STATE OF ART REPORT

Scientific Contribution
No. : INCOH/SAR-2/95

HOW TO CONDUCT RIVER SURVEYS

V. P. Thergaonkar
A. M. Deshkar

INDIAN NATIONAL COMMITTEE ON HYDROLOGY
(Committee Constituted by Ministry of Water Resources, Govt. of India)

INCOH SECRETARIAT
NATIONAL INSTITUTE OF HYDROLOGY
ROORKEE - 247 667, INDIA
March, 1995

Scientific Contribution
No. : INCOH/SAR-2/95

HOW TO CONDUCT RIVER SURVEYS

V. P. Thergaonkar & A. M. Deshkar
National Environmental Engineering
Research Institute
Nagpur

INCOH SECRETARIAT
NATIONAL INSTITUTE OF HYDROLOGY
ROORKEE - 247 667, INDIA
March, 1995

The presentation of material throughout the publication do not imply the expression of any opinion what so ever on the part of Indian National Committee on Hydrology (INCOH) or the publishers.

Published by
Dr. K.K.S. Bhatia
Member Secretary, INCOH &
Scientist 'F'
National Institute of Hydrology
Roorkee -247 667, India.

PREAMBLE

It has been estimated that the total world population will increase from 4.5 billion in 1980 to about 6.5 billion by the year 2000, with the most rapid growth in the developing countries. By that time, the countries within the humid tropics and the other warm humid regions will represent almost one-third of the total world population. This proportion will continue to rise in the twenty-first century. The developing and under-developed countries thus quite clearly are the regions facing potentially serious water problems. Hence, it is urgent to question as to whether the fields of hydrology and water resources management have the appropriate methods in place to meet the rising demands that will be made on the water resources. Hence it becomes very important and expeditious to review and update the state-of-art in different facets of hydrology and component processes. This call for compiling and reporting present day technology in assessment of water resources and determining the quality of these water resources.

The planning of water as a national resource is not merely a question of ensuring the availability of water in the right quantity at the right time for diverse purposes, but also one of ensuring the right quality for the use in view. Over the years, the rapid industrialization and urbanization processes have contributed considerably to deterioration in water quality. The most important factor of the stream sanitation is its waste assimilation capacity. It is crucial to carefully evaluate the impact, beneficial or detrimental, of the other aspects of water resources development, and uses, on the waste assimilation capacity of the stream. In this report an attempt has been made to focus on conducting the water quality surveys in surface water (rivers) concentrating on sampling site selection, sampling, flow measurement, important parameters and water quality data.

The Indian National Committee on Hydrology is the apex body on hydrology constituted by the Government of India with the responsibility of coordinating the various activities concerning hydrology in the country. The committee is also effectively participating in the activities of Unesco and is the National Committee for International Hydrology Programme (IHP) of Unesco. In pursuance of its objective of preparing and periodically updating the state-of-art in hydrology in the world in general and India in particular, the committee invites experts in the country to prepare these reports on important areas of hydrology.

The Indian National Committee on Hydrology with the assitance of its Panel on Water Quality, Erosion and Sedimentation has identified this vital topic for preparation of this state-of-art report and the report has been prepared by Mr.V.P. Thergoankar and Mr. A.M.Deshkar of the National Environmental Engineering Research Institute, Nagpur. The guidance, assistance and review etc. provided by the members of the Panel are worth mentioning. The report has been compiled and finalised by Dr.K.K.S. Bhatia, Member-Secretary, Indian National Committee on Hydrology

It is hoped that this state-of-art report would serve as a useful reference material to practicing engineers, researchers, field engineers, planners and implementation authorities, who are involved in correct estimation and optimal utilization of the water resources of the country.

(S.M.Seth)
Executive Member, INCOH
& Director, NIH

Roorkee,
April 10, 1995.

TABLE OF CONTENTS

INTRODUCTION

It has been well established by now that man's entry into terrestrial, aquatic ecosystems has been responsible for alterations in the nature's orderly system. Man-made river developments and water uses have had effects which were detrimental to the waste assimilation capacity and associated water quality of the rivers. In typical urban-industrial complex systems which are increasingly growing along the rivers, there is a competition for the limited water resources whose potential uses are; (i) community and industrial water supply, (ii) power generation, (iii) irrigation, (iv) fish and wild life, and (v) the unavoidable accepter of wastes/residuals etc.from communities, industries, agricultural and natural run-offs.

Each of these uses are important and therefore conflict of interest can arise. The matter of priority and degree of use among users may change in place and time. But whatever be the use, the key to appropriate use of a water resource is the satisfactory, scientific disposal of the residuals of the waste products of man's activities. If waste products are discharged with regard to various factors governing the stream sanitation, then incompatibility among uses can be avoided.

The most important factor of the stream sanitation is its wastes assimilation capacity. It is crucial to carefully evaluate the impact, beneficial or detrimental, of the other aspects of water resource development and uses, on the waste assimilation capacity of the stream. It is observed that the pressures of urban-industrial growth have resulted in the multiple uses of water which are inextricably interrelated. It has to be realised that each use, may it be for drinking purposes, or irrigation or industrial purposes, cannot be viewed in isolation. A rational, integrated approach is essential. Attention is drawn to the Hooghly estuary at Calcutta, Mahi river near Baroda, Sabarmati near Ahmedabad, Subarnarekha in Orrisa, Kali in Bombay, the Damodar. A few of these rivers were being used, as sources of water supply for drinking or irrigation. But in a few stretches they have been overloaded by industrial wastes. As a result they have become useless as sources of water supply and have been converted into wastewater channels. Many tributaries of the Ganga in U.P., Bihar and Bengal bring in agricultural run offs, domestic sewage, industrial wastes; thereby water quality is grossly affected.

Now, the time is ripe to evaluate civilizations by the methods of disposal of wastes, or by methods and efficiency of environmental management. The wastes may be gaseous, liquids or solids but indiscriminate disposal results in fouling of environment which is indicated by altered quality of air, pattern of land use and by water quality. Of these three facets of environment, water is physiologically important to man and animals.

Efforts are necessary to maintain the water quality in a river so that it adequately supports its natural fauna and flora, and inturn is not harmful if consumed by people. In order to achieve this, water quality standards, guidelines, effluent discharge limits are laid down by advisory, and regulatory agencies like the WHO, ICMR and Water Pollution Control Boards respectively.

A constant vigil on the water quality has to be maintained. If water quality is important for a water supply engineer, quantities are the main concern of the irrigation and agriculture departments. They have established stream gauging stations on various river systems. Besides quantities, they also keep a track of salinity. Water Pollution control Boards keep record of effluent quality being discharged into a river. Central Water Commission, also keeps a record of the sediments or of silting in the rivers.

Such records can be obtained only after extensive programmes. Water quality monitoring programmes, or stream gauging programmes or silt-estimation studies cannot be carried out cheaply. Therefore each department has to exert independently to get information, about the same river. It is realised that Irrigation Departments, Water Pollution Control Boards, or Central Water Commission have different charters of work. However, looking to the importance of, preservation of water quality and of knowing the trends in water quality it will be justified to make an attempt to evolve one unified approach for river monitoring which could be followed by all departments. Any specific additional information required by a department can be collected. But this will ensure proper utilization of money, and manpower inputs which go in during such surveys.

One such effort is being presented here. The data generated out of such an approach will help in :

i) identification of areas requiring improvement;
ii) determination of the efficiency of pollution control measures;
iii) identification of the trends in water quality over protracted period, and;
iv) assessment of total pollutant loads of rivers.

The same data can be used to provide the information which will be required by the planners in futures. These information can be :

i) information on water quality and quantity for future requirement.
ii) prediction of the effect of future development on the quantity of water.
iii) estimation of the effects of proposed hydrological changes upon the water regime.
iv) information on the incidence and trends of specific dangerous substances.

River water quality monitoring programmes comprise of a number of activities. The main are :

(a) sampling-site selection,
(b) sampling procedures,
(c) analytical procedures,
(d) hydrological measurements.

The information generated systematically will help in the proper utilization of data by water supply authorities, by irrigation or forest departments, with only minor additional inputs. In fact such surveys should preferably be carried out by organizations which have confidence, capabilities and facilities.

SAMPLING SITE SELECTION

It is necessary to collect some information on geography, topography, climate weather, hydrology, land use, extent of urbanization and industrialization, and on agricultural practices in and around stretch of the river which is to be monitored. This information will indicate different uses of water and water quality requirement. It will also help in identification of those factors which can affect water quality. Once this information is collected, a preliminary water quality survey can be undertaken. During this short term river survey basic water quality parameters and a few specific estimations should be considered.

The objective of the short term survey is to select sampling sites which during the detailed surveys will provide additional information. Figure 1. may be reffered for the following.

Sampling point	Why selected
1	Entry into a urban ecosystem
2	Water supply to town
3	Effect on aquatic life
4	Agricultural irrigation
5	Exit from urban ecosystem
6	Industrial water supply
7	Down stream of industrial effluent discharges
8	Baseline station for water quality

Sampling Site Requirements

Though preliminary survey will indicate site of sampling, the location of the exact spot should be governed by a few important factors. The two important factors are; representative nature, and flow measurement facility. Accessibility, distance from the laboratory, influences which are characteristics of the site, safety of the sampling spot are other considerations.

Representative Sample

A sample is representative when the value of a parameter is the same as in water body at the place and time of sampling. This implies that complete mixing should be ensured at the sampling spot.

Velocity, turbulence and the size of the river control the lateral dispersion of the discharges. Vertical dispersion can be affected in case of temperature differences between the river and the receiving wastewater or a tributary.

Homogenicity over the cross-section at the river sampling point can be checked by depth samples. Parameters to check homogenicity are conductivity, dissolved oxygen, pH

or temperature. These can be estimated at the site. In Indian rivers, homogenicity should be checked at high and low flows. Average flow measurement discharges in the rivers should be known. These can be gathered from Irrigation Departments. River surveys are conducted for long periods of time and therefore it will be worthwhile to measure the flows by the agency which is conducting the river survey.

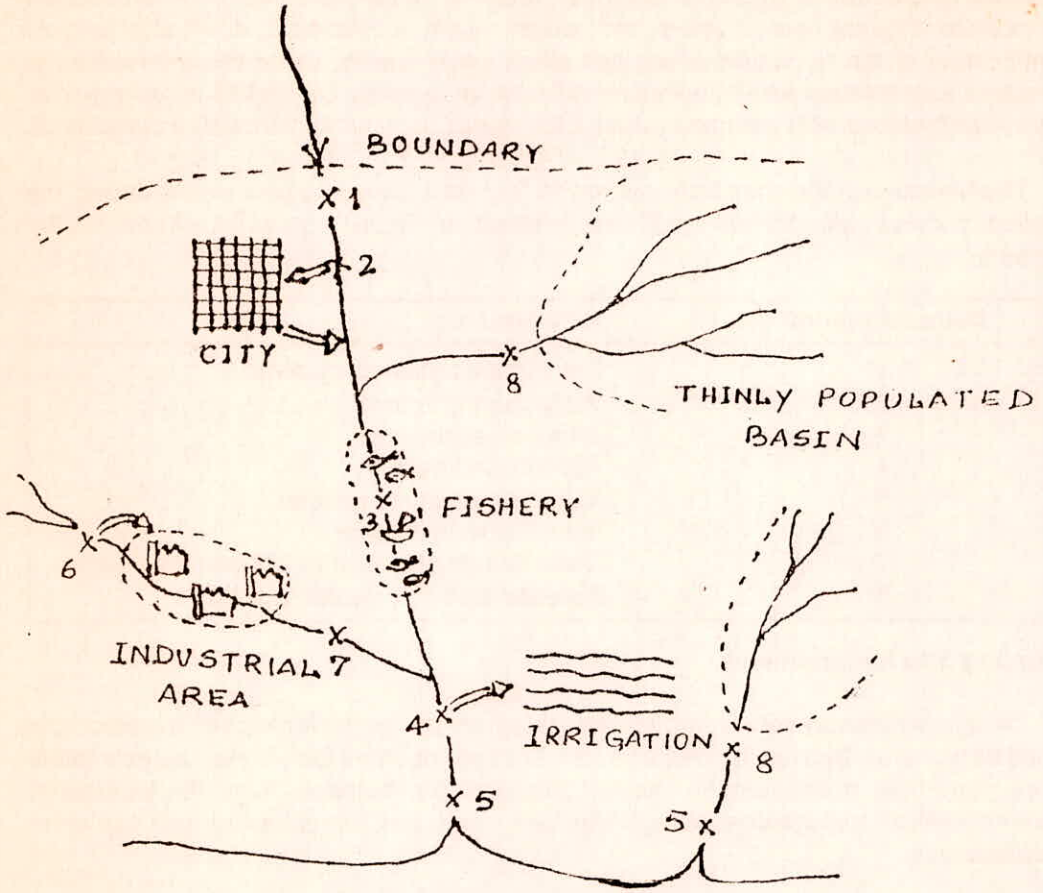

Fig. 1. Sampling station selection

If the annual average discharge is less than 5 m^3 /sec, then depth samples may not be possible. If it is 5-150 m^3 /sec, then two depth samples (bearing 30 cm below surface and 30 cm above bottom) should be taken. If the discharge of the river varies from 150-1000 m^3/ sec, then six vertical samples are possible. When the discharge is greater than 1000 m^3 / sec then minimum six samples are necessary. The cross section should be evenly spaced.

When the rivers are non-homogeneous due to addition of some external impurities then it is advisable to move the sampling site to the downstream where the river will be homogeneous.

Flow Measurement

It is imperative to measure the discharge of a river at the station so that mass discharge of different pollutants can be asserted. To be able to do this there two alternatives.

i) Locate the water quality monitoring station near a stream gauging station so that the flow data can be easily available. If this is not possible and if the sampling station is in between two river gauging station, then the flow can be computed.
ii) If (i) is not possible, then it is necessary to install one discharge measuring site at the water quality monitoring station.

Gauging procedure is lengthy but is necessary which is neglected by most of the water quality investigators. The guidelines given below are useful. Similarly it will be worthwhile to collect some basic water quality parameters at gauging station. These parameters will be discussed later.

Other Considerations

Sample collector is required to carry sampling kit with some analytical tools like pH meter, conductivity meter and a battery operated colorimeter. These kits are heavy. Therefore, it is necessary that the sampling point should be accessible in all the seasons. Following could be kept in mind while locating suitable sites.

(a) Bridges are identifiable and are convenient.
(b) Boats allow flexible sampling. The sampling point has to be marked by a landmark. Boats should not disturb the bottom sediments. Indian rivers are dry in summer seasons. Therefore, in summer while approaching the sampling point (from which a sample was taken from a boat during monsoon) the bottom deposits are likely to be disturbed.
(c) Bankside sampling can be resorted to and is permissible only when there is no alternative. Sample should not be taken from a place where water is turbulent or from a place which is at the outer bend where water flow is faster and deep.
(d) There can be some disturbing influences like location of the sampling site near a weir, or is located at places of excessive vegetation growth.

SAMPLING

Proper selection of site for sampling ensures that samples will be valid and representative. Valid samples mean that the value of a parameter or of parameters will be the same as those in the water at the time of sampling at that site. Representative samples depend on sampling techniques and on their preservation.

A true picture of water quality at a sampling station is determined by the place, time and frequency of sampling and on the representativeness of the samples.

Sampling is the crucial link in water quality monitoring programmes. Reliability and accuracy of the final result depends on the representative nature of the sample and analytical procedures.

Frequency of Sampling

Water quality in water bodies is seldom constant. The closeness of the measured value depends upon (i) variability of the parameter, and (ii) number of samples taken. It is usual to measure the mean, maximum and minimum value of a water quality parameter. More number of samples for calculation of the mean will ensure narrower difference between observed and true values. Statistics suggest that confidence limits are not directly proportional to the number of samples but to the square of the number. Therefore, the number of samples will have to be increased by four, if the reliability of the mean is to be doubled.

It is necessary to optimize the benefits of increased reliability (measured by confidence limits) and the cost of collection of samples.

River water quality changes depend on the quantities that are being put in it, and also on the changes in water volume and flow. Random or cyclic variability of water quality can be due to natural or artificial reasons. Sudden storms, and consequential increase flows in river and the polluted run offs, sewer overflows can indicated as examples of random variations.

Increased river turbidity in monsoon followed by algal blooms in post-monsoon season, and severe depletion in water quantity and flows, (even drying of river beds) are examples of annual cyclic variations. Daily inputs of wastes by an industry between fixed timing are examples of daily cycles of variation.

In case of the rivers, variability is most pronounced. Ranges of variability of water quality are greater if the sampling point is close to the source of variation. Longitudinal mixing in the river smoothens out the irregularities and then fewer samples will be required. But such effects as dilution, self purification, deposition and adsorption have to be evaluated, if the sampling point is to be kept away from the point of discharge.

Number of Samples

It is strongly recommended that a statistical approach to the question of numbers of samples should be adapted.

Confidence interval indicates the given range of values within which an arithmetic mean of normally distributed values will lie. This is expressed in percentage of occasions (p%) and is bounded by confidence limits e.g. if the 95% confidence limits are ±10, then the probability is that on 95 occasions of 100, then observed mean will not differ from the true mean by more than 10.

Let $\bar{x}$ be the mean concentration from N samples which are normally distributed, then:

$$p\% = \bar{x} + L \qquad \text{where, } L = \frac{KS}{N}$$

S being the standard deviation and K a factor depending upon p values of K for given confidence levels are :

Confidence level %	K
99	2.58
98	2.33
95	1.96
90	1.64
86	1.28
68	1.00
50	0.67

This table is useful when number of samples are more then 30; if they are less than 30, then K should be replaced by Students t test.

Generally 95% confidence limits are employed. The following table shows the effect of sample size on the confidence limits. For example if the true mean is 40, and standard deviation is 20, then :

No. of samples	Frequency	95% confidence limits for mean in terms of standard deviation S	L	95% confidence limits.
4	Quarterly	1.50	30	10-70
6	Two monthly	1.00	20	20-60
12	Monthly	0.60	12	28-52
26	Fortnightly	0.40	8	32-48
52	Weekly	0.30	6	34-46
365	Daily	0.15	3	37-43

It can be assumed that distribution of parameters of water quality at a sampling point is normal. Turbidity of suspended solid values show widest range of values and their distribution is taken to be log normal, due to extremely high and low flows. Therefore accuracy, of mean values of suspended and insoluble parameters will be lower than that for dissolved parameters at the same sampling points.

It is necessary that sampling programme should envisage (i) random sampling which is spread more or less evenly throughout the year and (ii) a rolling time table with an interval of 7±1 day so that the sampling day advances or retreads by one day, throughout the week. This will account for any cyclic variables at a sampling point.

In rivers in India it is necessary to increase a sampling rate during low flow conditions in hot and dry season or during intensive industrial and agricultural activity.

Every station will have to be assessed independently for sampling frequency depending on the conditions which influence water quality. Following scheme will serve as preliminary guide though some minor adjustment can be made with the local facility.

i) Weekly sample for one year;
ii) Daily samples for 7 consecutive days and once in 13 weeks;
iii) Hourly samples for 24 hrs. once in 13 weeks;
iv) Every 4 hrs. for 7 consecutive days and once in 13 weeks.

Total number of samples will be 344. The number of parameters can be restricted to the most important ones which are discussed in a subsequent chapter. These parameters should have relevance to the activity prevailing in that area e.g. if there is a textile mill discharging its effluent then colour,. Na^+, residual chlorine etc. should be monitored; if domestic sewage is being added then dissolved oxygen, bacterial count will be pertinent.

Such a preliminary survey will confirm the importance of different parameters, indicate their variations, and also the frequency of their occurrence. Therefore confidence limits and accuracy of estimation of different parameters can be established. If a particular organization has limited resources then it is strongly suggested to reduce the number of sampling points but the frequency of sampling should not be curtailed. It is always better to obtain the reliable results at one place than to have ambiguous and dubious data from two points.

Sample Containers

It is always advantageous to measure the quantity of water in situ by means of sensors which are lowered into position rather than by withdrawing samples. However, it is not always possible. Water samples are, therefore, collected in suitable containers. A sample container must satisfy the following requirements.

- It could easily be freed from contamination.

- It should not change the relevant water characteristics on contact.
- It should have adequate capacity for storing the samples.
- It should be resistant to impact and to internal pressure which is increased by expansion of water or by release of dissolved gases at elevated temperature on storage.

The sample bottle may be made of either glass or plastic, usually polyethylene. It must be capable of being tightly sealed either by stopper or cap. The bottles should be soaked with 10% HCl for 24 hours and then thoroughly cleaned and rinsed with distilled water.

Sampling Equipment

Numerous types of sampling equipment have been devised. However, the sampler design is generally immaterial except for dissolved gases or constituents which are particularly affected by atmospheric gases. Sampling equipment are briefly described below :

(1) Ball-valve type sampler - This sampler is used for the collection of sample at any desirable depth. The sampler is lowered up to desired depth and then vaive is opened by rapidly raising and lowering several times in succession, which opens the ball valves at either end and traps the water.

(2) Dussart sampler - It is a bottle of convenient size surrounded by lead sheath and closed by a rubber bung containing two holes. Through one hole passes a glass tube leading nearly to the bottom of the bottle and through the other a short glass tube. The two being connected at the top by rubber tubing. The bottle is suspended by a 0.3 m long stirring whose both ends are fastened round the neck of bottle. This elastic device and a piece of cord attached to the rubber tube joining the glass tubes are connected with a metal loop to which is also attached the cord used for lowering the bottle. In taking samples, the bottle is lowered to the required depth and the suspended cord is given a sharp jerk. This removes the rubber tube and allows the water to be filled in the bottle.

(3) Freedinger sampler : The equipment consists essentially of a hollow tube with hinged flaps at each end, the lower one including a tap for final withdrawal of the sample. It is lowered to the required sampling depth with flaps open at the end of the wire passing over a pulley on a gantry which records, the depth to which the apparatus has been let down. Sending a 'messenger' down the wire operates an arrangement which causes the flaps to close tightly this including in the water only from the depth to which the tube has been lowered. The apparatus is finally raised to the surface and water emptied from the bottle using the sampling cock in the lower flap.

(4) Kemmerer & Ruttner type sampler : The basic equipment consists of an open tube of 1 litre to 3 litre capacity with a hinged lid at each end. The lids may then be closed down by a messenger (a weight slide down the suspending cable). The Ruttner tube is made of polymethyl methacrylate (perspex, plexiglass) and Kemmerer of copper. The lids are open

but they do impede water flow through the tube. Once the desired depth is reached the sampler must be alternatively raised and lowered (25 cm), several times to flush out contaminant water.

(5) Walas (flask) sampler :- This is similar in principle to the Dussart flask but the flask closure is magnetic and more complicated. The first jerk opens the flask. The second seals it again. It is most suitable for bacteriological sampling.

(6) Watt flask or J.Z. sampler :-Evacuated glass flasks are used for this sampler. These are closed by an expendable glass seal. The 'messenger' smashes the seal.

FLOW MEASUREMENT

Introduction

It is always advisable to entrust the flow measurement part of the river surveys to the hydrologists. It is best to locate water quality monitoring station near a stream gauging station. References to manual of stream gauging, or other books on hydrological practices will be useful. But the present concern is to emphasize the role of hydrological measurements in water quality monitoring. The hydrological data can be used for (a) estimation of a parameter concentration across the cross-section of a river, (b) mass flow computations and (c) estimation of self purification capacity of the river.

Two types of data are required. They are (a) water levels, velocity, flow, slope etc. and (b) information regarding suspended matter carried by the river, bed load data. This information is traditionally measured by hydrologists.

The two further subgroups in the data are information to be collected at the time of sampling and during the record period.

Discharge Measurement at the Time of Sampling

It is necessary to ascertain from the irrigation department or any concerned river authority if the river whose water quality is being monitored has a stable stage discharge relationship. If this exists then only water level reading at the time of sampling is sufficient.

If the stage-discharge relationship shows loops which are connected to increasing or decreasing stages then careful readings before, after and during sampling are necessary. Either single point or multiple point sampling in the cross-section is common. In both these cases, it is advisable to take the sample in the section of the water level and measure the discharge in the same cross section. Velocity should be measured at all sampling points. Preferably sampling and velocity measurements should be carried out as close in time as possible. Velocities in rivers vary rapidly with time, and water quality can change with the velocity. If 1 litre sample is collected in a period of 1 to 2 minutes (most velocity measurement methods require this time) then variations can reduce.

Mass flow computations can be conveniently computed if daily river flows are recorded. This is true for majority of rivers. But if the fluctuations in the flow during the day is large accompanied by large variation in the concentration of a parameter, then flows measurements at shorter intervals may be necessary.

Large variation in flow can be defined as a day in which the maximum flow of that day is larger than twice the average flow.

Hydrological Measurement Techniques

It is again emphasised that stream gauging station should be located in the same section of the river in which water samples will be taken. In case this is not possible then

the maximum distance between stream gauging station and sampling station is ± 5% of the difference in the river basin areas at these two stations. When the river water quality is not homogeneous then it is necessary to put both the stations together.

Water levels, velocities, discharges, temperatures and suspended sediments are required to be measured. Levels should be measured continuously (occasionally twice a day or daily) but the other parameters can be measured at other convenient intervals. In case of suspended sediments, relationship between water discharge, sediment transportation should be established. If this is not available then sediment concentration should be taken daily.

Water levels should be measured by using sounding probes. Velocity and discharge measurement should be carried out by current meters. Interferences from sampling boats should be kept in mind. For discharge measurement, one river velocity measurement point should always be the one from which water quality is sampled.

If current meter is not available then float discharge measurement is allowed. Dilution method measurement is acceptable under required conditions. A tributary with a constant flow can be used as a tracer to carry out discharge measurement by dilution method, which will also require the measurement of tracer (sodium chloride) on the river upstream and downstream of the tributary.

A notch weir is not recommended because the weir structure can modify the normal water quality conditions. Ultrasonic or electromagnetic methods though used in limited places are not practical.

Temperature measurements in river will indicate anomalous water quality conditions. Therefore temperature surveys by measurement of temperature as recommended in standard books are important. For very large rivers remote sensing infrared radiation thermometer are useful.

Mass Flow Computations

Generally water quality analyses are carried out with a view to obtain average values of a few significant parameters and also to know the total quantities of substances which are being transported. If the surveys are carried out scientifically then, water quality can be predicted on the basis of the data generated and its analysis. Correlation between mass flow values and mass quantities of substances over a definite periods of time has to emerge on the basis of actual water quality analyses and the flow measurements.

Three methods have to be applied depending on the situation. These are (i) direct methods which can be applicable when measurements are available for a given point of time or for a definite period of time. (ii) methods requiring interpolation in time, which are applicable when measurements are not available for a given point of time but are available for times during a period of time and (iii) methods requiring interpolation in space and time

or in space only which is necessary when measurements are not at all available at the sampling point but are available for different points of the river.

Direct Methods

Sl. No.	Sampling Situation	Assumption	Instantaneous mass flow (Qm)
i	One sample	Conc. is C of a parameter and it is uniform in the cross section.	$Qm = K_1 CQ$ K_1 is constant that takes into account the units of Qm, C and Q
	e.g. BOD of a river 20 mg/L on 31.3.1986., flow of the river 3 m^3 /s on 31.3.1986. $Qm = 20 \times 3 = 60$ mg BOD/sec.		
ii	One Sample	Concentration is not uniform and a non uniformity coeff. is K_n ,K_n is derived by comparing detailed multiple point sampling with single sample results.	$Q = K_1 K_n CQ$ K_n will vary with Q
iii	Several samples (not more than one in each of several velocity measurement.)	Analytical procedure is rapid	$Q_m = K_1 \sum_{1}^{n} c_i v_i \Delta b_i h_i$ where n is the number of verticals from which samples are taken. i = 1 to n c_i = conc. in vertical i v_i = velocity in vertical i Δb_i = river width corresponding to i h_i = river depth at vertical i Δb_i = is half of the width between vertical i-1 and i+1, Δb_i at first and last verticals, banks are "virtual verticals" of depth.

iv	Several samples (more than one in each of several velocity measurment verticals.)	Analytical	$Q_M = K_1 \sum_{I=1}^{n} b_i \sum_{1}^{m} c_{1,,}jv_{i\ ,}j\Delta h_{i,}j$ Q_M = inst. mass flow K_i = const. to account for units in which Q , C, & Q are expressed. b_i = as above $c_{i,j}$ = conc. at pt j of vert. i. $v_{i,j}$ = velocity at pt j of vert. i. $\Delta h_{i,j}$ = section of the vertical for which vel. $v_{i,j}$ and $c_{i,j}$ are applicable.

Uppermost (& lower most) points are equal to the depth above (or below) the point plus half the distance to the next sampling point. For other points it is half the distance to the adjacent sampling points.

Interpolation Methods in Time

It is possible that water quality determinations are carried out at long intervals, say seven days, fortnightly or monthly. Under such circumstances the mass flow is valid for a period of time and is usually based on the assumption that concentration of a parameter at time 'i' is valid for half the preceding and following interval. But this is applicable to a very few rivers, with a little variation of concentration in time.

Simple and multiple regression procedure and techniques based on conceptual model are available and can be applied to allow for interpolation in time of values of concentration of various substances.

Interpolation Methods In Space

These methods are required for water quality maps, for statistical models and conceptual models. These methods depend on results of water quality monitoring in one river and its application to compute the mass flow from the same area.

If therefore, follows that this method is valid in areas where density of scientifically monitored rivers exceeds that of the ungauged rivers. In such a case maps showing factors which are likely to influence water quality are useful. The factors are soil types, vegetation, geology, climate and runoffs, etc. These will help to give a reasonable, mapping of water quality in an ungauged river.

Precautions for Hydrological Measurement

Accuracy of a discharge measurement depends on the reliability of the current meter used, conditions of flow, number of depths (vertical) and velocity points in the cross section. Generally standard error of 2 to 5% should be expected for measurements using 20 to 25 depth samples and two velocity points. Therefore it will be worthwhile to mention the types of errors. Errors arise from single flow measurement as shown above, errors can also arise from single flow estimates etc.

The practical procedure to estimate the error of single measurement is based on the consideration that each flow measurement is carried out under different circumstances which can be meteorological, hydrological using different equipment and human. The other important consideration is that the errors cannot be estimated by repeated measurement because the flow conditions continuously change.

It will be worthwhile to mention the data which has to be collected at the time of sampling.

i) water level and water level trends
ii) water clarity and visual water colour
iii) water flow and estimated error.
iv) water velocities in the different points of cross-section in case of multiple sampling.

These following information will also be useful if available.

i) water slope.
ii) suspended sediment data and particle size distribution.
iii) bed load data
iv) observation on river bottom deposit.

WATER QUALITY PARAMETERS

There are three categories under which the water quality parameters can be divided. These are (i) primary parameters, which have to be measured at all the sampling stations in order to obtain an overview of the water quality, (ii) optional parameters which depend on the location of sampling point, use to which water will be put to and the significance of that parameter; and (iii) parameters which assume significance by vide change in the flow pattern of the river.

Determination of primary parameters in river samples should be done by all the agencies which are involved in stream gauging. Only such parameters are proposed in this report, whose determination will need only basic chemistry knowledge. This will facilitate irrigation department to obtain water quality data.

Primary Parameters, their Significance and Measurement

i. Temperature : Measurements of temperature are required in case self purification of rivers is to be studied. Water temperature is important to aquatic life e.g. fish and other zooplankton. Solubility of oxygen and carbon-di-oxide depends on temperature. Thermometer with 0.1 C divisions is sufficient. A thermister or a reversing thermometer is used for depth temperature measurement.

ii. ph : pH of an aqueous solution is the negative logarithm of the hydrogen ion activity (concentration for practical purposes in moles per litre). pH less than 7 indicates acidity, whereas more than 7 shows that the sample is alkaline. pH of most natural waters lies in the range of 4.5 to 8.5. This is controlled by CO_2 /HCO_3^- /CO_3^- equilibria. This can be affected by biological activity like growth of algae, addition of wastewaters and polluted water. pH is important because it causes corrosion and has significance in analytical work. pH meter are freely available and are both line and battery operated.

iii. Conductivity : Conductivity is the capacity of water to carry an electrical current and varies both with the number and types of ions the solution contains, which in turn is related to the concentration of ionized substances in the water. Most dissolved inorganic substances in water are in the ionized from and hence contributed to conductance. Rough estimation of dissolved ionic contents of water sample can be done by multiplying specific conductance (in U siemens/cm) by an empirical factor which may vary from 0.55 to 0.9 depending on the soluble components of water and on the temperature of measurement. Conductivity measurement gives rapid and practical estimate of the variation in the dissolved mineral contents of a water supply.

iv. Chlorides : Chloride anion is generally present in natural waters. The presence of chloride in natural waters can be attributed to dissolution of salt deposits, contamination resulting from salting on roads to control ice and snow discharge of effluents from chemical industries, oil well operations, sewage discharges, irrigation drainage contamination from refuge leachates, and seawater intrusion in coastal areas. Each of these sources may

result in local contamination of both surface water and ground water. The salty taste produced by chloride depends on the chemical composition of the water. A concentration of 250 mg/l may be detectable in some waters containing sodium ions. On the other hand, the typical salty taste may be absent in water containing 100 mg/l chloride when calcium and magnesium ions are predominant. A high chloride content also has a deleterious effect on metallic pipes and structures as well as an agricultural plants.

Three methods are suggested for the estimation of chloride. (i) involving titration against standard mercuric nitrate solution, (ii) an argentomatric method, and (iii) a potentiometric method. The mercurimetric method is recommended when an accurate determination of chloride is required, particularly at low concentrations. The potentiomertic method is suitable only when the sample is coloured or turbid, argentometric method is the simplest one and can easily be carried out. Chloride is determined in a natural or slightly alkaline solution by titration with standard silver nitrate, using potassium chromate as an indicator silver chloride is quantitatively precipitated before red silver chromate is formed.

v. Turbidity : Suspension of particles in water interfering with passage of light is called turbidity. Turbidity is caused by wide variety of suspended matter which range in size from colloidal to coarse dispersions depending upon the degree of turbulence and also ranges from pure inorganic substances to those that are highly organic in nature. Turbid waters are undesirable from aesthetic point of view in drinking water supplies and may also affect products in industries. Turbid water also poses a number of problems in water treatment plants. Turbidity is measured to evaluate the performance of water treatment plants. Turbidity can be measured either by its effect on the transmission of light which is termed as turbidimetry or by its effect on the scattering of light which is termed as Nephelometry. Turbidimeter can be used for samples with moderate turbidity and nephelometer for samples with low turbidity. Higher the intensity of scattered light higher the turbidity.

vi. Dissolved Oxygen (DO): All living organisms are dependent upon oxygen in one form or the other to maintain the metabolic processes that produce energy for growth and reproduction. Aerobic processes are the subject of great interest for their need for free oxygen. Dissolved oxygen is also important in precipitation and dissolution of inorganic substances in water. The solubility of atmospheric oxygen in fresh water ranges from 14.6 mg/l at 0 ^{0}C to about 7.0 mg/l at 35 ^{0}C under one atmospheric pressure. Since it is poorly soluble gas its solubility directly varies with the atmospheric pressure at any given temperature. Analysis of DO is a key test in sanitary engineering, practice.

The following illustrations reveal importance of DO as a parameter :

a. It is necessary to know DO levels to assess quality of raw water and to keep a check on stream pollution.
b. In liquid waste dissolved oxygen is the factors that determines whether the biological changes are brought out by aerobic or anaerobic organisms.
c. DO test is the basis of BOD test which is an important parameter to evaluate pollution potential of wastes.

d. DO is necessary for all aerobic biological waste-water treatment processes.
e. Oxygen is an important factor is corrosion. DO test is used to control amount of oxygen in boiler feed waters either by chemical or physical methods.
f. DO is necessary for all aerobic biological waste-water treatment processes.

Oxygen present in sample oxidizes the divalent manganous to its higher valancy which precipitates as a brown hydrated oxide after addition of NaOH and KI. Upon acidification, manganese reverts to divalent state and liberates iodine from KI equivalent to DO content in the sample. The liberated iodine is titrated against $Na_2 S_2 O_3$ (N/80) using starch as an indicator. Optional parameters

The parameters mentioned in this section are those which can be estimated by organizations which have a fairly well established laboratory. As mentioned earlier these depend on location of the sampling point and the use to which the water is to be put to e.g. if the river is to be used for drinking water supply then bacteriological examinations become indispensable; if the water is to be used for industrial purposes then the selection of parameter will depend on the type of industry e.g. a textile mill or a power plant will need water with low total dissolved solids. A list of such parameters is given below :

OTHER	IMPORTANT	PARAMETERS
BOD	Nitrogen	Potassium
COD	Phenols	Cadmium
Heavy metals	Fecal Streptococci	Pesticides
Phosphorus	Sodium	Phenols

Water quality required for various uses, industries and irrigation practices is given below :

Inorganic Constituents of Health Significance

Constituents	Unit	Guideline Value	Remarks
arsenic	mg/l	0.05	
asbestos	-	no guidelines value set.	
barium	-	no guidelines value set.	
beryllium	-	no guidelines value set.	
cadmium	mg/l	0.005	
chromium	mg/l	0.05	
cyanide mg/l	mg/l	0.1	
fluoride mg/l	mg/l	1.500	natural or deliberately added local or climatic conditions may neccessitate adapation.

hardness	-	no health related guide-line value set
lead mg/l		0.05
mercury	mg/l	0.001
nickel	-	no guideline value set
nitrate	mg/l(N)	10
nitrite	-	no guideline value set
selenrium	mg/l	0.01
silver	-	no guideline value set
sodium	-	no guideline value set

Organic Constituents of Health Significance

Constituents	Unit	Guideline Value	Remarks
aldrin and dieldrin	ug/l	0.03	
benzene	ug/l	10.00	
benzo pyrone	ug/l	0.01	
carbon tetrach-loride	ug/l	3.00	tentative guidelines value
chlordane	ug/l	0.30	
chlorobenzenes	ug/l	no health related guideline value set	odour threshold concentration between 0.1 and 3 μg/l.
chloroform	ug/l	30.00	disinfection efficiency must not be compromised when controlling chloroform content.
chlorophenols	ug/l	no health related guideline	odour threshold concentration 0.1 μg/l. value set.
2, 4-D	ug/l	100.00	
DDT	ug/l	1.00	
1,2 dichloroethane	ug/l	10.00	
1,1 dichloroethane	ug/l	0.30	
heptachlor and hepatachlor expoxide			
hexach	ug/l	0.10	
lorobenzene	ug/l	0.01	
gamma-HCH (lindane)	ug/l	3.00	
methoxychlor	ug/l	30.00	
Pentachlorophenol	ug/l	10.00	
Tetrachloroethene	ug/l	10.00	
Trichloroethene	ug/l	30.00	Tentative guideline value

2,4,6 trichloro-phenol	ug/l	10.00	Odour threshold concentration 0.1 ug/l.
trihalmethanes		no guidelines value set.	See chloroform

Aesthetic Quality

Constituents of characteristic	Unit	Guideline Value	Remarks
Aluminium	mg/l	0.20	
Chloride	mg/l	250.00	
Chlorobenezenes and chlorophenols	-	no guidelines value set	These compounds may affect taste and odour.
colour	True colour TCU	15.00	
copper	mh/l	1.00	
detergents	—	no guidelines value set	There should not be any foaming or taste and odour problems.
hardness	mg/l (as $CaCO_3$)	500	
hydrogen sulfide	—	not detectable by consumers	
iron	mg/l	0.3	
manganese	mg/l	0.1	
Oxygen dissolved	—	no guidelines value set	
pH	—	6.5-8.5	
sodium	mg/l	200	
solids total dissolved	mg/l	1000	
sulfate	mg/l	400	
taste and odour	—	inoffensive to most consumers.	
temperature	—	no guidelines value set	
turbidity	nephelmetric turbidity units (NTU)	5	preferably 1 for disinfection efficiency.
zinc	mg/l	5.0	

Radioactive constituents

Constituents	Unit	Guideline Value	Remarks
Gross alpha activity	Bq/l	0.1	(a) If the levels are exceeded more detailed radionuclide analysis may be necessary.
Gross beta activity	Bq/l	1.0	(b) Higher levels do not necessarily imply that the water is unsuitable for human consumption.

APPLICATION OF RIVER WATER QUALITY DATA

The exercise in monitoring water quality should culminate in meaningful conclusion. Whatever be the uses of the river water, the primary concern of all the agencies should be to maintain the healthy aquatic ecosystem. If the effects of human activities have been deleterious to the aquatic life, then huge efforts are required to revive the system in that particular stretch of the river. The parameter which can be singled out for the assessment of water quality is dissolved oxygen. It is customary to talk about the creditors and benefactors in oxygen balance of river. The creditors which demand oxygen from a river are ·

i) Organic matter in the river - determined by BOD
ii) Slimy growths on the rocks, shores, banks of the river
iii) Bottom deposits
iv) Dead Algae
v) Increase in temperature - solubility of oxygen is less at high temperature, oxygen is lost.
vi) Respiratory requirements of fish and other organisms.
vii) Salinity (in case tidal rivers mostly) - oxygen saturation value reduces from 8.2 to 7.6 mg/L, if salt concentration increases to 10,000 mg/L.

The benefactors can be listed as :

i) Photosynthesis
ii) Reaeration - due to air/water interphase
iii) Decrease in temperatures, percent saturation of oxygen increases.
iv) Dilution by fresh uncontaminated tributaries.

If the total demand of oxygen by creditors exceeds the contribution of benefactors then oxygen in the river will be deficient resulting in unhealthy situation. The most important step would be to reduce organic wastes being added, for which wastewater treatment has to be resorted to.

River surveys conducted on sound scientific basis, measurement of parameters by standard analytical procedures should be such that the data will help in assessment of total demand of oxygen vis-a-vis total reaseration capacity of the river.

Such information will help to compute DO curve from the combined effects of deoxygenation and reaeration. This curve shows the course of dissolved oxygen along a stretch of a river.

Effects of deoxygenation and reaeration depend on their rates viz. K_1 and K_2 respectively. K_1 , the deoxygenation constant depends on time, temperature, the type of organic matter and biological, chemical and physical condition of the river. If domestic waste (sewage) is being added, then its daily rate of deoxygenation in India is 0.2 per day at 25 ^{0}C. If the temperature of the river is 30 ^{0}C, then K is 0.22. If the rate of deoxygenation is more

than this, and if the waste is being added to the river, then oxygen will be depleted faster from water and the vice versa. Mathematical calculation of rates of deoxygenation is possible. The reader is referred to Ref.

This rate constant is shown as K_1. Curve of deoxygenation will be curve of the BOD reaction minus the rate of withdrawal of oxygen. This is maximum at the start and comes down to zero continuously. Reaeration is also a rate phenomenon. There are different factors which affect the process of reaeration. Reaeration is nature's mechanism to counteract the effects of deoxygenation. Reaeration like deoxygenation is a property governed by a rate. These are a number of formulae which enable to calculate rates of reaeration. Streeter and Phelps gave two such formulations :

$$\frac{dD}{dt} = K_1L - K_2D$$

(D is oxygen deficit, L is ultimate carbonaceous demand). This is a differential equation, which can be solved to give :

$$D = \frac{K_1L_A}{K_2 - K_1}\left(10^{-K_1t} - 10^{-K_2t}\right) + DA.10^{-K_2t}$$

This equation is very widely used and is based on the fact that rate of aeration is proportional to the oxygen deficit. This equation, does not consider the benthic decomposition on the river bed, needs measurement of (i) time of travel, (ii) dissolved oxygen, (iii) ultimate carbonaceous BOD and (iv) K_1.

Oxygen Sag Analysis

The course of dissolved oxygen along a scratch in a river can be depicted in the form of a curve from the combined effects of deoxygenation and reaeration.

Curve of deoxygenation will be curve of BOD reaction minus the rate of withdrawal of oxygen. This starts at a maximum and diminishes to zero.

Reaeration curve starts at zero, because water is assumed to be saturated. Reaeration rate is proportional to oxygen saturation deficit. Therefore, the rate of reaeration increases as deficit increases.

There is a critical point, when DO is minimum. Then, the reaeration is conspicuous and D.O. rises.

WATER QUALITY STANDARDS

Three types of water quality standards are in use. They are (i) drinking water quality standards, (ii) receiving water standards and (iii) affluent standards. Out of these receiving water quality standards are impractical. Therefore, (i) and (iii) are in common use in India. Drinking water quality standards have been laid by Indian Council of Medical Research (I.C.M.R.) and Bureau of Indian Standards (BIS), whereas (iii) i.e. effluent standards have been based on B.S.I. standards. Many state water pollution control boards have evolved their own standards. At this point it will be appropriate to distinguish between standards and criteria. Standards are levels derived from various considerations like, economic, social, political and have a legal binding. Criteria indicate main scientific information to formulate the standards, which also depend on uses of water.

Scientific river surveys will relate discharge quality with the resultant quality of receiving water. As has been explained in this report, river surveys should help in the quantification of effects of physical (mixing, dilution), chemical (adsorption, complexation etc.) and biological processes which take place when wastes are added to a river. This can lead to appropriate water quality criteria and subsequently to the standards of water quality.

Drinking water quality guidelines of WHO, are given below :

WHO guidelines for Drinking Water Quality

A. Inorganic constituents of health significance

Constituents	Unit	Guideline value
Arsenic	mg/L	0.050
Cadmium	mg/L	0.005
Chromium	mg/L	0.050
Cyanide	mg/L	0.100
Fluoride	mg/L	1.500
Lead	mg/L	0.050
Mercury	mg/L	0.001
Nitrate	mg/L (N)	10.00
Selenium	mg/L	0.01

ಪ. Aesthetic quality

Constituents	Unit	WHO Guideline value
Aluminium	mg/L	0.2
Chloride	mg/L	250.0
Colour	True Colour	15.0
Copper	mg/L	1.0
Hardness	mg/L	500.0

Iron	mg/L	0.3
Manganese	mg/L	0.1
pH	--	6.5-8.5
Sodium	mg/L	200.0
Dissolved solids	mg/L	1000.0
Sulphate	mg/L	400.0
Turbidity	NTU	5.0
Zinc	mg/L	5.0

C. Substances and characteristics affecting the acceptability of water for domestic use

Substance or Characteristics	Units	Highest/ desirable level	maximum permissible level
Colour	TCU	5 units	25
Turbidity	JTU	5	25
Dissolved Solids	mg/L	500	1500
pH		7-8.5	6.5-9.2
Hardness	mg/L	300	600
Calcium	mg/L	75 Ca	200 Ca
Mangnesium	mg/L	Not more than 50 mg Mg/L if there are 200 mg SO_4 /L.	100, magnesium upto 100 mg/L may be allowed @ 1 mg/L for every 4 mg/L decrease in sulphate.
Copper	mg/L	0.05	1.5
Iron	mg/L	0.1	1.0
Manganese	mg/L	0.1	0.5
Chloride	mg/L	200	1000
Sulphate	mg/L	200	400
Nitrate	mg/L	200 mg NO	More information required

CONSTITUTION OF INDIAN NATIONAL COMMITTEE ON HYDROLOGY

i.	Chairman Central Water Commission New Delhi.	Chairman
ii.	Director National Institute of Hydrology, Roorkee.	Executive Member
iii.	Dy. Director -General Geological Survey of India, Calcutta.	Member
iv.	Chairman Central Ground Water Board, Faridabad	Member
v.	Dy. Director -General Indian Meteorological Department, New Delhi.	Member
vi.	A Senior Scientist of National Remote Sensing Agency, Hyderabad.	Member
vii.	Member (D&R), Central Water Commission New Delhi	Member
viii.	Director, Railway Design Standards Organisation Lucknow	Member
ix.	Additional Director Indian Institute of Tropical Meteorology Pune	Member
x.	Director, Central Designs Organisation, Gandhinagar, Gujarat	Member
xi.	Chief Engineer (Design) Irrigation Department, U.P. Roorkee,	Member
xii.	Director, Central Designs Organisation, Calcutta, West Bengal	Member
xiii.	Director, BODHI, Bhopal, Madhya Pradesh	Member
xiv.	Chief Engineer & Director Water Resources Designs Organisation, Bangalore, Karnataka.	Member
xv.	Chief Engineer, Central Designs Organisation, Nasik, Maharashtra	Member
xvi.	Prof. B.V Rao, Indian Institute of Technology, Bombay.	Member
xvii.	Dr. T. Prasad, Director Centre for Water Resources Studies Patna.	Member
xviii.	Dr. Pandari Kanthan Director, Centre for Water Resources, Anna University, Madras,	Member
xix.	President, Indian Association of Hydrologists, Roorkee	Member
xx.	Director (R&D&SA) Central Water Commission New Delhi	Member
xxi.	Senior Scientist, National Institute of Hydrology Roorkee	Member- Secretary

composed & printed by : anubhav printers, roorkee © 71237, 72007