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Water Quality Simulation in Qarresu River and the Role of Wastewater Treatment Plants in Reducing the Contaminants Concentrations

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Abstract— ***This paper presents a water quality simulation model considering the some main sources of pollution for Qarresu River near Kermanshah city in Iran . The pollutants such as biochemical oxygen demand (BOD), Total Nitrogen (TN) and Total Phosphorous (TP) descend from some industrial units. QUAL2K software is employed for simulation and estimation of pollution loads during a year. The comparison and assessment of pollutants density shows the best location of any wastewater treatment plant considering the economic and environmental condition.***

Index Terms—***BOD, TN, TP, Qarresu River, QUAL2K.***

I. INTRODUCTION

The Water Pollution Control Law legislated in 1970 defined Environmental Water Quality Standards (EWQS) as targets for water quality management and has regulated effluent quality from industries to comply with the targets. Water quality related to the protection of human health dramatically improved. River water quality parameters for living environments also improved. However, there has been little improvement in lake and estuary water quality.

Water quality in the environment is affected by many different factors. Such factors include increasing water demand, multiple-use, water pollution due to rapid urbanization, high development of water resources, eutrophication and degradation of water bodies and increasing costs related to water treatment. Furthermore, the quality of water resources is vulnerable to a wide range of chemical compounds including organic pollutants (material), salts, nutrients, sediments, heavy metals etc (Gamvroula et al. 2012, Korfali and Jurdi 2011, Mosley et al. 2012).

Wastewater treatment plants are designed to function as bacteria farms, where bacteria are fed oxygen and organic waste. The excess bacteria grown in the system are removed as sludge, and this "solid" waste is then disposed of on land. It is well known that loads of nutrients and organic matters transported by rivers depend on a variety of factors, such as discharge, land use, point and non-point pollution sources and weather conditions. Some important pollutants are BOD, Nitrogen and Phosphorous which lead to many water and wastewater treatment plants are designed to remove biological or chemical waste products from water. Water quality modeling (WQM) is considered a required element to support water quality management decisions (Vieira and Lijklema, 1989; Zou et al., 2007).

Three key issues need to be addressed before WQM can be used for practical management: (1) estimation of pollutant load; (2) estimation of model parameters; and (3) assessment of the uncertainties in model development and application (National Research Council, 2001).

In past decades, there have been many attempts at developing the pollutant loading models, from simple export coefficient models and regression models to complex mechanistic models (Ghenu et al., 2008; Shrestha et al., 2008). Uncertainty is another issue that requires addressing in model development and application, such as the dynamic interactions existing between pollutant loadings and receiving waters, and the uncertainties in parameters estimation and model outputs (National Research Council, 2001; Qin et al., 2007).

QUAL2K (or Q2K) is a river and stream water quality model that is intended to represent a modernized version of the QUAL2E (or Q2E) model (Brown and Barnwell 1987). (Pelletier et al., 2005) confirmed the flexibility and applicability of the QUAL2K model for simulation of river water quality. Some successful examples of QUAL2K have also been published in recent years (Anh D.T et al., 2006; Cho J.H and Ha S.R, 2010; Fan C et al., 2009; Kim D et al., 2003; Park S.S and Lee Y.S, 2002), for instance, (Fang et al., 2008) applied the QUAL2K model to evaluate the spatial distribution of BOD in the Qiantang River,(Zhang et al, 2012) selected the optimal water quality improvement program via simulation of various hypothetical scenarios using the QUAL2K model, so the QUAL2K model was chosen for the present study due to its popularity and ease of application.

II. QUAL2K MODEL

QUAL2K is a river and stream water quality model. It is typically used to assess the environmental impact of multiple pollution discharges along rivers. Pollutants can come from point sources such as industrial wastewater, municipal sewers, and storm water. Pollutants can also come from non-point sources such as agricultural or urban runoff, and commercial activity such as forestry, mining, and construction. It is available as freeware from the United States Environmental Protection Agency.

QUAL2K was developed by Steve Chapra, Greg Pelletier and Hua Tao in connection with the Environmental Protection Agency and Tufts University. The model is written in MS Windows Visual Basic, and Microsoft Excel is used as the graphical user interface. All input and outputs are organized in a series of worksheet tabs.

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Different color tabs correlate to the various inputs and outputs. All numerical calculations are implemented in Fortran 90 in order to decrease the time of calculation. The program is intended to represent a modernized version of the QUAL2E model developed by Brown and Barnwell in 1987. QUAL2K has been enhanced with two species of CBOD and internal sediment processes. In addition, QUAL2K now models pH and alkalinity. The model uses *one-dimensional modeling; t*he river is assumed to be fully-mixed in the vertical and lateral directions. *Steady-state is also assumed by the program;* pollutant inputs and predicted water quality parameters cannot evolve over time. The model also assumes a trapezoidal cross section of the channel being modeled. A wide range of chemical and biological pollutants within a river can be modeled, including carbonaceous biochemical oxygen demand (CBOD), nitrogen and phosphorus species, suspended solids, algae, pathogens, phytoplankton and detritus. Physical-chemical processes simulated by the model include water quality kinetics, chemical equilibrium, advection, dispersion, settling, and interactions with the atmosphere and riverbed (sediment oxygen demand). Water quality parameters predicted throughout the modeled river include dissolved oxygen concentration, pH, salinity and temperature, in addition to the various pollutant quantities.

Qual2K requires various input parameters such as river hydraulics, rates and constants, and pollutant source quality. River hydraulics includes channel length, elevation, widths, slopes, and roughness. Manning's equation is used to calculate the flow rate from these parameters. Flow rates are required for the river entering the model and for each pollution source. Rates and constants include the processes to be simulated such as CBOD decay coefficients, re-aeration rate, algal growth rate, turbulent eddy diffusivity, and settling velocity. The pollutant source quality needs parameters such as dissolved oxygen, CBOD, nitrogen and phosphorus species, alkalinity, and pH.

There are two output types that are produced by QUAL2K, spatial and temporal outputs. Spatial outputs are defined by pink tabs for each parameter. The graphs generated for these outputs show the change in each parameter through the entire section of river defined at one specified time period. Temporal outputs are defined by light blue tabs for each parameter. The graphs generated show the change in concentration at one specified river reach over a 24 hour period. Thus, the user can see how each measured parameter in the river changes with space and time.

Jared worked with Rueben and Patricia in developing an example situation to demonstrate the capabilities of QUAL2K. Rueben spoke English very well and was able to translate for Jared so Patricia could understand. Both Rueben and Patricia took turns using Google Earth to define river reaches, determine river widths, and record river elevations for the Cazones River. This hydraulic data was then input into QUAL2K. Using pictures of the Cazones River and a website depicting various values of Manning's n, they determined a suitable roughness coefficient for the Cazones River. Jared then helped them determine the parameters of a wastewater point source. Using QUAL2K, they were able to see how each parameter was affected by the addition of this point source. Rueben and Patricia were able to see the benefits that QUAL2K has in modeling various river parameters.

III. STUDY SITE LOCATIONS

Karkheh River, with a basin area of 42000 (km2), is considered Iran's third major river. The River rises in Zagros Mountains and empties into the Persian Gulf. Seymareh, Kashkan, Qarresu, Gamasyab, and Chardawol are the main headwaters that form Karkheh River. In this study Qarresu sub-basin with about 5350 (km2) is considered. Qarresu sub-basin is located in the Northwest of Karkheh river basin with maximum 3351 (m) and minimum 1300 (m) altitudes. Mardak River joins to Ravansar and Garab rivers and forms the Qarresu River. Also some tributaries release to Qarresu River which the most important one named Razavard Rive. Finally Qarresu River releases to Gamasyab River. Some charactristics of Qarresu sub-basin are shown in table below.

IV. WATER QUALITY MODEL

All general information should be entered in QUAL2K first sheet but in the second one (Headwater sheet) the Headwaters should be defined. Two headwaters are considered which for each of them water quality characteristics should be defined that are shown in table 1. Then rivers should divide into some units named Reach. The main point is that the reaches should be selected in such a way that in each of them only one source of pollution is located because this strategy increases the accuracy. Figure 1 shows the situation and segments of Qarresu River. Also geographic coordinates can be assigned using ARC-GIS software. This software provides the geographic coordinates in UTM system that it can be turns to applied geographic coordinates by EXCEL.

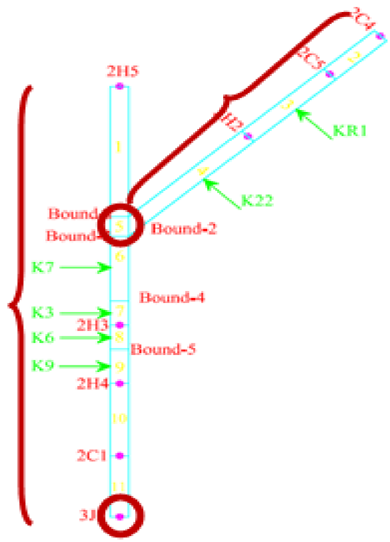

Fig.1 Situation and segments of Qarresu River

Table1. Water quality characteristics

station		BOD (mg/l)	TP (ppm)	TN (ppm)
2C4	Sample1	57	0.12	19.72
	Sample2			
	Sample3			
	Sample4	5.3	0.35	0.89
2H5	Sample1	3.4	1.14	19.36
	Sample2			
	Sample3			
	Sample4	3.1	0.41	1.68

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V. INTRODUCTION OF HYDRAULIC CHARACTERISTICS

To determine other characteristics such as hydraulic flow velocity and depth, two methods are proposed in QUAL2K. Model parameters when only one of these methods can be introduced.

A. *Curve method*

Based on the values calculated for each velocity, flow depth and flow level considered in the sampling stations and using the Rating Curves in equations (1) and (2), each of the values a, b, α and β in the upstream and downstream are calculated in each assuming reach.

$$U = aQ^b z \qquad (1)$$

$$H = \alpha Q^{\beta} \qquad (2)$$

Where U= Velocity, a= Velocity coefficient, b= Velocity power, H= Depth, α = Depth coefficient, β = Depth power

B. *Manning's equation*

In this method, each Reach is considered as a trapezoid. Under stable conditions, the Manning's equation between flow and depth is indicated as below.

$$Q = \frac{S_0^{1/2}}{n}\frac{A_C^{5/3}}{P^{2/3}}$$

Where Q=Cross section average discharge, S= slope of the water surface, n= Manning coefficient, A= Cross sectional area of flow, P= Wetted perimeter. Given these parameters, velocity, flow depth and flow in the stations are sampled and specified 4 times. In the modeling process, curve fitting method is used to determine the hydraulic parameters. Also Barnwell, in 1989, proposed appropriate values for hydraulic parameters as follows.

Table2. Hydraulic parameters proposed by Barnwell

Equation	Exponent	Typical Value	Range
$U = aQ^b$	b	0.43	0.4-0.6
$H = \alpha Q^{\beta}$	β	0.45	0.3-0.5

VI. ESTIMATION OF POLLUTANT LOADS

In prevent, reduce and control pollution of the Karkheh River studies, sampling and measurement of the quantity and quality of the river should be four times (winter, spring, summer and autumn) during a year. In this study merely point source pollution is modeled which four sources are in the main branch and two sources in tributary. Table 3 and Figure 3; show the type of pollutant sources and their locations.

Table3. Sources of pollutant locations

Location	Name	load name
Tributary	Kamyaran sewage	**KO1**
Tributary	Industrial town of Kermanshah	**K22**
Main Road	Shahid hadadeadel sugar factory	**K7**
Main Road	Zamzam company	**K3**
Main Road	Sahra milk and dairy company	**K6**
Main Road	Oil refinery	**K9**

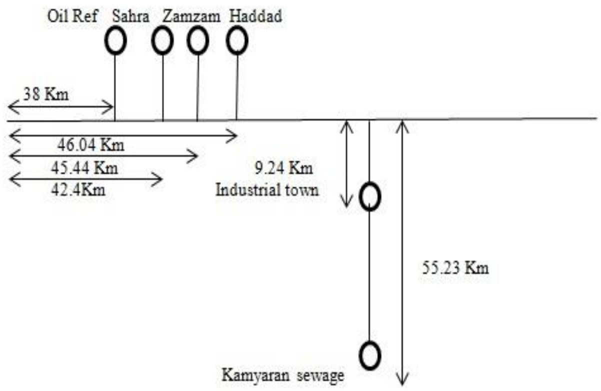

Fig.2 Schematic of sources of pollution

For each pollutant the amount of BOD, TN and TP that they release into the river, enter the model regarding their characteristics.

VII. RESULTS, CONCLUSIONS AND DISCUSSIONS

There are several graphs are obtained from modeling. In this section few of them are analyzed. For example, figure 3 shows the BOD trend in the main river for firs sampling.

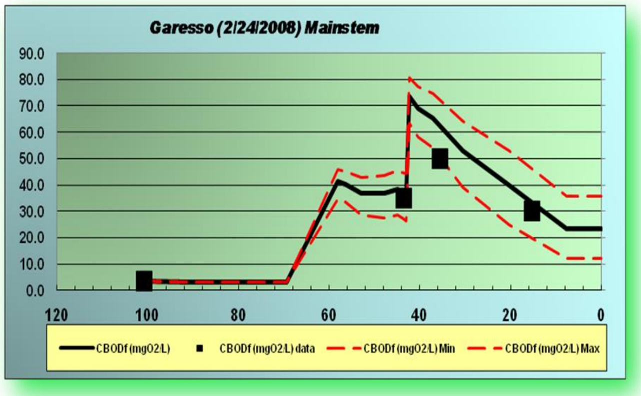

Fig.3 BOD trend in the main road (sample1)

In the 40 Km the BOD increases rapidly because Sahara Company is in this site and has a significant effect on oxygen consuming. Figure 4 to 6 illustrate the comparison between the presence and absence of wastewater treatment.

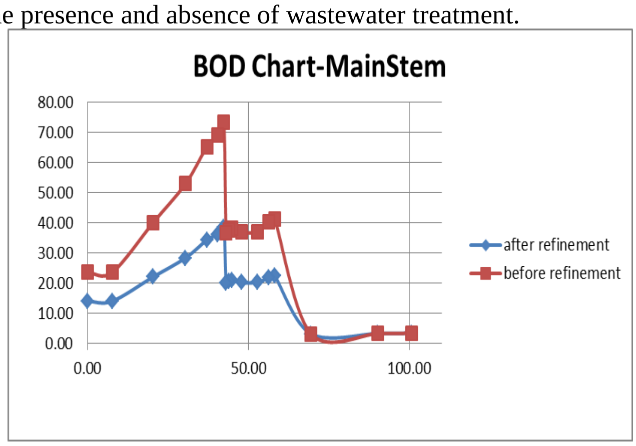

Fig.4 BOD trend in the main road in two situations

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As can be seen the blue line (after establishment of wastewater treatment) and red line (before establishment of wastewater treatment) denote that wastewater treatment reduces BOD significantly especially in the middle way that pollutants releases into the river.

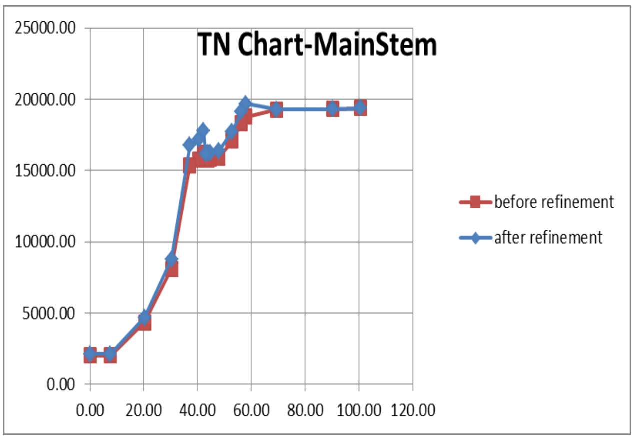


Fig.5 TN trend in the main road in two situations

TN shows that wastewater treatment does not have tangible improvement to decrease the TN. So for planning it is necessary that designers do not consider the wastewater treatment to decrease the TN term because it is not suitable economically.

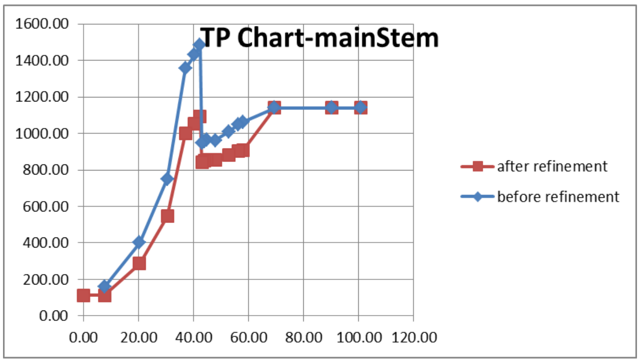


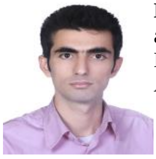
Fig.6 TP trend in the main road (sample1)

TP trend is between last two tends. If TP is critical in the middle of the main river, the establishment of wastewater treatment has beneficial aspects economically.

REFERENCES

1. Azzellino,A., et al .2006, Combined use of the EPAQUAL2E simulation model and factor analysis to assess the source apportionment of point and non point loads of nutrients to surface waters. Science of the total environment. 371. pp.214222.
2. Carney,E. 2009, Relative influence of lake age and watershed land use on tropic state and water quality of artificial lakes in Kansas. J. Lake Reserve. Manage. vol. 25. pp. 199207.
3. Chapra, S. C. (1997), Surface Water Quality Modeling, McGraw-Hill Boston, MA.
4. Chapra, S. C., G. J. Pelletier, and H. Tao (2004), QUAL2K: A Modeling Framework for Simulating River and Stream Water Quality, Version 1.3: Documentation and Users Manual., edited, Civil and Environmental Engineering Dept., Tufts University, Medford, MA.
5. Cho, J. H., and S. R. Ha (2010), Parameter optimization of the QUAL2K model for a multiplereach river using an influence coefficient algorithm, Science of The Total Environment, 408(8), 1985-1991
6. Environmental Protection Division (1989), The Amplified Long-Term BOD Test, Protocol/Procedures and Test Specifications. , edited by D. o. N. Resources, p. 38 pp., Atlanta, GA.
7. Fechrul,M.F., D.,Hendrawan, A.,Sitauati .2006, Land use and water quality relation ships in the cilliwung river basin, Indonesia. Dept. of Environmental Engineering Trisakti University.
8. Flynn, K., and M. W. Suplee (2011), Using a computer water quality model to derive numeric nutrient criteria: Lower Yellowstone River, MT, edited by M. D. o. E. Quality, Montana Department of Environmental Quality Helena.
9. Gamvroula, D., Stamatis, G. (2012) Diagnosis of groundwater quality and assessment of contamination sources in the Megara basin (Attica, Greece) Arab J geosci. DOI 10.1007/s12517-012-0533-6
10. Kannel, P. R., S. Lee, Y. S. Lee, S. R. Kanel, and G. J. Pelletier (2007), Application of automated QUAL2Kw for water quality modeling and management in the Bagmati River, Nepal., Ecological Modelling, 202(3-4), 503-517.
11. Monaghan,R.M., et al .2007, Linkage Between Land Management Activities and Water Quality in an Intensively Farmed Catchment in Southern New Zealand. Agriculture Ecosystems & Environment, 118:211222.
12. Prakash Raj Kannel,S., et al .2007, Application of automated QUAL2K for water quality modeling and management in the Bagmati River, Nepal. Ecological Modeling. Vol. 202, Issues 34: 503517.

AUTHOR PROFILE



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