SR-3

WATER QUALITY AND SEDIMENT MODELLING IN SURFACE WATERS

STATUS REPORT

K K S BHATIA

NATIONAL INSTITUTE OF HYDROLOGY

JAL VIGYAN BHAVAN

ROORKEE (U.P.) INDIA

1983-84

PREFACE

The National Institute of Hydrology is an autonomous Society under the Ministry of Irrigation, Government of India. The Institute is a national research organisation entrusted with carrying out systematic,scientific research activities in basic, theoretical and applied Hydrology which have great relevance to national planning and developmental activities in the area of water resources.

Water quality and sediment modelling is one of the research areas in the work plan of National Institute of Hydrology. It is envisaged in the work plan, to implement, test and validate simulation models for water quality in streams, reservoirs and estuaries and to implement, test and validate sediment routing models through river reaches, reservoirs etc. It is also aimed to develop procedures for control of water quality in streams, including low flow augmentation, effluent standards etc.

The preparation of status report on the subject of "Water quality and sediment modelling in surface waters" is the first step initiated in this direction. The preparation of status reports by the scientists who are likely to proceed abroad for training under UNDP Project, has also been recommended by the Sub-Committee of Technical Advisory Committee.

This report is a collection of literature on the subject of water quality and sediment routing, to bring out the status of the research in the area, so that the gaps in knowledge are brought out, to help in formulating the research plans for future, at National Institute of Hydrology. Though the literature available on the water quality and sediment is voluminous and the research needs are of interdisciplinary nature yet an attempt has been made to review the literature as far as possible.

Very little work has been done in India on the modelling aspects of water quality and sediment routing. It can be inferred from the literature review that though a number of good works are available on the surveys for sedimentation but there is a definite need for modelling studies for sedimentation of reservoirs in Indian context.

As this report covers water quality and sediment routing, two related but different aspects of water, there may be some instances of overlapping as well as gaps, not covered here. To overcome this, an exhaustive, reference list is given at the end of the report.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

The report has been divided into nine chapters. Chapter 1 sets the stage for general introduction of water quality and sediment modelling, the needs of such studies and covers the day by day increase of water resources requirements. Chapter 2 deals with the mathematical modelling, its advantages and classification of various mathematical models. It also gives a step by step method of building a model. Chapter 3 describes the various water quality parameters and gives the standards for various water uses e.g.irrigation water, industrial water, domestic water and water for drinking purposes. It also gives the envisaged planning for a systematic study of Indian rivers. Various parameters stressed by Central Board for Prevention and Control of Water Pollution, for survey, are also discussed. Some of the Indian studies are also discussed. Chapter 4 gives a detailed account of various water quality models available, their advantages and limitations, their capabilities etc. A mention has also been made of non-point source pollution models.

Chapter 5 details the sedimentation concepts giving definitions of various terms encountered in such studies. A comprehensive review of literature on stream load has also been attempted here, touching upon various types of loads e.g.dissolved load, suspended load and bed load. Chapter 6, enumerates reservoir sedimentation, its importance, damages caused by it and importance of carrying out sediment surveys and modelling studies. Various factors causing sediment erosion are also discussed. The sedimentation of few Indian reservoirs and the deposition of sediment and its pattern are also given. Siltation in rivers is included in Chapter 7. The siltation of various rivers of the world is discussed in this chapter. Chapter 8 gives various mathematical models in vogue today. As the literature on this portion is very complex and voluminous it has been attempted to give only a brief introduction of various models.

Chapter 9 brings out the status of the research in the area of water quality and sediment modelling and the needs of research. The report ends with an exhaustive bibliography on the topic.

1.0 INTRODUCTION

1.1 General

Water is one of the most essential constituents of the human environment. Man needs it, in the first place for his physiological existence, just as every other living organism does, and secondly for many other purposes such as industrial water supply, irrigation, power generation, propogation of fish and other aquatic life etc.

Man is making increasing demands upon his surroundings and thereby altering his own natural environment and that of the other organisms living with him on the earth. The demands are increasiang not only because of the rapid growth of human population but also due to the increase in the standards of living.

As part of the general concern for environment, water quality became the important water resources issue in the 1970s. Obvious pollution, existing for decades, had been ignored to pursue water quantity ventures. Suddenly, the situation appeared to be worse and it was. Population growth and urbanisation overloaded the municipal plants and waste waters were discharged with no or little treatment. Most industries, in a pressure to expand their production capacities, dumped their waste water discharges and effluents in nearby lakes and rivers. Mining and petroleum operations were also major pollutants. Too much of pesticides use in irrigation and agriculture also stressed the water environment. The quantities of waste from all these activities exceeded the self purification capacity of many rivers and streams.

Changes in technology created new,and sometime exotic,waterborne wastes, either discharged from manufacturing operations, or appearing in waste water as a result of using the product. Being common in domestic and flood processing waste waters, biodegradable organic matter had been the contaminant of concern and dissolved oxygen concentration the principal indicator of pollution of surface waters. There were no longer adequate parameters for measuring the characters of complex industrial wastes that frequently contributed non-biodegradable substances or compounds poisonous at extremely low levels.

Water quality in flowing water is closely linked to the total water quality in the basin and hence it becomes imperative that water quality assessment and river basin planning are closely related. For any proper river basin planning, whether long range or short term, before going into alternative plans for development it is very essential to combine it with water quality problems, hydrology and analyses (figure 1)

As mentioned, water quality is characterized by many parameters which can be classified as physical, chemical and biological. The number of water quality parameters in each category is limitless. The importance of one over another is dependent on the future uses of the water and background of its users. Until just recently, water quality was the primary concern of sanitary engineering therefore much of the information concerning water quality is in terms of (1) dissolved oxygen, which is a measure of pollution levels and the potential of the water environment of sustaining an aerobic ecosystem,(2) biochemical oxygen demand, a measure of biodegradable organic loading and (3) coliform bacteria, a measure of possible contamination by pathogenic bacteria.

Sedimentation in rivers is also of great concern to hydrologists. Sediment can be classified as wash load -which is the very fine material washed into the stream, suspended load-which is sediment from bed material and bed load -which is bed material that moves along the stream bottom. Sedimentation and water quality are two of the important criteria while going in for river basin planning . .

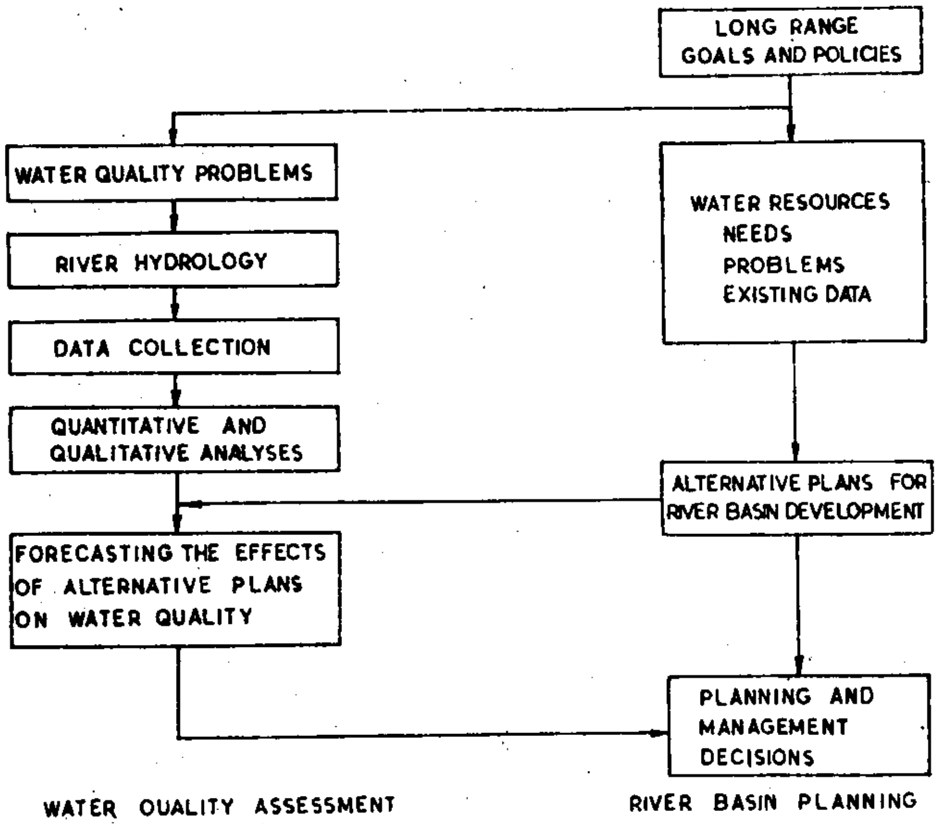


FIGURE 1- WATER QUALITY IN FLOWING WATERS

1.2 Need for Water Quality, Sedimentation Studies

Here it would be inevitable to stress the need for data for testing or using any mathematical model. Water quality and sediment data which are both accurate and readily available in sufficient quantity are necessary pre-requisite in the formulation and verification of mathematical models. In many cases, unfortunately, the costs of collecting such data are becoming prohibitive. Although there will be abundance of data available, the utility of such data for modelling studies would be questionable because rational criteria in specifying sampling frequency, station location and data analysis are non existent in the planning and design of networks. Hence it is firstly needed to have proper design of such networks. The design of such networks can be arrived at, based on various uses to which the analysis would be put to, as well as on the quality of source water and expected contaminations in it.

Impounded waters often have low concentrations of dissolved oxygen, resulting in poor quality water and declining fishing resources. Designing methods for minimizing conditions of low dissolved oxygen are very necessary but they require a careful modelling and in some cases forecasting of dissolved oxygen. Though rivers have a natural tendency of recouping their water quality yet it has certain limitations which are balooned because of growing needs for water. Deforestation also causes loss of rich soil in the form of erosion which is deposited at crucial locations affecting the performance of man-made structure e.g.siltation in reservoirs, lakes etc.

As water quality is related to many diversified factors which are very basic and are natural sciences, it is influenced by any changes in the total system. Any human interference, which affects the total system or any of its sub-system indirectly affects the water quality (figure 2). Hence while classifying any type of water suitable for any use, we should consider various aspects affecting the cycle.

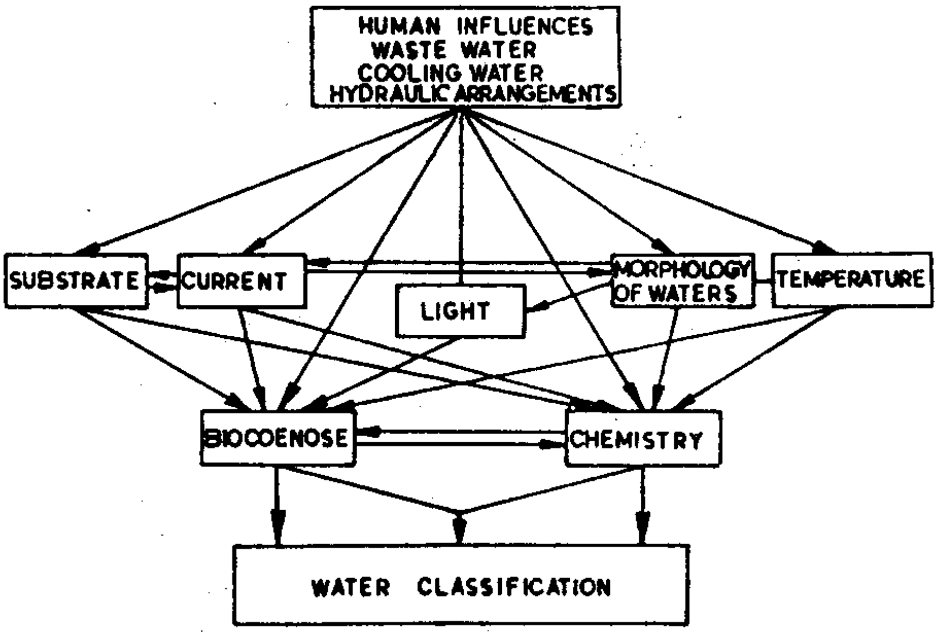


FIGURE 2 - FACTORS AFFECTING WATER QUALITY

Water put to various uses should have standards according to the uses it is put to. We can not define the standard of water for various uses in similar way, as well as too rigid standards may indirectly affect the economy of its users. Water suitable for one purpose may be completely unsuitable for other purpose. Hence this also stresses the need for forecasting and predicting the water quality at various points, in the sources of water.

Similarly many problems in water resources systems, river mechanics and hydraulic structures are directly related to the transport of material by flow. In general, the flow in natural and man-made systems are time variant. Specially the rivers which have not achieved equilibrium conditions after an initial disturbance are likely to have sediment transport problems. The management of watersheds and river basins for the optimum benefit to the people in general requires a complete knowledge of the interrelations between the ecology and environment.

1.3 Planning for Water Quality

Water quality and sediment modelling is advantageous for testing of conditions under alternative scenarios. It gives a better understanding of systems performance. As well as systems modeling gives an opportunity to the modeller to test various scenarios like flooding, sedimentation, drought, water quality stress etc. It also gives a clear understanding of various relationships between cause-effect phenomenon. The total system of new projects, which are to be implemented as well as projects needing updating, can be studied from environmental point of view.

Such studies would benefit in many ways:

(1) improvement in project specific studies and research by providing generalized techniques to address problems in the planning and design process, (2) reduction in costs due to proper assessment of environmental impacts and (3) elimination

of a portion of benefit losses attributable to environmental water quality problems by providing techniques to assess their potential or by providing corrective actions.

2.0 MATHEMATICAL MODELLING - A GENERAL DESCRIPTION

2.1 Introduction

Models can be defined as formal expression of the essential elements of the problem in either physical or mathematical terms. A problem has to be normally expressed verbally, in the first place. This is the first, preliminary but compulsory step in the building of a model. The term systems analysis, is sometimes used synonymously with modeling, but this does not seem correct. Systems analysis is defined as the orderly and logical organization of data into models, followed by their rigorous testing to provide validation and improvements.

In National Institute of Hydrology, we are mainly concerned with mathematical models, and physical models are mentioned only as alternate solutions. The strength of mathematics lies in its ability to provide a symbolic logic which is capable of expressing ideas and relationships of very great complexity but at the same time retaining its simplicity or expression. The various mathematical operations enable us to make predictions of changes which we expect to occur in the systems as external variables are changed. The adequacy of the model can be tested by comparing our predictions and the real systems that the model is intended to represent.

2.2 Classes of Mathematical Models

So many classifications of mathematical models are given in the literature that it is not possible to include all these classifications. The classification of any model depends upon its uses. A pairwise comparison of models is given here:

2.2.1 Research models and management models

It is very difficult to distinguish the two from the point of view of usefulness. Management models are mostly used as management tools whereas research models are used as research tools. For example eutrophication mod have been widely used as research tools in addition to its use for management. Similarly CO_2 climate model is at present more useful to make further research rather than as a predictive model.

2.2.2 Deterministic and stochastic models

In case of deterministic models the values are computed exactly whereas in the stochastic models the predicted values depend upon probability distribution. Mostly the models used in water quality and sediment routing are deterministic. It can be concluded from the literature that our experience in this field is not advanced enough to allow the use of stochastic modelling, although some-attempts have been made.

2.2.3 Compartment models and matrix models

In the case of compartment models, the variables defining the system are quantified by means of time-dependent differential equations whereas in case of matrix models matrices are used in the mathematical formulations Mostly the models used in water quality are sedimentation field are compartment type but some biodemographic ecological models and using matrix models.

2.2.4 Reductionistic models and holistic models

The difference between these two types is that the holistic models use general principles whereas the reductionistic models include as many relevant details are as possible. In this field limited attempts have been made to use holistic models.

2.2.5 Steady state models and dynamic models

In case of steady state models the variables defining the system are not dependent on time (or space), whereas in the case of dynamic models the variables defining the system are functions of time. Normally in water quality and sedimentation field steady state models do not find much use as they do not predict the time varying phenomena. Though there are some models which are steady state.

2.2.6 Distributed models and lumped models

In the case of distributed models the parameters are considered function of time and space and in the case of lumped models the parameters are within certain prescribed spatial locations and time, and are considered constants. Distributed models are used normally when large ecosystems are to be modelled. For the purpose of our studies lumped models are sufficient.

2.2.7 Linear models and nonlinear models

In the case of linear models first order equations are consecutively used whereas in non-linear models one or more of the equations are not of the first order. In principle there is no difference between linear and non-linear models, only thing is that linear type has a simpler form than the non-linear type. Most of the environmental systems models contain nonlinear expressions such as hyperbolic or exponential expressions. With the advent of modern computer techniques there seems to be no reason to force such models into linearity for the sake of saving some milliseconds of computer time.

2.2.8 Causal models and black box models

In case of causal models inputs, state variable and output are inter-related, whereas in the other case the input disturbances affect only the output responses. In case of environmental modelling, an understanding of the system is required and hence causal modelling is normally used. The black box models do not contain any understanding of the system constituents and their relationship.

2.3 Components of Models

An environmental or ecological model consists, in its mathematical formulation, of five components:

1. External variables
2. State variables
3. Mathematical equations
4. Parameters
5. Universal constants.

External variables also called forcing functions are variables or functions of external nature that influence the state of the ecosystem. The problem of modelling can be reframed as: if the values of some of the forcing functions are varied what will be the influence on the state of the total system. The example of some of the forcing functions are the input of polutants to the system of rivers, addition or removal of fishery etc. Temperature, solar radiation and precipitation are also forcing functions, which at present, can not be manipulated.

State variables, as name implies define the state of the system. The selection of these variables is crucial but the choice is also obvious. If, for example we want to model the sediment deposit in a reservoir, it is natural to include the sediment concentration and velocity of streams as state variables. When the model is used in the content of management studies, the values of the state variable predicted by changing the forcing function can be considered as the result of the model, as the model will contain relationships between the forcing function and state variables. Most models will consist more state variable than are directly required for the purpose of management.

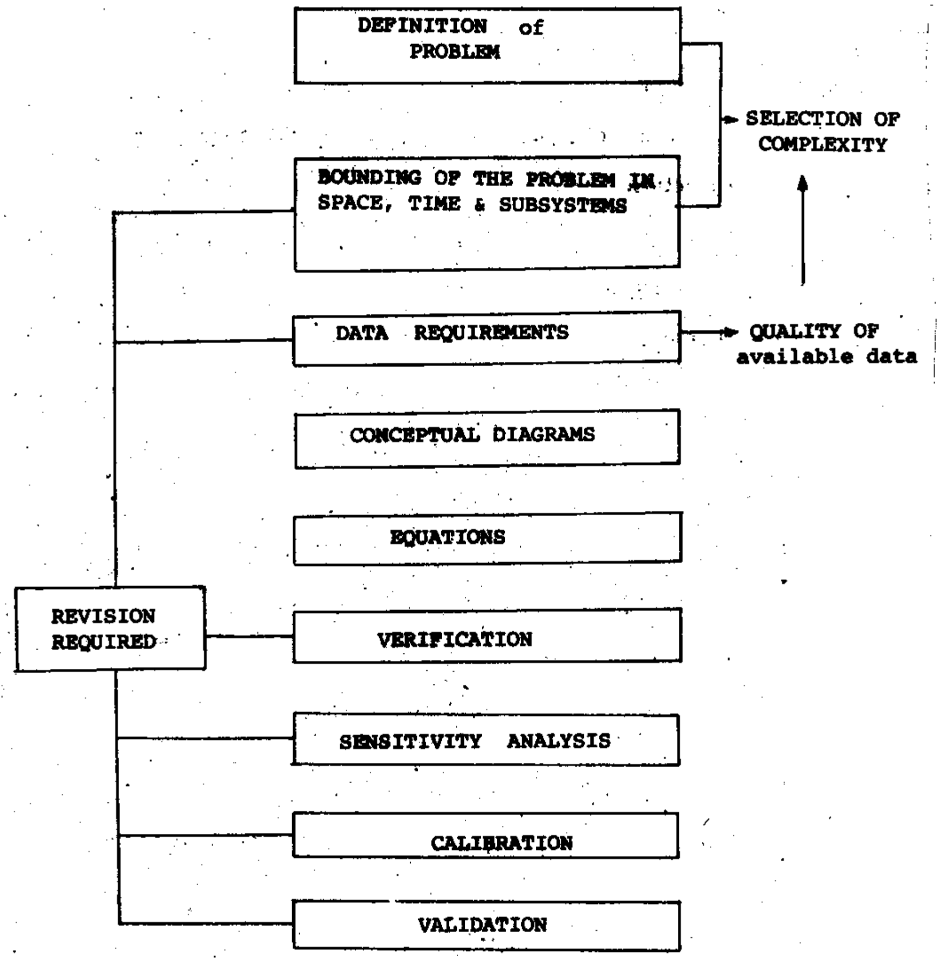
The biological ,chemical and physical processes in the ecosystem are represented in the model by means of mathematical equations. These are the relationships between two or more state variables and between forcingfunction and state variables. It is, however, not possible that one equation represents whole system, most of the processes have several mathematical representation.

The mathematical representation of processes in the system contain coefficients or parameters. They can be considered constant for a specific purpose or system. Many parameter values are known within limits. However, only a few parameter values are known exactly and hence it becomes necessary to calibrate others.

Most models will also contain universal constant such as gas constant, molecular weight etc. such constants are of course not subject to calibration.

2.4 Modelling Procedure

The primary focus of all research at all times is to define the problem. Only in that way it can be ensured that limited research resources can be correctly allocated and not dispersed into irrelevant activities. The steps involved in modelling of ecological and envionmental systems in special and any system in general are defined step by step in the diagram given on the next page.


DEFINITION of PROBLEM
BOUNDING OF THE PROBLEM IN SPACE, TIME & SUBSYSTEMS
SELECTION OF COMPLEXITY
DATA REQUIREMENTS
QUALITY OF available data
CONCEPTUAL DIAGRAMS
EQUATIONS
REVISION REQUIRED
VERIFICATION
SENSITIVITY ANALYSIS
CALIBRATION
VALIDATION

3.0 WATER QUALITY - A RESUME

On its journey, from clouds to earth(as rainfall), to rivers, lakes, ponds wells, and irrigation fields; water gathers a large variety of dissolved solids, suspended solids and organisms. On these 'foreign' substances depend the 'quality' of water.

3.1 Quality Parameter

Water is judged according to the following broad categories for its quality:

1.	Physical properties:	Color;temperature;turbidity, suspended solids, etc.
2.	Microbiological organisms	Bacteria, viruses, etc.
3.	Inorganic chemicals	Alkalinity; dissolved oxygen,pH; total dissolved solids; hardness; and several specific inorganic ions including metal ions, etc.
4.	Organic chemicals	Carbon-chloroform extract (CCE); oils and greases; phenols; cyanide; several individual pesticides etc.
5.	Radioactivity	Radium-226; strontium-90; gross beta emitters, etc.

The water which has characteristics suited to a given requirement is called good quality water' with reference to that requirement. The set of characteristics given in table 1 make the water 'excellent for drinking' as per World Health Organisation specifications. The water suitable for discharge on land (table 2) will however be termed'bad quality' for drinking purposes.

Standardized tests for determining the characteristics or 'properties'

TABLE 1 - WHO International Standards for Drinking Water

Substance of characteristic	Highest desirable level
Substance causing discoloration	5 units (Platinum-cobalt)
Substances causing odours	Unobjectionable
Substances causing tastes	Unobjectionable
Suspended matter	5 units(of turbidity)
Total Solids	500 mg/l
pH range	7.0 to 8.5
Amonia detergents	0.2 mg/l
Mineral oil	0.01 mg/l
Phenolic compounds(as phenol)	0.001 mg/l
Total hardness	100 mg/l $CaCO_3$
Calcium(as Ca)	75mg/l
Chloride(as Cl)	200 mg/l
Copper(as Cu)	0.05 mg/l
Iron(total as Fe)	0.1mg/l
Magnesium(as Mg)	Not more than 30 mg/l,if there are 250 mg/l of sulfate; if there is less sulfate, magnesium upto 150 mg/l may be allowed
Manganese(as Mn)	0.05 mg/l
Sulfate(as SO_4)	200 mg/l
Hydrogen Sulfide (as H_2S)	
Zinc(as Zn)	5.0 mg/l
Nitrate(as NO_3)	
Amonia(as NH_4)	
Free carbon dioxide(as CO_2)	
Dissolved oxygen	

From: Twort AC/Hoather RC,Law FM, 'Water Supply' Cox and Wyman, 1974. 198-202

TABLE -2 Tolerance Limits for Industrial Effluent Discharged on Land for Irrigation Purposes *

Sl.No.	Characteristics	Tolerance Limit
(i)	pH value	5.5 to 9.0
(ii)	Total dissolved solids (inorganic),mg/1, Max	2100(See Note 1)
iii)	Sulphate (as SO_4),mg/1 Max	1000
(iv)	Chloride (as Cl) mg/1 Max	600
(v)	Percent Sodium, Max	60 (See Note 2)
(vi)	Boron(as B),mg/1,Max	2
(vii)	Biochemical Oxygen demand (5 days at 20°C),mg/1,Max	500 (See Note 1 and 3)
(viii)	Oils and grease,mg/1,Max	10
(ix)	Alpha emitters, uc/1 Max	10^{-9}
(x)	Beta emitters, uc/m1,Max	10^{-8}

Note 1 : Limit is subject to relaxation or tightening by the local authorities.

Note 2 : Taking into account the nature of soil and the crop, the limit may be relaxed up to a maximum of 75 by the local authorities.

Note 3 : It should be noted that BOD of even 500 mg/ can have adverse effect if the nature of the soil and application rates are not taken into account.

* Methods of sampling and test for industrial effluents.

of water have been devised by the co-operative efforts of scientists from private and public institutions and local,state and central governments. The Water Quality Office of the Environmental Protection Agency (and its predecessors) the American Public Health Association, the Indian Standard Institution, the World Health Organisation etc. have all participated in the development of standards and analytical techniques for water quality. Water used for drinking, cooking, and food processing as well as for swimming should have no odor and no color, and essentially no turbidity. The temperature does not affect safety to humans (within limits, of course), but thermal pollution is a serious environmental problem.

Normally the bacteria dwelling in the human intestinal tract are harmless. However, they serve as useful indicator organisms. If they are found in a water supply, the water has been contaminated by focal matter and possibly, therefore, by disease-causing bacteria. Some viruses may also be present, and may cause outbreak of diseases.

The substances or properties under the category of inorganic chemicals require a number of specific measurements, some of which overlap. Dissolved solids, for example, include not only inorganic salts-generally carbonates, bicarbonates, chlorides, sulfates, phosphates, and sometimes nitrates of sodium, potassium, and traces of calcium, magnesium, iron, and other metal ions-but also nonvolatile organic substances that are solids at room temperature. Some dissolved solids make the water alkaline. Some are responsible for the hardness of water(the salts of calcium, magnesium, etc.). Some are poisons or provoke allergic reactions if present at excessive levels. The pH of water is a measure of its acdity. The deficiency of complete absence of dissolved oxygen makes the water a poor habitat for fish and aquatic life, and when oxygen is absent the water more easily develops smelly products from the anaerobic decomposition of organic or microbiological contaminants. Too much oxygen in the water hastens the corrosion of metal water pipes and the machinery used by industry for cooling purposes.

The Carbon Chloroform Extract(CCE) level of water is the concentration of any substance(s) removed by a special chloroform-soluble, carbon-filter extract method. These include oily substances, organic solvents, paint materials, and many other industrial oroganic wastes that are not necessarily degraded by bacteria. At a CCE value of 0.2 milligram/liter, 0.2 parts per million CCE, the water generally has a noticeably bad taste and odor. At sites well removed from industries, the CCE value is less than 0.04 milligram/liter (40 ppb).

Radioactive substances may enter surface water and groundwater by natural causes or because of human activities. Many springs and deep wells pick up radioactivity from minerals through which their waters seep and percolate. The testing of nuclear devices in the atmosphere has produced fall-out that has added radioactive substances-particularly strontium-90, cesium-137, and iodine-131-to water supplies. Underground nuclear tests have apparently not affected underground water except possibly in the immediate vicinity of the tests. The third source of radioactive contaminants is the civilian nuclear power industry.

3.2 Biochemical Oxygen Demand

Biochemical oxygen demand (BOD) is a measurement of the amount of oxygen that would be needed by micro-organisms to cause the decomposition of certain organic and inorganic matter in the water. The measurement is made under standardized conditions (eg. at 20^{o}C and 5 days). The result is called the 5-day BOD and is expressed in milligrams of oxygen per liter of water. BOD is an indicator of pollution. It measures no particular substance but a family-any substance that micro-organisms can consume (using oxygen as they do) or any material attacked under the condition of the test. The substance decomposed in the test may be food used by the micro-organisms or certain chemicals that are readily attacked by oxygen, perhaps with the aid of enzymes released by the micro organisms.These chemicals include sulfites and sulfides(from paper mills),ferrous iron,and some easily oxidised compounds.Many organics,however,make no contribution to the BOD but still render the water unfit for human use. BOD values of several hundred milligrams per liter characterize 'strong' sewage. BOD value are important when they signify that the oxygen supply dissoved in the water will be so greatly reduced that desirable animals like fish no longer can survive or when they signify that condition for the propogation of dangerous bacteria exist.

3.3 Chemical Oxygen Demand

The chemical oxygen demand(COD) is a measure of the concentration in a water supply of substances that can be attacked by a strong chemical oxidizing agent in a standarized analysis(dichromate oxidation is commonly used). The results of the analysis are expressed in terms of the amount of oxygen that would be required to oxidise the contaminants to the same final products obtained with the standarized analysis. COD values do not necessarily correlate with BOD values. Textile wastes, paper mill wastes, and other wastes with high level of cellulose have COD values considerably higher than their BOD values because cellulose is not readily attacked in the BOD test. Distillery and refinery wastes often have BODs higher than CODs. In the nature of the two tests, the BOD of a given water supply tends to decrease faster than its COD.

3.4 Important Parameters in Water Quality According to Indian Standards

The following nineteen parameters have been adopted by Central Board for the Prevention and Control of Water Pollution(CBPCWP)after a careful consultation with State Boards.Two hundred monitoring locations with one month frequency of sampling have alsoa been selected(Annual Rt,CBPCWP, 1979 -80). The monthly collection of 200 data cards containing values of 19 parameters amounting to 3800 figures a month is envisaged to be computerised. Hence, we can expect a good data bank for attempting water quality modelling studies. The parameters along with their method of analysis are given in table 3. For details of these methods a reference can be made to "Standard Methods for the Examination of Water and Wastewater", American Public Health Association, 1971(13th Edition). A comprehensive bibliography for water analysis is given in the end of this report.

3.5 Inter State Yamuna Project

A river basin is the appropriate geographical boundary for the administrative management of river water quality. The quality of a water of a river along with its tributaries is affected at various reaches due to human settlements, industries, agriculture etc., all along the river and anywhere within the river basin. The Inter State Yamuna River Project attempts to assess:

1. The pollution potential in the river basin due to all types of human activities.
2. The present organized use of the river and tributary waters and the quality requirements to sustain these organized uses.
3. The impact of the pollution potential on the rivers and tributary waters as reflected by the present water quality status.

The project was undertaken by CBPCWP as a first attempt to identify best uses of the river and the tributaries along the courses, and would aid in evolving pollution control strategies to be adopted for maintaining or restoring the water quality for these best uses.

The project is examplary as it is being taken up by a number of State Pollution Boards. The Yamuna Basin area extends to 3,66,223 sq.km. and the main river stretches over approximately 1380 km. between its source at Yamunotri and its confluence with Ganga at Prayag. The major tributaries of the

Table 3- Selected Water Quality Parameters

Parameter		Method of Analysis
A.	Physical	
	1. Temperature	Thermometric method
	2. Turbidity	Visual method
	3. Velocity of flow	1. Current meter 2. Float method 3. Chemical method
B.	Chemical	
	1. pH	Electrometric method
	2. Dissolved oxygen	Iodometric method
	3. Biochemical oxygen demand	Dilution method
	4. Total Kjeldahl nitrogen	1. Digestion 2. Distillation 3. Ammonia estimate by a. Titration method (mg/l) b. Nesslerization method (5mg/l)
	5. Nitrogen (Nitrate+Nitrite)	Amalgamated cadmium reduction method for reduction of Nitrate by diazotization method
	6. Conductivity	Conductometric method
	7. Chloride	1. Argentometric method 2. Mercurimetric method
	8. Hardness	EDTA Titrimetric method
	9. Calcium	EDTA Titrimetric method
	10. Magnesium	By difference of 8 & 9
	11. Alkalinity	1. Electrometric method 2. Visual titration method
	12. Sulphate	Turbidimetric method, Flame photometric method
	13. Sodium	Flame photometric method
	14. Chemical oxygen demand	Diohromate method
C.	Bacteriological	
	1. Total Coliform(MPN)	Multiple Tube Dilution Technique
	2. Fecal Coliform	Multiple Tube Dilution Technique

river are Chambal, Sind, Betwa and Ken with a total discharge(at Allahabad) of 93,020 million cubic meters. The Basin in shown in figure 3.

3.6 Classification and Zoning of Water

The river reaches are always put to different uses like irrigation, drinking, industrial use, power generation, fisheries, wild life use, navigation, recreation etc. and are also used as the carriers of effluents. However, every reach would be suitable for one type of use but that use would be demanding a quality level that would be of highest order. This use is termed as "Designated Best Use". The "Designated Best Use" of each stretch when marked on the water use map leads to the scheme of classification and zoning of natural waters which is a pre-requisite for the introduction of discipline in water abstraction from and wastewater disposal to natural streams.

Methodology

The classification and zoning of water comprise the following:

1. Evolving the basis for classification
2. Preparing a scheme for classification
3. Zoning of waters based on the scheme of classification.

The details of procedure of classification and zoning are given by Chaudhari(1981). The various steps are self explanatory in figure 4. Once the classification and zoning of a reach is completed, it enables water pollution control authorities to base and frame the control measures for the wastewater discharges into a particular stretch of a water body having regard to the background of the zoned class of the particular stretch and water quality required to sustain the zoned class. As depicted in figure 5 the scheme aids in evolving the rational basis for allocating pollutional load to the different zoned class of water bodies which in turn guides in the evaluation of effluent standards for the polluting sources within that reach of water bodies.

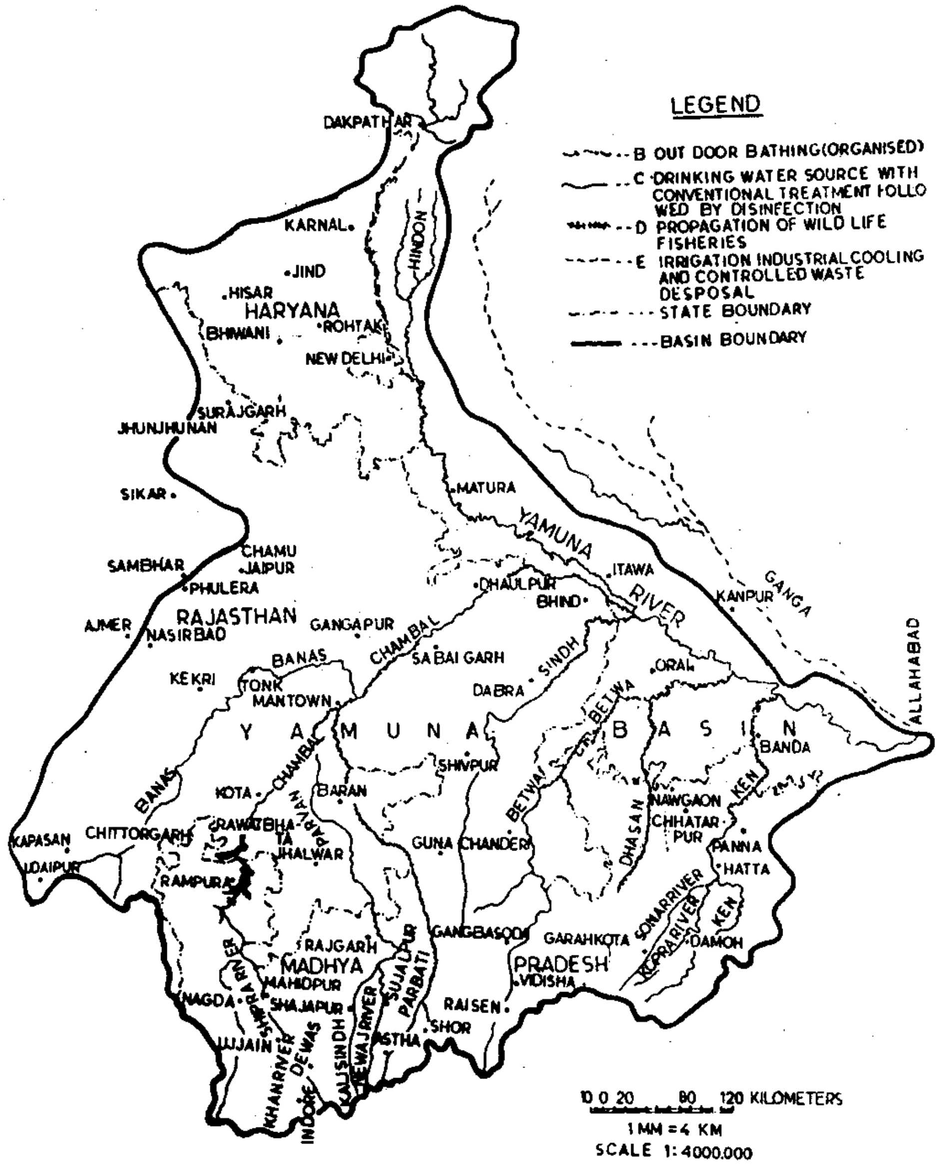


FIGURE 3 - CLASSIFICATION OF RIVERS IN YAMUNA BASIN
(FROM ANNUAL REPORT 1978-79, CBPCWP,BOARD, NEW DELHI)

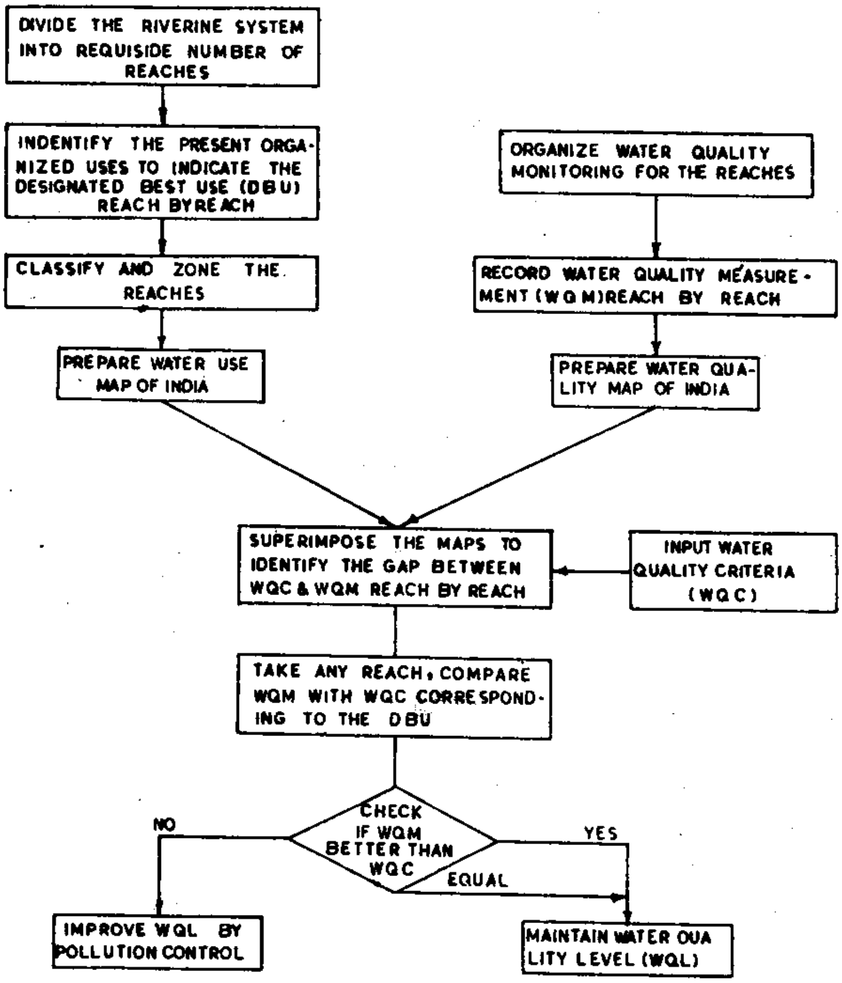


FIGURE 4 - CLASSIFICATION AND ZONING OF RIVERS FOR POLLUTION CONTROL
(FROM : CHAUDHURY N, 1981)

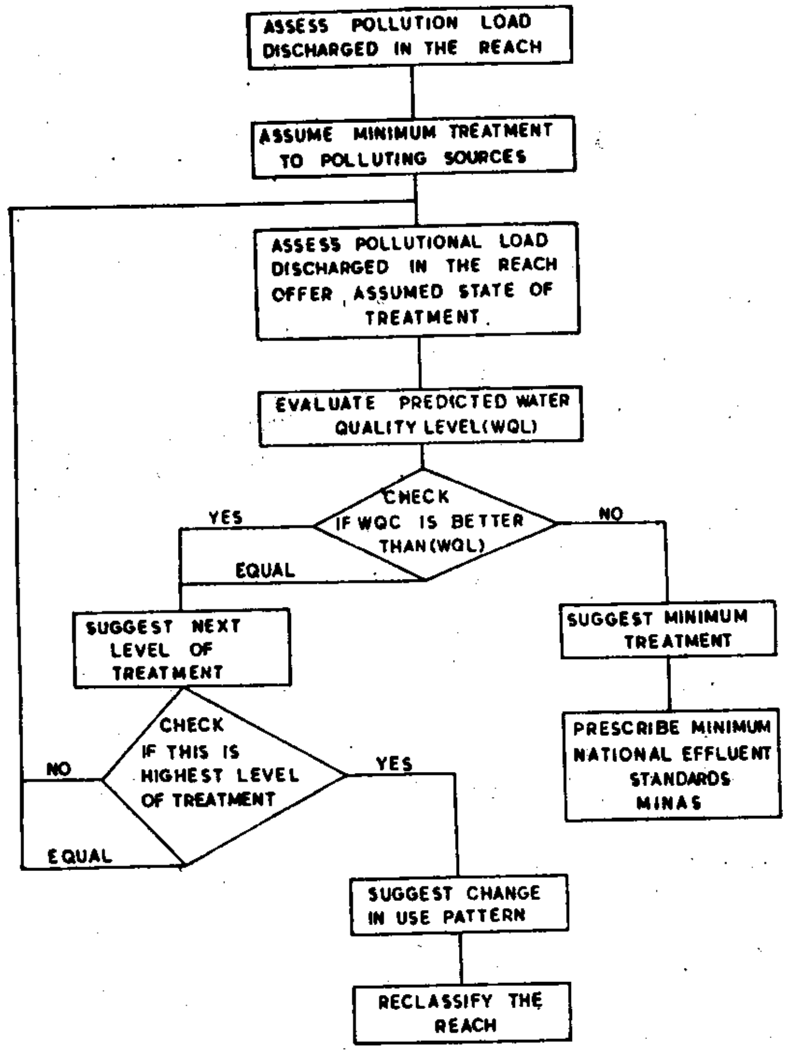


FIGURE 5 - RATIONAL BASIS FOR POLLUTION LOAD

(FROM: CHAUDHURY N.1981)

CBPCWP has also evolved a industry specific, and location specific effluent standard. The industries specific effluent standard which is being evolved at national level is termed as Minimal National Standard(MINAS). The model envisages a minimum treatment to the wastewater consistent with the annual burden of expenditure a particular industry can bear. The annual burden is reckoned as the percentage of total turnover. The methodology suggested for evolving MINAS is explained in the flow chart which can be used for computer modelling also, here

N = Total number of pollution control stages

J = Stage of pollution control under consideration

C = Critical percentage of annual turnover of the industry.

SC = Supercritical percentage of annual turnover of the industry.

EQ = Quality of treated effluent

AB = Annual burden of any stage of treatment

AT = Annual turnover of the industry

P = AB/AT

LD = Location details of disposal of treated effluent, land, inland surface water, estuaries, coastal waters.

WQL = Water quality criteria for the location.

The flow chart is given in figure 6.

3.7 Water Quality Requirement for Beneficial Uses

Water is put to a wide variety of demand. Water of a particular quality may be unsatisfactory for one use, may be perfectly acceptable for another. The level of acceptability is often governed by the scaricity of the resource or the availability of water of better quality.

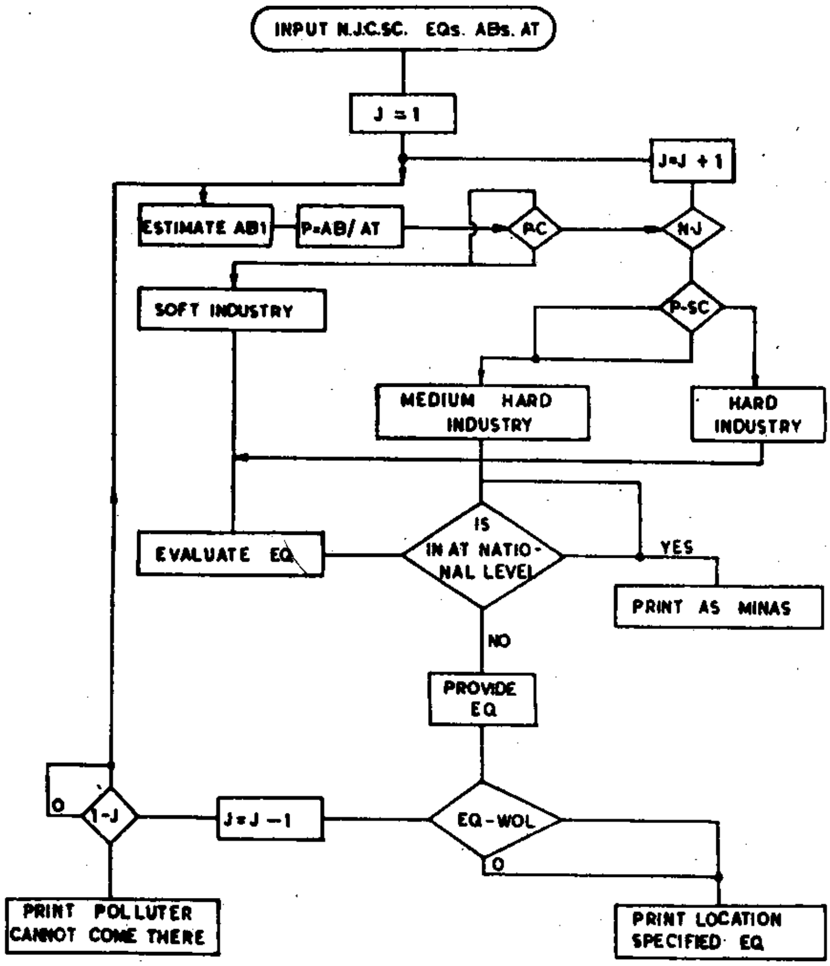


FIGURE 6 - MODEL FOR EVOLVING INDUSTRY SPECIFIC AND LOCATION SPECIFIC EFFLUENT LOAD

(FROM : ANNUAL REPORT 1978-79,CBPCWP BOARD, NEW DELHI)

3.7.1 Drinking water standards

Drinking water standards for the world as a whole have been set up by the World Health Organisation(WHO). It should be clearly kept in mind that these standards do not describe ideal or necessarily desirable water, but are permitted standards. It is highly desirable to have water of much better quality.

Generally the standards are divided into three categories, namely:

1. Bacterial

2. Physical and

3. Chemical characteristics

Bacterial quality is defined by establishing the sampling sequence, the method of analysis and the interpretation of test results for the coliform organisms which serve as presumptive evidence of bacterial contamination from intestinal sources. Analysis is normally made for:

a. Total coliform

b. Fecal coliform and

c. Streptococci coliform

In the European Standards of WHO, the arithmetic mean coliform density is specified to not exceed one per litre. The United States Public Health Services(USPHS) and the International Standards of the WHO establish an arithmetic mean density of one per 100 ml of water. The Indian Standards specify a figure of 50 per 100 ml of water as per 1977-78 standards of Central Board for the Prevention and Control of Water Pollution (CBPCWP).

Such physical parameters as turbidity, colour, odor and temperature are specified to the extent that they can be evaluated.

The limits for chemical elements or compounds in water are divided into mandatory requirements for certain substances and recommended criteria for others. The table 4 gives Indian Standards for Drinking Water.

TABLE - 4 Indian Standards for Drinking Water

Fresh Water Class	Best Use	Criteria
A	Drinking Water Source without conventional treatment but after disinfection	1.Total coliform organisms MPN/100 ml. shall be 50 or less . 2.pH Between 6.5 to 8.5 3.Dissolved oxygen 6mg/l or more 4. BOD(5 day at 20°C) 2mg/l or less

3.7.2 Quality of source water

The drinking water standards are the end product of a production line which begins with the source water as a raw material and proceeds through the various unit processes of water treatment and finally water distribution. Table 5 gives the standards for raw-water sources of domestic water supply. Although this table covers some important parameters, it should not be taken as a set of criteria for source water because of the absence of some important water quality parameters and because of the variation in treatment processes. It is presented in this status report so as to get an idea, at a glance, of water as to their desirability for domestic supply.

3.7.3 Water quality for industrial uses

The industry puts water to various uses such as transport medium, cleansing agent, coolant, for heating and for power production, often the quality required for this purpose is significantly higher than that required for human consumption. The availability of this water of high quality is often an important

Table 5 - Standards for Source Water As Domestic Water Supply

Constituents	Excellent source	Good source	Poor source
1. BOD(5 day)mg/l			
Monthly average	75-1.5	1.5-2.5	> 2.5
Max.day	1.0-3.0	3.0-4.0	>4.0
2. Coliform MPN 100 ml			
Monthly	50-100	50-5000	> 5000
Max.day	less than 5% over 100	Less than 20% over 5000	Less than 5% over 20000
3. D.O.			
mg/l	4.0-7.5	4.0-6.5	4.0
% saturation	>75%	>60%	-
4. pH average	6.0-8.5	5.0-9.0	3.8-10.5
5. Chloride	50	50-250	>250
6. Flourides	<1.5	1.5-3.0	>3.0
7. Color,Units	0-20	20-150	>150
8. Turbidity, Units	0-10	10-25	>250