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APPLICATION OF AUTOMATED QUAL2Kw FOR WATER QUALITY MODELING IN THE RIVER KARANJA, INDIA

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ABSTRACT
The river Karanja, a major drinking water source for the Bhalki municipality is under threat by the disposal of effluents from the industries such as Sugar, Paper and distilleries. Water samples from this river were collected on hourly basis for two seasons at different locations along the river and their quality was assessed. As per the criteria specified by Central Pollution Control Board of India, the present water quality of the river is not acceptable as drinking water source. To study the effect of effluent disposal on this river, one dimensional steady-state stream water quality model was developed using QUAL2Kw. In this model pre-monsoon data is used for calibration and post monsoon data for validation. RMSE of calibrated and validation data using genetic algorithms showed nearly the same values for pH, alkalinity and biochemical oxygen demand(i.e., 2.50%, 2.20%; 9.8%, 10.00%; and 19.60%, 24.60% respectively), and the RMSE difference was more for dissolved oxygen, nitrate nitrogen and ammonia nitrogen (i.e., 5.5%, 14.06%; 57.6%, 65.3%; and 27.0%, 39.6%), these differences can be attributed to changes in environmental conditions between the two periods. From the sensitivity analysis, it was observed that the model is sensitive for temperature, bottom width, discharge and biochemical oxygen demand. Simulations were carried out for several scenarios such as bottom algae, head water release, shade and temperature under dry weather flow condition. All these profile did not meet the requirement of minimum DO concentration, to get it bottom algae is to be reduced to 75%, head water BOD is to be reduced to 8mg/L, and shade is to be increased up to 30% therefore different suitable methods are suggested for improving water quality.

KEY WORDS: Stream water quality, water quality management and QUAL2Kw.

INTRODUCTION
Environmental pollution is one of the serious threats faced by mankind. This has accelerated the discovery of environmental problems during the past few decades. Rapid population growth, urbanization, industrialization and land development along the stream have increased the stress on river pollution and have resulted in its deterioration (Surindrasuthar 2009). River plays a vital role in assimilation/carrying off the municipal, industrial wastewater and run-off from agricultural land. The municipal and industrial wastewater discharge are the continuous pollutants, the surface run-off is a seasonal phenomenon largely affected by climate in the basin. Seasonal variations in precipitation, surface run-off, interflow, groundwater flow and pump in and out flows have a strong effect on river discharge and subsequently on the concentration of pollutants in river water (Singh, 2004). The deterioration of aquatic ecosystem results from decrease in the dissolved oxygen concentration and also, due to pollutant degradation by micro-organisms, chemical oxidation, plant, algal and phytoplankton respiration (Drolc and Konkan 1996). The impact of low dissolved oxygen concentration or even of anaerobic conditions causes mortality of fish and other aquatic organisms. It also results in unpleasant odors, and other aesthetic damage (Arruda Camargo 2010). Hence, it is essential to monitor water quality changes in the entire river, but it is tedious, time consuming and un-economical. The mathematical models are the alternative way to describe the relation between waste loads and water bodies, since they allow immediate remediation before problems become prohibitively difficult to solve. This practice has grown in popularity in recent years and is becoming a common tool for the management of water resources (Droll and Konkan 1996). The widely used mathematical model for conventional pollutant impact evaluation is QUAL2E (Brown and Barnwell, 1987) developed by United States Environmental Protection Agency (USEPA). However, several limitations of the QUAL2E have been reported (Park and Uchrin 1990; Park and Lee, 1996). One of the major inadequacies is the lack of provision for conversion of algal death to carbonaceous biochemical oxygen demand (Ambrose *et al.* 1987; Park and Uchrin, 1996, 1997). Park and Lee (2002) developed QUAL2K, 2002 after modification of QUAL2E.The modifications include the expansion of computational structures and addition of new constituent interactions: algal BOD, De-Nitrification and DO change caused by fixed plants. Pelletier and Chapra (2005) developed a model QUAL2Kw, by modifying QUAL2K, 2003 originally developed by Chapra and Pelletier (2003), which is intended to represent a modernized version of QUAL2E, and is useful for shallow river (Fluvial Bottino et al., 2010;Ghosh and Mcbean,1998).

QUAL2Kw is one-dimensional steady state stream water quality model; it uses unequally-spaced reaches. In addition, multiple loadings and abstractions can be input to any reach and is implemented in the Microsoft Windows environment. It is well documented and is freely available. QUAL2Kw includes many new elements (Pelletier and Chapra, 2005).It includes DO interaction with fixed plants, conversion of algal death to CBOD and reduction in the amount of CBOD due to denitrification. It uses two forms of carbonaceous biochemical oxygen demand to represent organic carbon: slowly and rapidly oxidizing forms. It accommodates Anoxia by reducing oxidation reactions to zero at low oxygen levels. Simulates attached bottom algae explicitly, models models sediment-water fluxes of dissolved oxygen and nutrients internally. In addition to this, its simulation includes de-nitrification, pH and sediment pore water quality.

A conventional sensitivity analysis is performed by varying important parameters that which has effect on the model output (Nikolaos P. Nikolaidis et al., 2006). For the management of water quality, several scenarios are studied by changing model input parameters during the dry period (Ritu Paliwal and Prateek Sharma 2007). considering i) Bottom algae modification, ii) temperature modification iii) head water modification and iv) Shade modification.

The main motive of the study is (i) to analyze water quality of the river (ii) to apply water quality model to assess the impact of waste discharges in the river (iii) to determine the maximum pollution loads that the river can receive without violating the standards specified by the Central Pollution Control Board of India. The water quality modeling software QUAL2Kw is used to predict water quality and visualize the effect of different remedial measures to improve the river water quality.

MATERIAL AND METHODS

Study area

The Karanja river is one of the tributaries to the Godavari river. It originates near Kohir village of Andhra Pradesh state of India and joins another tributary of Godavari i.e. Manjera river at 122 km downstream. This river has a dam called Karanja which in near Bhyalhalli village and it has got pumping station on Humanabad Bhalki Road Bridge which is about 21.85 km downstream of the reservoir. Figure 1 shows the study area, which has spread between N 17^{o} 49^{l} , E 77^{o} 20^{l} and N 18^{o} 02^{l} , E 77^{o} 12 with an altitude of 554-575 m above MSL. Meteorological data from 1967 to 2010 was collected from Indian Meteorological department of Karnataka.

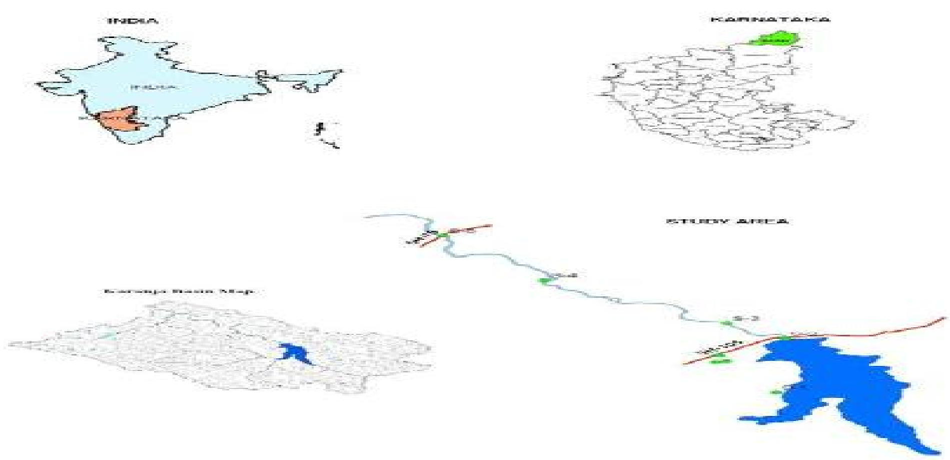


FIGURE 1 Location map of the study area

The average annual rain fall is 830mm and average temperature ranges between 35^{o}c to 42^{o}c. The entire district forms a part of the Deccan plateau and is made up mostly of solidified lava.The northern part of the district is characterized by expanses of level and treeless surface punctuated here and there by flat and undulating hillocks, black soils and basaltic rocks. The southern half of the district is a high plateau, and is well drained. Alluvial deposit is normally found along the banks of the Manjra river and its main tributaries. The district has 5460.12 sq km of geographical area out of which 277.07sq km are forest, which is 5.07% of the total area of district. Land not available for cultivation in the district is 688.40 sq km and uncultivable land is 440.66 sq km. Actual agriculture land is 3543 sq km out of that 851.4 sq km area is cultivated more than once. The catchment area of the river at the proposed dam site is 2,025.38 sq. Km. Currently three major industries such as sugar factory, paper mill& distillery are situated on the bank of the reservoir, due to lack of will to implement statutory regulations by the authorities, these industries are freely discharging their trade-effluent continuously in to the river. This has resulted in the deterioration of the water quality of Karanja reservoir.

Water quality monitoring sites

Based on the topographical, nature of water flow, nature of river bed, and disposal of effluent and considering the accessibility for sampling, a total of four sampling points were selected covering 21.85 km stretch of Karanja river for the present investigation. The samples were collected at various locations along the river.

Sampling point R-2

This station is about 2 kilometers away from station 1 on the Downstream of the karanja reservoir, along the river near Humnabad Bidar Road Bridge.

Sampling point R-3

This station is about 4 kilometers away from Station S2 on the downstream of the Karanja reservoir, along the

Karanja river near Railway Bridge. Source of pollution for this station is agricultural runoff from adjoining fields, which is predominant during monsoon, and due to domestic activities of the villagers, like washing of clothes, bathing and washing of animals.

Sampling point R-4

Along the Karanja river near Davargaon village. This station also receives agricultural runoff from adjoining fields during the rainy period and also the usual domestic pollution load due to washing of animals, clothes, bathing etc.

Sampling point R-5

Along the Karanja river near Humnabad Bhalki Bridge. Source of pollution for this station is agricultural runoff from adjoining fields, which is predominant during monsoon, and due to domestic activities of the villagers, like washing of clothes, bathing and washing of animals.

River descretization

The stretch of the river between karanja reservoir and Bhalki pump station was selected for the study. The length of 21.85 km was deseretization into 19 reaches with unequal lengths, based on the geography of the study area. The releases from the Karanja reservoir were taken as head water data. Fig. 2 shows the river system unequal segmentation along with the reservoir in which effluents are being dischared.

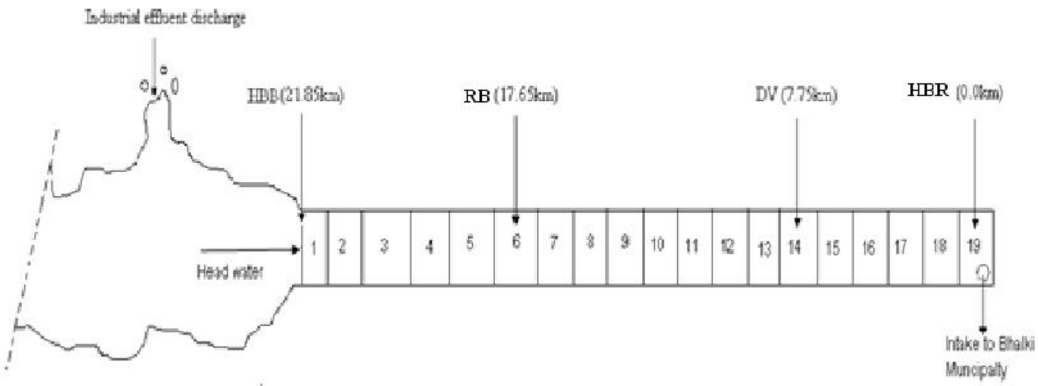


FIGURE 2 Discritization of Karanja River

Sampling and analysis

studies were carried out on hourly basis for 24 hours pre-monsoon (30th June 2010) and post-monsoon (1st April 2011) and analyzed for the parameters such as temperature, pH, dissolved oxygen(DO), 5-days biochemical oxygen demand $(BOD)_5 20^oc$, nitrate nitrogen (NO_3-N), ammonia nitrogen (NH_4-N), conductivity, velocity, and water depth were measured along the river at sampling locations. All the activities such as sample collection, preservation, transportation and analysis were carried out as per the standard methods (APHA-1995).Water analysis for temperature and pH were performed in-situ with a portable thermometer and pH-meter respectively. Dissolved oxygen was measured in-situ with a portable DO probe as well as in the laboratory by titration. Conductivity was measured with a portable probe. BOD (carbonaceous biochemical oxygen demand, CBOD) was determined by azide modification method during five days incubation at 20^oc. Nitrite-nitrogen was determined by spectrophotometric method (diazo method). Nitrate-nitrogen was determined by ultraviolet (UV) spectrophotometric screening. Ammonia nitrogen was determined by titration.

Modeling tool

The modeling tool QUAL2Kw has a general mass balance equation for a constituent concentration c_i (Fig.3) in the water column (excluding hyporheic) of a reach i (the transport and loading terms are omitted from the mass balance equation for bottom algae modeling) as (Pelletier et al., 2006).

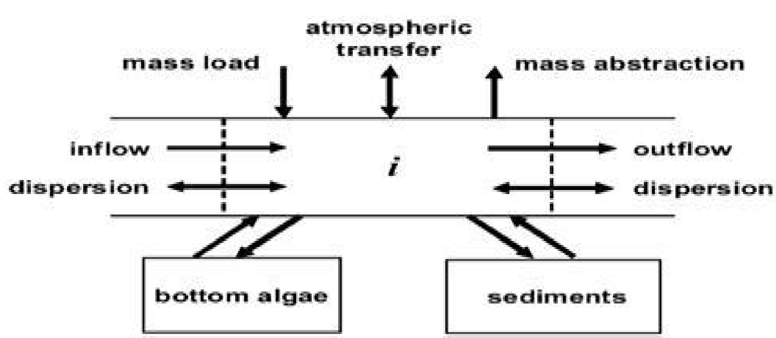
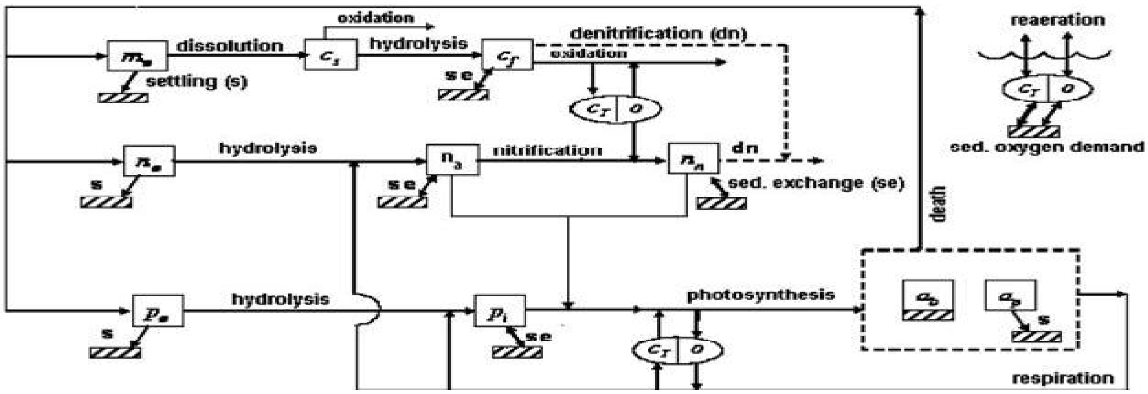


FIGURE 3 Mass balance in a reach segment i. Source: (Pelletier and Chapra, 2005)

$$\frac{dc_i}{dt} = \frac{Q_{i-1}}{V_i}c_{i-1} - \frac{Q_i}{V_i}c_i - \frac{Q_{ab,i}}{V_i}c_i + \frac{E'_{i-1}}{V_i}(c_{i-1} - c_i) + \frac{E'_i}{V_i}(c_{i+1} - c_i) + \frac{W_i}{V_i} + S_i \quad (1)$$

Where Q_i= flow at reach i(L/day), $Q_{ab,i}$= abstraction flow at reach i(L/day), V_i= volume of reach i(L), W_i= the external loading of the constituent to reach i (mg/day), S_i= sources and sinks of the constituent due to reactions and mass transfer mechanisms (mg/L/day), E_i= bulk dispersion coefficient between reaches (L/day), E_{i-1}, E_i are bulk dispersion coefficients between reaches i−1 and i and i and i + 1 (L/day),c_i= concentration of water quality constituent in reach i(mg/L)and t= time (day). Figure 4 represents the schematic diagram of interacting water quality state variables. The complete description of the process of interacting water quality state variables is available in Pelletier and Chapra (2005).



(Note: *ab*: bottom algae, *ap*: phytoplankton, mo: detritus, *cs*: slow BOD, *c f* : fast BOD, *cT*: total inorganic carbon, *o*: oxygen, *no*: organic nitrogen, *na*: ammonia nitrogen, *nn*: nitrite and nitrate nitrogen)

FIGURE 4 Schematic diagram of interacting water quality state variables Source: (Pelletier and Chapra, 2005)

For auto-calibration, the model uses genetic algorithm (GA) to maximize the goodness of the fit of the model results compared with measured data by adjusting a large number of parameters. The fitness is determined as the reciprocal of the weighted average of the normalized root mean squared error (RMSE) of the difference between the model predictions and the observed data for water quality constituents. The GA maximizes the fitness function *f*(*x*) as:

$$f(x) = \left[\sum_{i=1}^{q} w_i\right]\left[\sum_{i=1}^{q} \frac{1}{w_i}\left[\frac{\left[\frac{\sum_{j=1}^{m}(P_{ij}-O_{ij})^2}{m}\right]^{1/2}}{\frac{\sum_{j=1}^{m} O_{ij}}{m}}\right]\right]^{-1} \quad (2)$$

Where $O_{i,j}$= observed values, $P_{i,j}$= predicted values, m=number of pairs of predicted and observed values, w_i = weighting factors and n=number of different state variables included in the reciprocal of the weighted normalized RMSE. Detailed descriptions of auto-calibration method can be found in Pelletier et al., (2006).

Model Calibration and Validation

Model input

The model allows the use of input data for the hydraulic characteristics of various reaches which are as shown in Table1. Each reach is idealized as a trapezoidal channel.Under condition of steady flow, the Manning's equation was used to calculate mean velocity and depth as a function of the stream width, bottom slopes and manning's roughness co-efficient. The Karanja river is a natural stream channel with weeds, windings and pools. For such a stream, manning's roughness co-efficient may be assumed between 0.06-0.07 (Pelletier et al., 2006).

$$Q = \frac{S_0^{0.5}}{n}\frac{A_c^{5/3}}{P^{2/3}} \quad (3)$$

Where Q = flow rate [m^3/s], So = bottom slope [m/m], n = the manning's roughness coefficient, Ac = the cross-sectional area [m^2], and P = the wetted perimeter [m].As model simulates ultimate CBOD, the measured 5 day CBOD ($CBOD_5$) was transferred to ultimate CBOD ($CBOD_U$) using the following relationship (k=the CBOD decomposition in the bottle, 1/day) (Chapra et al., 2006).The bottle rates for sewage derived organic carbon are of the order of 0.05-0.3 day^1 (Kannel et al., 2007).

$$CBOD_U = \frac{CBOD_5}{1 - e^{-5k}} \quad (4)$$

In the head water boundary condition sheet of the model, the required parameters such as flow rate, temperature, conductivity, dissolved oxygen, ultimate carbonaceous biochemical oxygen demand, ammonia nitrogen, nitrate nitrogen, alkalinity and pH are given as input. The phytoplankton and pathogen were not measured and the inputs were left blank. The initial condition water quality data of all the reaches from 1 to 19 are calculated by knowing the initial condition water quality data at (HBB), (RB), (DV) and (HBR) by linear interpolation method. During sampling, it was observed that the maximum surface of the river bed was covered by algae and bottom sediment; therefore the algae cover and bottom-sediment oxygen demand were both assumed to be 100%. The sediment/hyporheic zone thickness, sediment porosity and hyporheic exchange flow were assumed to be 10 cm, 40%, and 5% respectively.

TABLE1-Reach hydraulic characteristics along Karanja river

Distance (km)	Reach no	Channel slope m/m	Manning's coefficient (n)	Channel width (m)
21.850	0	0.00121	0.0600	8.60
21.550	1	0.00082	0.0600	8.20
21.100	2	0.00037	0.0600	9.00
20.100	3	0.00031	0.0600	7.90
18.500	4	0.00057	0.0600	6.80
16.800	5	0.00058	0.0600	5.90
15.850	6	0.00025	0.0650	8.80
14.350	7	0.00044	0.0650	7.90
13.050	8	0.00111	0.0650	8.90
11.650	9	0.00057	0.0650	6.90
10.250	10	0.00042	0.0650	8.50
9.050	11	0.00046	0.0700	6.20
8.150	12	0.00066	0.0700	7.80
7.350	13	0.00084	0.0700	6.90
6.300	14	0.00111	0.0700	8.80
5.600	15	0.00121	0.0700	7.30
4.300	16	0.00121	0.0700	6.80
2.700	17	0.00141	0.0700	7.90
1.000	18	0.00131	0.0700	7.10
0.000	19	0.00131	0.0700	7.20

TABLE 2. Calibrated Kinetic parameters for the Karanja River water quality modeling in 2010

Parameters	Values	Units	Min.Valu	Max.Valu
Carbon	40	gC	3	50
Nitrogen	7.2	gN	3	9
Phosphorous	1	gP	0.4	2
Dry weight	100	gD	100	100
Chlorophyll	1	Ga	0.4	2
Inorganic Suspended Solids Setting Velocity	0.8705	m/d	0	2
Slow CBOD Hydrolysis Rate	2.59355	/d	0	5
Slow CBOD Oxidation Rate	0.06117	/d	0	0.5
Fast CBOD Oxidation Rate	0.873	/d	0	5
Organic N Hydrolysis	4.3187	/d	0	5
Organic N Setting Velocity	1.1737	m/day	0	2
Ammonia Nitrification	0.3379	/d	0	10
Nitrate de-nitrification	1.77236	/d	0	2
Sediment de-nitrification Transfer Coefficient	0.22872	m/d	0	1
Organic Hydrolysis	1.86105	/d	0	5
Organic P setting Velocity	0.28358	/d	0	2
Inorganic P setting velocity	1.40378	m/d	0	2
Inorganic P sediment oxygen Attenuation half saturation constant	1.97752	mgO2/L	0	2
Bottom Plants:				
Maximum Growth Rate	49.628	gD/m2/d	0	100
Excretion Rate	0.416735	/d	0	0.5
Death Rate	0.31285	/d	0	0.5
External nitrogen half Saturation constant	242.451	mgN/L	0	300
External phosphorous half Saturation constant	97.458	mgP/L	0	100
Inorganic carbon half saturation constant	7.54E-05	moles/L	1.30E-06	1.30E-04
Light constant	88.15366	Layers/d	1	100
Ammonia preference	10.9891	mgN/L	1	100
Subsistence quota for nitrogen	1.0466244	mgN/L	0.072	72
Subsistence quota for phosphorous	7.2045982	mgN/L	0.01	10
Maximum uptake for nitrogen	363.662	mgN/gD/d	350	1500
Maximum uptake for phosphorous	111.9995	Mg P/gD/d	50	200
Internal nitrogen half saturation ratio	4.1545502		1.05	5
Internal phosphorous half saturation ratio	2.7959		1.05	5
Detritus dissolution rate	1.16205	/d	0	5
Detritus setting rate	1.13735	m/d	0	5

Kinetic parameters

The ranges of model kinetic parameters were obtained from QUAL2Kw user manual (Pelletier and Chapra, 2005) and documentation for the enhanced stream water quality model QUAL2E and QUAL2E-UNCAS (Brown and Barnwell, 1987).To calculate re-aeration rate coefficient, Owens–Gibbs formula (Owens et al., 1964) was applied, it was developed for shallow depths. Exponential model was chosen for oxygen inhibition for CBOD oxidation, nitrification, de-nitrification, photo respiration and bottom algae respiration. The other parameters were set as default in QUAL2Kw.The model was calibrated by using pre-monsoon data.The calibrated pre-monsoon and validated post-monsoon produce the minimum RMSE value of important parameters such as dissolved oxygen and biochemical oxygen demand. Hence, the pre-monsoon calibrated model was used for further study and the calibrated kinetic rate parameters for pre-monsoon were presented in Table 2.

Model implementation

The measured data of pre-monsoon season (30th June 2010) were used for calibration. The calculation step was set at 5.625 minutes. The solution of integration was done with Euler's method, as Euler's method is suggested as the default because it usually yields sufficiently accurate results at a moderate computational price. For the pH modeling, we used the Brent method, as it is considered being the best method. To simulate exchanges in the hyporheic zone level-I option was chosen, which includes simulation of zero-order oxidation of fast-reacting dissolved CBOD with attenuation from temperature, CBOD and dissolved oxygen.

To obtain the best adjustment, the modeling system assigns standard weights to various parameters; here trial weights were found to minimize error between the observed and simulated data. The weight for dissolved oxygen was given as 50 and is justifiable as it is the most influenced parameter. Weight 5 was given for BOD and weight 1 was given to other parameter. The model was run until the system parameters were appropriately adjusted and the reasonable agreement between model results and field measurements were achieved. The model was run for a population size of 100 with 100 generations. This is because a population size of 100 performs better than smaller numbers and as nearly as a population size of 500 (Pelletier *et al.*, 2005). In order to test the ability of the calibrated model to predict the water quality conditions during different condition, the model was run again without changing the parameters that were calibrated for the pre monsoon period by using different data set. Then the model was used to simulate the water quality under different assumed changes (scenarios). During model validation, all parameter values were was set to those values for model calibration except field and weather data specific to the verification period.

RESULT AND DISCUSSION

The results for the water quality parameters are shown in Table 3 (water quality measurement as on 30th June 2010), Table 4(water quality measurement as on 1st April 2011). Calibration and validation results are shown in Figure 5 and 6 respectively. The various scenarios of water quality for Karanja river are shown in Figure 7.

TABLE 3. Water quality measurement at monitoring station along the Karanja river as on 30th June 2010

Station	Length (km)	Cond. (mg/L)	D O (mg/L)	$UBOD_5$ (mg/L)	NH4 (µg/L)	NO3 (µg/L)	Alkalinity (mg/L)	PH
HBB	21.85	140	3.8	11.24	510	1800	100	7.9
RB	17.65	170	4.52	10.00	440	1520	100	7.6
DV	7.75	170	5.00	7.40	380	750	105	7.7
HBR	0.00	160	5.95	6.42	320	630	108	7.7

TABLE 4. Water quality measurement at monitoring station along the Karanja river as on 1stApril 2011

Station	Length (km)	Cond. (mg/L)	D O (mg/L)	$UBOD_5$ (mg/L)	NH4 (µg/L)	NO3 (µg/L)	Alkalinity (mg/L)	PH
HBB	21.85	140	4.0	13.14	510	1800	100	7.9
RB	17.65	150	4.5	10.22	400	1200	100	7.9
DV	7.75	150	5.2	8.10	310	810	95	7.7
HBR	0.00	150	5.8	6.40	220	310	95	7.6

Calibration and verification

The model was calibrated by using pre-monsoon water quality data; the calibrated model ability was tested to predict the water quality during different conditions. Hence, the pre-monsoon calibrated model was used to simulate water quality with different scenarios.The model calibration results for the water quality data at four monitoring stations are shown in Figure 5. The model calibration result is well in agreement with the measured data with some exceptions. As seen in Figure 5 dissolved oxygen increase continuously as distance from head water increases, but at 16.33 km and 9.65 km dissolved oxygen slightly decreases due to constant washing clothes, goat, cattle by villagers, which probably decreases the dissolved oxygen at 16.33 km and 9.65 km.

Biochemical oxygen demand continuously decreases up to a distance of 9.65 km, from this point onwards BOD remains constant with slight variation may be due to conversion of algal death to carbonaceous biochemical oxygen demand (park and ucbrin 1997).

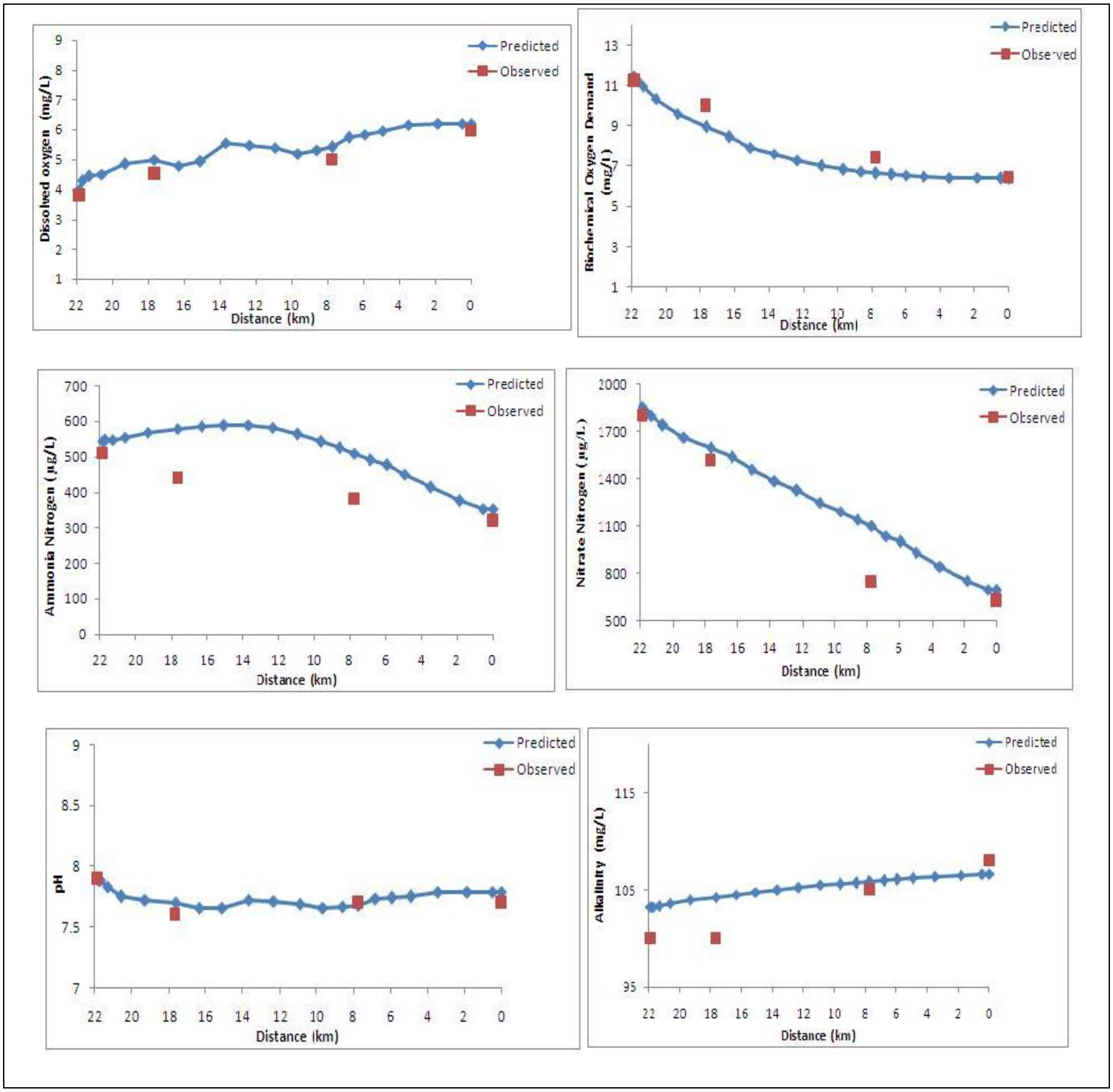
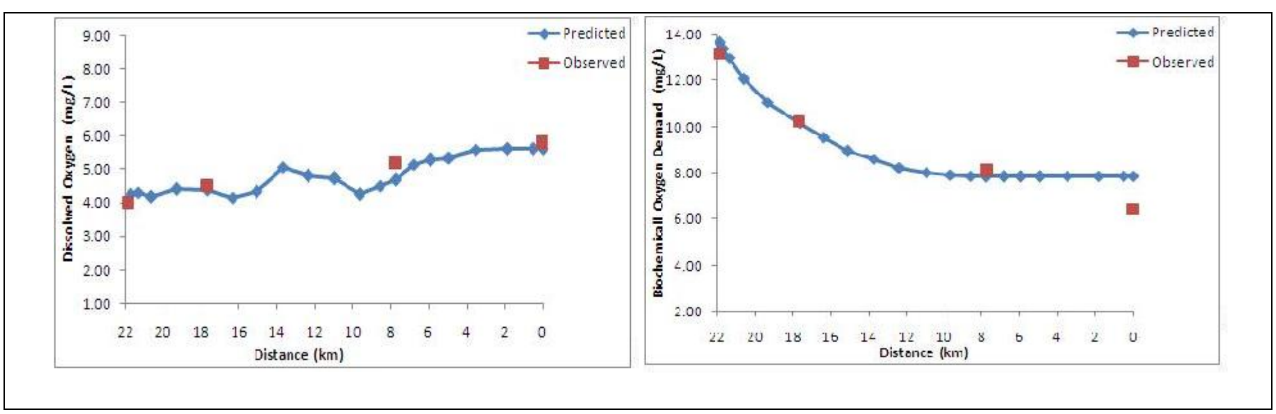
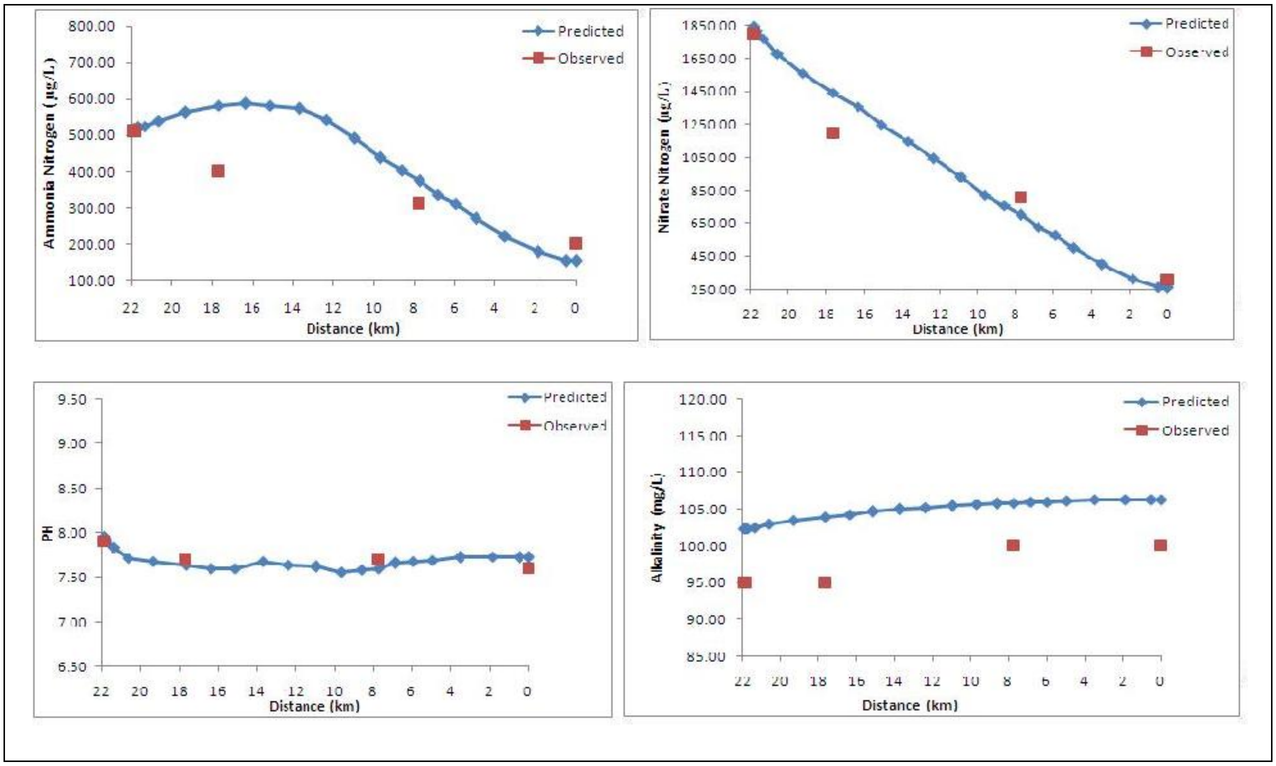


FIGURE 5 Model calibration results for the water quality parameters in Karanja River using Pre-monsoon data





`**FIGURE 6.** Model validation results for the water quality parameters in Karanja River using Post- monsoon data

In addition, other activates along the bank of the river are also responsible for constant BOD along the river. Ammonia nitrogen was increasing up to 15 km and decreasing slowly towards the end, and nitrate nitrogen rapidly decreasing from head water towards downstream. pH is slightly decreasing at 16.33 km and 9.65 km, may be due to constant human activity, and again slightly increases with distance; Finally alkalinity remains constant from head water to towards the of river. The validated values for the post-monsoon season are shown in Figure 6. The validated results for post-monsoon season were similar to the calibrated results for pre-monsoon season, little variation of ammonia nitrogen. From the above result it is clearly indicated that, the Karanja river water is not yet highly affected. The calibrated and validated results are acceptable especially for developing countries like India where financial resources are limited for frequent monitorin.

Root –Mean –Square errors (RMSE)

The root mean square error values between the simulated and observed value for the calibration period (pre-monsoon) and for the validation period (post-monsoon) of pH, alkalinity and biochemical oxygen demand are 2.50%, 2.20%; 9.8%, 10.00%; and 19.60%, 24.60% respectively (Table 5). High difference RMSE value was observed for dissolved oxygen, nitrate nitrogen and ammonia nitrogen, these differences can be attributed to changes in environmental conditions between the two periods. The nitrate nitrogen, ammonia nitrogen was observed to have the greatest root means square error values 57.60%, 65.30%; 27.00%, 39.60% respectively for calibration and validation period.

TABLE 5. Root-Mean Square error value of Karanja River

	RMSE%	
parameters	Calibration	Validation
	Pre-monsoon (June-2010)	Post-monsoon (April-2011)
pH	2.5	2.2
Alkalinity	9.8	10.0
Ammonia-N	27. 0	39.6
Nitrate-N	57.6	65.3
BOD	19.60	24.64
DO	5.5	14.06

Sensitivity analysis

Model sensitivity analysis is carried out in order to identify the parameters of river water quality that have the greatest effect on the model output. The analysis was performed for six parameters (Table 6), by keeping all the parameters constant, one being increased or decreased by 20%. It was found that the model was sensitive for temperature, bottom width, discharge and biochemical oxygen demand.

TABLE 6. Sensitivity analysis for the data on Karanja river in 2010

		%DO change	
Sl. No.	Parameters	+ 20%Parameters	-20% parameters
1	Temperature	-3.38	+3.70
2	Bottom width	-2.73	+2.89
3	Discharge	+2.09	-3.22
4	Biochemical oxygen demand	-0.97	+0.97
5	Nitrate Nitrogen	-1.61	+0.00
6	Ammonia Nitrite	0.000	+1.61

Scenario for water quality

In order to identify what strategies should be adopted to protect water quality in the study area, the calibrated model was applied to develop several management scenarios by changing the model input parameters during pre-monsoon period to maintain the targeted water quality criteria considering. i) Bottom algae modification, ii) head water modification iii) temperature modification and iv) shade modification.

Dissolved oxygen profiles obtained from different management scenario are shown in Figure 7. The simulated dissolved oxygen profile was produced by different bottom algae modification, in which all the profiles did not meet the required minimum dissolved oxygen concentrations, whereas the bottom algae was kept below 75% to maintain minimum dissolved oxygen (i.e.5 mg/L) along the selected length of river.

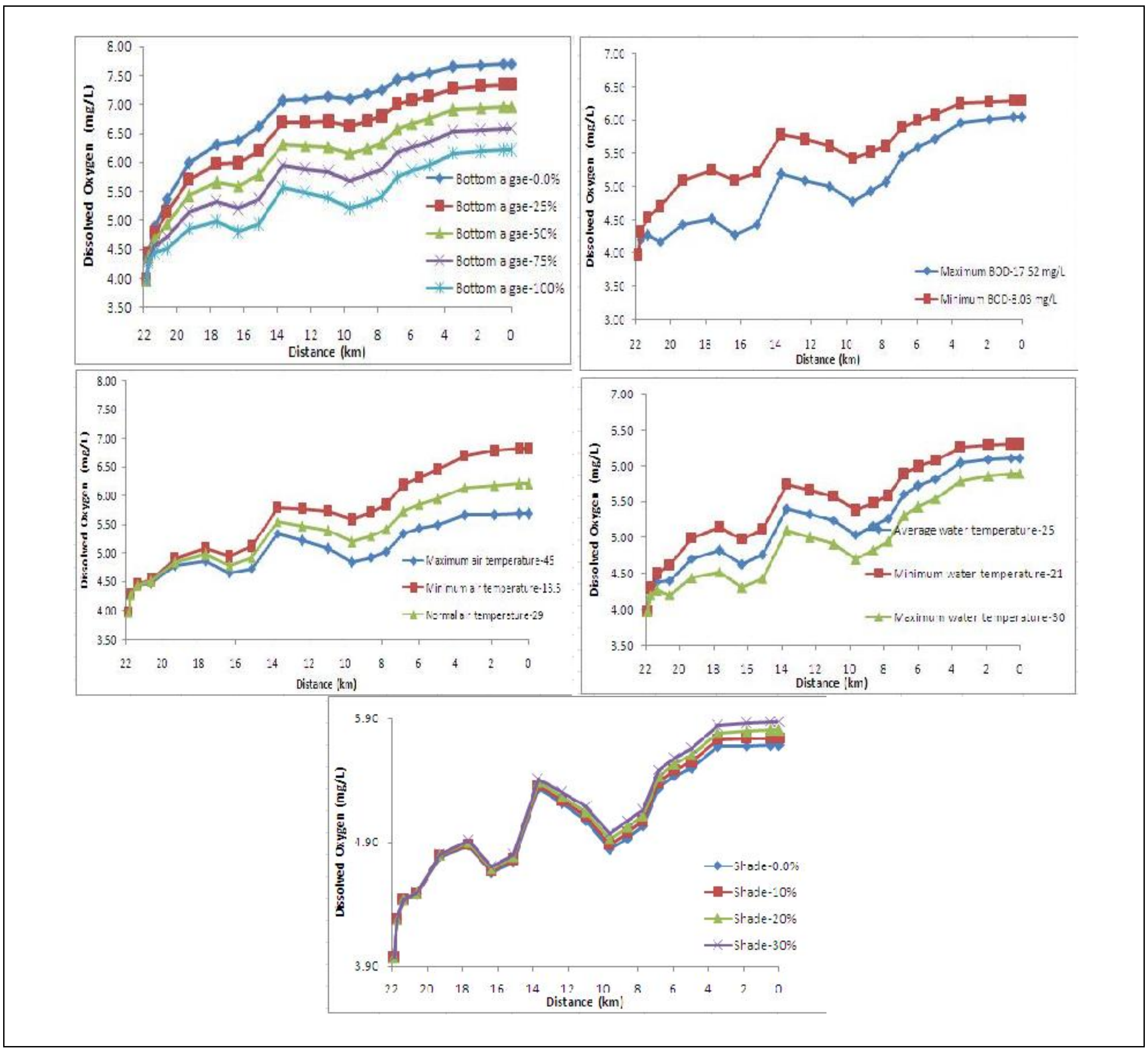


FIGURE 7 Various scenario of Karanja River for water quality management

ii) The biochemical oxygen demand from the head water is maximum (i.e.17.52 mg/L) during summer, due to which the dissolved oxygen level along the river is less than minimum permissible limit. From this it was observed that, the biochemical oxygen demand is to be reduced to minimum (i.e.8 mg/L) in summer from head water to ensure minimum dissolved oxygen along the study area. Hence to achieve this, the load from head is to be reduced (i.e.8 mg/L). iii) During the study period the maximum air temperature observed is 45^{0}c, and minimum air temperature is 13.5^{0}c, whereas average temperature is 29^{0}c, Temperature affects the physiology and behavior of fish and other aquatic life. Highest temperature typically occurs in the month of April and May, which is critical for both air and water temperature. iv)To minimize the temperature of water, shade is an important parameter that controls the stream heating resulting from solar radiation, from this, it was observed that the minimum percentage of shade (i.e.30%) is to be maintained to minimize the undesirable water temperature and to maintain minimum dissolved oxygen (i.e.5 mg/L). The combination of bottom algae modification, head water modification and minimization of water temperature is necessary to ensure minimum dissolved oxygen concentration along the study area.

CONCLUSION

The water quality analysis studies are carried out on an hourly basis for 24 hours pre-monsoon (30^{th} June 2010) and post-monsoon (1^{st} April 2011). The steady- state stream water quality model QUAL2Kw, was calibrated by using pre-monsoon (30^{th}June-2010) data. The calibrated pre-monsoon and validated post-monsoon QUAL2Kw model produces the minimum RMSE value of important parameters, such as dissolved oxygen and biochemical oxygen demand. Hence, QUAL2Kw model was selected for the present study.The root mean square error values between the simulated and observed values for the calibration period (pre-monsoon) and for the validation period (post-monsoon) ofpH, alkalinity and biological oxygen demand are 2.50%, 2.20%; 9.8%, 10.00%; and 19.60%, 24.60% respectively. High difference of RMSE value was observed for dissolved oxygen, nitrate nitrogen and ammonia nitrogen. Model sensitivity analysis was carried out in order to identify the parameters of river water quality which have the greatest effect on the model output. It was found that the model was sensitive for temperature, bottom width, discharge and biochemical oxygen demand. In order to identify what strategies should be adopted to protect water quality in the study area, the calibrated model was applied to develop several scenarios by changing the model input parameters during pre-monsoon period. They are i) by bottom algae modification, ii) head water modification iii) temperature modification and iv) shade modification. The results show that the bottom algae should be maintained below 75% to maintain minimum dissolved oxygen of 5mg/L along the selected length of river, and in summer, biochemical oxygen demand of the head water should be minimized (i.e.8mg/L) to maintain minimum dissolved oxygen level along the river. To minimize temperature of water, shade is an important parameter that controls the stream heating resulting from solar radiation, Trees provide shade to stream and minimize the undesirable water temperature and increase the dissolved oxygen level. The combination of bottom algae modification, head water modification and minimization of water temperature is necessary to ensure minimum dissolved oxygen concentration along the study area.

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