Mathematical Modelling and Experimental Study of Water Quality Parameters of Kuakhai River Down Stream, Bhubaneswar

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***Abstract*— Water is an indispensable asset in every field. It is used for domestic purposes, professional practice (growing crops and street washing), safety and recreation. With the advancement of civilisation, the utility of water has increased enormously and thus well-organized public water supply scheme is the need of the present scenario. Along with this, the selection of a proper water source, purification of water and assurance of consumable water quality are of utmost importance. Thus, maintenance and assessment of water quality are necessary in modern society. Though the organoleptic parameters (those which humans can see, touch, smell etc. through their sense organs) can be considered sufficient for assessment, water being a good solvent, adheres to more scientific and analytical techniques for its evaluation. Over the years, not only the surface streams have got reduced to a typical waste dump yard, but also the ground water depletion is there. Now a days the rivers are considered as the main sourse for the dumping of regular waste(home waste) as well as the industrial waste. So remedies should be taken in order to make the water bodies which are at least used for the use of water for regular basis. For this purpose river quality modelling were done time to time for the awareness for the water body to keep the water body waste free.**

In this paper the details of the physico-chemical properties of the KUAKHAI river near Bhubaneswar city has been analysed and the trend of change of the properties along the stretch along the downstream of the input of the sewage(untreated) from the area PATIA. The effect is estimated by implementing the model for the BOD change due to various factors like environmental and human. As there is a village along the stretch so the possible effect is analysed and implemented in this paper using graphs and the future trend in the change of the BOD has been implemented using simple mathematical modelling. The modelling consists of modified version of the Streeter Phelps equation in which the equation is represented w.r.t. distance instead of time. A stretch of 1.8 km has been selected along the river from the starting point of the disposal of the sewage from PATIA area. The physico-chemical properties like pH, alkalinity,conductivity,total & suspended solids, DO,BOD has been implemented using graphs and mathematical models to study the trends and suitability of the model for future.

***Keywords*— Water Quality Modelling , BOD, Kuakhai river, Streeter-Phelps equation**

I. INTRODUCTION

Water is important to individuals, society and natural ecosystems as life cannot exist without a dependable supply of suitable quality water. The water in rivers plays an important role in meeting the essential requirements for the development of a country and serves as a source of water supply for domestic and industrial purposes, for agriculture, fisheries and hydro-power development. With growth and development, the demand for water has increased tremendously and its uses have become much more varied.

According to Central Pollution Control Board, water quality of major rivers varied widely with respect to DO, BOD, TC, and FC. The pollution strength and potential demand for oxygen of effluent is indicated by the BOD concentration. The amount of oxygen that is consumed by microorganisms to decompose the organic matter from a unit volume of water, during a specified period of time is termed as BOD. Another most important constituent of water systems is dissolved oxygen (DO) and a river must have about 2 mg/l of DO to maintain higher life forms. In addition to these life-sustaining aspects, oxygen is important because it produces aesthetically displeasing colours, tastes, and odours in water during chemical and biochemical reactions in anaerobic systems. The rate at which dissolved oxygen is used will depend on the quantity of the organics, the ease with which they are biodegraded and the dilution capacity of the stream. Mainly, the dissolved oxygen in water bodies is dependent upon temperature, salinity, turbulence and atmospheric pressure. Bio-depletion and re-aeration processes also control dissolved oxygen contents. If the dissolved oxygen concentration drops below that required by certain organisms living in the water, these organisms will die. This is sometimes evidenced by fish kills, and in the extreme, by the production of obnoxious gases such as methane and hydrogen sulfide. In Bhubaneshwar, the water from River Kuakhai serves as the main source of water supply. Originating as a branch of the Mahanadi, the Kuakhai enters the Bhubaneshwar block area from Jhinkardina and Marichia villages. On account of misuse and pollution, the water quality of this river is degrading day by day. In this project, we have made an attempt to examine all possible water quality parameters and establish a mathematical model for the same.

II. REVIEW OF LITERARURE

The classic surface water quality modelling is the BOD model developed by Streeter and Phelps in 1925. A linear dynamic concept developed originally for the OHIO river is still the basis for many river models today. In the late 1950's the development of numerical methods for different equations facilitated the use of the more complex equation than those of Streeter and Phelps. Then so many new models are developed to determine the BOD-DO for a river up to some extent. The evaluation of different physico-chemical properties along with the trend has been accomplished through the normal laboratory practices with empirical and closed approximation to the diffusion convection equation. Even though the process is well understood and the method is quite reasonable, the subjectivity inferred creates a wide range of solutions depending on each indivisual.

Guru (2012) had already done simulation of BOD-DO Modelling in Mahanadi River System lying in Odisha using ANN, India . Nagarnaik et al(2012) have tested different parameters like PH, Temperature, Total Dissolved Solid, Alkalinity, Hardness, Suspended Solid, Dissolved Solid, Chloride, Turbidity, ions, and MPN. After examination and testing of different Physico-Chemical and Biological parameters (using WHO and INDIAN STANDARDS) they have decided that suitability of ground water for drinking and domestic purposes. Dhonde and Kulkarni(2012) have tested the different water quality parameters of Nimgaon-choba project at Ashti Taluka in Beed District and analyzed to assess their suitability for drinking and domestic purposes. Khan Et Al (2012) had tried to estimate the water quality of Triveni Lake, Physicochemical parameters has significant seasonal variation and most of the parameters were in normal range and indicated better quality of lake water. Verma Et Al (2012) has studied the details of different water parameter of chandola lake. Chandola is the largest lake of Ahmedabad city. Sujitha Et Al (2011) have analysed of various physic chemical parameters of salinity, TSS, TDS, DO, BOD, turbidity, pH, temperature, alkalinity, hardness and dissolved nutrients of surface water and sediments collected from different points (5 stations) of Karamana River. Siwiec Et Al (2011) had presented the method of measuring BOD in wastewater and characteristic different models which can by used for describing changes of BOD in next days Comparison the models suggests that changing of BOD during the time are better describes by models second order or double exponential model (Manson et al. 2006) than models the first order. Simpi et al(2011) had dealt with physic - chemical Parameters of Hosahalli water Tank in Shimoga District, Karnataka. Sinha and Biswas(2010) had done project based on different fifteen physico-chemical parameters of a lake at Kalyani, West Bengal were monitored for a period of one year to assess the pollutional status of the lake. The Water Quality Index (WQI) was calculated using twelve parameters only. Srivastava and Srivastava (2010) had done a study aimed to estimate current status of Physico-chemical chararacterstics and level of sewage pollution indicator bacteria and their variation at whole stretch of river Gomti. The classical Streeter–Phelps (Streeter and Phelps, 1925) model is of little value as an accurate prediction of BOD and DO in a polluted stream as it does not account for BOD removal due to bioflocculation (followed by sedimentation) which invariably takes place after the discharge of partially treated sewage into the streams. The classical equations of Streeter and Phelps for the biochemical oxygen demand and dissolved oxygen profiles along a natural stream to take into account various sources of oxygen supply and demand, was modified and extended by Dobbins (1963,1964), the effects of which were not included in the original equations.

Velz and Gannon (1962) added a factor a to the BOD rate constant, k1, of the exponential form of a first-order kinetics to account for the BOD removal through sedimentation. But this is neither rational nor scientific as the settlement of particles cannot continue for an indefinite time. The effect of algal growth and bacterial action on oxygen deficit was studied by O.Connor and Di Toro (1967).

Effects of paper mill wastes on river Hindon have been studied by Verma and Mathur (1980). It was found that the waste of the pulp and paper mill changes the water quality of river Hindon.

A lumped parameter differential equation for the description of the dynamic interaction between biochemical oxygen demand and dissolved oxygen in a non- tidal stream and improved the model by including a pseudo-empirical term, which accounts for the effects of algal populations on BOD and DO were presented by Beck and Young (1977).

These shortcomings are removed by Bhargava (1981). Bhargava considered that the total BOD (B) of partially treated or untreated waste entering into the river consists of the settleable part (B_s) and the dissolved parts (B_d). It was assumed that the settleable part is removed at a very fast rate obeying the linear settling law (Bhargava, 1983). A one-dimensional water quality model addressing nutrient transport and kinetic interactions of phytoplankton, nitrogen, phosphorus, carbonaceous biochemical oxygen demand and dissolved oxygen into the water column in river system by adopting a finite segment approach were developed by Karim and Budruzzaman (1999).

Dissolved oxygen mass balance was computed for different reaches of river Kali to obtain the reaeration coefficient (k2) a refined predictive reaeration equation for the river Kali was developed by Jha et al. (2001).

The various dispersion models developed to date account for the BOD which is present entirely in the dissolved form and not the least in settleable form. They do not account for BOD removal due to bioflocculation (followed by sedimentation) which normally takes place after partially treated or untreated sewage outfalls drain into the stream. The benthic material, immediately after the outfall, undergoes anaerobic stabilization at the bottom. This effect is assumed to be negligible in the model. These models are therefore of little value for an accurate predication of BOD and DO after the sewage disposal points into the stream. In the present work, an attempt is made to find a numerical solution to the proposed model using an alternate finite difference scheme which is free from numerical dispersion.

III. DESCRIPTION OF STUDY AREA

The site is near the village Kalyanpur which is at a distance of about 2.5 km from Rasulgarh square, Bhubaneswar, Odisha through NH-5. The site has a latitude of 20°18′N and a longitude around 85°52′E. Width of river at the site is about 100meters and depth is about 10meters. River Kuakhai originates as a branch of Mahanadi and enters Bhubaneswar block from the north near Jhinkardiha and Marichia villages. It flows touching the eastern boundaries of Kalyanpur, Barimund, Basuaghai and Sisupal G.P. and passes amidst Mancheswar.

FIGURE 1. KUAKHAI RIVER, BHUBANESWAR

The samples were collected from the river near the NH-5 over Bridge up to a stretch of 1.8 km alongside the river downstream near the village Kalyanpur. The samples were collected under bright sun-shine from a depth of about 1m below the water level in air-tight containers on 10th March, 2013 at around 10am (temperature about 35°C and humidity 60%).

The water treatment plant near Palasuni which supplies water to a major portion of the city Bhubaneswar draws water from this site. Different important parameters of river water is determined by collecting samples from the site before it is sent for purification so that the water quality before and after purification can be compared and based on that the modeling work can be done easily.The sites has been choosen from the geographical point of view like the best possibilities of change of properties.

IV. NUMERICAL MODELLING

The cross-section of the river is divided into two zone's namely the main zone in the centre of the river and the scattered storage zone where the velocity is assumed to be zero. A mathematical model is developed for the above stated system based on the following assumptions.

The entire BOD in the waste is in two forms namely dissolved and settleable. The dissolved part of BOD is decaying according to first order kinetics, while the settleable part of BOD is being removed by a linear law. The ratio of settleable part to total BOD is assumed to be fixed at the outfall.

The size of storage zone is As and it consists of two parts located near the two banks of the river while the size of main zone is A which is located in the centre of river.

No transverse gradient exists within any of the two zones. However, there is exchange of mass between the two zones which is linearly related to the difference in the respective concentrations. In the main zone, advection, reaction and exchange of mass are considered to be the relevant phenomena. In the storage zone only exchange of mass with the main zone and reaction within the storage zone are considered.

In the storage zone the settle able BOD is settled at the outfall itself while in the main zone it is carried forward with the flow and is settled only after a particular distance downstream. Hence the effects of advective forces are considered and included in the transition time Ts, in which all the settle able part get removed from the waste. The transition time Ts = d/v would be longer for deeper rivers and for smaller flocculated particle size.

1. Exchange of mass between two zones is considered only for dissolved part of BOD.
2. The temperature effect on decomposition rates is same in each zone.
3. There is no other source and sink of BOD in the river.

Using the above stated assumptions, the steady-state mass balance equations for BOD in the main zone and the storage zone respectively are given as follows:

$$D_L \frac{\partial^2 L}{\partial x^2} + V \frac{\partial L}{\partial x} - (K_1 + K_s)L + B = 0$$

D_L = Dispersion coefficient(m^2/s)

L = Final bod of the river segment $\left(\frac{m^2}{s}\right)$

V = Stream velocity of the steam(m^2/s)

K_1 = Decay coefficient (Day^{-1})

K_s = Sedimentation rate coefficient(Day^{-1})

B = Benthic oxygen demand

The BOD model is designed using 'C' language. The coding is compiled and ran using Turbo C.

V. RESULTS AND DISCUSSION

The data collected during the investigation are analysed along with the trend and the effect. The effectiveness of the model can be analyzed by comparing with the actual results. Also by calculation of error in the data calculated.

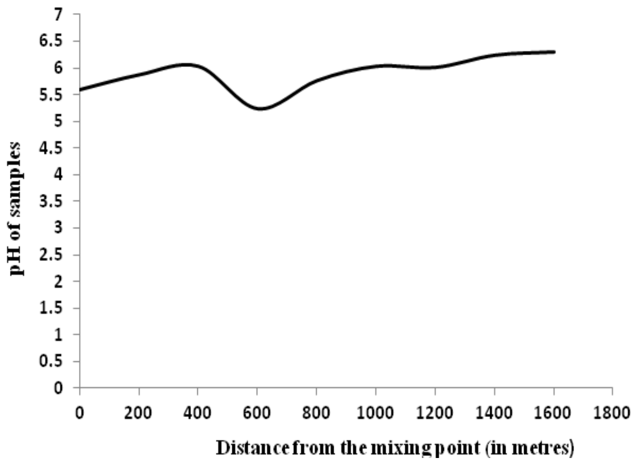

FIGURE 2. VARIATION OF pH

As we can see the P^H of the river from the entry of the sewage having very less amount of organic material with respect to the distance is increasing the P^H so alkalinity increases away from the point of mixing. After 400 meter the river is affected by the solid sewage of the households (waste from mandir). So there is a sudden drop in the value of the Ph but after some distance the trend goes same as the previous i.e. the increasing alkalinity.

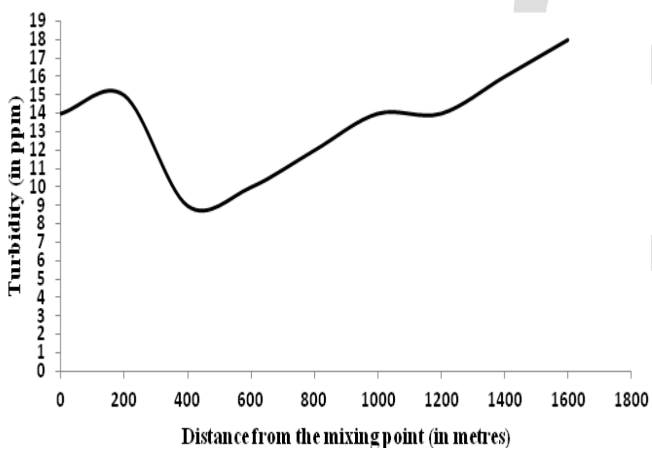

FIGURE 3. VARIATION OF TURBIDITY

The calculated turbidity of the water samples are projected on the graph and analysed. The increasing trend of turbidity is only due to the disposable and non disposable wastes from the population along the stretch.

As we know due to the self cleaning capacity of the river has a huge effect on the contamination and the chemical configuration in the water so due to the effect as we see from the graph the total dissolved solid and the suspended solid content is continuously decreasing with respect to the distance.

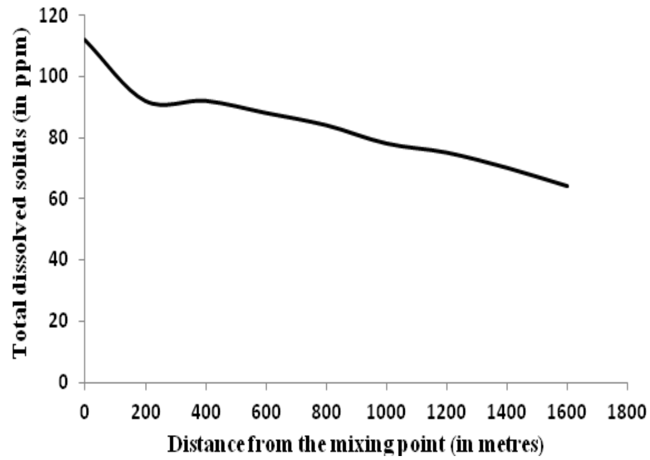

FIGURE 4. VARIATION OF TDS

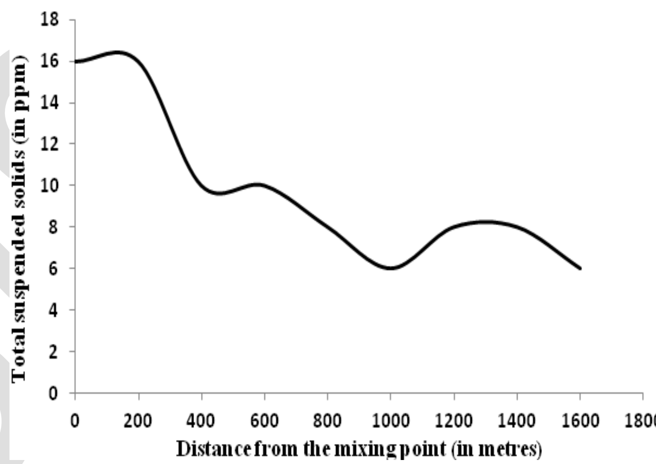

FIGURE 5. VARIATION OF TSS

The threshold number of the water samples are constant and "1".So as conclusion we can tell that that the water in the river is odour free.

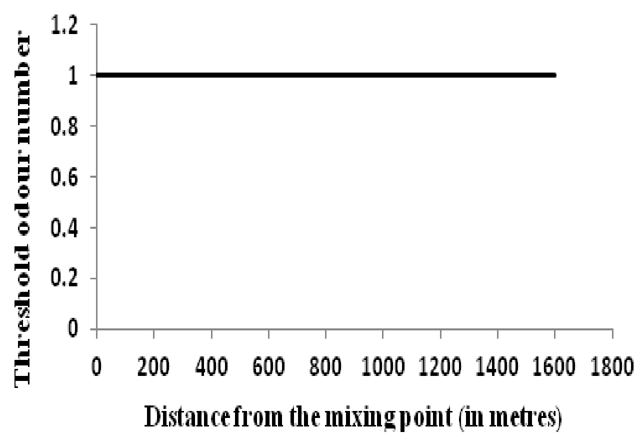

FIGURE 6. VARIATION OF THREESHOLD ODOUR

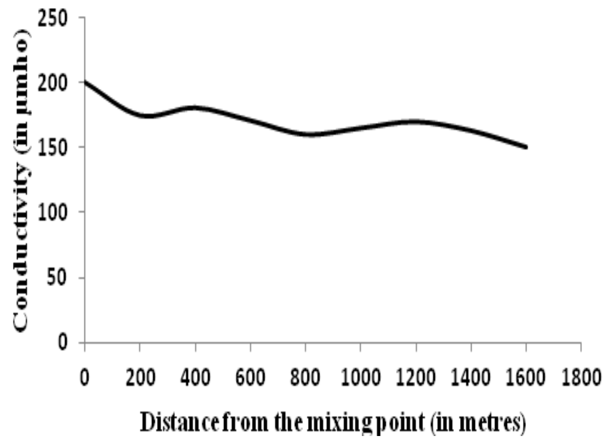

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FIGURE 7 VARIATION OF CONDUCTIVITY

Conductivity of the samples over the reach was found to be decreasing steadily. It shows that the dissolved salt content goes on reducing from the source of pollution.

Table:1. Details comparison of modelled value and calculated value

Sample no	Distance of the point from the point of pollution(m)	BOD actually obtained	BOD obtained from model	ERROR%
1	0	7.32	6.786	7.29
2	200	5.28	4.982	5.64
4	600	3.75	2.432	35.14
5	800	1.62	1.900	14.73
7	1200	0	0.921	100
8	1400	0	0.553	100

Details of BOD obtained by using model as well as actually in laboratory

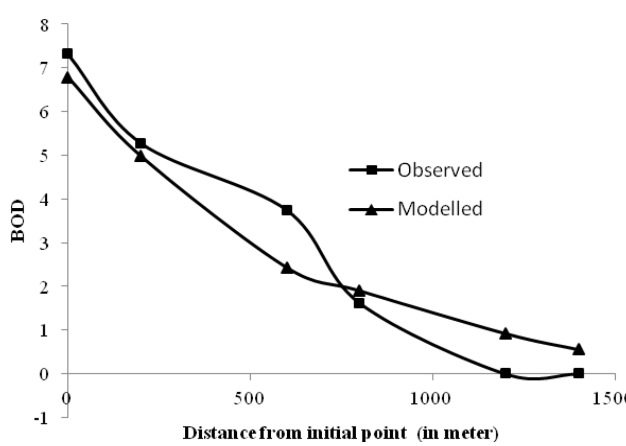

FIGURE 8. COMPARISON BETWEEN MODELLED AND CALCULATED VALUES

VI. CONCUSIONS

The water quality of Kuakhai River has been analysed with respect to BOD only. The designed model gives nearly actual values with max. of 15% error, so it can be fit for future reference.The water is less affected by the surrounding pollutants as the amount of total solid in the water is found to be continuously decreasing.The water is found to be acidic in nature so treatment should be done to increase P^H up to the standard limit.The water is free from heavy metal and toxic pollutants but due to some pollutant the water should go through general treatment processes like sedimentation-filtration-disinfection for domestic use.As BOD content is very low and after some distance it comes to zero indicates that it is free from micro organisms.

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