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A BRIEF OVERVIEW ON WATER QUALITY MODELS

Madhusmita Ghadai
Research Scholar, Civil Engineering, Centurion University of Technology and Management, Odisha, Assistant Professor, GMR Institute of Technology, India

Deba Prakash Satapathy
Assistant Professor, Civil Engineering, CET, Bhubaneswar, Odisha, India

M.L. Narasimham
Professor, Centurion University Of Technology and Management, Odisha, India

ABSTRACT

For existence of life, water is an important element, which is now a day's become worst due to rapid growth of industries and population. For conservation and proper utilization of water, proper assessment required, which requires constant monitoring in terms of its quality as well as quantity is effective. In some way modeling can control water quality pollution. In water body to predict and simulate the levels as well as the distribution and risk of amount of pollutants can be measured by using a tool known as water quality model. The result from the water quality model helps to environmental agencies to take the right decision. The aim of this paper is to discuss about the different water quality models which can provides the basic knowledge about water quality modeling. For developing country like India water quality models are very much required to predict the water quality of different sources.

***General Terms:** WASP Model, QUAL2K Model, MIKE Model, MIKE SHE Model, DRAINMOND Model, INCA Model, STREETER PHELPS Model, TOP Model, HSPF Model.*

Key words: Water quality model, continuity equation, hydrodynamic, eutrofication

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1. INTRODUCTION

The rapid growth of population, modernization, industrialization and agricultural practices causes the pollution of water bodies. The practices increase the concentration and the number of pollutants in the water bodies. The degradable wastewater causes the reduction of

Dissolved amount of oxygen present in the waterbed [1]. The water quality management strategy includes a no. of progressive inter-disciplinary decisions depends on hypothesize responses of water quality [2]. The mathematical model describes the complex relation between waste load coming from different sources and the quality of water influenced by it [3]. Furthermore developing mathematical model will enable quality assessment of inaccessible waters [4]. The accuracy of the environmental assessment using models depends on understanding of the process which occurs in the environment, on appropriate choice of mathematical equation, on availability of data set i.e. parameters, coefficients etc [5]. The main motto of the water quality modeling is to build a mathematical model which will track the changes of water quality and to simulate it with help of boundary condition [6]. Water quality models are of two types: (a) Physical models, (b) Mathematical models, it includes “analytical models” based on exact solution of mathematical equation and “Numerical Models” based on approximate solution. Water quality models are also classified into three types according to the complexity of computer simulation: one dimensional model, two dimensional models and three dimensional models [7,8]. Due to the development of model theory and fast updating computer system, a huge number of water quality models have been developed with various algorithms for different topography, water bodies and pollutants at different space and time [9]. In the present paper a brief discussion of various water quality models are made which will help in decision making for choosing models that matches with the condition of the study region and primary data available.

2. OVERVIEW OF WATER QUALITY MODELS.

Water quality models are useful tools for predicting the impurity in water bodies like rivers, reservoirs, lakes and estuaries. These models are also useful for water resource management. Currently available models are discussed below.

2.1. WASP Model

The US Environmental Protection Agency (UEPA) developed WASP model in 1983 [10]. Steady or unsteady water quality process can be simulated by it in stream, lakes, reservoirs, and estuaries. WASP is an one, two and three dimensional dynamic model and it allows variety of pollutants like Nitrogen, Phosphorus, Dissolved Oxygen, BOD, Sediment Oxygen Demand, Algae, Periphyton, Organic Chemicals, Metals, Mercury, Pathogens, Temperature etc. Currently it has eight versions (WASP 1-8). @WASP-8 deals with the sediment digenesis model linked to the advanced eutrofication sub model which predicts SOD and nutrient fluxes from the underlying sediments. It consists of two models (a) Advanced Eutrofication (EUTRO), (b) Advanced Toxicant (TOXI)[11,12]. Advanced Eutrofication model solves pollution associate with DO, BOD, CBOD, phytoplankton, periphyton, detritus, dissolved organic Nitrogen, ammonia, nitrate, dissolved organic phosphorus, salinity, solids, sediment digenesis. Advanced Toxicant model deals with the pollution causes by simple toxicant (copper, lead, zinc, cadmium), Non Ionizing Organic Toxicant (Arsenic, tin, selenium, PAHS, chlorinated solvents, etc), organic toxicant (pesticides, organic acids), mercury (elementary mercury, divalent mercury, methyl mercury) (WASP tutorials). It can be freely downloaded from www.epa.gov (US EPA). WASP model based on the conservation of mass and momement equation, by which the depth, velocity, top width and flow rate is determined [13]. The continuity equation Eq^n1 and momentum equation Eq^n2 used in WASP model as follows:

$$\frac{dQ}{dt}+\frac{1}{B}\left(\frac{dQ}{dx}\right)=q_s \quad (1)$$

$$\frac{dQ}{dt}+\frac{\partial}{\partial x}\left(\frac{Qw}{A}\right)+gA\left(\frac{\partial z}{\partial x}+\frac{Q|Q|}{K^2}\right)=0 \quad (2)$$

Where Z, Q, B, A, t, x, K, g and q refers to water surface elevation, flow rate, the wetted width, wetted cross sectional area, the time, distance along the channel, conveyance of the channel, gravitational acceleration and the discharge per unit channel length respectively [14].

WASP has some limitations: (1) it does not include some variables and process like mixing zone process, non aqueous phase liquids, sediments drying and metal specification reaction. (2) It does not allow large external hydrodynamic files. (3) It cannot separate eutrofication and toxicant fat modules. (4) It can't be smoothly run in batch mode i.e. automatic calibration program and Monto Carlo programs. (WASP tutorials).

2.2. QUAL2K

The US Environmental Protection Agency (EPA) released a series of QUAL models, those are QUAL2E, QUAL2E-UNDAS, QUAL2K and QUAL2KW [20]. QUAL2K is the updated version of QUAL2E and QUAL2KW is the updated version of QUAL2K [40].It is a 1D model and can be applied to a river with approximately constant flow and the pollution load. This model can use for both steady and dynamic state [15, 16]. It can simulate water quality constituents like temperature, EC, pH, (CBOD), Sediment Oxygen Demand(SOD), DO, ON, NH_4^+ , NO_3^- , NO_2^-, ISS, Organic Phosphorus(OP), Inorganic Phosphorus (IP), phytoplankton, and bottom algae[17]. The calculation of TN and TP can be done. It can simulate re-aeration, algal respiration and growth, organic matter degradation, mineralization, nitrification, denitrification, sedimentation, and benthic activity [18,19]. The geometric properties of the river (which includes channel slope, channel width, side slope, and manning roughness coefficient), flow rate, pollutant loads, and meteorological parameters are the major data inputs [20]. Various new elements are included to QUAL2K; those are (1) for graphical representation of input, running of the model and viewing the output, Excel, Microsoft office macro language (Visual Basic for Application) is used. (2) The size of the element can be varied from reach to reach; multiple loadings and withdrawals can be input to any elements. (3) To represent the organic carbon, two forms of carbonaceous BOD (slow and fast) are used. It also represents organic carbon with the model accepting anoxia by reducing oxidation reactions to zero to low at low oxygen levels. (4) At low oxygen concentration, the de-nitrification is modeled as first order reaction. (5) In that model, oxygen and nutrient fluxes are simulated as a function of settling particulate organic matter. (6) The model also simulates the bottom algae, light extinction, pit and pathogens. QUAL2K is based on mass balance. Equation3 represents the mass balance equation for a constituent concentration (C_i) in the water column of a reach (excluding hyporehic exchange) [21].

$$\frac{dCi}{dt}=\frac{Qi-1}{vi}C_i\text{-}1 - \frac{Qi-1}{Vi}C_i - \frac{Qabi-1}{Vi}C_i + \frac{E\prime i-1}{vi}(C_{i-1} - C_i) + \frac{E\prime i}{vi}(C_{i-1} - C_i) + \frac{Wi}{vi} + S_{i} \text{ -} \qquad (3)$$

Where Q_i is flow (m^3/d), ab is abstraction, V_i for volume (m^3), E'_I refers to the bulk dispersion coefficient between reaches i and i+1 (m^3/d), W_i represents the external loading of the constituent to reach i (g/d or mg/ d) and S_i for the sources and sinks of the constituent due to reactions and mass transfer mechanisms (g/ m^3/d or mg/ m^3/ d). If bottom algae are present in water column, then the transport and loading terms are removed from mass balance differential equation. The limitation of the model is that it cannot simulate the branches of river system.

2.3. Mike-Model

MIKE-II is an one dimensional hydrodynamic model which is having the property to simulate the dynamic water movement in a river [22]. Researchers are mainly using the MIKE- II model for river and lakes. MIKE-II has hundreds of applications. Some of the most important applications of this model are ecological and water quality assessments in rivers and wetlands , sediments transport and river morphology, salinity intrusion in rivers and estuaries, flood analysis and alleviation design, real time flood forecasting, dam break analysis, optimization of reservoir and canal gate/ structures operations (https://en.wikipedia.org/wiki/MIKE_11). MIKE-II water quality file includes the river water quality parameters and the default values. The list of coefficient and water quality parameter include degradation of BOD, influence of DO, concentration on the BOD decay, settling velocity of BOD, re suspension of BOD from the bed, oxygen demand by nitrification per unit mass as ammonia converted to nitrate, rate of ammonia release, nitrification rate constant, concentration dependence of nitrification and emitted heat radiation from the river. MIKE-II output includes time series of depth of flow and pollutant concentration for any reach as well as statically option to describe the result [23]. MIKE-II model is based on the Saint-Venant equations and is given below.

$$\frac{\partial Q}{\partial x} + \frac{\partial A}{\partial t} = q \quad (4)$$

$$\frac{\partial Q}{\partial t} + \frac{\partial}{\partial x}\left(\alpha \frac{Q^2}{A}\right) + gA\left(\frac{\partial h}{\partial x}\right) + \frac{n^2 gQ|Q|}{AR^{\frac{4}{3}}} = 0 \quad (5)$$

Where Q, A, q, h, x, t, n, R, g and α refers to discharge, cross sectional area, lateral inflow, water level above a reference datum, downstream direction, time, Manning's coefficient, hydraulic radius, acceleration due to gravity and the momentum distribution coefficient respectively.

MIKE-II has some limitation: (1) Huge amount of data is required for simulation. (2) Sensitive to data appropriateness (3) Calibration and evaluation of results for exact channel cross-sectional boundaries are required at each reach [24].

2.4. MIKE SHE

MIKE SHE is an universal software for surface and ground water modeling. The model accounts various process models for overland flow, unsaturated flow, vegetation based on evapo transpiration, groundwater flow, fully dynamic channel flow and irrigated water quality(www.dhigroup.com). This model is having the capability to simulate surface and ground water movement, sediment, nutrient and pesticide transport in the model area and various water quality problems. This model can be applied for large watershed [25].

2.5. DRAINMOD

DRAINMOD model is used to calculate at the scale of an individual field, the daily nitrate leaching for a given crop, farming, soil and geo-hydrological condition. The required information for the application of the model include (a) soil type, (b) water and nitrogen status of the soil profile at the start of the period to be simulated, (c) land use, (d)climate, and (e) nitrogen fertilizer practices [26]. DRAINMOD-N and to determine daily soil water contents and fluxes a new model known as DRAINMOD-S which is a modified version of DRAINMOD is used [23].The basic difference between DRAINMOD-N and DRAINMOD-S is that the DRAINMOD-N is capable to predict nitrogen concentration in the soil and in surface and subsurface drainage whereas DRAINMOD-S is able to predict salt concentration of drainage water, soil salinity distribution and the effect of salinity on the crop yield [27].

2.6. Streeter Phelps Models

Streeter Phelps models Streeter and Phelps established the first S-P model in 1925. This model is used as a water quality modeling tool for measuring the water pollution in a river or a stream [28]. S-P models focused on oxygen balance and one-order decay of BOD. Streeter-Phelps equation also known as the DO sag equation. It is a one-dimensional steady-state model. Streeter- Phelps equation is based on the linear first order differential equation [29, 30].

$$\frac{\partial D}{\partial t} = K_1 L_t - K_2 D \qquad (6)$$

Where D refers to the saturation deficit which is derived from-

(the dissolved oxygen concentration at saturation) – (the actual dissolved oxygen concentration.) K_1 refers to the de oxygenation rate, K_2 for the reaeration rate and L_t is the oxygen demand remaining at time t.

This model first used in the Ohio River in the US by a Sanitary Engineer Harold Warner Streeter and the Consultant Earle Berhand Phelps (1876-1953). Like other model , in this models some imitation are there, those are – Due to considering single BOD input, single Do sink and single DO source , simplification rises errors in model [29].

2.7. INCA Model

INCA (Integrated Catchment model) is dynamic in nature and used for stream which allows integrating hydrology and watering quality into it [31]. This model also provides the presentation of soil and plant system dynamic. It is widely used to deal with the environmental change issues in catchments in addition with land use change, climate change, changing pollution environments including point and diffuse pollution (www.waters.com/software/INCA). According to Whitehead INCA model used for simulation of pathogen in catchments. It also simulates fluxes of pathogen from both diffuse and point sources. Manto-Carlo sensitivity scheme has been used to evaluate the model. INCA-N allows simulating the hydrology flow pathway in both the surface and ground water system. In a daily time stem, this model tracks fluxes of solutes or pollutants in both terrestrial and aquatic portions of catchments. It also allows the spatial nature of a river basin or catchment to modify reach length, rate coefficient, land use, flow velocity relationship and to alter input pollutant deposition loads from point sources, diffuse land sources and diffuse atmospheric sources. INCAN-N allows simulating a single stem of a river in a semi distributed manner with tributaries treated as aggregate inputs [31]. This model is relying on a series of interconnected differential equation, which can be solved by using numerical integration method, on the basis of the fourth order Rungi Kutta technique. The solution of all equation can be obtained simultaneously through its technique and it’s the superiority of this technique [32].

2.8. TOPMODEL

TOPMODEL is common and wide utilized in watershed scales. The semi distributed topographical hydrologic model could be a precipitation runoff model supported an easy theory of water shed hydrological similarity with the topographical index [33,34,35] . It simulates infiltration excess overland flow, saturation overland flow, infiltration, exfiltration, subsurface flow, evapotranspiration and channel routing. This model conjointly simulates the specific well water or surface water interaction by predicting the movement of ground water level. It helps to see the saturated land expanse and also the potential for supply saturation land flow. The surface and subsurface saturated areas are calculable on the premise of storage discharge relationship that is established from a simplified steady state theory for down slope saturated line. This model has some limitations these are: 1) TOPMODEL only simulates watershed hydrology. 2) TOPMODEL works accurately for watershed which do not suffers from excessively long dry period and have homogeneous soil and moderate topography.3) model results are sensitive to grid size and grid size <= 50m is recommended.

2.9. HSPF

HSPF (Hydrologic simulation program Fortan). It is a hydrology and water quality model [36]. It simulates hydrology and water quality for both conventional and toxic organic pollutants on pervious and impervious land surface and in stream. For simulation, model uses parameters such as time history of rainfall, temperature, and solar radiation, land surface characteristic such as land use pattern and land use management. The model provides results about quantity and quality of runoff from an urban or agricultural watershed, flow rate, sediment load, and nutrient and pesticide concentration. To process the large of simulation input and output, it includes an internal database management system (scientific software group) [37,38]. There are some limitations of this model such as: 1) problems in algorithms and procedures. 2) The accuracy of the model limited by spatial and attribute data due to high standard input data. 3) The model is applicable only for well mixed rivers, reservoirs and one dimensional water bodies [39,40,41].

A compilation of the above models, their source and accessibility for researches is given in table1below.

Table 1 List of preferred water quality models with their special characteristic.

Model	Type	Description	Access	Organization
WASP	1D,2D, 3D -	Advanced model, works for measuring pollutants and pollution in the water.	Free	U.S. ENVIRONMENTAL PROTECTION AGENCY
QUAL2K	Stream water quality	Ecologically-focused model that simulates daily water quality, as either steady-state or dynamic system. Includes estimation of BOD, N, P, coliforms and pH.	Free	U.S. Environment protection Agency.
MIKE models	Stream hydrology	simulates runoff and stream hydrology; compatible with other modeling systems	No	Danish Hydraulic Institute
Mike-SHE	Steam and groundwater hydrology and water quality	Advance model, integrated modeling system to simulate hydrological processes in both surface and groundwater systems, in-addition with evapo-transpiration, runoff, discharge, groundwater recharge and environmental fate of contaminants.	Purchase	DHI
DRAIMOND	-	Prediction on a continuous basis of water table depth, drainage rates, surface runoff	Free	Soil & Water Management Group, North Carolina State University
MONERIS	Semi – static	Semi – empirical conceptual model. Based on data run-off water quality for the area along with GIS	No	Leibniz institute for freshwater Ecology and Island Fisheries (IGB)

Streerter – Phelps models	1D steady state	S-P models emphasize on oxygen balance and one-order decay of BOD	free	U.S. Public health service
HSPF	Stream hydrology and water quality	Integrated modeling system to simulate runoff and water quality (e.g. nutrients, pesticide, sediments) from agricultural and urban sources.	Free	US-EPA
Top model	Stream hydrology	semi distributed topographical hydrologic model, conjointly simulates the specific well water or surface water interaction by predicting the movement of ground water level.	Free	Lancaster University
INCA	Stream water quality	Dynamic in nature and used for stream which allows integrating hydrology and watering quality into it. Allows simulating the hydrology flow pathway in both the surface and ground water system.	By request	Reading University

3. CONCLUSION

In the changing environmental scenario the water quality models are playing very important role in predicting the present and future status of water pollution. In this paper several of water quality models discussed with their characteristic and uses. Prediction of a suitable water quality model for a particular river or stream is a very difficult task. From the description of the above model, WASP model is preferred for modeling the water quality of Brahmani River Odisha, India. Wasp model helps to predict and simulate the water quality changes in streams, rivers, estuaries, artificial reservoirs and depressions. This model considers point and non point sources, aerial tributaries and boundaries of the exchange. It is also a three dimensional program consisting of two programs i.e. DYNHYD and WASP which can works together as well as independently. DYNHYD is a hydrodynamic program which deals with the creation with the data sets to determine the flows and other transport value. Wasp deals with modeling and spread and interaction of pollutants in the water. WASP model consists of two models i.e. EUTRO and TOXI. EUTRO models related to the water eutrification by solving problems of the dynamics of dissolved oxygen (DO), BOD, nutrient concentration and phytoplankton. The TOXI model related to toxic pollutant like chemical oxygen demand (COD) and heavy metal. WASP model was successfully used for modeling the eutrofication of Tampa Bay, inflow of phosphorus to Okeechobee Lake, eutrofication of the Neuse river and its estuaries, organic pollutants and heavy metals contamination of the of the Deep River. Brahmani river basin is full of mines area, industrial area and urban area. The waste water from mines area, industrial area and urban area pollutes water of river Brahmani.

REFERENCES

[1] Nakhaei, N. and Shahidi, A.E. (2010) Waste Water Discharge Impact Modeling with QUAL2K, Case Study: The Za- yandeh-Rood River. International Environmental Modelling and Software Society (IEMSS), Ottawa.

[2] McIntyre, N.R., Wheater, H.S., (2004). A tool for risk-based management of surface water quality. Environ. Model. Software 19, 1131–1140.

[3] Deksissa, T., Meirlaen, J., Ashton, P.J., Vanrolleghem, P.A., (2004).Simplifying dynamic river water quality modelling: a case study of inorganic dynamics in the Crocodile River, (SouthAfrica). Water Air Soil Pollut. 155, 303–320.

[4] Q. G. Wang, W. N. Dai, X. H. Zhao, F. Ding, S. B. Li, and Y. Zhao,(2009), "Numerical model of thermal discharge from Laibin power plant based on Mike 21," Research of Environmental Sciences, vol. 22, no. 3, pp. 332–336, (Russian).

[5] Gromiec MJ. (2008), Mathematical Modeling of the Quality of Surface Waters. Warszawa: Instytut Meterologii Gospodarki Wodnej; QUAL2Kw- A framework for modeling water quality in streams and rivers using a genetic algorithm for calibration. *Environmental Modeling & Software*, 21: 419-425

[6] Holnicki P, Nahorski Z, Zochowski A, (2000), Modeling of Environmental Process. Warszawa: Wydawnictwo , Wyzszej Szkoly Informatyki Stosowaneji Zarzadzania.

[7] Aleksandra ZIEMINSKA-STOLARSKA, Jerry SKRZYPSKI , (2012) Review of Mathematical Models of Water Quality, Ecological Chemistry and Engineerings,19(2):197-211.

[8] Maryna Strokal, J Emiel Spanier, Carolien Kroeze, Albert A Koelmanset.al. Global multi-pollutant modeling of water quality :scientific challenges and future directions. Current Opinion in Environmental Sustainability 2019, 36:116–125.

[9] M. A. Ashraf, M. J. Maah, and I. Yusoff, (2012), "Morphology, geology and water quality assessment of former tinmining catchment," The Scientific World Journal, vol. 2012, Article ID 369206, 15 pages, 2012. View at Publisher · View at Google Scholar.

[10] Danish Hydraulic Institute, (1996), MIKE 3 Eutrophication Module, User Guide and Reference Manual, Release 2. 7, Danish Hydraulic Institute, Horsholm, Denmark.

[11] Lai Y C ,Tu Y T, Yang C P, Suramplli R Y ,Kao C M . , (2013), Development of a water quality modeling system for river pollution index and suspended solid loading evaluation .Journal of hydrology,478:89-101.

[12] Yang C P ,Kuo J T, Lung W S , Lai J S ,Wu J T.(2007), Water quality and ecosystem modeling of tidal wetlands . Journal of Environmental Engineering, 133(7):711-721.

[13] Ambrose B, Wool T A, Martin J L. (2001), The water quality analysis simulation program, WASP6 (user manual). US EPA: Athens, GA, 2001.

[14] Lai Y C, Yang C P, Hsieh C Y , Wu C Y ,Kao C M ,(2011), Evaluation of non-point source pollution and river water quality using a multimedia two-model system. Journal of Hydrology,409

[15] S.-M. Liou, S.-L. Lo, and C.-Y. Hu, (2003) "Application of two-stage fuzzy set theory to river quality evaluation in Taiwan," Water Research, vol. 37, no. 6, pp. 1406–1416.

[16] W. J. Grenney, M. C. Teuscher, and L. S. Dixon, (1978), "Characteristics of the solution algorithms for the QUAL II river model," Journal of the Water Pollution Control Federation, vol. 50, no. 1, pp. 151–157.

[17] L. C. Brown and T. O. Barnwell Jr.,(1987), The Enhanced Stream Water Quality Models QUAL2E and QUAL2E—UNCAD: Documentation and User Manual, US Environmental Protection Agency, Environm ental Research Laboratory, Athens, Ga, USA,.

[18] Kuo J, Lung W, yang C, Yang M, Lui W, Tang T. , (2006), Eutrophication modeling of reservoir in Twain. Environmental Modeling and software, 21(6):829-844

[19] X. J. Cao and H. Zhang, (2006), "Commentary on study of surface water quality model," JournaI of Water Resources and ArchitecturaI Engineering, vol. 4, no. 4, pp. 18–21.

[20] Deepshikha Sharma, Arun Kansal, Greg Pelletier (2015), Water quality modeling for urban reach of Yamuna river, India(1999–2009), using QUAL2Kw,.

[21] Gregory J. Pelletier, Steven C. Chapra, Hua Tao. (2006)., QUAL2KW-A framework for modeling water quality in streams and rivers using a genetic algorithm for calibration, Environmental modeling and software, DOI: 10/1016/J.entsoft.2005.07.002.

[22] DHI(1998) MIKE-11: A microcomputer based modeling system for rivers and channels. Reference of the Danish Hydraulic Institute, Hoersholm, Denmark.

[23] G-Tsakiris and D.Alexakis (2012) water quality models: an overview, European Water 37:33-46, 2012.

[24] Cox B A. (2003), review of currently available in-stream water quality models and there applicability for simulating dissolved oxygen in low land rivers. *Science of the Total Environment* , 314:335-377.

[25] Gayatri K Devi, Ganasri D P, Dwarakish G S (2015), " Review on Hydrological Models", International Conference on water resources, costal and water engineering(ICWRCOE2015), ScienceReport, Aquatic Procedia4,1001-1007.

[26] El.-Sadek, A.(2007) upscalling field scale hydrology and water quality modeling to catchment scale, water resource manage.21:149-196.

[27] Skaggs, R.W.,N.R.Fausey and B.H. Nolte(1981) Water Management evaluation forNorthCentral Ohio. Transactions of the AAE.24(4)922-928.

[28] J. H. Bai, H. F. Gao, R. Xiao, J. J. Wang, and C. Huang,(2012), "A review of soil nitrogen mineralization in coastal wetlands: issues and methods," CLEAN—Soil, Air, Water, vol. 40, no. 10, pp. 1099–1105.

[29] Streeter H.W., Phelps E.B, (1985), A study of the pollution and natural purification of the Orhio river. III. Factors concerned in the phenomena of oxidation and reaeration. Public Health Bulletin no. 146, ISBN B001BP4GZI.

[30] H. W. Streeter and E. B. Phelps, (1925), A Study of the Pollution and Natural Purification of the Ohio River, United States Public Health Service, U.S. Department of Health, Education and Welfare.

[31] P. G. Whitehead, E. barbour, M.N Futter, S.Sarkar, H.Rodda, J.Caser, D. Butterfield, L.Jin, R.Shina, R. Nicols and M. Salehin (2015). "Impact of climate hange and socio economic scenarios on flow and water quality of the Ganges, Brahmaputra and Meghna (GBM) river system: low flow and flood stastic".

[32] Schoor J., 1986, Environmental Modeling, Fate and Transport of pollutants in Water, Air and Soil, Wiley- Interscience.

[33] Lianqing Xue, Fan Yong, Chang bing, Guang hui Wei, Wenqian Li, Xinlin He, (2017), Hydrogeological simulation and uncertainty analysis using the improved TOPMODEL, in the arid Manas River basin, China, Scientific Reports.

[34] Tran Van, T., Sunada, K. & Ichikawa, Y. (2012), Water resources management under future development and climate change impacts in the Upper Srepok River Basin, Central Highlands of Vietnam. *Water Policy* 14(5), 725–745.

[35] Yong, B., Zhang, W., Niu, G., Ren, L. & Qin, C. (2009).Spatial statistical properties and scale transform analyses on the topographic index derived from DEMs in China. *Computers & Geosciences* 35(3), 592–602

[36] Huan Jing ke XUe (2012) "Review on HSPF model for simulation of hydrology and water quality process". July 33(7):2217-23.

[37] Liangliang GAO, Daoliang LI. (2014), A review of hydrological/ water quality models, Agri Sci. Eng. 1(4): 167-276.

[38] Xue L. *et al.*(2017)Identification of potential impacts of climate change and anthropogenic activities on streamflow alterations in the Tarim River Basin, China. *Scientific Reports* 7.

[39] Burigato Costa, C.M.d., da Silva Marques, L., Almeida, A.K. *et al.* Applicability of water quality models around the world—a review. *Environ Sci Pollut Res* 26, 36141–36162 (2019).

[40] P.G. Whitehead, E.J. Wilson, D. Butterfield and K.Seed,(1998), A semi – distributed Integrated Notrogen model for multiple source assessment in catchments (INCA) : part I- model structure and process equations, Sci. Total Environ,, 210/211, 547-558.

[41] Paliwal R, Sharma P, Kansal A. water quality modeling of the river Yamuna (India) using QUAL2E- UNCAS. *Journal of Environmental Management*, 2007,83 (2):131-144.