International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-9 Issue-1, May 2020

Water Quality Modelling Qual 2KW for River Tungabhadra (India).

S.Ranjith, Anand.V. Shivapur, P. Shiva Keshava Kumar, Chandrashekarayya.G. Hiremath, Santhosh Dhungana.

Abstract: The River Tungabhadra takes its course through the Davangere district of Karnataka state of India. Along this course lies Harihar, the administrative headquarters of Harihar Taluk and other villages which are linear settlements on the bank of the River. These human settlements discharge untreated domestic waste and industrial effluent into the water as it flows. Therefore, it is imperative to study the degree of pollution of this water and ascertain its suitability for various uses. In this study, we shall make use of QUAL2Kw water quality model to predict the quality of water in the sections of the River that have been polluted. While making use of this Model, it was calibrated and validated for Dissolved Oxygen (DO), Biochemical Oxygen Demand (BOD), and Total Nitrogen (TN) during the pre-monsoon season. The data derived from the field and laboratory measurements were applied for the calibration and validation. The statistical method applied for the evaluation of the model performance was Standard Errors (SE) and Mean Multiplicative Error (MME). It was found that the Model is a good representation of the field data, but there are some minor exceptions. Although there are differences between the simulated data and the one measured in some instances, the results of the calibration and validation data are still acceptable. This type of result is applicable, especially in developing nations, where there are insufficient funds for frequent monitoring campaigns or more accurate research methodologies.

Keywords: Water quality modeling, QUAL2KW, River pollution, Tungabhadra and BOD-DO modeling.

I. INTRODUCTION

In many developing countries, it is common scenarios to see the untreated city and industrial wastewater being discharged into rivers. This act of negligence has led to concerns about the decline in the quality if river waters in communities. This continued pollution is a threat to the wellbeing of people and other living entities that derive their source of water from these rivers. This is why it is essential to take urgent steps to ascertain the usability of water sources through water quality modeling in various watercourses.

A tributary from the River Krishna (the second largest River in south India) formed the River Tungabhadra. The untreated waste deposited in the River from Harihara and other villages by the banks of the River poses a high risk to water quality from this River. It is essential to note that many settlements along the course of this River depend on it as the primary source of drinking water. Therefore, the effective management of the polluted segment of this River is crucial to protect human health and aquatic life.

The QUAL2E Model, which was developed by the United States Environmental Protection Agency (US EPA), has been the most prevalent mathematical Model applied for predictable pollutant impact evaluation [1]. Although some researchers have shown concerns about the limitations of the QUAL2E Model [2-4]. Prominent among the shortfalls is the apparent exclusion of data indicating the conversion of algal death to carbonaceous biochemical oxygen demand (BOD). In 2002 Park and Lee [5] modified the QUAL2E Model to what is now referred to as the QUAL2K.

The improvements in this new Model include the expansion of the computational structure, along with the inclusion of additional constituent interactions. These additions are algal BOD, de-nitrification, and dissolved oxygen (DO) change caused by fixed plants. The QUAL2K, 2003, which was developed by Chapra and Pelletier [7] was modified by Pelletier and Chapra [6] to form the QUAL2Kw Model. After that, the QUAL2K (Version 2.04) was created by Chapra et al. [8], it is intended as a modernized version of the QUAL2E Model. Some studies carried out with the QUAL2K Model showed that the results represent the field data well. This high level of accuracy makes the QUAL2KW Model a feasible option for future water quality analysis projects (Refer to Refs. [5] and [9] for samples).

The primary objective of this study is to make an accurate prediction of the water quality of the polluted segments of the River Tungabhadra. This objective shall be achieved with the use of the comprehensive application of water quality model QUAL2KW. After that, we shall evaluate the performance of the Model with the use of the Standard Errors (SE), and Mean Multiplicative Errors (MME) statistical analysis methods. This study focuses on an area of 40.5 km stretch of River Tungabhadra. The focal area starts at 18.6 km upstream of Mudenuru Village which is the upstream boundary of the stretch and extends 21.8 km to the downstream boundary of the research segment of the River.

Manuscript received on April 02, 2020.
Revised Manuscript received on April 15, 2020.
Manuscript published on May 30, 2020.

* Correspondence Author

S.Ranjith: Research Student in VTU-PG studies, Belagavi-590018, India.

Anand.V. Shivapur: Regional **Director** and PG-coordinator VTU-PG studies, Belagavi-590018, India.

P.Shiva Keshava Kumar: Professor and Head, Department of Civil Engineering, PDIT Engineering College Hosapete-583201, **India**.

Chandrashekarayya.G. Hiremath: Assistant prof. Department of water and land management, VTU, Belagavi-590018, India.

Santhosh Dhungana: School of Environment, Resources and Development (SERD), Pathumthani 12120, Thailand.

There are eight village settlements by the bank of this River going downstream of Harihara town. The villages are Nalawagal, Airani, Mudenuru, Rajanahalli, Somalapura, Heribidri and the Kumarapatanam. The population of these villages, which is between 250 – 35,000 people depends on this River for their drinking water.

II. MATERIAL AND METHODOLOGY.

A. Study Area:

This case study chooses River Tungabhadra that takes its course through the Davangere district in the Karnataka state of India. Unfortunately, this segment of the river has been subjected to extensive pollution as a result of industrial waste discharge, and seepage of domestic sewage at various locations downstream of Harihara. River Tungabhadra originates from a confluence between River Tunga and River Bhadra at an altitude of 610 meters above sea level. The confluence site is a village called Koodli, located within the Shimoga District of Karnataka. River Tungabhadra continued travelling through Kamataka, down to Andra Pradesh where it joins River Krisha. Harihara and its environs can be described as a semi-arid region; the summer ranges from moderate to hot with sparse rainfall, the winter is moderate, and rainfall is also sparse.

The Study area selected for the purpose of this research is Mudenuru to Somalapur. These eight communities which have socio-economical and industrial importance are located downstream Harihara. All Eight communites discharge their city wastewater directly in the river course. The two industries located at the banks of the river which are Harihara Poly Fiber company and the Rayon industry discharge about 30,000, and 10,000 liters of industrial waste respectively. The industrial wastewater is channeled into the river. The choice of the sampling stations was based in the width and depth of the stream where the effluent had mixed maximally with the water from the river.

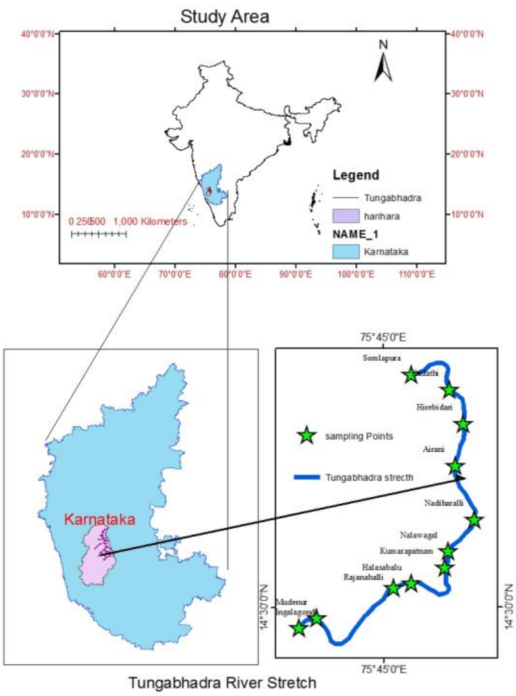

Fig. 1. Representation of sampling station

B. Sampling and Analysis

The sample collection includes the water quality data of the River and the wastewater of Harihara town, and the other sampling sites were collected on the 16th March 2018 for calibration. However, the validation was carried out on the 21th of April 2018 during the pre-monsoon season.

The samples taken in the pre-monsoon season were scheduled such that it monitors the critical low flows very closely. The water samples were collected at a depth of 15 cm to avoid the contamination from floating materials. Samples were taken from three different points (1/3, 1/2, and 2/3 of the river width) at every sampling location. The “dip and grab” sampling method was used, and the samples were stored in clean sampling bottles.

A Current Meter was used to measure the headwater flow of the main River. The velocity of the flow was measured across the entire width of the River. A leveling staff was used to measure the depth of the water. The velocity and cross-sectional area were used to ascertain the discharge from the source. The standard methods referenced in [10] and [11] were applied during the analysis.

C. About the Software

QUAL2KW (Version 6.0) is a Microsoft Windows application developed by Chapra et al. [8] it is designed as a modeling framework for simulating the quality of river and stream water. While Microsoft Excel was used for management of the frontend data, the backend computation was done with Fortran 90.

The Microsoft Office Macro (Visual Basic for Applications) was used for programming the interface operations. This method divides the system into reaches and elements. However, this system varies from the QUAL2E in that the element size is permitted to vary from one reach to another. Moreover, the researcher has the freedom to input multiple loading and withdrawal to each element. Moreover, it also allows the stipulation of various kinetic parameters on a reach specific basis. Further details can be found in the QUAL2K Documentation and Users Manual [8].

D. The implementation of model.

The entire 40-kilometer length of the River Tungabhadra which is the focal area of this project was separated into 40.5 reaches of 2.5 km each. The headwater data is represented by the upstream boundary condition. The steady-state data that was measured 20-21 April 2018 in the pre-monsoon season was used for calibration. The tie step for the calibration was set to 11.25 minutes to enhance the stability of the Model.

Euler’s method was the preferred technique used for integration. The Model was repeated until the parameters of the system were adjusted appropriately until the reasonable agreement between model results and field measurements was attained.

After this, the Model was run with various samples of water quality data which was taken on the 15-16 March 2018, and another data taken on the 20-21 December 2018 for validation. The detailed report of the data taken on the15-16 March 2018 is attached herein in this paper.

E. Input.

A current meter was used for measuring the headwater flow of the River. Moreover, this experiment considers the surface water recharge by the groundwater as insignificant. River Tungabhadra passes through a winding natural stream channel with some weeds along the water banks. Previous studies put the Manning's coefficient of such streams between 0.03 to 0.05 [12].

However, Manning's coefficient and the Channel Slope of the stretch of the stream in this study during the pre-monsoon season was taken as 0.034 and 0.0026 respectively.

F. System Parameter.

Reference was made to several pieces of literature to derive the model rate parameters. Some of the literature referenced include the Environmental Protection Agency (EPA) guideline documentation [13], the Model User Manual [6] and documentation for the Enhanced Stream Water Quality Model QUAL2E, and QUAL2E-UNCAS [1].

A test was also carried out to determine the CBOD de-oxygenation constants of different sections of the stream from the BOD5 concentration values, and the estimated travel time within the stream reaches. Limited amount of algae was found in the river water and did not cause any significant variation in the Dissolved Oxygen (DO) as a result of photosynthesis and respiration. Consequently, the system parameters that pertain to bottom algae, respiration, and photosynthesis were not considered during this study.

The Owens and Gibbs formula was used to determine the Re-aeration Coefficient. This formula was designed for streams that have a depth ranging from .12 to 3.3 m, and velocity between 0.03 to 1.5 m/s [15].

Table- I: water quality of surface water along Tungabahadra river in premonsoon

Sampling Date	Sampling station	Up stream	Down Stream	Reach length	pH	DO	BOD	TN	TP	Organic -N	NO3-N	NH4-N	Organic -P	Inorganic -p	Total alka
		Km	Km	Km		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/l	µg/l	
21-4-2018	SS1	40.69	32.42	8.27	7.2	7.8	2.44	5.65	0.27	0.43	0.19	5.03	184.1	85.9	84.84
	SS2	32.42	28.83	3.59	7.9	8.2	7.68	11.48	1.17	2.465	1.385	7.63	26.18	905.8	141.35
	SS3	28.83	23.78	5.05	7.65	8.4	5.62	12.45	1.15	2.27	1.88	8.3	876	624	151.6
	SS4	23.78	20.26	3.52	8.2	4.1	7.6	11.95	2.15	1.66	1.89	8.4	1053.5	1096.5	168.71
	SS5	20.26	17.43	2.83	8.16	4.85	6.45	14.23	3.84	2.42	2.2	9.6	1167.4	2627.5	162.28
	SS6	17.43	12.08	5.35	8.1	5.5	5.62	15.32	3.9	3.62	2	9.7	1095.9	2804.1	153.1
	SS7	12.08	2.54	9.54	7.8	7.65	4.4	15.4	2.85	3.14	1.96	10.3	883.5	1966.5	154.7
	SS8	2.54	0	2.54	7.4	8.85	3.1	13.2	2.16	2.44	2.36	8.4	475.2	1684.8	151.31

Table- II: another data set water quality of surface water along Tungabhadra river in premonsoon

Sampling Date	Sampling station	Up stream	Down Stream	Reach length	pH	DO	BOD	TN	TP	Organic -N	NO3-N	NH4-N	Organic -P	Inorganic -p	Total alka
		Km	Km	Km		mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	mg/l	µg/l	µg/l	
21-4-2018	SS1	40.69	32.42	8.27	7.6	7.9	7.4	11.0	1.1	2.4	1.3	7.3	25.1	869.6	135.7
	SS2	32.42	28.83	3.59	7.3	8.1	5.4	12.0	1.1	2.2	1.8	8.0	841.0	599.0	145.5
	SS3	28.83	23.78	5.05	7.9	3.9	7.3	11.5	2.1	1.6	1.8	8.1	1011.4	1052.6	162.0
	SS4	23.78	20.26	3.52	7.8	4.7	6.2	13.7	3.7	2.3	2.1	9.2	1120.7	2522.4	155.8
	SS5	20.26	17.43	2.83	7.8	5.3	5.4	14.7	3.7	3.5	1.9	9.3	1052.1	2691.9	147.0
	SS6	17.43	12.08	5.35	7.5	7.3	4.2	14.8	2.7	3.0	1.9	9.9	848.2	1887.8	148.5
	SS7	12.08	2.54	9.54	7.1	8.5	3.0	12.7	2.1	2.3	2.3	8.1	456.2	1617.4	145.3
	SS8	2.54	0	2.54	7.6	7.9	7.4	11.0	1.1	2.4	1.3	7.3	25.1	869.6	135.7

III. RESULTS

The attached figure 2 and 3 represents the results of the calibration and validation of the Model for BOD, DO, and TN at the six monitoring locations during the pre-monsoon season. The simulated results received from the Model were represented by the continuous lines, while the measured data are presented as symbols.

The results show that the values derived from the model prediction align with the values obtained from the field measurements, besides a few exceptions. Considering that water derived from this River is used for drinking in Harihara and the surrounding villages, it is essential that the category is of Class C. According to the Central Pollution Control Board (CPCB) of India, Class C which represents Drinking water source with conventional treatment must align with the minimum standards of BOD<3 mg/L and DO>4 mg/L.

In this research, the BOD value after a distance of 3 km ranges from 7-20 mg/L. The highest value of 7.6 mg/L was observed at a distance of 12.9 km. This value is as a result of the untreated municipal sewage and industrial waste discharged from kumarapatanam and Nalawagalu village. The value of dissolved oxygen (DO) that was derived from the samples ranges from 4 to 8.1 mg/L; The lowest value was obtained at a distance of 4.8 km. In essence, all the locations meet the minimum DO minimum requirements for class C. Finally, the value of TN foud at all location is also within the Class C that qualifies it for drinking water (IS: 10500, 1992)

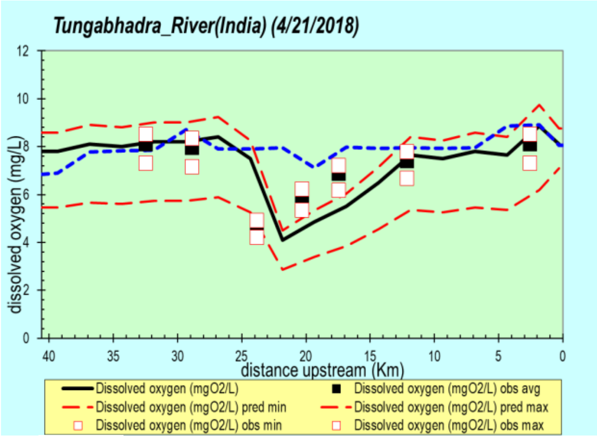

Fig. II. Dissolved oxygen in Tungabhadra river

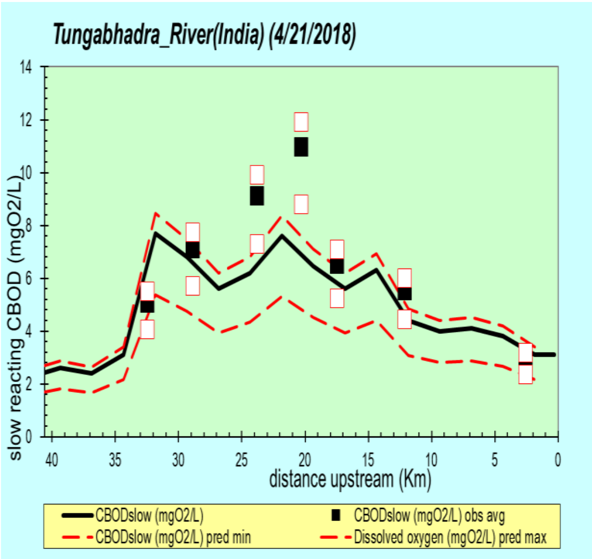

Fig. III. CBOD in Tungabhadra river

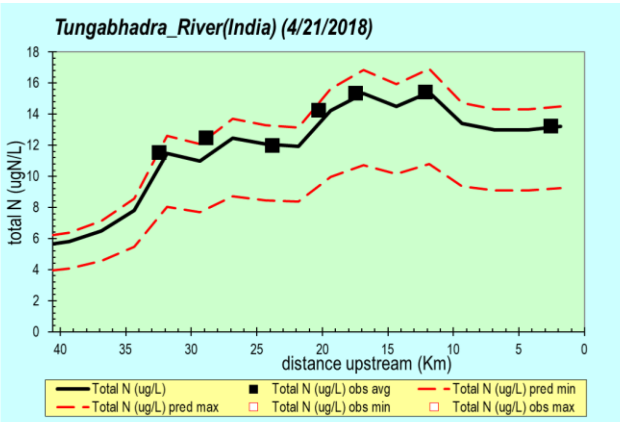

Fig. III.TN in Tungabhadra river

IV. CONCLUSION.

The QUAL2KW stream water quality model was used to calibrate and validate the Tungabhadra river during the pre-monsoon season of 2018. The results show that the values the Model predict agree with the field values except in a few locations. Standard Errors (SE) and Mean Multiplicative Errors (MME) were the statistical methods used in evaluating the performance of the Model.

After the evaluation, it was apparent that the variation between the calibration and the validation were negligible. The values of SE and MMR computed during calibration is as follows: BOD = 1.52(1.0), DO = 0.61(1.01), and TN = 1.34(1.12) respectively. Where the value in bracket refers to MME. The SE and MME values during validation are BOD=1.79(1.125), DO=0.71(0.89), TN=1.78(0.9). Where the value in bracket refers to MME.

Although there are some differences between the measured and simulated values at some point, the calibration and simulation results are still acceptable. This type of result is applicable, especially in developing nations, where there are insufficient funds for frequent monitoring campaigns or more accurate research methodologies.

REFERENCES

1. [L.C. Brown, T.O. Barnwell, Jr., The enhanced stream water quality models QUAL2E and QUAL2E-UNCAS, Environmental research laboratory, Athens, GA, USA, documentation and user manual, 1987, EPA/600/3-7/007, USEPA.
2. S.S. Park, C.G. Uchrin, Water quality modelling of the lower south branch of the Raritan river, New Jersey, Bulletin of N.J. Academy of Science 5 (1990) 17-23.
3. S.S. Park, Y.S. Lee, A multiconstituent moving segment model for the water quality predictions in steep and shallow streams, Ecological Modelling 89 (1996) 121-131.
4. R.B. Ambrose, T.A. Wool, J.P. Connolly, R.W. Shanz, WASP5, a hydrodynamic and water quality model, U.S. Environmental Protection Agency, Athens, GA., EPA, 1987, 600/3-87/039.
5. S.S. Park, Y.S. Lee, A water quality modeling study of the Nakdong River Korea, Ecological Modeling 152 (2002) 65-75.
6. G.J. Pelletier, S.C. Chapra, QUAL2Kw theory and documentation (Version 5.1), a modelling framework for simulating river and stream water quality, 2005, available online at: http://w.w.w.ecy.wa.gov/programs/eap/models/.
7. S.C. Chapra, G.J. Pelletier, QUAL2K: A modeling framework for simulating river and stream water quality (Beta Version): documentation and users manual, Civil and Environ. Eng. Dept., Tufts University, 2003, Medford, MA.
8. S.C. Chapra, G.J. Pelletier, H. Tao, QUAL2K: A modelling framework for simulating river and stream water quality, Version 2.04: documentation and users manual, Civil and Environ. Eng. Dept., Tufts University 2005, Medford, MA.
9. R.K. Prakash, L. Seokheon, R.K. Sushil, S.L. Young, A. Kyu-H, Application of QUAL2Kw for water quality modelling and dissolved oxygen control in the river Bagmati, Environ. Monitoring and Assessment 125 (2007) 201-217.
10. American Public Health Association (APHA), Standard Methods for the Examination of Water and Wastewater, 6th ed., Washington DC, USA, 1985.
11. American Public Health Association (APHA/AWWA/WEF), Standard Methods for the Examination of Water and Wastewater, 21st ed., Washington DC, USA, 2005.
12. S.C. Chapra, Surface Water Quality Modeling, McGraw-Hill Publication, New York, 1997.
13. L.B. George, B.M. William, B.P. Donald, L.C. Carrie, R.P. James, L.R. Gretchen, M.J. Kay, W.H.C. Peter, A.G. Steven, E.C. Charles, Rates, Constants and Kinetic Formulations in Surface Water Quality Modelling, 2nd Ed. U.S. Environ. Protection Agency, 1985, EPA/600/3-85/ 040.
14. Texas Water Development Board, Simulation of water quality in streams and canals, Report No. 128, Texas Department of Water Resources, 1971.
15. N.C. Ghosh, E.A. McBean, Water quality modeling of the Kali River, India, Water, Air, and Soil Pollution 102 (1998) 91-103.