International Journal of Scientific Research in Science and Technology
Print ISSN: 2395-6011 | Online ISSN: 2395-602X (www.ijsrst.com)
doi : https://doi.org/10.32628/IJSRST

Application of Automated QUAL2Kw for Water Quality Modeling in the Kabini River, Mysuru

R. Leela*[,1], Najamussahar H Mulla[2], B.M. Krishna[3], B. Manoj Kumar[4], B. P. Shiva Kumar[5]
(M. Tech Student[1], Research Scholar[2], Associate Professor[3], Professor[4], Assistant Professor[5])
Department of Environmental Engineering, JSS Science and Technology University (Formerly SJCE), JSS TI Campus, Mysuru, Karnataka, India
{*Corresponding author's email: leela3star@gmail.com}

Article Info
Volume 8, Issue 4
Page Number : 130-136

Publication Issue
July-August-2021

Article History
Accepted : 01 July 2021
Published : 08 July 2021

ABSTRACT

River Kabini, during its course through Sutturu village, Mysuru district in Karnataka state (India), receives agricultural runoff and untreated domestic waste on the bank of the river. The present study involves the application of water quality model QUAL2Kw to predict the water quality of the selected river stretch. The model was calibrated and validated for Dissolved Oxygen, Organic Nitrogen, Ammonium Nitrogen, Nitrate Nitrogen, Organic Phosphorus, and Inorganic Phosphorus in pre-monsoon season. Data for calibration and validation were obtained after the field and laboratory measurements. The performance of the model was evaluated using statistics based on Root mean square errors (RMSE). The RMSE for Dissolved Oxygen, Organic Nitrogen, Ammonium Nitrogen, Nitrate Nitrogen, Organic Phosphorus, and Inorganic Phosphorus during calibration are 2.86, 11.42, 14.11, 12.68, 3.25 and 12.70. Corresponding values for the validation are 1.04, 1.16, 0.05, 0.04, 0.29 and 0.68. In spite of some differences between the measured and simulated data sets at some points, the calibration and validation results are acceptable.

Keywords : QUAL2Kw, Calibration, Validation, DO, Kabini River

I. INTRODUCTION

Water is one of the most indispensable resources and is the elixir of life. A big amount of agricultural, municipal and industrial wastewaters discharges to rivers around the world. These discharges of degradable wastewaters in water bodies result in decrease in water quality generally and particularly DO concentrations. According to above mentioned problems of wastewater discharges, it is important to manage the water quality of hydrological sources and predict the impact of contaminants on them. There are a lot of models available but the most appropriate is the one that meets the research objectives.

The QUAL2K model is the new version of the widely used QUAL2E. QUAL2K is distributed by USEPA (United States Environmental Protection Agency, 2007) and it is based on differential equations for one-dimensional systems and steady state flow. This model is efficient to simulate water quality and hydrological conditions of streams as well as systems with diffusive pollution loads. QUAL2K developed in order to correct the QUAL2E limitations. Therefore QUAL2K has many new elements; it is useful in data limited conditions, is freely available and is not reserved for large rivers (i.e. deep and wide). The main objective of this study is to predict nutrient concentration in river Kabini, Sutturu, using readily available software QUAL2Kw[16]-[18].

II. MATERIALS AND METHODS

2.1 Study Area

The Kabini or Kapila is a river of southern India. It originates in the Wayanad District of Kerala state from the confluence of the Panamaram River and Manathavady River, and flows eastward to join the river Cauvery at Tirumakudal Narasipur in Karnataka, which drains into the Bay of Bengal.

2.2 Data and Sampling sites

For the present study, River Kabini on the banks of Sutturu is a village has been selected and it is located in Nanjangud taluk, Mysuru district. . Its coordinates are 12° 10′ 2.28″ N, 76° 47′ 42.29″ E. It has an average elevation of 667 meters above sea level. According to 2011 census, the total population of Sutturu village was 4006 and annual average rain fall was 670mm. Kabini river acts as a major source of water for agriculture, recreation and total agricultural land use area in sutturu is about 580 hectares. Major field crops - Paddy, Ragi, Maize, Pulses, Cotton, horticulture crops (fruits) - Mango, Sapota, Banana, horticulture crops (vegetables) - Tomato, Chilli, Brinjal, Medicinal and Aromatic crops/spices - Ginger , Turmeric and Plantation crops – Coconut. The six macronutrients, nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S) are required by plants in large amounts. Various fertilizers (e.g. urea, potash, rock phosphate etc.) which consist of these macronutrients will be provided by JSS Krishi Vigyan Kendra. Fig. 1 shows the sampling sites for water quality testing along the river stretch selected for the study[16] and [18].

2.3 Samplnig and Analysis

The water quality data of the river was collected on
29th January, 2019 for calibration and on 27th March, 2019 for validation during the pre-monsoon season. Water samples were collected at about 15 cm depth (to avoid floating material) from three points across a location of the river (1/3, 1/2 and 2/3) using the dip and grab sampling method and stored in pre-cleaned polythene bottles. To measure the head water flow of the main river, current meter was used to measure the velocity of the water at 0.6 d (where d=depth of the water at any flow location) across the width of the river and the leveling staff was used to measure the water depth. The discharges from the point sources were calculated using the velocity and cross-sectional area. All the analysis was done using standard methods given in Refs. [10] and [11].

Fig. 1 Location of river segment of Kabini selected for the study

2.4 Description of the Model

QUAL2K (Version 6) is a modeling framework for simulating river and stream water quality developed by Chapra et al. [8]. It is implemented within the Microsoft Windows environment. Numerical computations are programmed in Fortran 90. Excel is used as the graphical user interface. All interface operations are programmed in the Microsoft Office macro language: Visual Basic for Applications (VBA). It divides the system into reaches and elements. However, in contrast to QUAL2E, the element size for QUAL2K can vary from reach to reach. In addition, multiple loadings and withdrawals can be input to any element. It allows specifying many of the kinetic parameters on a reach-specific basis. A complete discussion of the model theory is described in QUAL2K Documentation and Users Manual [8].

A steady-state flow balance is implemented for each model element as

$$Q_i = Q_{i-1} + Q_{in,i} - Q_{out,i} \quad (1)$$

Where, Qi: outflow from element i into the downstream element i+1 cubic metre per day (m3/d), Qi–1 : inflow from the upstream

$$\frac{dc_i}{dt} = \frac{Q_{i-1}}{V_i} c_{i-1} - \frac{Q_i}{V_i} c_i - \frac{Q_{ab,i}}{V_i} c_i + \frac{E_{i-1}}{V_i}(c_{i-1} - c_i) + \frac{E_i}{V_i}(c_{i+1} - c_i) + \frac{W_i}{V_i} + S_I \quad (2)$$

element i-1 (m3/d), Qin,i : the total inflow into the element from point and non-point sources (m3/d), and Qout,i : the total outflow from the element due to point and non-point withdrawals (m3/d). The external loading of the constituent to element i, gram per day (g/d) or milligrams per day (mg/d), Vi: volume (m3), Si: sources and sinks of the constituent due to reactions and mass transfer mechanisms (g/m3/d or mg/m3/d), Ei: Bulk dispersion coefficient between reaches (m3/d), ci: concentration of water quality constituent (mg/m3 or g/m3), t: time in days. Kinetic processes included in the model are dissolution, hydrolysis, oxidation, nitrification, denitrification, photosynthesis, death and respiration/ excretion. Various mass transfer processes are reaeration, settling, and sediment oxygen demand. Manning equation is employed to compute the flow, depth, and velocity where each element is idealized as a trapezoidal channel.

2.5 Implementation of the Model

The total study length of 1.3 km of Kabini River was descretized into 13 reaches of 0.1 km each. The steady state data measured on 29th January, 2019 in pre-monsoon season were used for calibration. The calibration time step was set at 1.406 minute to avoid instability in the model. The solution of integration was done with Euler's method. The model was run until the system parameters were appropriately adjusted and the reasonable agreement between model results and field measurements were achieved. In order to test the ability of the calibrated model to predict water quality under different conditions, the model was run using a different set of water quality data taken on 27th March, 2019.

3. INPUT DATA

3.1 Hydraulic Characteristics

The head water flow of the river was measured using current meter. The surface water recharge through ground water is considered to be insignificant. River Kabini is a natural stream channel with a clean, winding and some weeds. For such a stream, Manning's coefficient varies from 0.03 to 0.05 [12].

3.2 Water Quality Data

The water quality and data measured for calibration of the model in pre-monsoon season is given in Table 1. The data measured for validation is given in Table 2.

3.3 System Parameters

The ranges of model rate parameters were obtained from various literatures including Environmental Protection Agency (EPA) guidance document [13] and [18], the model user manual [6] and documentation for the enhanced stream water quality model QUAL2E, and QUAL2E- UNCAS [1]. It was found that the algae present in the river water are very limited and do not cause any variation in DO due to photosynthesis and respiration process. Hence, the system parameters concerned with bottom algae, photosynthesis and respiration are not considered in the study. For reaeration coefficient, Owens and Gibbs formula which was developed for streams with depth ranging from 0.12 to 3.3 m, and velocity ranging from 0.03 to 1.5 m/s is used [15].

III. RESULTS AND DISCUSSIONS

The results of calibration and validation of the model for Dissolved Oxygen, Organic Nitrogen, Ammonium Nitrogen, Nitrate Nitrogen, Organic Phosphorus, and Inorganic Phosphorus at six monitoring locations in pre-

TABLE 1. Water Quality measurements of river in pre-monsoon season for calibration

TABLE 1

Water Quality measurements of river in pre-monsoon season for calibration

Reach	Distance (km)	Date	Temperature (degC)	Dissolved oxygen (mgO2/L)	Organic N (ugN/L)	Ammonium N (ugN/L)	Nitrate + nitrite N (ugN/L)	Organic P (ugN/L)	Inorganic P (ugP/L)
Headwater	1.30	1-29-19	22.91	7.04	20.00	20.00	60.00	401.10	745.00
1	1.25	1-29-19	22.91	7.06	20.82	19.80	59.51	400.58	745.07
2	1.15	1-29-19	22.90	7.07	21.62	19.59	59.03	400.05	745.15
3	1.05	1-29-19	22.89	7.09	22.41	19.40	58.55	399.53	745.22
4	0.95	1-29-19	22.88	7.10	23.18	19.20	58.07	399.01	745.29
5	0.85	1-29-19	22.88	7.12	23.94	19.01	57.59	398.48	745.37
6	0.75	1-29-19	22.87	7.13	24.68	18.82	57.11	397.96	745.44
7	0.65	1-29-19	22.86	7.15	25.41	18.63	56.64	397.44	745.52
8	0.55	1-29-19	22.86	7.16	26.12	18.45	56.17	396.91	745.59
9	0.45	1-29-19	22.90	7.14	27.50	18.55	57.44	396.78	746.29
10	0.35	1-29-19	22.89	7.16	28.20	18.36	56.97	396.26	746.36
11	0.25	1-29-19	22.89	7.17	28.87	18.18	56.50	395.73	746.44
12	0.15	1-29-19	22.88	7.19	29.54	18.00	56.03	395.21	746.51
13	0.05	1-29-19	22.95	7.16	30.97	18.16	57.63	395.17	747.48
Terminus	0.00	1-29-19	22.95	7.16	30.97	18.16	57.63	395.17	747.48

TABLE 2

Water Quality measurements of river in pre-monsoon season for validation

Reach	Distance (km)	Date	Temperature (degC)	Dissolved oxygen (mgO2/L)	Organic N (ugN/L)	Ammonium N (ugN/L)	Nitrate + nitrite N (ugN/L)	Organic P (ugN/L)	Inorganic P (ugP/L)
Headwater	1.30	3-27-19	28.97	4.91	20.00	0.00	0.00	210.00	390.00
1	1.25	3-27-19	28.97	4.97	19.97	0.02	0.00	209.74	390.13
2	1.15	3-27-19	28.97	5.02	19.95	0.04	0.01	209.48	390.27
3	1.05	3-27-19	28.96	5.08	19.92	0.07	0.01	209.22	390.40
4	0.95	3-27-19	28.96	5.13	19.90	0.09	0.01	208.96	390.53
5	0.85	3-27-19	28.96	5.18	19.87	0.11	0.01	208.71	390.66
6	0.75	3-27-19	28.96	5.23	19.84	0.13	0.02	208.45	390.79
7	0.65	3-27-19	28.95	5.27	19.82	0.15	0.02	208.19	390.92
8	0.55	3-27-19	28.95	5.32	19.79	0.17	0.02	207.93	391.05
9	0.45	3-27-19	28.94	5.36	20.31	0.52	1.68	209.21	393.98
10	0.35	3-27-19	28.93	5.40	20.30	0.55	1.68	208.96	394.11
11	0.25	3-27-19	28.93	5.44	20.28	0.57	1.68	208.70	394.24
12	0.15	3-27-19	28.93	5.48	20.27	0.59	1.68	208.44	394.37
13	0.05	3-27-19	28.92	5.51	20.90	1.00	3.63	210.01	397.92
Terminus	0.00	3-27-19	28.92	5.51	20.90	1.00	3.63	210.01	397.92

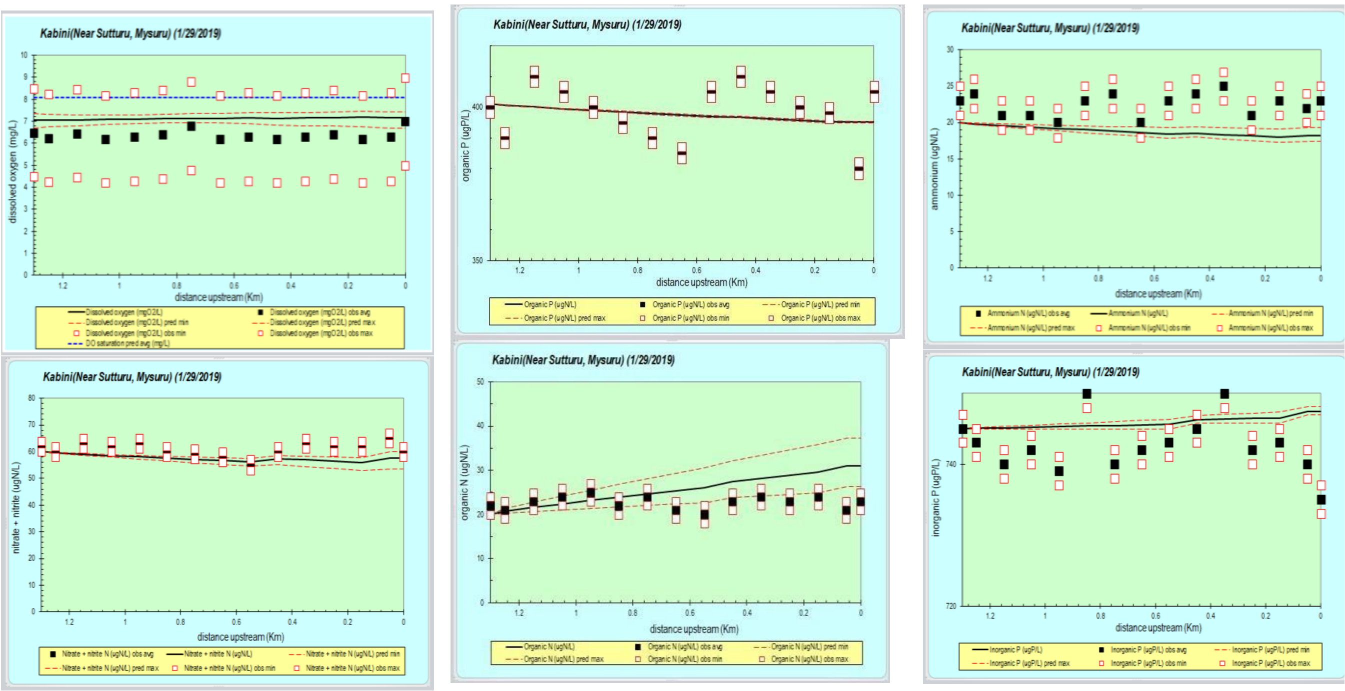

Fig. 2 Calibration results of river Kabini.

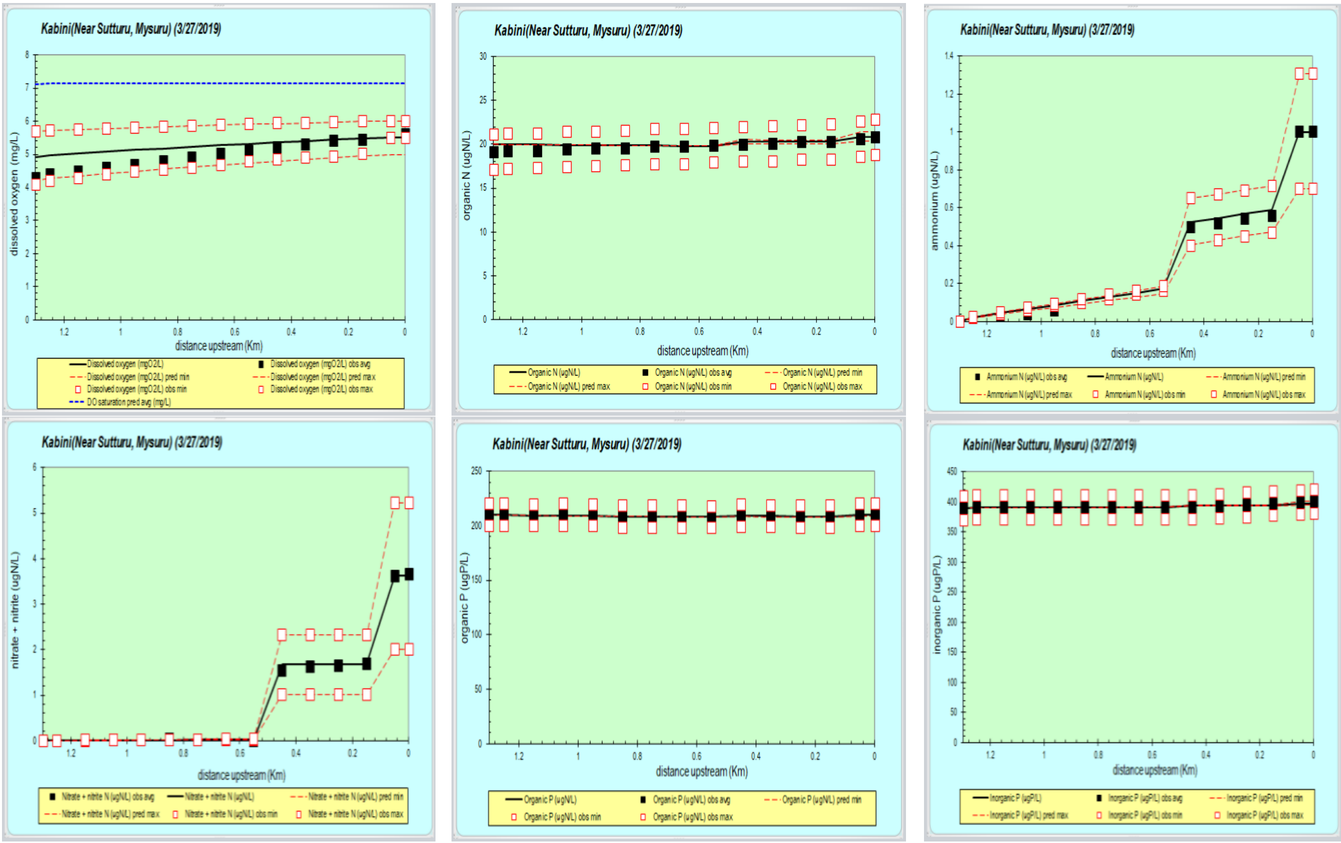

Fig. 3 Validation results of river Kabini.

monsoon season are shown in Figs. 2 and 3 respectively. The simulated results (predicted by the model) are presented as continuous lines and the measured data as symbols. From the results it can be observed that the values predicted by the model are in close agreement with the measured values except at few locations. According to predicted and simulated water quality results, Dissolved Oxygen, Organic Nitrogen, Ammonium Nitrogen, Nitrate Nitrogen, Organic Phosphorus, and Inorganic Phosphorus results are satisfactory and within the permissible limit, hence no treatment is required.

IV. CONCLUSION

A stream water quality model, QUAL2K, was calibrated and validated for the Kabini River in pre-monsoon season 2019. From the results it can be observed that the values predicted by the model are in close agreement with the measured values except at few locations. The performance of the model was evaluated using statistics based on Root mean square errors (RMSE). Dissolved Oxygen, Organic Nitrogen, Ammonium Nitrogen, Nitrate Nitrogen, Organic Phosphorus, and Inorganic Phosphorus during calibration are 2.86, 11.42, 14.11, 12.68, 3.25 and 12.70. Corresponding values for the validation are 1.04, 1.16, 0.05, 0.04, 0.29 and 0.68. In spite of some differences between the measured and simulated data sets at some points, the calibration and validation results are acceptable.

V. 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.

[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, vol.5, pp. 17-23, 1990.

[3]. S.S. Park, Y.S. Lee, "A multiconstituent moving segment model for the water quality predictions in steep and shallow streams", Ecological Modelling, vol.89, pp.121-131, 1996.

[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.

[5]. S.S. Park, Y.S. Lee, "A water quality modeling study of the Nakdong River Korea", Ecological Modeling vol.152, pp.65-75, 2002.

[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.

[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.

[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.

[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, vol.125 pp.201-217, 2007.

[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 QualityModelling", 2nd Ed. U.S. Environ. Protection Agency, 1985.

[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, vol.102, pp.91-103, 1998.

[16]. Najamussahar H Mulla, Dr. B. M. Krishna, Dr. B. Manoj Kumar, Dr. Arunkumar K and Mudassira Tahneet B. Lahori, "River water quality modeling using automated QUAL2Kw", International Journal of Interdisciplinary Global Studies, vol.14, issue.04, pp.447-459, 2020.

[17]. Najamussahar H Mulla, Dr. B. M. Krishna, and Dr. B. Manoj Kumar,"A Review on water quality models:

[18]. QUAL, WASP, BASINS, SWAT and AGNPS", International Journal of Scientific Research in Civil Engineering, vol.3, issue.04, pp.58-68, 2019.

[19]. Najamussahar H Mulla, J. Mohammed Nayaz Baig, Dr. B. M. Krishna, Dr. B. Manoj Kumar and Mudassira Tahneet B. Lahori, "Estimation of Rate Constants for Nutrient Transformations", International Journal of Recent Technology and Engineering (IJRTE), vol.8, issue.03, pp.2437-2441, 2019.

Cite this article as :

R. Leela, Najamussahar H Mulla, B. M. Krishna, B. Manoj Kumar, B. P. Shiva Kumar, "Application of Automated QUAL2Kw for Water Quality Modeling in the Kabini River, Mysuru", International Journal of Scientific Research in Science and Technology (IJSRST), Online ISSN : 2395-602X, Print ISSN : 2395-6011, Volume 8 Issue 4, pp. 130-136, July-August 2021. Journal URL : https://ijsrst.com/IJSRST217491