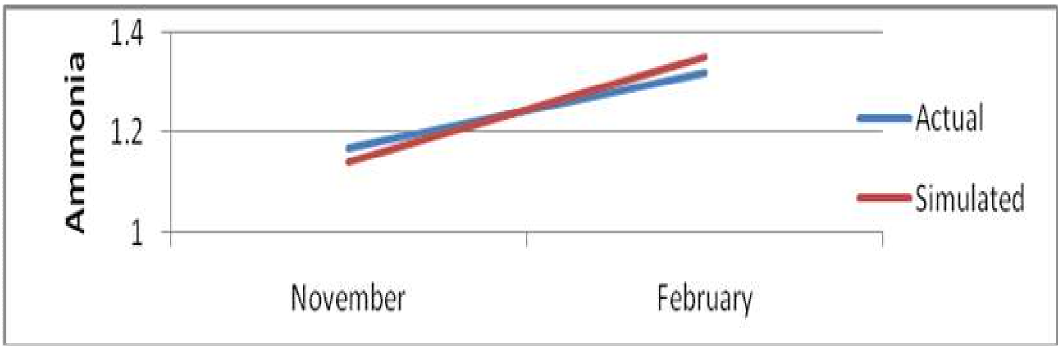


**Figure (15) amounts of Ammonia at the stage of verification for the Abdolkhan station**

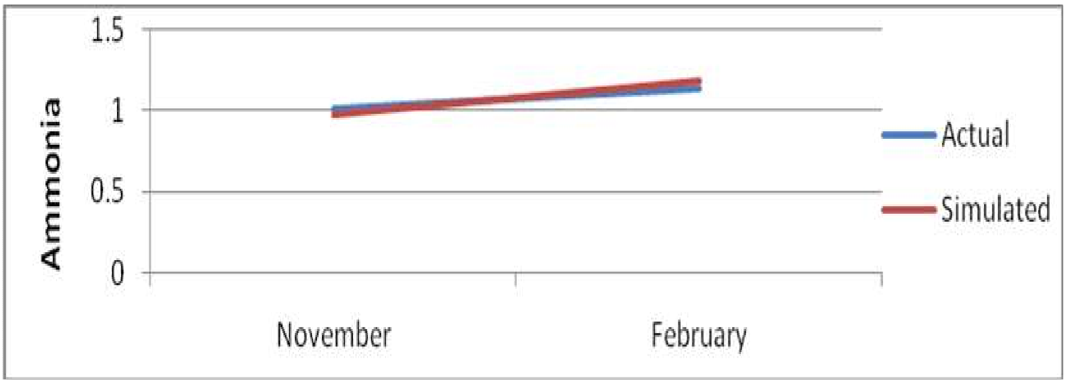


**Figure (16) amounts of Ammonia at the stage of verification for the Alhayy station**

For study contamination of water sources used parameter called BOD, biological oxygen demand BOD is the oxygen that microorganisms need organic matter to decompose completely. According to the standard for survival of fish in the river, BOD shouldn't be more than 5 mg / lit [12]. Diagrams obtained from simulations in the figs of (9) to (12), indicating the suitability of this parameter in all seasons. The convergence results of the simulation results with the observations made in the period under study, diagrams can be found in most simulation models contain excellent agreement with the observational results.

Nitrification, the oxidation of ammonia to nitrate in water can be used as a major factor in oxygen demand. If nitrogenous oxygen demand act by plants lowly decreases, nitrification can be severely reduces oxygen source [13].

## CONCLUSION

The U.S.E.P.A. mathematic model WASP 7 was used to simulate the water quality parameters of Karkheh River. The calibration and the verification of this model were achieved with measurements taken for the period 2012-2013. The model gave satisfactory results for the water quality parameters of Karkheh River. Given the range field is studied in terms of flow and contaminant entry and exit point, other factors increasing concentrations of pollutants entering the non-point pollution can be named as waste land around the river. Among the parameters studied in the Karkheh River, biological oxygen demand (BOD) was considered relevant but due to the influence of surface water and drainage water parameters, ammonia is higher than allowed limit. The major advantage WASP6 model than it is for the public availability of commercial models, as well as easily installed on the operating system and does not use a lot of complexity. Recommended water quality simulation in high and low flow conditions and water pollution study to compare these two options to be evaluated and River water quality modeling and other simulators such as HEC-5Q and Qual2E be done and the results are compared with the model WASP6.

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