PREDICTION OF WATER QUALITY OF A STREAM CARRYING INDUSTRIAL TREATED WASTE WATER USING QUAL2K

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Submitted By

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DECLARATION

I, Aryavart Chaudhary, hereby declare that the work prepared in thesis entitled "Prediction of water quality of a stream carrying Industrial treated waste water using QUAL2k" in fulfillment of the requirement for the award of degree of Master of Engineering in Infrastructure Engineering in the Civil Engineering Department, Thapar Institute of Engineering and Technology (Deemed to be University), Patiala is an authentic work carried out under supervision of Dr. Bholu Ram Yadav, Assistant Professor, School of Energy and Environment and Dr Dwarika Nath Ratha, Associate Professor, Department of Civil Engineering, Thapar Institute of Engineering and Technology, Patiala during July 2016 to July 2018. The matter presented in this has not been submitted either in part or full to any other university or institute for the award of any degree.

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ABSTARCT

Water is essential to life, and its contamination affects all living beings on earth. Dissolved oxygen (DO), Biochemical Oxygen Demand (BOD), pH are some of the most important water quality parameter not only for human beings but also for the survival of aquatic life. Discharge of organic, industrial, agricultural, biodegradable wastewater into rivers, results in decrease of DO concentration and increase of BOD concentration in downstream waters. In this work, we have considered point sources of pollution and their effect on the river water quality. Qual2K model is used for analysis of river water quality. The water quality parameters included in the model were DO, BOD, among others.

In real situations, the water quality monitoring stations are located at some distance and many point sources might discharge water into the river between two monitoring stations. In such situations, the contributions of the various point sources to the degradation in water quality become difficult to ascertain. The QUAL2K model has proved to be especially useful in predicting the impact of point sources on DO in downstream water quality.

The experiments for the study were chosen using statistical designs. The values of various parameters were considered at various points along the stretch. The model was run with the values of two-point source discharges and head water. The water quality was predicted for a point at a distance from the last sampling point. The results predicted by the model were validated by testing the water quality at five points along the stretch.

The data from simulations were analyzed using analysis of variance (ANOVA) and explicit and implicit regression models were obtained to explain the data using simple equations.

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LIST OF ABBREVIATIONS

ABBREVIATION	FULL FORM
B	BETA VALUE
BOD	BIOCHEMICAL OXYGEN DEMAND
CBOD	CARBENOCOUS BIOCHEMICAL OXYGEN DEMAND
$CBOD_{FAST}$	FAST CBOD
$CBOD_{SLOW}$	SLOW CBOD
CBOD U	ULTIMATE CBOD
COD	CHEMICAL OXYGEN DEMAND
CPCB	CENTRAL POLLUTION CONTROL BOARD
D_F	DEGREE OF FREEDOM
DO	DISSOLVED OXYGEN
D/S	DOWNSTREAM
EC	ELECTRICAL CONDUCTIVITY
GA	GENERIC ALGORITHM
HW	HEADWATER
I_1	INDUSTRY-1
I_2	INDUSTRY-2
N	NITROGEN
NH_3	AMMONIA
NH_3-N	AMMONICAL NITROGEN
NO_3^-	NITRATE
ORG. N	ORGANIC NITROGEN
ORG. P	ORGANIC PHOSPHOROUS
P	PHOSPHOROUS
pH	POUVOIR HYDROGENE
R	PEARSON CORELATION
SIG.	SIGNIFANCE VALUE
SOD	SEDIMENT OXYGEN DEMAND
TN	TOTAL NITROGEN
TP	TOTAL PHOSPHOROUS

TSS	TOTAL SUSPENDED SOLIDS
US EPA	UNITED STATES ENVOIRNMENTAL PROTECTION AGENCY

CHAPTER: 1

INTRODUCTION

India is a large country with a total area of 32 lakh sq. kilometers out of which around 9% is covered by water bodies and streams. According to this fact it comes out to be that India has ample amount of water resources for the people of the country.

But, this is not the scenario in the present day. The uncontrolled and uneconomical use of water streams by the people has led to an increased pressure on the water bodies.

India has seven major rivers mainly Ganga, Yamuna, Brahmputra, Godavri etc. Other than rainfall these seven rivers along with their tributaries constitute to be the major source of water required by the people for drinking, irrigation and other day to day activities.

Due to the increased, uncontrolled, unmonitored use of water bodies the quality as well as quantity of water bodies has depleted at a very fast rate. This depletion has become a great issue of concern, which requires to be instantly looked after.

1.1 ORIGIN OF STUDY

Most of the industries operating in the country discharge their waste materials in the water bodies. Though now the environmental agencies and many NGO's have started raising voice against the uncontrolled depletion and pollution of the water bodies. Earlier there was no controlling authority over the industries and not much interest was shown by the Government towards the protection of the water bodies, which thereby led to the depletion of the water bodies and it has now become a major concern for the Government of India to protect and preserve the water bodies so that they can be used by the future generations.

So, to maintain the quality standards of the rivers such that the coming generations can also benefit from them various river protection schemes have been implemented by the government of India. Also, to minimize the pollution loading in the water bodies various guidelines and waste pollutant parameters have been set by the Central Pollution Control Board (CPCB). These guidelines have acted as a check to the pollutants emitted into the rivers, but the damage done in the past still requires a lot of care to be taken care of.

1.2 NEED OF STUDY

The city of Patiala has a total area of 3430 sq km with a population of 18, 92,282 people. A lot of waste water is generated every day in the city. There are a lot of industries in the vicinity of the city which discharge their waste water in the small water streams passing through the city and ultimately falling off in river thereby polluting the river and also leading to an increase in the load on the water treatment plants located along the river body. Though the dispersion coefficient of the water body dilutes and reduces the pollutant level in the water body to some extent but the excess pollutant discharge and uneconomical use reduces quantity of water, which makes the dispersion very less effective.

1.3 OBJECTIVE OF STUDY

1. To predict the effect of the industrial discharge on the water stream.
2. To develop an equation to predict the impact on the various water quality parameters.
3. To optimize the various water quality parameters using QUAL2K.

1.4 SCOPE OF STUDY

The scope of the study is to determine the effect of the discharge from the industries on to the water stream. And, for the purpose of determining the effect on the water stream several steps shall be undertaken in a proper sequence.

1. First, of all waste water samples shall be collected from all the major points of inflows and headwater in the stretch.
2. The samples collected shall then be analyzed in the laboratory and the values of various parameters shall be determined. The sampling shall be repeated again so as to determine any change in parameter values.
3. After, the sampling has been done and parameter values decided the model shall be run. Before, running the model to predict results the model shall be calibrated to meet the field conditions.
4. The model shall then be run and the values of parameters at various distances shall be predicted.

5. For the validation of the predicted values sampling shall again be done. 5 points situatedevenly all along the stretch shall be selected and again analyzed in the laboratory for determination of values of parameters.
6. The results obtained shall then be compared with the predicted results. If the predicted results are not in accordance to the observed values, the model shall be run again.
7. The model shall be again and again calibrated and run till the observed and predicted values are in accordance with each other.
8. After the predicted and observed values are in accordance with each other SPSS shall be used to check the significance of the model and to create equations for every parameter modelled by us. Simple linear regression shall be used for this purpose.

1.5 OUTLINE OF THESIS

The thesis comprises of five chapters starting with the present one which throws light on introduction to the water scenario in the country and the scope and objective of the study. The second chapter includes the literature review of the research done on the various water bodies and on various parameters of water, important for various purposes and also tells about the various other water quality models. Chapter three deals with experimental programme which includes materials, tests conducted and procedure adopted for the experimental study. Chapter four has all the results and findings of the experimental study. Further, the comparison of predicted and observed values is also included in this and new equations derived are also included in this chapter. After, this chapter follows the conclusion.

CHAPTER: 2

LITERATURE REVIEW

In this chapter we discussed about the previous research done on river bodies. We also discussed about the various water quality models available for the purpose of water quality modelling and why one is different than other and which the best is.

2.1 PREVIOUS STUDIES DONE ON WATER STREAMS

Park S.S. and Lee S.Y.(2001) conducted water quality modelling of the Nakdong River (situated in Korea). Both QUAL2K and QUAL2E were applied to the model to predict the results. The river was divided into 54 reaches. Each reach was further subdivided into uniform computitional elements. Both, QUAL2K and QUAL2E were calibrated and verified using March to May and September to November data Dissolved Oxygen (DO), Biochemical Oxygen Demand(BOD), Nitrogen (N), Phosphorous (P) and Chlorophyll are the parameters included in the model. The model was run until the observed and predicted values were in agreement with each other. It was concluded that the results predicted were same and quite reasonable for both QUAL2K and QUAL2E.

KannelR.P. et al. (2007) performed water quality modeling for river Bagmati. A stretch of 20 kms which receives the maximum pollution load is selected for the study purpose. The data was collected for 30-hour duration for pre monsoon season and for post monsoon season. The pre monsoon season testing was done to monitor critical flows as clearly as possible. 11 monitoring stations were set up all along the downstream. The flow was assumed to be constant and uniformly distributed over time. Temperature, pH, Nitrite + Nitrate nitrogen, Organic Nitrogen (Org. N), DO, BOD and many more important water quality parameters were monitored. The 20.5 km stretch was divided into 41 reaches with 0.5 km length each. The calculation time step was taken as 5.25 minutes. Euler's method was used for integration. Model was run for a population size of 100 with 50 generations. The results obtained were well in agreement with the measured data with a few exceptions. In spite of the variations in the measured and observed values of some parameters the calibration and validation results are acceptable for developing countries with financial limitations.

Fan C, Ko Han C and Wang S.W.(2009) assessed the water quality of a tidal river in northern Taiwan using QUAL2K and HEC-RAS. The various parameters used for simulation were BOD,Ammonical Nitrogen (NH_3-N), Total Phosphorous (TP) and Sediment Oxygen Demand (SOD). Estimation of hydraulic constants for atmospheric re-aeration constant calculation and the estimation of the water level profile variations was done by HEC RAS. Different loading combinations showed that BOD is the most important contaminant. The results obtained showed excellent agreement with the observed data.

Oliveria B et al. (2011) conducted a study on Certimariver situated in Portugal. A stretch of 25.7km was selected for the purpose of study. It was further divided into 4 segments of same geometrics and physical properties. Each segment was further sub divided into 500m interval. The channel slope varied from 0.003 to 0.0008, with a side slope varying from 0.35 to 0.25. The input parameters used were temperature, pH, Conductivity (EC), DO, BOD, Total Suspended Solids(TSS), Ammonia (NH_3), Nitrate (NO_3^-), TP, Average Daily Flow, Depth Profile and Flow Velocities. The model response for DO was in good agreement with the data. Sensitivity Analysis conducted that Ammonium Nitrification rate, Bottom plants death rate, Bottom plants maximum growth rate, Manning coefficient are the parameters to which the model is most sensitive.

Zhang R et al. (2015) conducted a study on the Taihulake and Hongqui river, which is a polluted tributary of Taihu lake in China, so as to facilitate the selection of an optimal program for the water improvement. These scenarios consisted of a series of three water treatment technologies in different configurations, from upstream to downstream. The results showed that the optimal scenario comprised a bio-contact oxidation system upstream, followed by an ecological floating bed, and a vertical moveable eco-bed downstream. The reduction rates achieved by this scenario for BOD,NH_3–N, Total Nitrogen (TN) and TP were 49.50%, 32.81%, 35.94%, and 45.27%, respectively. The QUAL2K model proved to be an effective tool in the comparative evaluation of potential water quality improvement programs. The method applied in this study can prevent the implementation of water quality improvement programs that would not achieve the desired goals.

Sarda Dr P (2013) presented an approach for water quality modelling of Godavari River. A 15 km stretch was taken for the purpose of analysis. It was divided into 2 reaches depending on the point of inflows. The hydraulic parameters considered wereflow rates, dimensions of river reaches, location of upstream and downstream ends, height, width, shape of weirs, dams and waterfalls, rating curve parameters, Manning's 'n' for river reaches. The water quality data considered included temperature, EC, Organic Phosphorous (Org P), DO, phytoplankton, Slow Carbenacous Biochemical Oxygen Demand ($CBOD_{slow}$), Fast Carbenaceous Biochemical Oxygen Demand ($CBOD_{fast}$), pathogens, Org. N , Alkalinity, pH. Air temperature, Wind speed, and Dew point temperature. The state variable plots were obtained for Temperature, EC, DO, $CBOD_{slow}$, $CBOD_{fast}$, pH, Pathogens, Alkalinity, TN, Total P. The model was run and calibrated for the data of 2000-2008. The model represented the field data quite well with some exceptions. Senstivity analysis predicted that the model was sensitive to TN, Carbenecous Biochemical Oxygen Demand (CBOD), depth coefficient.

Gupta R.C., Gupta K.A. and Shrivastava R.K.(2013) conducted the water quality modelling of river Kshipra. A stretch of 19.79 km was selected for the study which was further divided into 20 reaches. Manning's coefficient was taken as 0.7. Reareation model was selected through internal calculations. Euler's method was used for the solution of integration. pH modelling was done with the help of Newton-Raphson. The model was calibrated for the data of 3 months(April-June) The model was run for a population of 100 with 50 generations. The model was validated using the results from the data of October- December. The discripency in the validated and observed data was found to be maximum upto 10%.

Lakshmi E and G Dr Madhu(2014) conducted a study for the modelling of the Dissolved Oxygen. and temperature on Periyar river in South India. Secondary data (surface water temperature, DO, air temperature) for a period of 28 years ie from 1980-2008 was obtained form the departments. For QUAL2K modelling the river was divided into 7 reaches. Temperature and DO were modelled using QUAL2K. Data obtained from sampling and secondary data was used for modelling. By simple linear regression equations for water temperature and DO were obtained.

Water Temperature = 22.858 + 0.202 x Air Temperature……………………………………2.1

DO = 9.197 – 0.103 x Water Temperature…………………………………………………...2.2

Calibration data of 2008 and 2013 also predicted that the data for all the reaches is in well agreement with the results of the model.

Kalburgi B.P., Shareefa N.R. and Deshannavas B.U.(2015) used QUAL2K to develop the BOD-DO model of river Ghataprabha in Karnatka. A 50km stretch was selected for the study.

Arc Gis technique is used to obtain some hydro-geometric data of the river for input to model QUAL2K. 6 different location were monitorred for calibration and validation. The calibrated model was validated to predict water quality using a different set of data under different conditions. The results showed that the predicted results were well in agreement with the observed results.

Sarda P and Sadgir P(2015) conducted a study and treid to explain how different parameters effect the water quality. All the parameters have an important effect on water be the usage of water be for irrigation, drinking or any other work. Temperature, pH, Total Dissolved Solids TDS, EC, DO, BOD, Chemical Oxygen Demand (COD) are the broad range of water quality parameters for drinking, irrigation, aquatic life for surface water.

Sharma D, Kansal A and Pelletier G(2015) performed water quality modelling of the urban reach of river Yamuna. For the purpose of calibration of the QUAL2K model 90 months' data was collected over 4 monitoring stations. Thirteen waste water channels and a tributary conveying household sewage have been considered in the investigation. The data was gathered for pH, DO, BOD, nitrogenous mixes, COD, alkalinity, temperature and EC. The river was divided into 21 sub reaches and 17 reaches. Various necessary worldwide parameters are adjusted to get the wellness while looking at the observed information and the model forecasts. The model was calibrated for the first 45 months and then modelled for the next 45 months. Time step of 5.625 minutes was set. Population of 200 with 100 generations was used for the purpose of Generic Algorithm (GA). The sensitivity analysis anticipated that DO is very delicate to CBOD, oxidation rate, alkali nitrification rate, HW stream and reareation rate. The observed and predicted values were well in accordance with each other.

Idris S, Abdu A.Y. and Saini G(2016) conducted a study on river Yamuna for the asssessment its surface water quality with the help of QUAL2K. The total study area of 22km was divided into 16 reaches of 0.3km each. The calibration of the model was done for DO, temperature, Alkalinity, TN and pH. The BOD value keep increasing as the sewage starts flowing in the river. The DO values were found to be below the permissible limits. The pH and temperature were also not in the prescribed limits. Senstivity analysis depicted that the model is highly sensitive to river flow and point source discharges and moderately sensitive to fast CBOD and nitrification rate. Overall the results predicted by the model were quite in agreement with the observed values.

Ashwani S et al. (2017) used QUAL2K to predict the water quality of Pamba river. A stretch of 12.63km was selected as the study area. Other than that a point 8.2km from the last sampling point was selected for which the water quality parameters were to be predicted. The stretch was divided into 22 reaches of unequal lenghts. Post monsoon data of a steady weather condition was taken for calibration. Time step of 5.65 minutes was used. pH, temperature, EC, TSS, TDS, DO, BOD,NO_3^-, Alkalinity, TP were the parameters consideed for model input. The parameters predicted were BOD, TSS, TN, TP and Alkalinity. Internal calculation was used. The results obtained were well in agreement with the observed data.

2.2 MODELLING OF RIVERS

Modelling of rivers is a great method of depicting the characteristics of the river in the form of a model and predicting the characteristics of the river which are not known to us. Different models are available for different river characteristics.

2.2.1 Use of Models

Due to the development and management policies the envoirnmental, social and economic effects are assesssed by the help of river basin models. Positive(descriptive) models are used to determine and predict the outcomes due to changing conditions. Models are generally chosen from a range of models so that they meet the best suited objective. The model which are used in almost all the conditions are normative models. Results obtained are interpreted so as to reveal the opportunities for improvement. The models behaves as an indespensible model for decision making. Models are generally divided on the type of problem to be solved by the. The models can be static or dynamic, deterministic or srochastic, single or multiple, economic or engineering oriented.

Static vs Dynamic : The examination of the condition due to change in system is depicted with the help of static models. For example, the nature of construction of a wastewater treatment plant on the river water quality. The transistory effects such as the changing landscape, alteration in water flows and many more are depicted by dynamic models. These are generally used to describe intertemporal behavior of some of the model components due to the change in conditions. [**Pandurang G.S. 2006**]

Deterministic vs Stochastic: Deterministic models are used in scenarios where the information affecting the outcomes is known or is assumed and the influence of unknown parameters is very small. Stochiastic model are generally used to incorporate information about the reliabilty of information in the model. Results from the stochiastic models can indictae the outcomes of alternative projects in probablistic terms. [**Pandurang G.S. 2006**]

Single vs Multiple Objectives : The most common used models single models are based on the assumption that the values effected can be denominated in a common unit and compared in that. Multiple Objective models are generally used when units don't have to be changed and they can be compared in completely different units. [**Pandurang G.S. 2006**]

2.2.2 Details of various Water Quality Models

Depending upon the type of flow, type of conditions, parameters modelled by the model various models are available and a person can use anyone which fulfills his needs.

MIKE 11: It is a deterministic, hydrodynamic model. It was developed by the Danish Hydraulics Institute and is used by the agencies all over the world. It has been applied in Africa, Australia, India and in many other countries. In England it is the recommended model for assesing the effect of discharges on river and eustaries. [**Pandurang G.S. 2006**]

Mike 11 is a one-dimensional powerful stream demonstrates which reproduces hydrodynamics, water quality and residue transport in conduits, estuaries, water framework structures, channels and other water bodies. It relies upon an isolated structure including modules for reproducing: precipitation overflow, hydrodynamics, change in climate conditions, water quality and deposit transport. The center of this model is a hydrodynamic module which grasps the Saint-Venant conditions and the kinematic wave or diffuses wave modifications to reenact the streams inside broadened and circled conduit systems. These can be portrayed either comprehensive or locally for each cross-section. [**Tsakiris G and Alexakis D. 2012**]

The rainfall-runoff component can be applied to produce sidelong inflows from contributing catchments. The shift in weather conditions(advection)—scattering condition is then solved utilizing a verifiable limited contrast plot for suspended or dissolved materials. The water quality module, combined with the yields of the shift in weather conditions—scattering module, reproduces the response forms of multi compound frameworks. The water quality module incorporates a few models among which the straightforward model; eutrophication and substantial models can likewise be spoken to utilizing different models.The basic model models theBOD—DO connections including the impacts of nitrification (ammonium, nitrates and nitrites) and the nearness of organic matters. [**TsakirisG and Alexakis D. 2012**]

Mike 11 requires time arrangement of stream and synthetic focus alongside a few other water-quality parameters, for example, degradation rates to mimic the developments of chemicals in an extended waterway network. The yields incorporate time arrangement of stream and substance fixations for each scope. [**Pandurang G.S. 2006**]

Models like MIKE 11 are very confusing and their nature of outcomes generally depends upon 'great quality stream' and water quality time arrangement

QUAL2E: It is a case of a steady-state state deterministic model. [**Pandurang G.S. 2006**]
QUAL2E is a one dimensional model created by the US EPA (U.S. Envoirnmental Protection Agency) and it recreates the water quality and stream systems by explaining the mass transport equations. The transport components (advection and dispersion), are just thought to be applicable along the principle waterway station. Be that as it may, various waste releases, tributary streams, withdrawals and incremental inflow and surge can likewise be incorporated. This model evaluates DO and BOD together with 13 more determinantss.The waterway network is schematically partitioned into reaches, every one of which is then isolated into computational components of equivalent length. The stream framework design requires the accompanying attributes:

- number of reaches for sectioning the stream
- number of stream intersections and headwater sources
- number of sources of inputs or withdrawals
- length of computational component

A unique reach number, reach name and reach length is defined to each reach. A maximum of 50 reaches can be represented in the model. Functional or Geometric representation is used to characterise the hydraulic characteristics of the model.Each span may include 7 unique kinds of computational components: headwater source, standard component (incremental inflow or surge), component on standard instantly upstream of an intersection, intersection, most downstream component, point source, and withdrawal component. The steering calculation for each computational component is then characterized by the sort of component chose. [**Pandurang G.S. 2006**]

Every intersection or juncture is in this manner described by a one of a kind number and a name, and also their numbering position contrasted with:

(i) the last component in the compass instantly upstream from the intersection,

(ii) the first component in the scope instantly downstream from the intersection and

(iii) the last component in the last reach of the tributary entering the intersection.

QUAL2E plays out the energy balance for heat exchange over the air—water interface to speak to the reliance of temperature on topography and climatology. Information are in this manner required for reach elevation, dust elevation, cloudiness, dry and wet bulb temperature, wind speed and barometric pressure would then be characterized. These information can be characterized as worldwide or reach specific values. Inside QUAL2E, the BOD concentration is reproduced by explaining a first order equation including BOD removal because of sedimentation and deoxygenation, which requires a deoxygenation rate and a settling rate. While recreating DO the impacts of algae, nitrogen, phosphorus and BOD forms are considered. Flow augmentation is modeled at the reach level so as to avoid the DO concentration from dropping below a certain level.Settling and benthos mechanisms are needed because non conservative determinants are modeled using them. Information on flow and determinant characteristics is defined once the river network and the determintant characteristics are explained. After all the values have been input then QUAL2K predicts the value of all the determinants in each specified reach. [**Pandurang G.S. 2006**]

QUAL2E just as MIKE11 does a realistic representation of the various procesess. Though it demands less data then MIKE11 but still the data requirement due to the complex proccesses included is quite high.

TOMCAT: an example of a steady-state stochastic model

In England and Wales, under the Water Resources Act 1991 , it is an offense to "cause or intentionally allow" pollutants to enter controlled waters without authorization. In this way, the release controlling conditions, called Consents, are set up for each release to control volumes and concentrations. TOMCAT was produced by Thames Water (England, UK) and intended to aid the survey of UK consents, specifically Ammonia, BOD and DO, on a catchment scale. It depends on the Hybrid Monte-Carlo deterministic strategy and recreates stream distribution and

concentration of key determinands (BOD, smelling salts, DO, and temperature) utilizing Monte-Carlo shots to give discrete examples from the user characterized distribution. As TOMCAT is a stochastic model, it requires the client to determine the number of shots to be embraced alongside the number of sub-catchments to be reenacted. There is in addtition a feature of defining the seasons and with different distributions and providing the mean monthly temperature corresponding to each catchment. The streams and concentrations inside TOMCAT are evaluated utilizing a straightforward mass balance equation which does not speak of advection (shift in weather conditions) and scattering. The synthetic procedures are solved utilizing a first order decay equation which just considers in-stream evacuation. DO is evaluated by use of the Streeter Phelps condition. [**TsakirisG and Alexakis D. 2012**]
The TOMCAT model is substantially less difficult than Mike 11 or QUAL2E, and the amount of input data required is less.

MONERIS (Modelling Nutrient Emissions in River Systems): MONERIS is a model that is built over 8 sub models that simulate and predict the generation and transport of sediments in the river system. MONERIS is a GIS-situated model which depends on the empirical way to depict complex connections basically. It is a reasonable model for the evaluation of nutrient emissions from point and non-point sources in stream catchments bigger than 50 km^2. The model consists of a scenario manager that helps to assess the effects of the nutrients on the different units and pathways. [**TsakirisG and Alexakis D. 2012**]

SIMCAT (Simulation of Catchments): SIMCAT was developed in United Kingdom somas to assist in the process of planning of measures for water quality management. It is a deterministic, stochiastic, steady state, one dimensional model that displays the outcome and transport of solutes in the stream and the inputs from point sources of discharges on the basis of the behavior of:

1. A relationship of temperature, reareation and BOD Decay is used to represent DO.

2. NO_3^- and BOD (non-conservative substances which decay)

3. Conservative Substances which do not decay.

1400 parameters of up to 600 reaches can be modelled in the model. The reaches have to be defined by the user himself generally depending on the points of abstractions and inflows. Random values from the given input are selected for quality and flow on every run of the model.

The output of the model is generally in the form of summary of each reach and each pollutant.In United Kingdom the model has been used successfully as it is a satisfactory management tool, though sediment interactions are not considered in it. The model can also not analyze complex scenarios.[**Pandurang G.S. 2006**]

GREAT-ER (Geo-referenced Regional Exposure Assessment Tool for European Rivers)
The goal of the software is to give exact forecasts of sea-going compound introduction and count of sensible circulation of down-the-drain chemicals ecological concentrations for use in the EU chance appraisal plot, in view of a particular approach. Not at all like the Mackay or EUSES models, the GREAT-ER manages georeferenced 'genuine' datasets rather than normal or nonspecific qualities, which permits more dependable forecasts, and accordingly higher-level hazard evaluation contrasted with models utilizing single qualities speaking to most pessimistic scenario situations. The model core is deterministic and gives a robotic meaning of the diverse procedures considered inside the stream and waste water drainage region. However a stochastic layer is included utilizing Monte-Carlo simulations where 'shots' are obtained before the deterministic model is run. Distributions of four types, each having different input data requirements are available i.e.: constant, normal, log-normal and uniform.[**Pandurang G.S. 2006**]

QUAL2K Model: QUAL2K (or Q2K) is a waterway and stream water quality model that is planned to represent a modernized variant of the QUAL2E (or Q2E) model. The Enhanced Stream Water Quality Model (QUAL2K) is a thorough and flexible one-dimensional stream water quality model. It reenacts the significant responses of nutrient cycles, algal generation, benthic and carbonaceous demand, air reaeration and their consequences for the dissolved oxygen balance. Furthermore, the program incorporates a heat balance for the calculation of temperature and mass balance for moderate minerals, coliform microorganisms, and non-conservative constituents, for example, radioactive substances. The model is proposed as a water quality planning instrument for creating total maximum daily loads (TMDLs) and can likewise be utilized as a part of conjunction with field examining for recognizing the magnitude and quality attributes of point and nonpoint sources. QUAL2K has been created for steady stream and steady waste load conditions and is thus a "steady state model" in spite of the fact that temperature and green algae functions can differ on a diurnal basis. [**ChapraS.C. and Pelletier G.J. 2003**]

Model inputs

QUAL2K requires some level of demonstrating refinement and mastery. The user must supply in excess of 100 individual information sources, some of which require extensive judgment to estimate. The information can be assembled into three classifications: a stream/waterway framework, global factors and forcing functions. The first group, input information for the stream/waterway framework, portrays the stream framework into a configuration the model can read. The general variable gathering portrays the general simulation factors. [**ChapraS.C. and Pelletier G.J. 2008**]

Model Outputs

QUAL2K produces three sorts of tables-hydrodynamics, reaction coefficient, and water quality-in the output document. The outputs can be effectively imported into other application, for example, spreadsheets for investigation and furthermore incorporates some graphic analysis of the model outcomes. State factors can be plotted at characterized distances along the reaches. Also, the user can include field observations for dissolved oxygen with minimum, average and maximum values. The model uses those values to plot the observed information versus the predicted ones. If there should be an occurrence of dynamic simulations, the model produces temperature and algae esteems on the characterized time step. [**ChapraS.C. and Pelletier G.J. 2008**]

Model Application:

QUAL2K is extremely appropriate for waste load allocation studies and other planning exercises. Waste load allocations are performed for states of steady low stream and most extreme allowed effluent discharge rate. QUAL2K is proposed particularly for the relentless stream flow, consistent effluent release conditions indicated in the water quality guidelines for waste load distribution. Accordingly, QUAL2K has been generally utilized by specialists and administrative organizations and is considered as the standard for water quality models. for example, units, water quality constituents and some physical attributes of the basin. The compelling capacities are client indicated inputs that drive the system being modeled.[**Pandurang G.S. 2006**]

2.2.3 Comparison of Various Models:

Each model is unique in its own way. Some model has some characteristics and some have the other one. So, a detailed comparison between the various models studied above is given in the Table 2.1.

Table 2.1 Comparison of various water quality models[(**Tsakiris G and Alexakis D 2012) (Pandurang G.S. 2006) (Chapra S.C. and Pelletier G.J. 2008)]**

MODEL	DIMENSION AND STATE OF HYDRAULICS	POLLUTANT TYPE	COMMENTS
MIKE 11	1D UNSTEADY	DO, BOD, NO_3, NH_4, coliforms, P	Full Hydrodynamic
MONERIS	Semi-Static	Total N, Total P, heavy metals and some priority substances	Semi-empirical, conceptual model. Based on data for run-off water quality for the study area along with a GIS.
SIMCAT	1D Steady State (time invariant)	DO, BOD, NO_3, CI, NH_4	Stochastic, deterministic, Monte Carlo analysis techniques.
TOMCAT	1D Steady state (time variant)	DO,BOD, NH_4	Monte Carlo analysis techniques
QUAL2K (Q2K)	1D Steady State(time invariant)	TN, TP, DO, BOD, SOD, algae, pH, periphyton, pathogen	Not Stochastic, Not dynamic
GREATER	-	Exact forecasts of down-the drain chemicals	Deterministic, uses Monte Carlo simulation.

Concluding Remarks

From the above provided literature it is quite evident that QUAL2K is a reliable model and the results predicted by the model are of great reliability and get validated also by the conditions prevailing. Amongst the various models available for the purpose of modeling of rivers QUAL2K is the best because it is easy to operate and also the results are correct also QUAL2K is the only model which predicts the maximum number of parameters. Though TOMCAT also predicts a number of parameters but it is not stable and the calculations take a lot of time.

From, the literature we are also able to decide that pH, Temperature, TDS, EC, BOD, COD and N are the most important parameters that affect the quality of water and generally influence the organic life of the water streams.

Gap Analysis: From, the literature it was quite evident that no such study has been conducted for water streams in Patiala. It is also seen that the studies done earlier only predict the values of the parameters. They do not make any relation between the dependent and independent characteristics of the parameter, which would aid in prediction in future studies.

CHAPTER 3

METHDOLOGY

In this chapter we discussed about the study area, the conditions prevailing there. We also discussed about the procedure of tests followed by us and the data input into the model and various other settings set in the model.

3.1 AREA OF STUDY

- The above said study was conducted for an old river known as "ChottiNadi" passing through the city of Patiala.
- A 1.3km stretch of the river was selected for undertaking our aforesaid study.
- The 1.3km stretch selected for the purpose of study had2 point sources of discharge in it which are the discharge point for two Paper Mills respectively.
- The first input point was situated at a distance of 0.35km from Headwater and the second input point was situated at a distance of 1.25 km from Headwater.
- The river had gone dry but the headwater of the river was taken as the discharge from the Effluent Treatment Plant which is discharged into the river and is the main source of water in the river.
- The discharge from the ETP is around 46 MLD which accounts for 0.532 m^3/sec.
- As the paper industries generally use recycled paper as their main source of raw material so the water discharge by them is low compared to other paper industries which use wooden pulp as their raw material.
- The discharge from both the industries was around 8640 L/day and 9000 L/ day. So, for the purpose of calculation the discharge from industries was taken as 0.0001 m^3/sec.
- The testing of the water quality parameters was done for 5 days varying over a period of a month, so as to check and determine the changes in the parameter values with respect to temperature and other conditions.

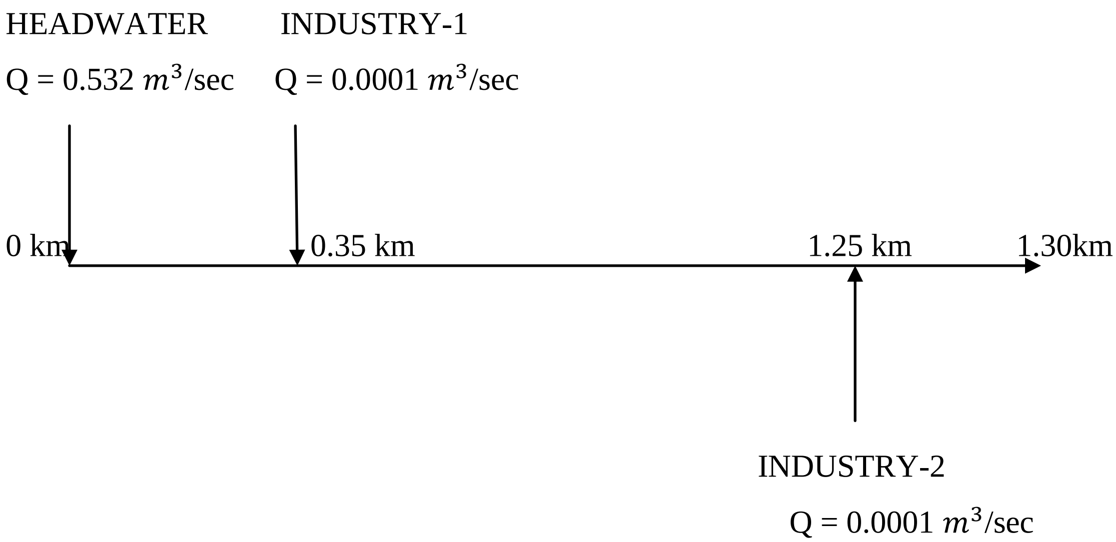

Figure 3.1: Line diagram showing the study area.

3.2 REGULATION FOR COLLECTION AND PRESERVATION OF SAMPLE

The main objective of sampling is to collect representative sample. Representative sample by means is a sample in which a relative proportion of all the pertinent components will be the same as in the material being sampled. Moreover, the sample should be handled in such a way that there is no change in composition of the sample before the sample is analyzed. The sample volume should be such that it is small enough that it is transported easily and large enough for analytical purposes.

3.2.1 Collection of Samples

Grab sampling was done in the study. The samples were collected over a selected location, depth and time. The variation in the source was easily represented in the samples. [**APHA 2015**]

3.2.2 Methods of Sampling

Manual sampling was done for the purpose of collection of samples. No equipment was brought into use for the purpose of sampling. [**APHA 2015**]

3.2.3 Sample Containers

As, the parameters to be tested were not toxic parameters. So, plastic containers were used for storing of samples. [**APHA 2015**]. Sample labeling is a very important part of sampling. The following information was properly included in the label. Water proof ink was used for labeling.

1. Date and Time of sampling
2. Sampling point
3. Notes

3.2.4 Sample Volumes

2-liter sample was collected for the purpose of testing of various parameters. [**APHA 2015**]

3.2.5 Sample storage and preservation

3.2.5.1 Sample Storage before Analysis: Zero head space was left in the bottles filled with the sample. The bottles were checked for air bubbles and it was taken care that no air bubbles were present in the bottle. The samples were taken as quickly as possible after collection to the laboratory for testing purposes because temperature changes lead to a change in the pH and DO values of the sample. [**APHA 2015**]

3.2.5.2 Preservation Techniques: Preservation of samples is very important because if the samples are not preserved properly the values tend to change thereby leading to discrepancies in the result. As, most of the tests were conducted on the day of the collection of the sample and the remaining sample was refrigerated at 4°C for further use. [**APHA 2015**]

3.2.6 Summary of Special Sampling and handling requirements

The type of container used, minimum sample volume collected and all the other required information about the parameters is discussed in the Table 3.1. All these points were decided in accordance with the APHA guidelines

Table 3.1 Summary of special sampling and handling requirements

Determination	Minimum Sample Size (mL)	Preservation	Max. recommended storage
Alkalinity	200	Refrigeration	24h
BOD	1000	Refrigeration	6h
COD	100	Refrigeration	7d
Conductance	500	Refrigeration	28d
Nitrogen Ammonia	500	Add H_2SO_4 to pH <2, refrigeration	28d
Organic Nitrogen	500	Add H_2SO_4 to pH <2, refrigeration	28d
Dissolved Oxygen	300	Analyze immediately, Titration may be delayed after acidification	0.25h
pH	50	Analyze immediately	0.25h

3.3 PROCEDURE OF VARIOUS TESTS TO BE PERFORMED FOR DETERMINING VARIOUS PARAMETERS:

3.3.1 DO: Oxygen is one of the most important component over which the living organisms are dependent in one way or the other. Measurement of DO is important because:

1. Concentration is very important in the testing of water and waste water samples for BOD.
2. Operation and control of aerobic biological treatment units.
3. Management of water streams for protecting them through monitoring the DO levels.

DO is determined by the help of the Wrinkler's method as mentioned in APHA. [**APHA 2015**] Complete procedure is mentioned in Annexure-I.

3.3.2 BOD: BOD is used to measure the quantity of oxygen required for oxidation of Biodegradable organic matter present in water samples by aerobic biological action.BOD bottle method as mentioned in the APHA is used for the determination of BOD. [**APHA 2015**]Complete procedure is mentioned in Annexure-I.

3.3.3 COD: COD Test is widely used as a means of measuring the organic strength of domestic and industrial wastes. The test allows measurement of a waste in terms of the total quantity of the oxygen required for oxidation to carbon dioxide water and ammonia. Closed Reflux Method as mentioned in APHA is used for the determination of COD. [**APHA 2015**]Complete procedure is mentioned in Annexure-I.

3.3.4 NH_3-N/ Org.N: In waste waters the forms of nitrogen of greatest interest are, in order of decreasing oxidation state,NO_3^-, NO_2^-, NH_3 and Org.N. Kjeldahl method as mentioned in APHA is used for the determination of nitrogen. [**APHA 2015**]Complete procedure is mentioned in Annexure-I.

3.3.5 Alkalinity: Alkalinity of water and waste waters is the capacity to neutralize acids. The alkalinity of water is mainly due to the presence of Hydroxides, Carbonates and Bicarbonates. The type and extent of alkalinity present in the water can be determined by titrating the sample with standard sulphuric acid (0.02N) at room temperature using phenolphthalein and methyl orange indicator. [**APHA 2015**]Complete procedure is mentioned in Annexure-I.

3.3.6 EC: EC is the measure of the water's capability to pass electrical flow. This ability is directly related to the concentration of ions in water. These ions which conduct electricity come from dissolved salts and inorganic materials such as alkalis, chlorides, sulfides and other compounds. Instrumental method is the most commonly used method of EC determination. [**APHA 2015**]Complete procedure is mentioned in Annexure-I.

3.3.7pH: pH is a logarithmic scale used to specify the acidity or basicity of an aqueous solution. A pH less than 7 is said to be acidic whereas a pH more than 7 is said to be basic. The pH determination is usually done by electrometric method, which is the most accurate one, and free from interferences. [**APHA 2015**]Complete procedure is mentioned in Annexure-I.

3.4 WATER QUALITY MODELLING BY QUAL2K

QUAL2K is a river and stream water quality model. It is typically used to assess the environmental impact of multiple pollution discharges along rivers.

Pollutants can come from point sources such as industrial wastewater, municipal sewers, storm water, agricultural or urban runoff, and commercial activity such as forestry, mining, and construction.

It is available as freeware from the US-EPA.

The model is written in MS Windows Visual Basic, and Microsoft Excel is used as the graphical user interface. All input and outputs are organized in a series of worksheet tabs.

Different color tabs correlate to the various inputs and outputs. All numerical calculations are implemented in Fortran 90 in order to decrease the time of calculation.

The model requires us to input various data which could help in the modelling of the river characteristics. A detailed table showing the type of data being entered is shown in Table 3.2.

The various other data entered are :

- The Local Standard Time was taken as 4 hours because the conditions prevailing to this time zone are very similar to the condition for our site and in all the studies done before on Indian rivers the time zone is taken as 4. [**Sarda P 2013**]
- The Calculation step is calculated by the model with the help of the GA present in it. The time step was found to be 1.4 minutes by the model. A time step lower than 1.4 minutes makes the model unstable and a time step bigger than 5 minutes gives inaccurate results.
- Repeating Diel method was used for simulation.
- Euler method was used for the purpose of integration. In addition to Euler method RangaKutta method is also available for integration but it is generally not used because Euler's method attains sufficiently accurate results at a moderate computational price. Though, where Euler's method produces unstable results in those places we can use a more computationally heavy RangaKutta 4^{th} order method. [**Chapra S.C., Pelletier G.J. and Tao H. 2008**]
- For the solution of pH, Brent method was used. Brent method is the advanced form of the Newton-Raphson method and the Bisection method. Bisection method is very slow and Newton Raphson method goes unstable at a lot of places. So, for the best results Brent method is being used. [**Chapra S.C., Pelletier G.J. and Tao H. 2008**]

Table 3.2 Primary settings done to the model

SYSTEM ID		
River Name	ChottiNadi	
Saved File name	Patiala 21-5-18	
Directory where the input/output file are saved	C:\Users\Chaudhary\Desktop\thesis\data\data files	
Month	5	
Day	21	
Year	2018	
Local standard time zone relative to UTC	4	hours
Daylight savings time	Yes	
Simulations and Output options		
Calculation Step	1.40625	minutes
Number of days for the simulation period	5	days
Simulation Mode	Repeating diel	
Selected date for output of longitudinal and 24-hr diel plots	22/5/2018	
Solution method (integration)	Euler	
Solution method (pH)	Brent	
Simulate hyporheic transient storage zone (HTS)	Level 1	
Simulate surface transient storage zone (STS)	Yes	
Option for conduction to deep sediments in heat budget	Lumped	
Display dynamic diel output for selected date	Yes	
State variables for simulation	All	
Simulate sediment diagenesis	No	
Simulate alkalinity change due to nutrient change	Yes	
Write dynamic output of water quality for entire simulation	No	
Print interval for dynamic output (multiple of time steps)	4	
Program determined calc step	1.40625	minutes
Time elapsed during last model run	0.65	minutes

- The model provides us the feature to divide the stretch of river into smaller reaches. Reaches are generally referred to segments having the same hydraulic characteristics. [**Chapra S.C. and Pelletier G.J. 2003**]
- So, we divided our stretch into to reaches of 100m each. In total, the 1.3km stretch was divided into 13 reaches. The exact details of the reaches are shown in table 3.3.
- In correspondence to these distance various other parameters such as the depth of the channel, width of the channel, slope of the channel, latitude longitude of the reaches were entered in the model.
- The average depth of the channel was found to be 2.8m. So, for the purpose of calculations depth of the channel was taken as 2.8m.
- The width of the channel was taken as 8.1m.
- The channel slope was calculated by the model itself taking into consideration the latitude and longitude coordinates. The latitude of the stretch was 30.28 whereas longitude variesbetween 76.37 to 76.36. The exact details of the latitude and longitude are given in the Table 3.3.

Table 3.3 Latitude and Longitude of Reaches

REACH NUMBER	REACH LENGTH	LATITUDE	LONGITUDE
0		30.28	76.37
1	0.10	30.28	76.37
2	0.10	30.28	76.36
3	0.10	30.28	76.36
4	0.10	30.28	76.36
5	0.10	30.28	76.36
6	0.10	30.28	76.36
7	0.10	30.28	76.36
8	0.10	30.28	76.36
9	0.10	30.28	76.36
10	0.10	30.28	76.36
11	0.10	30.28	76.36
12	0.10	30.28	76.36
13	0.10	30.28	76.36

- So, with the variation of the latitude and longitude the channel slope varied from 0.004 to 0.003.
- The Manning's Coefficient 'n' was taken as 0.1. Because in the mountain streams with boulders the value of 'n' varies from "0.04 - 0.1". And in streams with heavy brushes it varies from "0.05 – 0.20". As, our site has heavy brushes and an ample amount of boulders, so we took the value of 'n' as 0.1.
- The model provides for a feature of Auto- Calibration and all the parameters which are not know to us such as the Reaeration rates, CBOD Rates etc. The model uses Genetic Algorithm for the purpose of Auto- Calibration. [**Chapra S.C. and Pelletier G.J.2003**] For the purpose of Auto-Calibration the model is run for 50 generations of 100 population size.
- After the filling up of all the required data the Auto-Calibration feature was run so as to find the remaining parameters. Auto- Calibration is generally run till the predicted values are quite well in agreement with the observed values. The Auto- Calibration was run two times. In the second times the predicted results were quite in agreement to the observed values.

NOTE: though we had divided the reaches into 100m each but as the model changed the lengths of some reaches after the Auto- Calibration as it sought them to be of same parameters.

- The model requires us to input the water quality values of the headwater and all the inflows and outflows so that it can predict the model. As, in addition to the headwater the 1.3km stretch had two waste water inflows (input point 1 (situated at a distance of 0.35 km from the headwater) and input point 2 (situated at a distance of 1.25 km from headwater)), so the detailed values of the various parameters such as the flow, pH, alkalinity and many more of all the three point are given in Table 3.5.
- The model also requires us to enter some additional details about the site conditions (such as the air temperature, dew point temperature and a few more) in addition to the water quality inputs. The data entered in the model is given in Table 3.4.

Table 3.4 Metrological input values in the model

PARAMETER	VALUE
Air Temperature	26.9°C
Dew Point Temperature	14°C
Wind Speed	2m/sec
Cloud Cover	50%

The model requires us to input the details of all the parameters to be modelled by the model. The values have to be entered for all the input sources and the headwater.

Table 3.5 Characteristics of Head Water, Input Point 1&2

PARAMETER	UNIT	VALUE		
		HEADWATER	INPUT POINT 1	INPUT POINT 2
Flow	m^3/sec	0.532	0.0001	0.0001
Temperature	C	26	30	31
Electrical Conductivity	uS/cm 25ºC	0.46	0.2	0.2
Dissolved Oxygen	mg/L	4	7.5	6
BOD	mg/L	18	40	48
Organic Nitrogen	ugN/L	709	1120	840
Ammonical Nitrogen	ugN/L	16091	26508	21280
Generic Constituent / COD	mg/L	40	80	100
Alkalinity	mgCaCO_3/L	574	530	400
pH		8.28	8.35	8.36

3.5 VALIDATION STUDIES

For, the validation of the predicted results validation study was undertaken. For, the purposes of validation of the predicted values sample were collected from five different points in our stretch. The five points were 0.20km from headwater, 0.35 km from headwater, 0.50 km from headwater, 1.0 km from headwater, and 1.2 km from headwater.

- For, the purpose of validation samples was collected for 4 days over a period of 4 weeks. As, most of the values were close to each other so the most adverse values were used for the purpose of validation. The values obtained from validation studies are shown in Table 3.6.

Table 3.6 Characteristics of the 5 validation points

PARAMETER	UNIT	VALUE				
		0.20 km	0.35 km	0.50 km	1.0 km	1.20 km
Travel Time	Days	0.0116	0.012	0.0256	0.045	0.06
Electrical Conductivity	uS/cm 25ºC	0.2	0.2	0.2	0.2	0.2
Dissolved Oxygen	mg/L	4.587	5.324	5.435	6.26	6.39
BOD	mg/L	17.925	17.87	17.8	17.6	17.6
Organic Nitrogen	ugN/L	683.3	668.5	654.1	608.7	591
Ammonical Nitrogen	ugN/L	16040.69	16008.87	15976.2	15865.5	15820
Generic Constituent / COD	mg/L	40.011	40.011	40.011	40.013	40.015
Alkalinity	mgCaCO_3/L	573.83	573.75	573.67	573.45	573.28
pH		8.33	8.35	8.37	8.42	8.44

As, our main motive of conducting this study was to predict the water quality parameters of the water stream and this was done with the help of the QUAL2K model. But, to provide aid for the future studies and in helping them determine the values of the water quality parameters at specific distances form the headwater we can create equations by applying linear regression through SPSS.

So, here we have obtained equations for the point situated at 1.3 km from the headwater. The parameters for which the equations are determined are

1. Alkalinity
2. COD

3. BOD
4. DO
5. NH_3-N
6. Org. N

3.6 STATISTICAL ANALYSIS

Statistical Analysis was performed to develop the equation which could be used to predict the water quality parameter values. SPSS was used to perform the analysis.

Statistical Package for the Social Sciences also commonly known as SPSS is a Java platform software package developed by IBM and is basically used for batched and non-batched statistical analysis.

Regression analysis is a statistical technique that is used to predict the variable of interest (known as dependent variable, criterion or target, the outcome) from a set of other variables (known as independent variables, regressor or explanatory variables, the predictor). Generally, a regression analysis having two or more independent variables is called as multiple regression analysis.

Regression analysis can be used for forecasting and prediction of various models. The results of regression analysis also help in depicting the independent variable which has major effect on the value of dependent variable. Checking R-squared value of the model is most common way of deciding its reliability. Also, the *p*-value obtained by the ANOVA table can be used for determining the significance of generated models. [**Pandurang G.S. 2006**]

Multiple linear regression was used to develop a co relation between the final value at the end point and the independent parameters such as the values from the headwater and the input points. It was performed for all the important parameters and an equation was formed depending upon the input and output values.

- SPSS was used for the purpose of regression.
- 3 cases for every parameter were studied to obtain a data set for SPSS.
- 27 cases for every parameter were run in QUAL2K to obtain the resultant values.

3.6.1 Input data for Statistical Analysis of Alkalinity

The three different cases by which a set of 27 values was formed consist 1 for which the modelling is done and the other 2 sets consist of the less adverse conditions. The 3 sets are shown in Table 3.7

Table 3.7 Input values used for Alkalinity

HEADWATER	INPUT POINT 1	INPUT POINT 2
574	530	400
580	535	500
590	552	440

The 27 different combinations created by using the 3 sets of data available were used for the regression analysis. The 27 combination are shown in Table 3.8.

Table 3.8 Data set used for Alkalinity

HEADWATER	INDUSTRY-1	INDUSTRY-2	RESULT	HEADWATER	INDUSTRY-1	INDUSTRY-2	RESULT
574	530	400	573.27	580	535	500	580.006
574	530	500	574	580	552	400	579.99
574	530	440	573.996	580	552	500	580.009
574	535	400	573.989	580	552	440	579.998
574	535	500	574.01	590	530	400	589.982
574	535	440	573.997	590	530	500	590.001
574	552	400	573.993	590	530	440	589.99
574	552	500	574.011	590	535	400	589.983
574	552	440	574	590	535	500	590.002
580	530	400	579.98	590	535	440	589.991
580	530	500	580.005	590	552	400	589.987
580	530	440	579.994	590	552	500	590.005
580	535	400	579.987	590	552	440	589.994
580	535	440	579.995				

3.6.2 Input data for Statistical Analysis of COD

The three different cases by which a set of 27 values was formed consist 1 for which the modelling is done and the other 2 sets consist of the less adverse conditions. The 3 sets are shown in Table 3.9.

Table 3.9 Input values used for COD

HEADWATER	INPUT POINT 1	INPUT POINT 2
40	80	100
45	75	98
50	70	120

The 27 different combinations created by using the 3 sets of data available were used for the regression analysis. The 27 combination are shown in Table 3.10.

Table 3.10 Data set used for COD

HEADWATER	INDUSTRY-1	INDUSTRY-2	RESULT	HEADWATER	INDUSTRY-1	INDUSTRY-2	RESULT
40	80	100	40.02	45	75	120	45.016
40	80	98	40.0184	45	70	100	45.0162
40	80	120	40.01842	45	70	98	45.0164
40	75	100	40.0183	45	70	120	45.01682
40	75	98	40.018	50	80	100	50.015
40	75	120	40.01	50	80	98	50.0151
40	70	100	40.0181	50	80	120	50.0148
40	70	98	40.0179	50	75	100	50.01501
40	70	120	40.0186	50	75	98	50.0152
45	80	100	45.0169	50	75	120	50.0156
45	80	98	45.0165	50	70	100	50.0154
45	80	120	45.017	50	70	98	50.0156
45	75	100	45.0168	50	70	120	50.01501
45	75	98	45.01				

3.6.3 Input data for Statistical Analysis of BOD

The three different cases by which a set of 27 values was formed consist 1 for which the modelling is done and the other 2 sets consist of the less adverse conditions. The 3 sets are shown in Table 3.11.

Table 3.11 Input values for BOD

HEADWATER	INPUT POINT 1	INPUT POINT 2
18	40	50
20	37	45
22	35	52

The 27 different combinations created by using the 3 sets of data available were used for the regression analysis. The 27 combination are shown in Table 3.12.

Table 3.12 Data set used for BOD

HEADWATER	INDUSTRY-1	INDUSTRY-2	RESULT	HEADWATER	INDUSTRY-1	INDUSTRY-2	RESULT
18	40	50	17.58	20	37	52	19.5347
18	40	45	17.5831	20	35	50	19.5352
18	40	52	17.5843	20	35	45	19.53501
18	37	50	17.5824	20	35	52	19.53497
18	37	45	17.5839	22	40	50	21.487
18	37	52	17.5841	22	40	45	21.501
18	35	50	17.5828	22	40	52	21.485
18	35	45	17.5836	22	37	50	21.4903
18	35	52	17.5846	22	37	45	21.486
20	40	50	19.535	22	37	52	21.49
20	40	45	19.535	22	35	50	21.4876
20	40	52	19.5349	22	35	45	21.4902
20	37	50	19.5351	22	35	52	
20	37	45	19.5348				

3.6.4 Input data for Statistical Analysis of DO

The three different cases by which a set of 27 values was formed consist 1 for which the modelling is done and the other 2 sets consist of the less adverse conditions. The 3 sets are shown in Table 3.13.

Table 3.13 Input values for DO

HEADWATER	INPUT POINT 1	INPUT POINT 2
3.8	7.0	5.8
4.0	7.5	6.0
4.3	7.9	7.4

The 27 different combinations created by using the 3 sets of data available were used for the regression analysis. The 27 combination are shown in Table 3.14.

Table 3.14 Data set for DO

HEADWATER	INDUSTRY-1	INDUSTRY-2	RESULT	HEADWATER	INDUSTRY-1	INDUSTRY-2	RESULT
4	7.5	6	6.43	3.8	7	7.4	6.40099
4	7.5	5.8	6.429	3.8	7.9	6	6.40104
4	7.5	7.4	6.428	3.8	7.9	5.8	6.40103
4	7	6	6.4283	3.8	7.9	7.4	6.40108
4	7	5.8	6.42829	4.3	7.5	6	6.4725
4	7	7.4	6.42834	4.3	7.5	5.8	6.4726
4	7.9	6	6.4284	4.3	7.5	7.4	6.4723
4	7.9	5.8	6.42839	4.3	7	6	6.4725
4	7.9	7.4	6.42844	4.3	7	5.8	6.47251
3.8	7.5	6	6.401	4.3	7	7.4	6.473
3.8	7.5	5.8	6.4009	4.3	7.9	6	6.47261
3.8	7.5	7.4	6.40104	4.3	7.9	5.8	6.4726
3.8	7	6	6.40094	4.3	7.9	7.4	6.472
3.8	7	5.8	6.4				

3.6.5 Input data for Statistical Analysis of Org. N

The three different cases by which a set of 27 values was formed consist 1 for which the modelling is done and the other 2 sets consist of the less adverse conditions. The 3 sets are shown in Table 3.15.

Table 3.15 Input values for Org. N

HEADWATER	INPUT POINT 1	INPUT POINT 2
700	1100	800
709	1120	840
720	1140	860

The 27 different combinations created by using the 3 sets of data available were used for the regression analysis. The 27 combination are shown in Table 3.16.

Table 3.16 Data set used for Org. N

HEADWATER	INDUSTRY-1	INDUSTRY-2	RESULT	HEADWATER	INDUSTRY-1	INDUSTRY-2	RESULT
700	1100	800	580.2409	709	1120	860	587.5809
700	1100	840	580.2471	709	1140	800	587.575
700	1100	860	580.25	709	1140	840	587.5813
700	1120	800	580.244	709	1140	860	587.5844
700	1120	840	580.2501	720	1100	800	596.5234
700	1120	860	580.253	720	1100	840	596.5296
700	1140	800	580.2479	720	1100	860	596.5327
700	1140	840	580.254	720	1120	800	596.52696
700	1140	860	580.257	720	1120	840	596.5331
709	1100	800	587.568	720	1120	860	596.5362
709	1100	840	587.574	720	1140	800	596.53
709	1100	860	587.5773	720	1140	840	596.5367
709	1120	800	587.571	720	1140	860	596.5398
709	1120	840	587.5779				

3.6.6 Input data for Statistical Analysis of NH_3-N

The three different cases by which a set of 27 values was formed consist 1 for which the modelling is done and the other 2 sets consist of the less adverse conditions. The 3 sets are shown in Table 3.17

Table 3.17 Input values for NH_3-N

HEADWATER	INPUT POINT 1	INPUT POINT 2
16000	26400	21200
16091	26508	21280
16200	22600	21400

The 27 different combinations created by using the 3 sets of data available were used for the regression analysis. The 27 combination are shown in Table 3.18.

Table 3.18 Data set used for NH_3-N

HEADWATER	INDUSTRY-1	INDUSTRY-2	RESULT	HEADWATER	INDUSTRY-1	INDUSTRY-2	RESULT
16000	26400	21200	15720.357	16091	26508	21400	15809.643
16000	26400	21280	15720.3722	16091	26600	21200	15809.624
16000	26400	21400	15720.3944	16091	26600	21280	15809.638
16000	26508	21200	15720.3776	16091	26600	21400	15809.661
16000	26508	21280	15720.3924	16200	26400	21200	15809.466
16000	26508	21400	15720.4145	16200	26400	21280	15809.48
16000	26600	21200	15720.3948	16200	26400	21400	15809.503
16000	26600	21280	15720.4096	16200	26508	21200	15809.486
16000	26600	21400	15720.4317	16200	26508	21280	15809.501
16091	26400	21200	15809.5867	16200	26508	21400	15809.523
16091	26400	21280	15809.6016	16200	26600	21200	15809.503
16091	26400	21400	15809.623	16200	26600	21280	15809.518
16091	26508	21200	15809.606	16200	26600	21400	15809.54
16091	26508	21280	15808.63				

CHAPTER-4

RESULTS AND DISCUSSIONS

After all the testing and input of values was done the model was run and the values were predicted by the model for a stretch of 1.3km. The last point in the stretch was at a distance of 0.50km from the second input point. The predicted results and the comparison studies have been shown in this chapter.

4.1 RESULTS

The model predicted values very accurately.

- The water temperature varied from 26°C at the headwater to 24.76°C at the end point.
- The DO level varied from 4 mg/L at the headwater to 6.43 mg/L at the end point.
- The BOD level decreased along the stretch from 18.0 mg/L at the headwater to 17.58 mg/L at the end point.
- Alkalinity reduced from 574.00mgCaCO_3/Lat the headwater to 573.27 mgCaCO_3/Lat the end point.

All the other predicted values of the various parameters that were modelled are shown in Table 4.1.

The model was used to predict the values of various parameters over a stretch of 1.3km. The results predicted by the model are shown in the table below:

Table 4.1 Predicted values of various parameters

REACH	DISTANCE D/S (km)	T (°C)	EC uS/cm 25ºC	DO (mg/L)	BOD (mg/L)	COD (mg/L)	ORG. N (ugN/L)	NH_3-N (ugN/L)	ALKALINITY (mgCaCO_3/L)	pH	DISPERSION (m^2/sec)
Headwater	1.30	26.00	0.46	4.00	18.00	40.00	709.00	16091.00	574.00	8.28	
1	1.25	25.90	0.46	4.41	17.97	40.00	698.60	16070.79	573.95	8.30	0.266075
2	1.15	25.80	0.46	4.76	17.94	40.01	688.42	16051.08	573.86	8.32	0.266075
3	1.05	25.70	0.46	5.07	17.91	40.01	678.40	16029.96	573.81	8.34	0.266075
4	0.95	25.60	0.46	5.32	17.88	40.01	668.55	16008.50	573.75	8.36	0.266075
5	0.85	25.50	0.46	5.55	17.85	40.01	658.89	15986.73	573.70	8.38	0.26605
6	0.75	25.41	0.46	5.72	17.81	40.01	649.37	15964.53	573.65	8.39	0.26605
7	0.65	25.31	0.46	5.87	17.78	40.01	640.03	15942.15	573.59	8.41	0.26605
8	0.55	25.22	0.46	6.01	17.75	40.01	630.87	15919.61	573.54	8.42	0.26605
9	0.45	25.13	0.46	6.12	17.71	40.01	621.88	15896.94	573.49	8.43	0.26605
10	0.35	25.03	0.46	6.23	17.68	40.02	613.11	15875.15	573.43	8.44	0.26605
11	0.25	24.94	0.46	6.30	17.65	40.02	604.42	15852.07	573.37	8.45	0.26605
12	0.15	24.85	0.46	6.37	17.62	40.02	595.89	15828.96	573.32	8.46	0.26599
13	0.05	24.76	0.46	6.43	17.58	40.02	587.53	15805.82	573.27	8.47	0.26599
Terminus	0.00	24.76	0.46	6.43	17.58	40.02	587.53	15805.82	573.27	8.47	0.26599

The model very well predicted the scenario of the water stream. Various conclusions were predicted from the obtained results. The results predicted that

- With the increase in distance the DO level increases, which is an indication that the organic matter/biological matter disperses with distance.
- The BOD content of the water stream fell with the increase in the distance. It could also be implied from the fact that DO level was increasing in the water which was a clear indication that BOD level was falling.
- The water stream had a dispersion value of 0.26 which was almost constant throughout the length.

4.2 COMPARISON OF RESULTS

So, as to check that the predicted values are correct, sampling was done at 5 point along the 1.3 km stretch and the results obtained were compared to the results predicted by the model.The comparison so done is shown via means of various graphs. The predicted and observed results were found to be quite in agreement with each other. Figure 4.1 to Figure 4.8 show the comparison of the predicted and the observed values of the variousparameters that were considered for our study

4.2.1 Comparison for Alkalinity

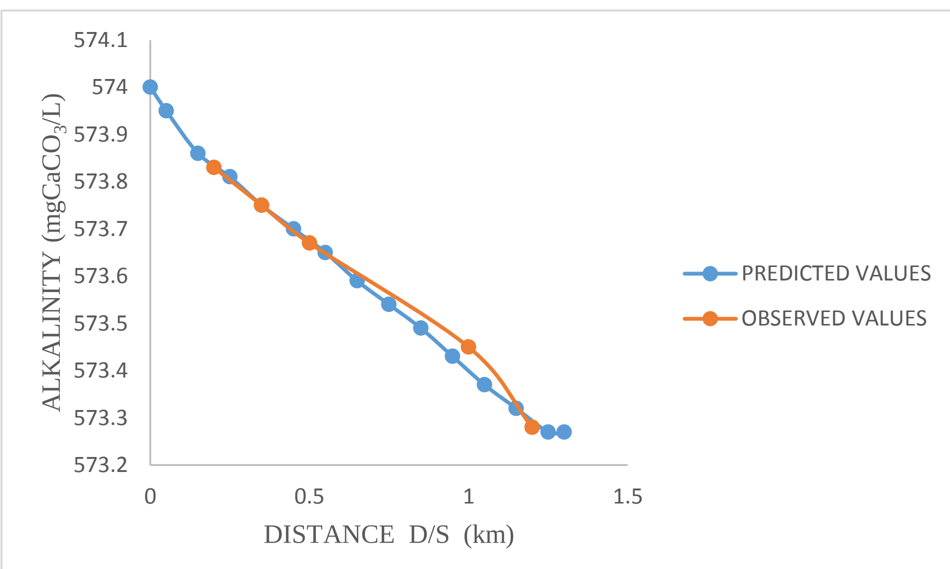

Figure 4.1 Comparison of results of observed and predicted values of Alkalinity

As, from the graph it is quite evident that alkalinity of the water is decreasing with the distance as predicted by the software. The blue line shows the predicted values. The observed values are depicted with the help of orange line. The observed and predicted values show that both the results are well in accordance with each other. The maximum error between the observed and the predicted values was found to be 0.0008%. The results predicted and observed both show that the alkalinity is decreasing with distance which is the main reason why we are seeing an increase in the pH of water with distance.

4.2.2 Comparison for BOD

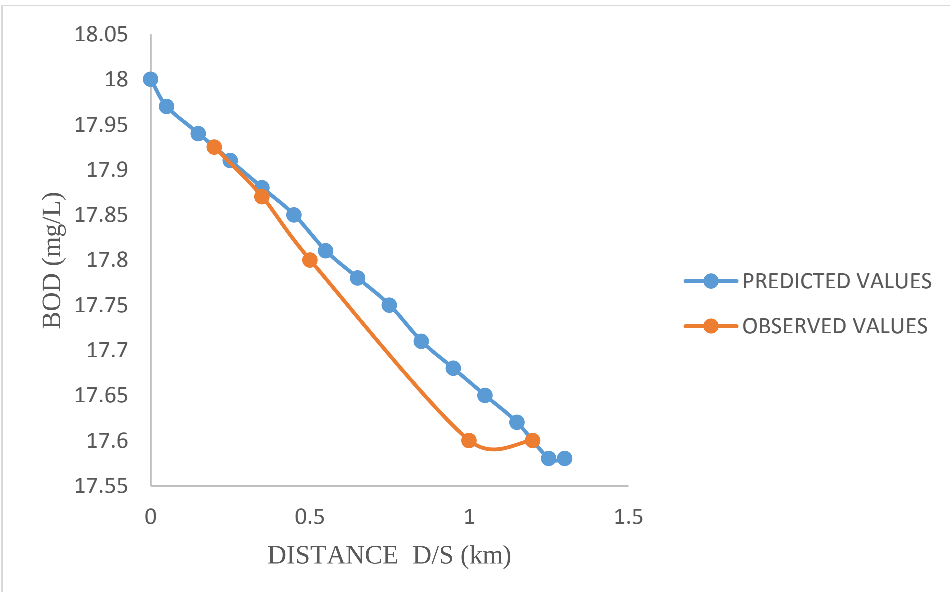

Figure 4.2 Comparison of results of observed and predicted values of BOD

As, from the graph it is quite evident that BOD of the water is decreasing with the distance as predicted by the software. The blue line shows the predicted values. The observed values are depicted with the help of orange line. The observed values show that the predicted results are well in accordance with the predicted values, though in some places the observed value is less than the predicted value which is good from the designing point of view. The maximum error between the observed and the predicted values was found to be 0.3679%. The decrease in BOD means that the biological content in the water stream is decreasing thereby leading to an increase in the DO content in the water stream, which is also seen in our results.

4.2.3 Comparison for COD

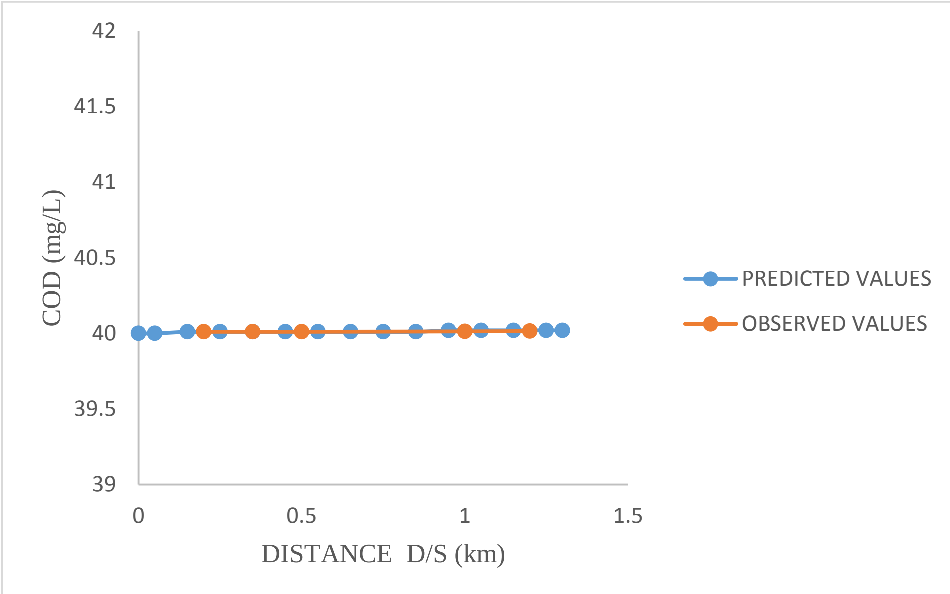

Figure 4.3 Comparison of results of observed and predicted values of COD

As, from the graph it is quite evident that COD of the water is increasing with the distance as predicted by the software. Though the increase is very small but in overall it would be said that COD is increasing. The blue line shows the predicted values. The observed values are depicted with the help of orange line. The observed and predicted values show that both the results are well in accordance with each other. The maximum error between the observed and the predicted values was found to be 0.01749%. As, from our results we can see that the BOD is decreasing but the COD is increasing though at a very slow rate but it is increasing, so that means that the bacteria present in the water stream is non oxidisable. That is the main reason why COD is not decreasing rather increasing.

4.2.4 Comparison for DO

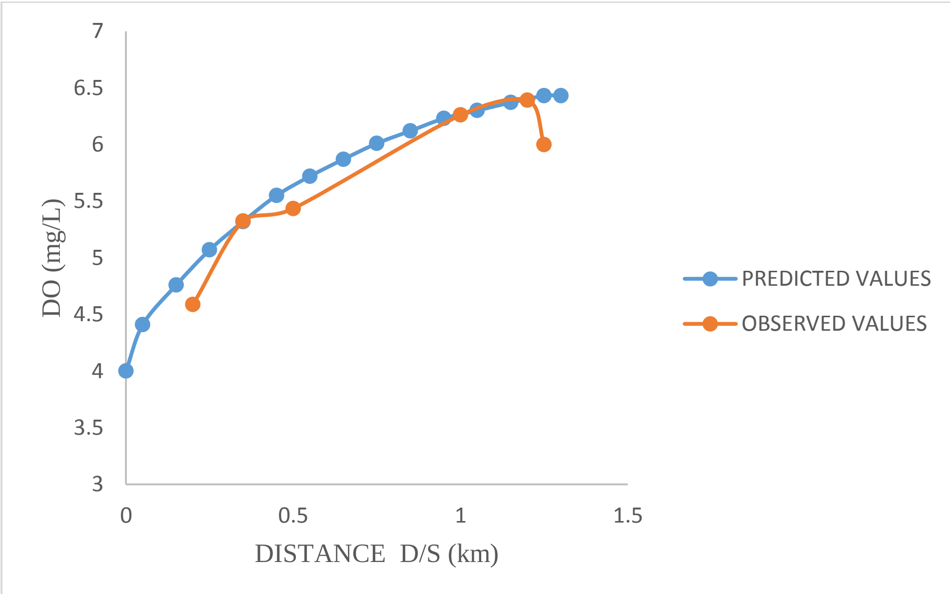

Figure 4.4 Comparison of results of observed and predicted values of DO

As, from the graph it is quite evident that dissolved oxygen of the water is increasing with the distance as predicted by the software. The blue line shows the predicted values. The observed values are depicted with the help of the orange line. The observed values show that the predicted results are well in accordance with the predicted values. The observed values are a little less than the predicted values and it is also in good accordance as BOD is decreasing so DO is increasing. The maximum error between the observed and the predicted values was found to be 0.7.15%.

4.2.5 Comparison for NH_3-N

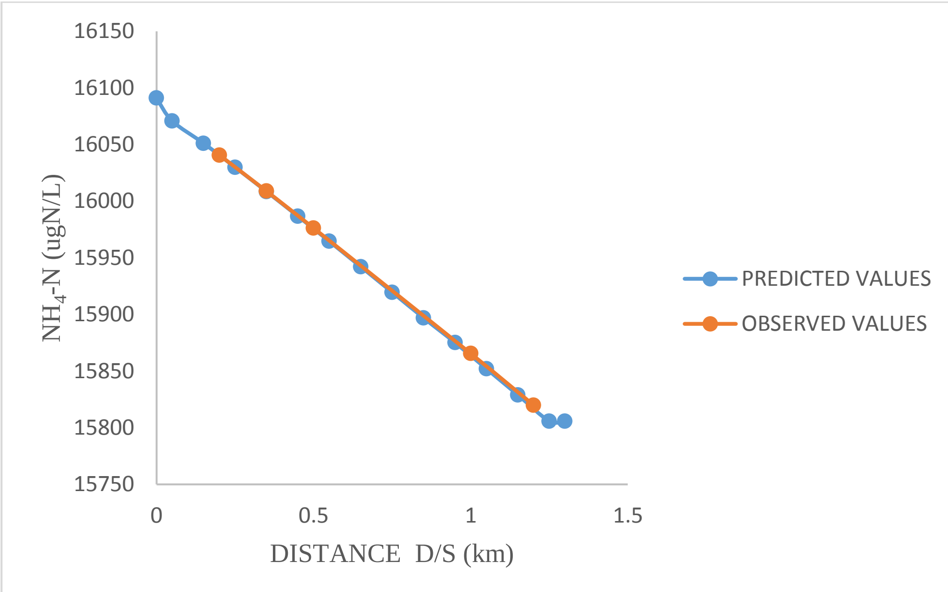

Figure 4.5 Comparison of results of observed and predicted values of NH_3-N

As, from the graph it is quite evident thatNH_3-Ncontent of the water is decreasing with the distance as predicted by the software. The blue line shows the predicted values. The observed values are depicted with the help of the orange line. The observed and predicted values show that both the results are well in accordance with each other. The maximum error between the observed and the predicted values was found to be 0.0001%.

4.2.6 Comparison for Org. N

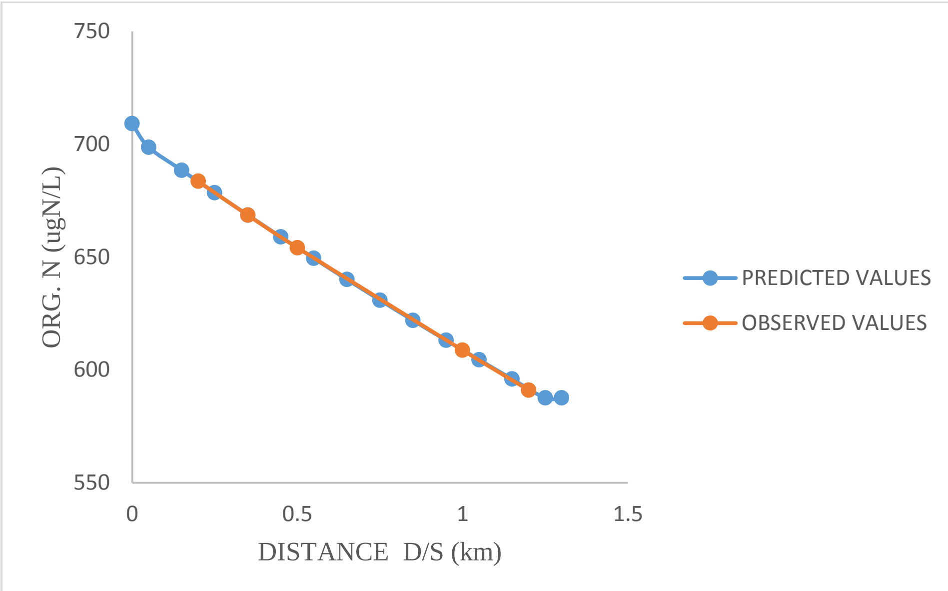

Figure 4.6 Comparison of results of observed and predicted values of Org. N

As, from the graph it is quite evident that organic nitrogen of the water is decreasing with the distance as predicted by the software. The blue line shows the predicted values. The observed values are depicted with the help of the orange line. The observed and predicted values show that both the results are well in accordance with each other. The maximum error between the observed and the predicted values was found to be 0.0001%.

4.2.7 Comparison for pH

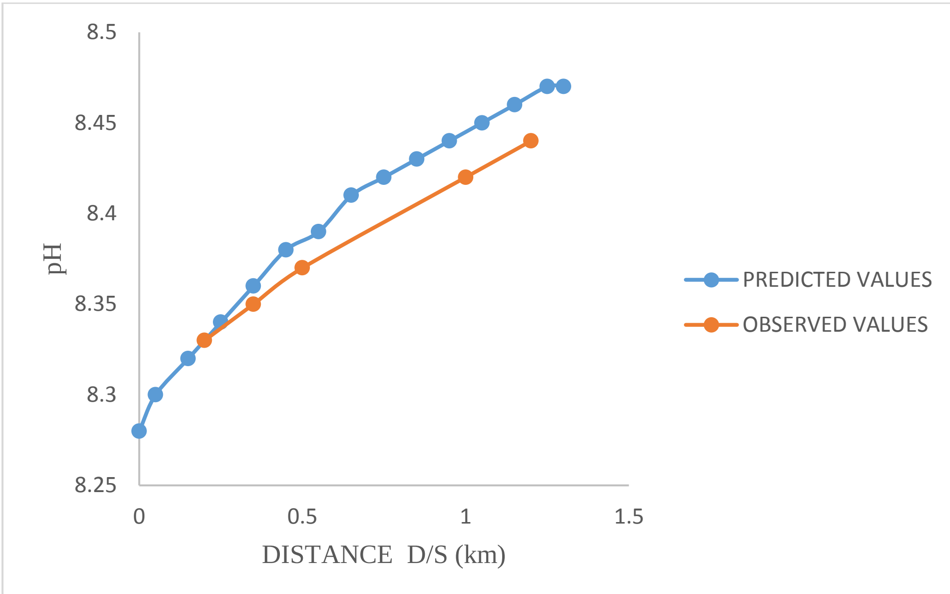

Figure 4.7 Comparison of results of observed and predicted values of pH

As, from the graph it is quite evident that pH of the water is increasing with the distance as predicted by the software. The blue line shows the predicted values. The observed values are depicted with the help of the orange line. The observed and predicted values show that both the results are well in accordance with each other. The maximum error between the observed and the predicted values was found to be 0.29%. The increase in pH is quite linear to the decrease in alkalinity. As, the alkalinity is decreasing with distance the pH is increasing with distance.

4.3 DEVELOPMENT OF ANALYTICAL EQUATIONS

Linear regression via SPSS was used for the formation of equations which would help the prediction of water quality of certain parameters of the water stream very easy.

4.3.1 Alkalinity:

The linear regression was run for the 27 cases formed earlier. The analysis showed that the model is significant. The model had a p value less than 0.05 (as shown in Table 4.3) and a R square value of 1.00 (as shown in Table 4.4) which is very good.

Table 4.2Anova Details of Alkalinity

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression Residual Total	1185.814 .430 1186.244	3 23 26	395.271 0.019	21151.889	0.00

a. Dependent Variable: Result
b. Predictors: (Constant), Indsustry-2, Industry-1, Headwater

Table 4.3 Model Summary of Alkalinity

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	1.00	1.00	1.00	0.1367	1.00	21151.8	3	23	0.00

a. Predictors: (Constant), INDUSTRY-2, INDUSTRY-1, HEADWATER
b. Dependent variable: RESULT

Final equation was derived from the results obtained in Table 4.5. The equation obtained is as follows:

Value of Alkalinity = $-4.432 + 1.004\ HW + 0.003I_1 + 0.001I_2$…………...................................4.1

Where,

HW stands for alkalinity value in Head Water

I_1stands for alkalinity value in Industry 1

I_2 stands for alkalinity value in Industry 2

Table 4.4 Coefficients for Equation of Alkalinity

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Zero-Order	Partial	Part	Tolerance	VIF
(CONSTANT)	-4.432	2.779		-1.595	0.124					
HEADWATER	1.004	0.004	1.00	251.89	0.00	1.00	1.00	1.00	1.00	1.00
INDUSTRY-1	0.003	0.003	0.004	1.051	0.304	0.004	0.214	0.004	1.00	1.00
INDUSTRY-2	0.001	0.001	0.006	1.441	0.163	0.006	0.288	0.006	1.00	1.00

a. Dependent Variable: Result

4.3.2 COD

The linear regression was run for the 27 cases formed earlier. The analysis showed that the model is significant. The model had a p value less than 0.05 (as shown in Table 4.6) and a R square value of 1.00 (as shown in Table 4.7) which is very good.

Table 4.5Anova Details for COD

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	449.790	3	149.939	32354467.791	0.00
Residual	0.00	23	0.00		
Total	449.790	26			

a. Dependent Variable: Result

b. Predictors: (Constant), Indsustry-2, Industry-1, Headwater

Table 4.6 Model Summary of COD

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	1.00	1.00	1.00	0.0021527	1.00	32354467.79	3	23	0.00

a. Predictors: (Constant), INDUSTRY-2, INDUSTRY-1, HEADWATER

b. Dependent variable: RESULT

Final equation was derived from the results obtained in Table 4.8. The equation obtained is as follows:

Value of COD = 0.27 + 1.0 HW + 2.32 x 10^{-5} I_1 + 2.386 x $10^{-5}$$I_2$…………………....…………4.2

Where,

HW stands for COD value in Head Water

I_1 stands for COD value in Industry 1

I_2 stands for COD value in Industry 2

Table 4.7 Coefficients for Equation of COD

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Zero-Order	Partial	Part	Tolerance	VIF
(CONSTANT)	-0.27	0.010		2.786	0.11					
HEADWATER	1.000	0.00	1.00	9852.076	0.00	1.00	1.000	1.000	1.00	1.00
INDUSTRY-1	2.322E-005	0.00	0.000	0.229	0.821	0.000	0.048	0.000	1.00	1.00
INDUSTRY-2	2.386E-005	0.00	0.000	-0.572	00.573	0.000	-0.118	0.000	1.00	1.00

a. Dependent Variable: Result

4.3.3 BOD

The linear regression was run for the 27 cases formed earlier. The analysis showed that the model is significant. The model had a p value less than 0.05 (as shown in Table 4.9) and a R square value of 1.00 (as shown in Table 4.10) which is very good.

Table 4.8Anova Details of BOD

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression Residual Total	68.673 0.00 68.673	3 23 26	22.891 0.00	2694084.99 0	0.00

a. Dependent Variable: Result
b. Predictors: (Constant), Indsustry-2, Industry-1, Headwater

Table 4.9 Model Summary of BOD

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	1.00	1.00	1.00	0.0029149	1.00	269084.99	3	23	0.00

Predictors: (Constant), INDUSTRY-1, INDUSTRY-2, HEADWATER
Dependent variable: FINAL

Final equation was derived from the results obtained in Table 4.11. The equation obtained is as follows:

Final value of BOD = $0.012 + 0.977\ HW + 3.667 \times 10^{-5}\ I_1 + 0.001\ I_2$……………………….…..4.3

Where,
HW stands for BOD value in Head Water
I_1 stands for BOD value in Industry 1
I_2 stands for BOD value in Industry 2

Table 4.10 Coefficients for Equation of BOD

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Zero-Order	Partial	Part	Tolerance	VIF
(CONSTANT)	0.12	0.015		0.776	0.446					
HEADWATER	0.977	0.00	1.00	2842.931	0.00	1.00	1.000	1.000	1.00	1.00
INDUSTRY-1	3.667E-005	0.00	0.000	0.134	0.894	0.00	0.028	0.000	1.00	1.00
INDUSTRY-2	0.001	0.00	0.000	1.055	00.303	0.00	-0.215	0.000	1.00	1.00

a. Dependent Variable: Result

4.3.4DO

The linear regression was run for the 27 cases formed earlier. The analysis showed that the model is significant. The model had a p value less than 0.05 (as shown in Table 4.12) and a R square value of 1.00 (as shown in Table 4.13) which is very good.

Table 4.11: Anova Details of DO

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	0.23	3	0.008	18451.51	0.00
Residual	0.00	23	0.00		
Total	0.23	26			

a. Dependent Variable : Result

b. Predictors: (Constant), Industry-2, Industry-1, Headwater

Table 4.12 Model Summary of DO

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	1.00	1.00	1.00	0.00065	1.00	18451.51	3	23	0.00

a. Predictors: (Constant), IDUSTRY-2, INDUSTRY-1, HEADWATER

b. Dependent Variable: Result

Final equation was derived from the results obtained in Table 4.14. The equation obtained is as follows:

Final value of DO = 5.855 + 0.143 HW + 0.001 I_1 + 6.711 x 10^{-5} I_2………………………..4.4

Where,

HW stands for DO value in Head Water

I_1 stands for DO value in Industry 1

I_2 stands for DO value in Industry 2

Table 4.13 Coefficients for Equation of DO

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Zero-Order	Partial	Part	Tolerance	VIF
(CONSTANT)	5.855	0.04		1576.242	0.00					
HEADWATER	0.143	0.01	1.00	235.275	0.00	1.00	1.000	1.000	1.00	1.00
INDUSTRY-1	0.001	0.00	0.001	0.317	0.754	0.01	0.066	0.01	1.00	1.00
INDUSTRY-2	6.711E-005	0.00	0.002	-0.381	0.707	-0.02	-0.079	-0.02	1.00	1.00

a. Dependent Variable: Result

4.3.5 Org. N

The linear regression was run for the 27 cases formed earlier. The analysis showed that the model is significant. The model had a p value less than 0.05 (as shown in Table 4.15) and a R square value of 1.00 (as shown in Table 4.16) which is very good.

Table 4.14: Anova Details of Org. N

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	1197.048	3	399.016	8617528472.19	0.00
Residual	0.000	23	0.00		
Total	1197.048	26			

a. Dependent Variable : Result

b. Predictors: (Constant), Industry-2, Industry-1, Headwater

Table 4.15 Model Summary of Org. N

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	1.00	1.00	1.00	0.0002152	1.00	8617528472.19	3	23	0.00

a. Predictors: (Constant), IDUSTRY-2, INDUSTRY-1, HEADWATER
b. Dependent Variable: Result
c.

Final equation was derived from the results obtained in Table No 4.17. The equation obtained is as follows:

Final value of Org. N = 10.028 + 0.814 HW + 0.001 I_1 + 0.001 I_2………………………...4.5

Where,
HW stands for Org. Nitrogen value in Head Water
I_1 stands for Org. Nitrogen value in Industry 1
I_2 stands for Org. Nitrogen value in Industry 2

Table 4.16 Coefficients for Equation of Org. N

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Zero-Order	Partial	Part	Tolerance	VIF
(CONSTANT)	10.028	0.05		2095.803	0.00					
HEADWATER	0.814	0.00	1.00	160787.35	0.00	1.00	1.000	1.00	1.00	1.00
INDUSTRY-1	0.001	0.00	0.000	69.118	0.00	0.00	0.998	0.00	1.00	1.00
INDUSTRY-2	0.001	0.00	0.001	93.986	0.00	0.001	0.999	0.001	1.00	1.00

a. Dependent Variable: Result

4.3.6NH_3-N

The linear regression was run for the 27 cases formed earlier. The analysis showed that the model is significant. The model had a p value less than 0.05 (as shown in Table 4.18) and a R square value of 0.704 (as shown in Table 4.19) which is very good.

Table 4.17: Anova Details of NH_3-N

Model	Sum of Squares	Df	Mean Square	F	Sig.
Regression	33528.679	3	1117.226	18.205	0.00
Residual	14119.616	23	613.896		
Total	47648.295	26			

a. Dependent Variable : Result
b. Predictors: (Constant), Industry-2, Industry-1, Headwater

Table 4.18 Model Summary of NH_3-N

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	0.839	0.704	0.665	24.7769314	0.704	18.205	3	23	0.00

a. Predictors: (Constant), IDUSTRY-2, INDUSTRY-1, HEADWATER
b. Dependent Variable: Result

Final equation was derived from the results obtained in Table 4.20. The equation obtained is as follows:

Final value of NH_3-N= $8832.201 + 0.431\ HW + 0.001\ I_1 + 0.001\ I_2$…………………4.6

Where,

HW stands for NH_3-Nvalue in Head Water

I_1 stands for NH_3-Nvalue in Industry 1

I_2 stands for NH_3-Nvalue in Industry 2

Table 4.19 Coefficients for Equation of NH_3-N

Model	Unstandardized Coefficients		Standardized Coefficients	T	Sig.	Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Zero-Order	Partial	Part	Tolerance	VIF
(CONSTANT)	8832.201	2190.388		4.032	0.01					
HEADWATER	0.431	0.058	0.839	7.390	0.00	0.839	0.839	0.839	1.00	1.00
INDUSTRY-1	0.001	0.058	0.000	0.003	0.998	0.00	0.001	0.00	1.00	1.00
INDUSTRY-2	0.001	0.058	0.001	0.004	0.997	0.001	0.001	0.001	1.00	1.00

a. Dependent Variable: Result

CHAPTER-5

CONCLUSION

The objective of the study was to predict the water quality parameters of water stream in which waste water was being discharged from two input points.

From, various studies conducted earlier it was quite evident that the parameters most dominant and effective in water streams are pH, COD, DO, BOD, NH_3 -N, Org N, EC. From the studies it was also evident that the most accurate and easy to use model available freely for water quality modelling is QUAL2K.

The results predicted from the model were found to be quite in agreement with the tests performed in the laboratory. From the tests performed it was quite evident that pollutant quantity decreases with distance and the pollutants from input sources were not that effective because the quantity of discharge from them was very less compared to the head discharge.

The functional relationship between the dependent and independent terms is made using SPSS and found that the predicted equation which is used to determine the various parameters such as BOD, DO, COD etc. associated well with the observed values.

5.2 FURTHER WORKS THAT CAN BE DONE:

1. A fresh water stream having a more dominant impact on the lives of the people can be taken up for study.
2. A larger stretch of the river can be taken up for the study purpose.
3. More advanced parameters such as phosphorous, sodium etc. can be included in the study.

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ANNEXURE-I

VARIOUS METHODS OF ANALYSIS

DO

DO is generally determined by the help of the Wrinkler's method. It is based upon the fact that oxygen oxidizes Mn^{2+} to a higher state of valency under alkaline conditions.

REAGENTS TO BE USED:

1. Manganese Sulfate Solution: Dissolve 480g $MnSO_4.4H_2O$in 600ml distilled water. Filter the sample after dissolution and make total volume one litre with distilled water.
2. Alakali-Iodide-azide reagent: Dissolve 500gm of NaOH and 135gm of NaI or 700gm KOHand 150gm KI in distilled water. Take 10gm of $NaN_3$and dissolve in 40ml distilled water. Add this solution in the above mixture and make total 1 litre solution.
3. Concentrated Sulfuric Acid
4. Starch Indicator: Add 2gm of soluble starch and 0.2gm of Salicylic acid in 100ml of warm distilled water.
5. Standard Sodium thiosulfate (0.025N): Dissolve 6.205g $Na_2S_2O_3.5H_2O$in distilled water. Make the total volume 1 litre.

PROCEDURE:

1. Fill the sample in 300ml bottle. Add 1ml $MnSO_4$solution and then 1ml alkali-iodide-azide solution at the bottom of the bottle or atleast 1/4 below from the top. Brown precipitate will appear.
2. Mix the precipitates by shaking the bottle up and down and allow them to settle for 2-3 minute. When the precipitates have settled sufficiently, add 2ml alkali-iodide azide solution.
3. Restopper and mix the content by inverting several times until dissolution of floc is complete.
4. Take 200 ml of sample in a conical flask and titrate it with 0.025N sodium thiosulfate in the presence of starch as indicator. The end point will be blue to colorless.

PRECAUTIONS:

1. Protect the stored sample from strong sun light.
2. Identify the end point by the first decolorization of the sample then addition of starch and again make it colorless.

BOD

If the analysis is done within 2 hours of sampling then no cold storage is required. But, otherwise the sample should be stored at 4 °C

REAGENTS:

1. Phosphate Buffer: Dissolve 8.5gmKH_2PO_4, 21.75gmK_2HPO_4, 33.4gm$Na_2HPO_4.7H_2O$, and 1.7gm NH_4Cl in 50ml distilled water and dilute it to 1 litre. The pH should be 7.2 without further adjustment.
2. Magnesium Sulfate Solution: Dissolve 22.5gm of $MgSO_{4.}7H_2O$in distilled water and dilute it to 1 litre.
3. Calcium Chloride Solution: Dissolve 27.15gm $CaCl_2$in Distilled water and dilute to 1 litre.
4. Ferric Chloride: Dissolve 0.25 $FeCl_3.6H_2O$in distilled water and dilute to 1 litre.

Calculate the dilution factor and then prepare the Dilution Water by aerating water for 24 hours by keeping it at 20C and then adding 1ml / lt each of phosphate buffer, $MgSO_4, CaCl_2 and FeCl_3$.

PROCEDURE:

1. Prepare the dilution water. (As mentioned above)
2. Collect the representative sample and find out the dilution factor of the sample.
3. Transfer the water into the BOD bottle through siphoning from aspirator bottle.
4. Fill atleast 5 bottles for 1 sample. Keep 3 bottles at 20C for incubation and measure the DO for the remaining 2 bottles.
5. For, the bottles incubated at 20°C ensure that the bottles have water in the funnel acting as a water seal. After the desired period of incubation test the bottle forthe DO concentration and consider this DO as the final DO

COD

Closed Reflux Method is used for the determination of COD. Here, the sample and blank are digested/ oxidized in a closed system of culture tubes with sealed ampulas placed in a block digester or in an oven preheated at 150 ± 2°C for 2 hours. The digested sample is cooled and then titrated with FAS. The sample used generally varies from 2.5 to 10ml. The method is cost advantageous and it generates minimum hazardous waste.

REAGENTS

1. Standard potassium dichromate solution 0.0167M: Dissolve 4.913gm of$K_2Cr_2O_7$, 167 ml of concentrated sulfuric acid and 33.3gm of Mercuric Sulfate in 500ml of distilled water, cool the solution and make a total volume of 1 litre.
2. Standard dichromate (0.0347M): Dissolve 10.216gm of Potassium Dichromate in the same amount of $H_2SO_4$and Mercuric sulfate.
3. Ferrous Ammonium Sulfate Solution (FAS) (0.01M): Dissolve 39.2gm of FAS in distilled water. Add 20ml concentrated sulfuric acid, then cool and dilute to one litre standardize the FAS solution.
4. Ferrion Indicator: Dissolve 1.485gm of Phenanthroline monohydrate and 695 mg $FeSo_4.7H_2O$ in distilled water and dilute to 100ml.

PROCEDURE:

1. Add 1.5 standard dichromate solution in culture tube and 3.5ml of sulfuric acid reagent. Take 2.5ml of sample and add it in the culture tube. Mix the content carefully by shaking the tubes up and down.
2. Place the sample for 2 hours in COD digestor at 150 ± 2°C
3. After 2 hours remove the culture tube from the digestor and transfer the sample into conical flask. Add 1 to 2 drops of ferrion indicator and titrate the contents with FAS and note down the amount of FAS used.

NH_3-N

In waste waters the forms of nitrogen of greatest interest are, in order of decreasing oxidation state, nitrate, nitrite, ammonia and organic nitrogen. There are two major factors that influence the selection of the method to determine ammonia are concentration and presence of interferences.

REAGENTS

1. Borate Buffer: Add 88ml of 0.1 NaOH solution in 500ml of 0.025M sodium tetra borate(9.5g $Na_2B_4O_7.10H_2O$/L of water)
2. Boric Acid: 20g H_3BO_3 in one litre of distilled water.
3. Sodium Thiosulfate: (Dechlorinating agent 3.5g of sodium thiosulfate in 250ml distilled water and make total volume of 1 litre.
4. Mixed Indicator Solution: Dissolve 200mg methyl red indicator in 100ml 95% ethyl alcohol. Dissolve 100mg methylene blue in 50ml 95% ethyl alcohol. Combine both solutions.

PROCEDURE

1. Use 500ml sample. Add 25ml of borate buffer solution and adjust the pH to 9.5 with 6N NaOH using a pH meter.
2. Take 50ml of Boric acid in a 500ml conical flask and place it at the receiving end of distillation unit.
3. Connect the distillation unit and start the heater. Start water circulation also in the unit.
4. Collect 250ml distilled sample in the conical flask.
5. Titrate the sample with standard 0.02NH_2SO_4 until the indicator turns pale lavender.

ORG. N

REAGENTS

1. Mercuric Sulfate: Dissolve 8g of red mercuric oxide, Hgo, in 100ml 6NH_2SO_4.
2. Digestion Reagent: Dissolve 134g K_2SO_4in 650 ml water and 200ml conc.H_2SO_4. Add with stirring, 25ml mercuric sulfate solution. Dilute the combined solution to one litre with water.

3. Sodium hydroxide Sodium Thiosulfate reagent: Dissolve 500g NaOH and 25g of $Na_2S_2O_3.5H_2O$in distilled water and dilute it to one litre.

PROCEDURE

1. The start of the experiment is the same as for Ammonical Nitrogen.
2. Cool the sample obtained after ammonical nitrogen determination. Add 50ml Digestion Reagent to the Kjeldahl flask.
3. Boil the sample again until only 25-50 ml of the sample is left.
4. Add 250-300ml of distilled water and 50ml of Sodium Thiosulfate and connect it to the distillation apparatus.
5. Collect 200ml of distillate in the conical flask containing 50ml boric acid connected to the other end of the distillation apparatus.
6. Titrate the sample with standard 0.02NH_2SO_4 until the indicator turns pale lavender.

ALKALINITY

Alkalinity of water and waste waters is the capacity to neutralize acids. The alkalinity of water is mainly due to the presence of Hydroxides, Carbonates and Bicarbonates. The type and extent of alkalinity present in the water can be determined by titrating the sample.

REAGENTS

1. Standard HCl or H_2SO_4 (N/50)
2. Phenolpthalein Indicator
3. Methyl Orange Indicator

PROCEDURE

1. Take 100ml of sample in a conical flask and add 2 drops of phenopthalein indicator. Titrate the sample with standard HCL until the pink colour just disappears. Note down the titre value as phenopthalein end point.
2. Add 2-3 drops of methyl orange indicator to the same sample solution and continue the titration until a sharp color changes from yellow to orange. Note the total titre value from the beginning of the experiment as methyl orange end point.

EC

EC is the measure of the water's capability to pass electrical flow. This ability is directly related to the concentration of ions in water. These ions which conduct electricity come from dissolved salts and inorganic materials such as alkalis, chlorides, sulfides and other compounds.

PROCEDURE

1. Take a 100ml beaker and weigh it.
2. Pass 100ml of sample from filter paper.
3. Fill the beaker with 100ml of filtered sample water.
4. Place the beaker in heater for a period till the water dries completely from it.
5. Weigh the dried beaker.
6. The difference between the two weights is the value of total dissolved solids
7. With the help of the relation: EC = TDS x 2/1000. We get the value of EC.

PH

pH is a logarithmic scale used to specify the acidity or basicity of an aqueous solution. A pH less than 7 is said to be acidic whereas a pH more than 7 is said to be basic.

PROCEDURE:

pH can be very easily checked with the help of an electronic pH meter.