International Journal of Engineering Research
Volume No.3, Issue No.12, pp : 769-773
ISSN:2319-6890)(online),2347-5013(print)
01 Dec. 2014

Development of River Quality Management (RQM) Information System for River Stretches Blending with Multi-Industrial Effluents

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Abstract*—RQM information system takes into account various non-conservative pollution parameters like Total Dissolved solids (TDS), Total Suspended Solids (TSS), Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD) and obtains the concentration of such parameters along the river stretch. The system incorporates various mathematical models for computation of velocity variation along the river stretch, flow rate computation, and cross-sectional area computation and finally uses a water quality dispersion model to compute the concentration of vivid pollutants at various points in the river stretch to predict the quality of river.

Keywords—**Information System, River Water Quality, Flow rate computation, Simulation of stream velocity, Multi-industrial outfalls, Water quality model**

I. Introduction

Management is a process by which organizational goals are achieved using resources. The resources are considered as inputs, while attainment of goals is viewed to be the output of the process. Information systems are the only user-friendly and cost effectivetools that reside at the heart of the management to solve severe complex environmental problems. It collect, process, store, analyze the data and aid the decision makers to make rational decisions in adverse situations.

An important aspect of information system is data visualization which is the study of the visual data representation. Information visualization is the use of computer-aided interactive visual representations of abstract of both numerical and logical data to amplify human cognition. It aims at helping users to effectively detect and explore the expected, as well as discovering the unexpected unapparent to gain insight into the data [1, 2, 3].Main goal of data visualization is to communicate information clearly and effectively through graphical means [4].It is all about understanding ratios and relationships, patterns and trends that exist in groups of numbers [3,5]. From the user point of view, it may be stated as providing the information from multiple views with multiple techniques. In reality, graphic portrayal of quantitative information has deep roots. These roots reach into histories of statistical graphics, and data visualization, which are intertwined with each other [5,6,7].

The fast growing population demands more energy in order to meet the need of the people, which intends the industrialization of the country. As a result, the environmental degradation has threatened the policy makers and environmentalists to protect the ecosystem and devise an appropriate control measures for sustainable environmental management of the industrial zones, which requires an effective and user-friendly information system for predicting the future environmental scenario of the industrial complexes and its surroundings for environmental impact assessment. A stretch of the Damodar River starting from Mahudah coal wahsery to the confluence Point of Gobai River with Damodar in Jharkhand state of North India has been identified as highly polluted zone. The tributaries carry the effluents of nearby coal washeries, surrounding mines and alliedindustries and finally blend with Damodar River [8-13].The stretch has been considered for applying a River Quality Management (RQM) Information System.

The RQM Information System takes into account several non-conservative pollution parameters like DO, BOD, TDS, and TSS to assess the current pollution level in a river stretch blended with multi-industrial outfall, analyze the situation, and take suitable measures to control the pollution level of the river stretch. The system uses appropriate mathematical models to compute the flow rate at the reference point of a river stretch, velocity variation along the river stretch, and cross-sectional area. It then simulates the variation in stream velocity due to continuous intake of water for industrial operation and discharges of effluents along the river stretches blended with multi-industrial outfalls. The system finally uses a three dimensional water quality model to compute the concentration of vivid pollutants at various points in the river stretch to predict the quality of river. For further analysis of processed data the system uses suitable data visualization techniques to provide graphical visualization of complex information.

II. Material and Methodology

A. River Quality Dispersion Model

The water quality prediction model for predicting the non-conservative parameters, whose initial concentration and maximum stream velocity just after the critical mixing distance are c_o and v_o respectively at the location x=0, y=0, z=0 used for the development of RQM system is given below[14]:

ISSN:2319-6890)(online),2347-5013(print)
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$$C(x,y,z)=p\left(\frac{c_o v(x,y,z)}{v_o}\right)\left[1-\frac{v_s^{'}e^{-k^{'}v(x,y,z)}}{\frac{D}{a_o^2}(a_o^2-x^2)}\left(\frac{z}{v(x,y,z)}\right)\right]+(1-p)\left(\frac{c_o v(x,y,z)}{v_o}\right)e^{-\frac{kz}{v(x,y,z)}}$$

where C(x,y,z) is the concentration of the water quality parameter,

$V(x,y)$ is the velocity distributive function, defined as follows:

(i) For Symetrical cross section:

$$V(x,y)=V_m\left[\left(1-\frac{y}{D}\right)-\left(\frac{x}{a_o}\right)^2\right]$$

(ii) For Asymetrical cross section:

$$V(x,y)=\begin{cases} V_m\left\{\left[1-\frac{y}{D}\right]-\left[\frac{x}{a_o}\right]^2\right\} & if\ a_o\le x\le 0 \\ V_m\left\{\left[1-\frac{y}{D}\right]-\left[\frac{x}{b_o}\right]^2\right\} & if\ 0\le x\le b_o \end{cases}$$

p is the fraction of the bio-flocculated particulate matters,
v's is its settling velocity in static condition of the river,
D is the maximum depth of the river over the width but average over the length of the stretch,
k is the dispersion coefficient of the pollutant species and
k' is the dispersability coefficient of the settleable bio-flocculated particulate matters.

B. Design and Development of RQM Information System

The information system for River Quality Management, which is known as RQM Information System follows the 3-Layer architecture of design. The system is typically built using the three layer architecture model consisting of a presentation layer, a business logic layer, and a data access layer. The presentation layer contains the components that implement and display the user interface and manage user interaction. This layer includes controls for user input and display, in addition to components that organize user interaction. The business layer represents the business rules that are enforced via programming logic regarding how those rules are applied. The data access layer consists of the definitions of database tables and columns and the computer logic that is needed to navigate the database.

The database of RQM information system consists of following tables:

a) *Reference_point_detail*(**rf_id**,station_name,lat,lon)
b) *River_dim*(**sample_date**, max_depth,vel_max_depth, left_x,right_x,area,flow_rate,***dref_id***)
c) *Sample_det_ref_point*(**sample_date**,temp,color,ph,ts, tss,tds,do,bod,cod,oil_grease,fe, mn,ni,cr,pb,cd,arsenic,hg,***ref_id***)
d) *Industrial_source*(**ind_s_id**,**sample_date,** station_name, intake,discharge,left_x, right_x, max_depth, ***sref_id***, area)
e) *Sample_det_industrial_source*(**ind_s_id**, **sample_date**,temp,color,ph,ts,tss,tds,do,bod, cod ,oil_grease, fe, mn, ni, cr, pb, cd, arsenic, hg, ***isref_id***)
f) *Flowrate_stretch*(**ind_s_id,stretch_id**,stretch_len,intake,fr_before_discharge,discharge, fr_after_discharge, area, velocity, ***fsref_id***)

The relation names have been depicted in italics where as the primary keys in each relation has been shown in bold and foreign keys are shown as bold Italics. The relationship diagram among the relations or tables is shown in **Figure 1.**

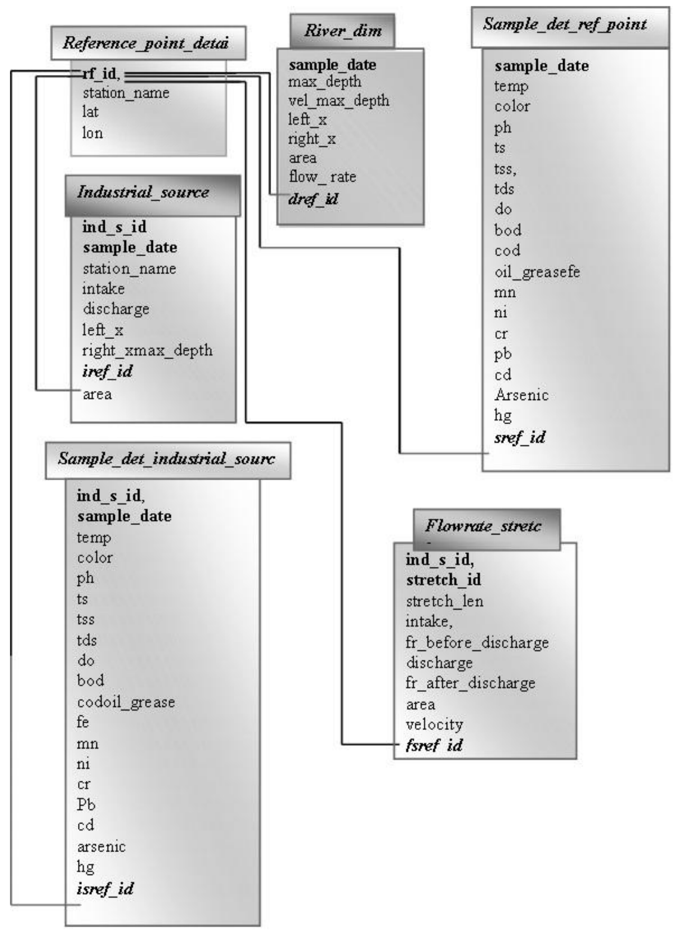

Figure 1: Relationship Diagram of RQM Information System

The data flow diagram (DFD) of the RQM information system has been designed after deciding of external entities, and their interaction with vivid processes showing data flow directions and appropriate descriptions using arrows and shapes in **Figure 2**.

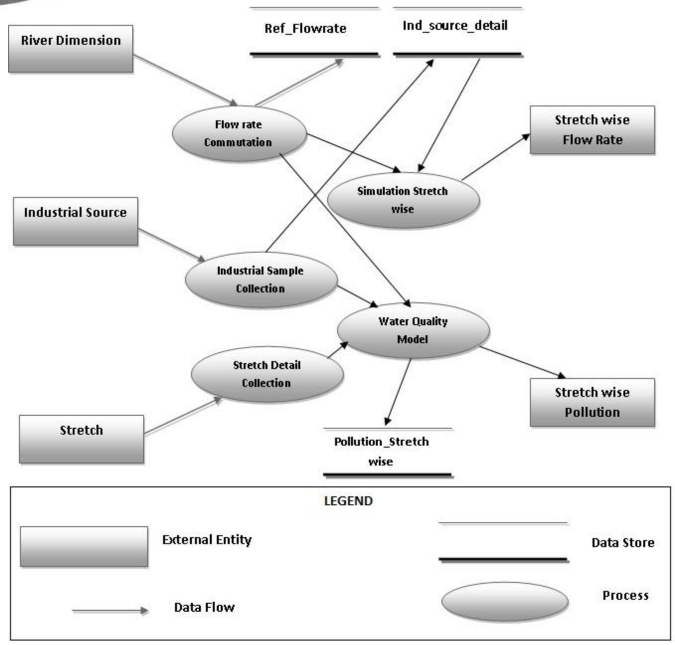

Figure 2: Data Flow Diagram for the RQM System

The traditional Linear Sequential/Waterfall model has been used to develop the information system. By following this classical model, the entire work is divided into sequential phases, with some overlap acceptable between phases. The major phases include planning, analysis, design, code, testing and implementation. Emphasis is primarily given on planning, time schedules, target dates, budgets and implementation of an entire system at one time. Further, tight control is maintained over the life of the research work through the use of extensive written documentation, as well as through formal reviews and approval/signoff by the user and information technology management occurring at the end of most phases before beginning the next phase. The major requirement of this information system is a good user friendly interface which can be easily accepted by the user, and a strong secured database. As such, for this module, Visual Studio 2010 with MS SQL Server 2008 database is used. The language used to develop the module is Visual Basic.NET.

III. Results and Tables

The system primarily accepts the required input parameters from the end user which includes the details of river dimensions such as maximum velocity, depth of the river, left x-axis value, right x-axis value, at reference station and industrial sources. Along with the details of river dimensions, it provides user friendly GUI to the user to accept details such as station name, intake and discharge from various industrial sources along with sample details at reference station as well as industrial sources. The data from various industrial sources are fed into the system. The system then calculates the flow rates and cross-sectional area of river along various sections of river and near industrial sources of discharges. Further, the system also provides options for editing of raw input data. Some snapshots of the system are provided in Figure 3.

Once the data are fed and visualized in tabular form for necessary edition and confirmation, the system is ready to use the database for executing the simulation model. The model takes into account the stretch details fed by the user and use the underlying database to obtain the Intake and discharge from each industrial source. Near the industrial source, the model takes as input various non-conservative parameters such as BOD, DO, COD, TSS, TDS, and TS. The model then simulates the flow rate of the river water along the entire stretch along with the concentration of the aforesaid non-conservative parameters. Finally, the system generates various graphs using the Data Visualization class provided in the .NET framework.

Figure 3: Snapshots of the RQM System

The output obtained after simulation is seen through proper data visualization technique using the step line graph which is provided in **Figures 4, 5 and 6.**

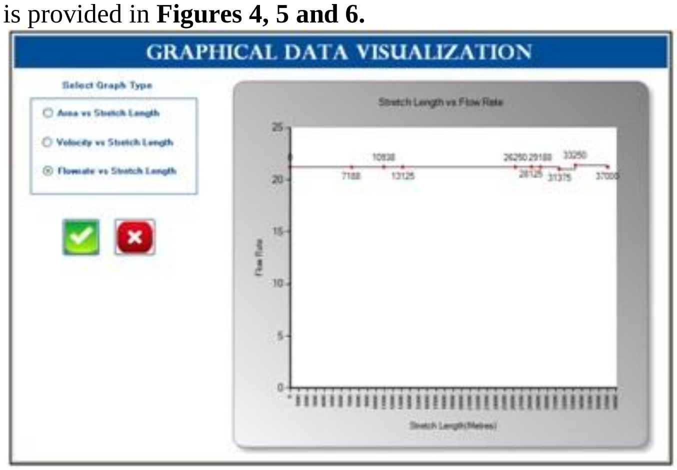

Figure 4: Plot of flow rates along the river stretch

ISSN:2319-6890)(online),2347-5013(print)
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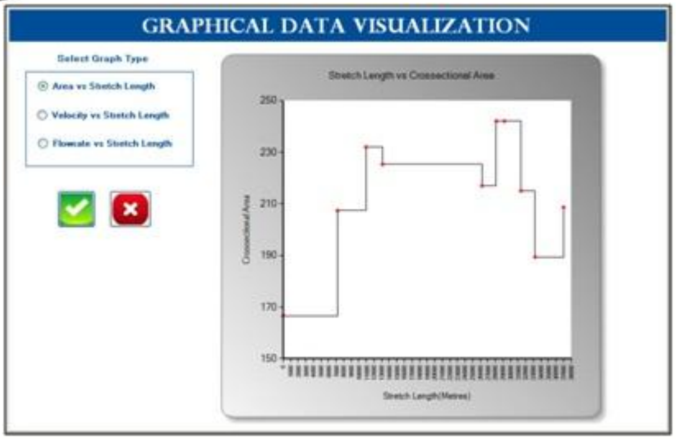

Figure 5: Plot of variation in river cross-sectional area along the river stretch

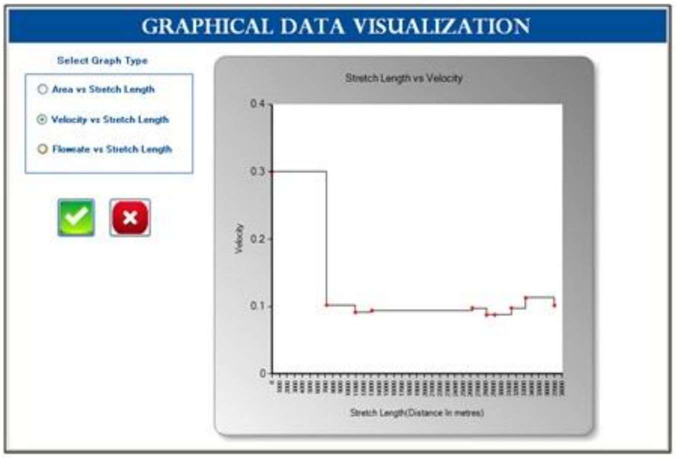

Figure 6: Plot of stream velocity variation along river stretch

Further, the module simulate the stream velocity by dividing the respective flow rates of each stretch which duly incorporates the intake quantity of water and discharging effluents of the industries located on the banks of upstream, by its cross sectional area. The simulated stream velocities for each stretch have been plotted against the stretch distance as shown in **Figure 6**.

In the next phase of the model, the quality of river water is predicted. Though the present system is capable of predicting both conservative and non-conservative water quality parameters, an illustration of river quality prediction along the Damodar River Stretch for only four parameters namely BOD, DO, TSS and TDS, is given. The dispersion coefficients for the aforesaid four parameters were computed using the standard methods and has been listed in **Table 1** [16]. The river quality with reference to the foresaid parameters has been predicted for the river stretches starting from the effluent discharging point of Mahudah coal washery to the point of confluence of Gobai River with Damodar. A snap of computation process has been presented in Figure 8 while the system was executed in order to have the apparent oracle of the entire scheme of dispersion modeling along with the river network including the distance to the previous outfall or reference point.

Table 1 Dispersion Coefficients of Parameters

Parameter Name	Dispersion Coefficient
BOD	0.0002
DO	-0.000014
TSS	0.00002
TDS	-0.00002

The graphs obtained after plotting the above four parameters using the dispersion coefficients provided in **Table 2** is shown in **Figures 7 to 10.**

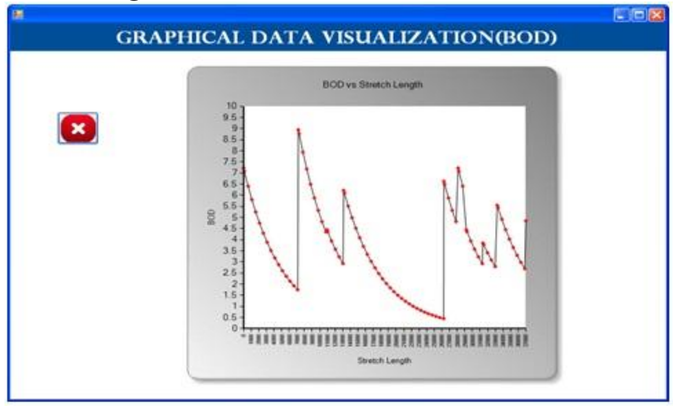

Figure 7: Plot of variation of BOD along river stretch

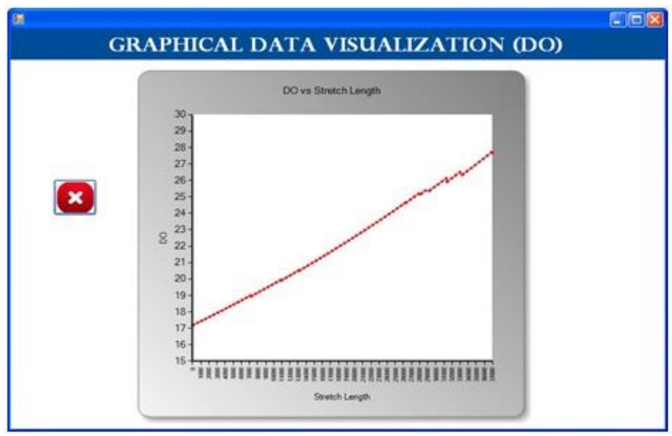

Figure 8: Plot of variation of DO along river stretch

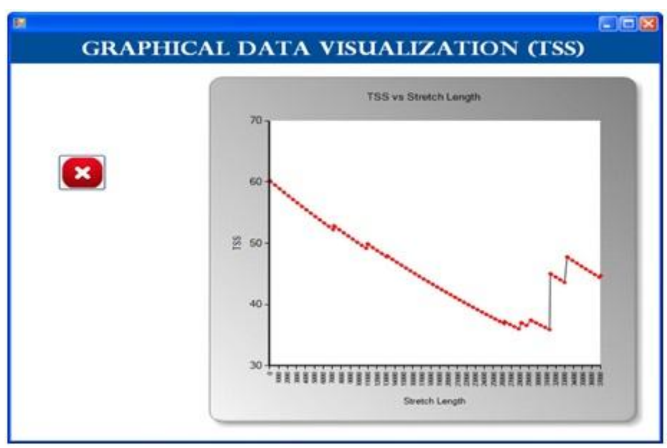

Figure 9: Plot of variation of TSS along river stretch

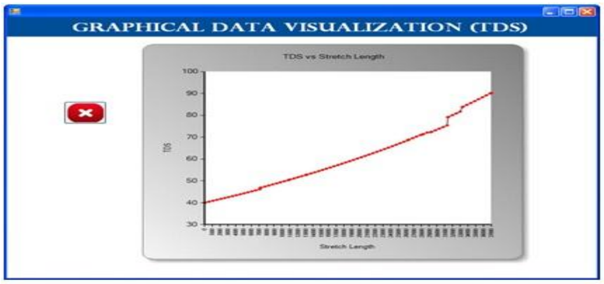

Figure 10: Plot of variation of TSS along river stretch

The variation of flow rate along the river stretch can be seen from the **Figure 4.** As different industrial sources intake river water and discharge effluents, the net flow rate keeps changing very slightly with the stretches. The flow rate varies significantly only when another tributary or stream mixes with the river. It is a fact that the dimensions of cross-sectional areas of river at different industrial outfall points keep changing, for instance, as sometimes the depth of the river may get shallow and width may get decreased, the stream velocity will increase and vice versa. This variation of area can be seen in **Figure 5**. As per the principle of fluid dynamics, the velocity of river decreases when the cross-sectional area increases, and vice versa.

The prediction of river water quality can be seen in **Figures 7 to 10**. **Figure 7** plots the variation of BOD along the river stretch. It can be visualized that the demand of oxygen increases with the increase in pollution in river water. As soon as the industrial effluents get discharged and it mixes with the river water, the BOD level increases suddenly. However, as the water flows along the river course, the pollution level decreases, and as such the demand keeps decreasing.

The variation of DO with river stretch has been shown in **Figure 8**. With the increase in pollution level, the DO decreases. In other hand, as we move along the stretch, the DO keeps on increasing unless another industrial effluent mixes with river water.

The variation of TSS and TDS with respect to river stretch can be seen in **Figures 9 and 10**. The value of TSS increases suddenly when the river water is blended with an industrial effluent. However, it has been observed that the river stretch has a characteristic to change the quality of water subject to TSS since a part of TSS dissolves in the water and constituted with an another parameters TDS while it transports through the stretch. As a result, the concentration of TDS keeps increasing along the stretch.

Thus, the dispersion scenario of various industrial pollutants along the river stretch may be mathematically studied and an appropriate effluent treatment may be devised before discharging the effluents into the river stretch. In order to validate the present system, it was applied to predict the river water quality along a river stretch blending with multi-industrial outfalls and the predicted results were compared with the laboratory analyzed data.

IV. Conclusion

The RQM information system has been developed in user friendly manner with appropriate graphical User interface (GUI). This system may be useful for environmental engineers, pollution control boards, policy makers for exercising Environmental Impact Assessment (EIA) in order to devise an appropriate Environmental Management Plan (EMP).

Acknowledgement

The authors are thankful to the Director, CSIR-CIMFR for permitting to publish this work. This the core work of Gaurav Chakrabarty, the Project Trainee, who carried out the present research work under the guidance and supervision of Prof. Dr. M.Sundararajan, Sr. Principal Scientist, CSIR-CIMFR, Dhanbad as a part of M.Sc IT under Vinoba Bhave University.

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