

**WORKSHOP
ON
SURFACE WATER QUALITY MONITORING
UNDER
HYDROLOGY PROJECT**

7-8 MARCH, 2000

TECHNICAL PAPERS

Organised By

**CENTRAL POLLUTION CONTROL BOARD
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**CENTRAL WATER COMMISSION
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HYDROLOGY PROJECT

Workshop on Surface Water Quality Monitoring

under Hydrology Project

(March 7- 8, 2000)

Date	Time	Topic of Discussion	Speakers	
Day 1	0930 – 1000	Registration		
	1000 – 1030	Inauguration	Chief Guest- Chairman, CWC; Chairman, CPCB; Member (RM), CWC; and Team Leader, HP	
	1030 – 1100	Tea		
	Technical Session I : Objectives, Issues & Mandates on SW-WQ Monitoring Session Chairman : Prof. Dilip Biswas, Chairman, CPCB			
	1100 – 1130	Objectives and issues	Shri Indra Raj, SJC(WM), PCS	
	1130 -- 1200	Mandates of different agencies for water quality monitoring	Shri A. R. Bakshi, Director (WM)	
	1200 --1230	Design of water quality monitoring network	Dr. R. H. Siddiqi, HP- Consultant	
	1230 -- 1300	Views of State Agencies on objectives and issues *	All	
	1300 - 1400	Lunch		
	1400 – 1500	Views of State Agencies on mandates and network *	All	
	1500 – 1530	Discussions and conclusions	All	
1530 – 1600	Tea			

	Technical Session II : Rationalisation of Monitoring Programme Session Chairman : Dr. J. G. Grijsen, Team Leader, Hydrology Project		
	1600 – 1620	Rationalisation of existing water quality monitoring programme including sampling location, parameters and frequency of sampling	Dr. M. C. Dutta, RO, RDD, CWC/ Dr. S. P. Chakrabarti, HP-Consultant
	1620 – 1640	Periodic review of monitoring programme	Er. S. C. Chadha, Director, CWC
	1640 – 1700	Discussions and conclusions	All
Day 2	Technical Session III : Data Analysis and Information Dissemination Session Chairman : Dr. R. H. Siddiqi, Consultant, Hydrology Project		
	0930 – 1000	Data validation and analysis	Ms M. Villars, HP-consultant
	1000 – 1030	Dissemination of Information : Design of Year Book	Dr. Roop Narain, CWC, HP Dr. S. P. Chakrabarti, Consultant, HP
	1030 – 1100	Discussions and conclusions	All
	1100 – 1130	Tea	
	Technical Session IV : Quality Assurance Session Chairman : Er. S. K. Das, Chief Engineer (P&D), CWC		
	1130 – 1200	Quality assurance – analytical quality control	Sh. A. K. Mitra, CWC
	1200 – 1230	Accreditation & recognition of Lab.	Dr. M. Q. Ansari, Sr. Scientist, CPCB Dr. S. P. Chakrabarti, Consultant, HP
	1230 – 1300	Discussions and conclusions	All
	1300 – 1400	Lunch	

Technical Session V : Concluding Session Session Chairman : Prof. Dilip Biswas, Chairman, CPCB		
1400 – 1445	Constraints in implementation of sustainable monitoring programme	CWC & State Agency representatives
1445 – 1530	Conclusions & recommendations	CWC-RD, HP
1530 – 1600	Tea	
1600 – 1700	Valedictory function	Chairman, CPCB; Sh. M. K. Sharma, Commissioner (WM) PCS; Dr. J. G. Grijssen. HP, Sh. Das, Chief Engr.(PD),

*Executive Engineers of Central & State Agencies to present

ISSUES AND OBJECTIVES IN SURFACE WATER QUALITY MONITORING PROGRAMME UNDER HYDROLOGY PROJECT

Shri Indra Raj, Sr. Joint Commissioner (WM)
Central Water commission

1. Introduction

The need for water to meet our daily requirements is ever-increasing with the growth in population and its thirst for improved standard of living. With the spate in industrialisation in recent years to support the human need, water requirement has further accentuated. Rain fall being limited only during monsoon period of about three months at a stretch, the surface water availability ranges precariously poised between flood and drought conditions. In the process, people suffer from non-availability of 'quality' water either because of contamination of this scarce resource out of human excretions and other pollutants from agricultural activities being carried to the water front in the form of surface wash-off, or non-availability of enough water in rivers to dilute the untreated/partially treated municipal sewage and industrial effluent to acceptable / permissible quality level. Health of the rivers also gets upset to support the aquatic life forms so essential for self-purification. Irrigation with polluted river water not only could create bio-accumulation of pollutants in crop, it has also potential for causing soil sickness and groundwater contamination.

The Indian Parliament enacted the Water (Prevention and Control of Pollution) Act, 1974 to maintain or restore wholesomeness of water bodies so that various beneficial usages out of this scarce wealth could be sustained.

It is, therefore, imperative to have a close watch on the quality of surface waters through frequent monitoring so that any impairment in their quality is taken cognisance of by the appropriate body/authority for action programmes in restoration of quality.

2. Monitoring of Surface Water Quality

The quality of surface water is being monitored in the country since several decades by various agencies viz. the Central Water Commission (CWC), the State Irrigation Departments and the Central & State Pollution Control Boards. However, the mandates and objectives of these agencies being different, there had been no unified procedure for monitoring to provide a holistic view of the characteristics of the water bodies. While the interest of the CWC was mostly oriented towards the development of the surface water resources, the river gauging & discharge measurement and determination of sediment transport & its characteristics at limited locations, the water quality was analysed for a few physico-chemical parameters, mainly for historical recording purposes. The State Water Resources agencies also were confined to similar activities, but their main interest was devoted to the determination of the suitability of the surface water resources for use in irrigation. The interest of the Pollution Control Boards were limited to determination of the health of the river in terms of pollution related parameters for surveillance of water quality and determination of impact due to discharge of pollutants through different sources. Thus the monitoring programmes of the various agencies were like mutually exclusive events with no virtual co-ordination among them.

The water quality monitoring programme under the Hydrology Project is currently under implementation by the Ministry of Water Resources envisages to improve upon the existing set-up. The Project aims to strengthen the water quality monitoring programme of the Central and State agencies with an integrated approach.

3. Issues to be Addressed

Investigation of the present incoherent and inadequate water quality monitoring system of the various agencies revealed that the following areas need attention :

- Even if there is no specific mandate for the Central and State surface water resources development agencies to monitor river water quality for maintaining or

restoring wholesomeness of water bodies, it is implied that the quality of the resources developed should be monitored to observe that it satisfies the quality criteria to sustain the designated-best-uses. In case of non-compliance, the information need to be passed on to the concerned agency for pollution control. Otherwise, it would necessitate duplication of effort by such agencies which would be expensive.

- Water quality monitoring mechanism should be uniform among all concerned agencies for comparative results.
- Quality assurance programmes should be in-built for reliability of data.
- Analytical capability of the laboratories in terms of modern instrumental facilities and trained manpower should be constantly upgraded at reasonable frequency.
- Monitoring programme should be reviewed at regular intervals by a State level Committee as the riverine system is dynamic and anthropogenic activities on river basins are fast changing due to rapid urbanisation and industrialisation.
- Water quality data generated from the monitoring programme should be validated before storage in the Data Centre for creating the database.
- Water quality data should be transformed into information at the Data Centre for fast dissemination among user agencies.

4. Objectives of the Hydrology Project

Keeping the above issues in view, the objectives of the Hydrology Project (HP) with special reference to water quality monitoring programme can be summarised as follows :

- Designing of the monitoring network for establishing baseline water quality, observing trend in quality changes and calculation of flux of water constituents at representative locations, avoiding duplication among participating agencies;
- Evolving Type-designs for a three-tier system of laboratories for analysing field parameters at level-I laboratories near to the sampling locations, physico-chemical and bacteriological parameters including pollution related parameters in level-II laboratories, and toxic substances including heavy metals and pesticides in level-II+ and level-III laboratories;
- Selection of monitoring parameters and frequency for different types of stations;
- Standardisation of analytical procedures for various parameters;
- Designing specifications for state-of-the-art instruments for procurement by the respective agencies;
- Designing methodology for ‘Analytical Quality Control’ (AQC) through ‘Within laboratory’ and ‘Inter-laboratory’ exercises;
- Standardising procedures for data validation and data entry system; and
- Dissemination of water quality information for user agencies

5. Concluding Remarks

The Hydrology Project planned for six year duration is operational for over 4 years. Attempts are being made on all fronts mentioned above. While considerable progress has been made on the design aspects of the monitoring programme, some of the activities are being delayed due to inescapable reasons in developing the infrastructure facilities, like construction of laboratory building, procurement of some of the analytical instruments, deployment of qualified laboratory personnel. Such obstacles do occur when multiple organisations are involved. But sampling and

analysis as per designed network should start with whatever resources / facilities are available at hand which will gradually be strengthened. Water quality data should start flowing to the Data Processing Centres for validation and for analysis, storage and dissemination with effect from January, 2001 if not earlier. This will enable reviewing of the monitoring mechanism for finer tuning before the Project duration ends.

The objective of the Workshop will be best served if the participants deliberate on the various aspects of the methodology of the monitoring programme to come to a consensus so that uniform and consistent procedures are adopted for comparable and reliable data generation required for water resource development and planning.

RATIONALISATION OF SURFACE WATER QUALITY MONITORING PROGRAMME

Dr. M. C. Dutta * and Dr. S. P. Chakrabarti **

1. Introduction

Surface water quality is being monitored since decades by several agencies of the Central and State governments. The Central Water Commission and the State Irrigation Departments are principally concerned with the development of surface water resources, including measurements of river water level and discharge for flood forecasting and flood control, and monitoring of sediment transport and its characteristics for prevention of soil erosion in the catchment area of the basin besides analysis of physico-chemical properties of water to ascertain its suitability for drinking and irrigation. However, there was no specific mandate for these agencies for protection of quality of the scarce water resources.

With the enactment of the “Water (Prevention and Control of Pollution) Act, 1974”, the Central and State Pollution Control Boards were constituted under the provisions of this Act with the sole objective of maintaining or restoring wholesomeness of water bodies to meet the requirements of various beneficial uses.

In view of the differences in the objectives of the afore-mentioned agencies, their monitoring programmes were at variance with one another. Each of these agencies has extensive and expensive network for monitoring stations with hardly any co-ordination among them to initiate a unified method of water sampling and analysis of surface water for the cause of protection of its quality through quality improvement programmes.

Being concerned with the problem, the Ministry of Water Resources, Government of India, has taken up the Hydrology Project (HP) of six year duration in collaboration with the government of The Netherlands, to develop a national Hydrological Information System (HIS) with user-friendly software for the benefit of the concerned agencies. The Hydrology Project Directorate of the Central Water Commission (CWC) has been

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involved in the development of the methodology for designing WQ monitoring networks, rationalisation of existing WQ monitoring programme including sampling locations, parameters and frequency of sampling, guidelines for analytical procedures, data validation, analytical quality control etc., which are ready for adoption by the monitoring agencies at the Central and State levels. However, it is imperative to have detailed deliberations on the above-mentioned issues to arrive at a consensus decision before adoption .

2. Monitoring Objectives

The main objectives for surface water quality monitoring, as conceived under the Hydrology Project, are as follows:

- Monitoring for establishing Baseline water quality
- Observing trend in water quality changes
- Calculation of flux of water constituents of interest
- Surveillance for ensuring quality requirements for various designated-best-uses for their sustenance
- Dissemination of data to user agencies for their water quality management programmes

3. Frequency and Parameters

3.1 Monitoring frequency and the selection of parameters are decided keeping in view the objectives of sampling at a particular location and the type of use the concerned stretch of the water body is subjected to. Although the surface water agencies do have considerable historical data stored in 'Water Quality Year Books', the data generated are incomparable in view of the difference in objectives of sampling and the varying monitoring system. Hence, it would be to consider all water quality monitoring stations as a combination of *Baseline* and *Trend* stations to start with.

3.2 Samples shall be collected every two months viz. May / June (pre-monsoon), August, October, December, February and April, which will fairly represent all seasons of the year. This will generate six samples from perennial rivers and 3-4 samples from seasonal rivers, every year.

3.3 After data are collected for three years, the stations will have to be reclassified as either *Baseline*, *Trend* or *Flux* stations after examining the data. The stations indicating no influence of human activity on water quality will finally be classified as the *Baseline* Station. Others will remain as *Trend* stations. If a station is classified as a *Baseline* station, it will have to be monitored, after every three years, again for one year at a frequency of every two months to observe the qualitative change, if any. If there is no considerable change, the station will continue to be the *Baseline* station and it will be monitored again after three years. Otherwise, it will have to be reclassified and monitored as a *Trend* station.

3.4 If a station is classified as *Trend* station, it will continue to be monitored but with an Increased frequency of once every month.

3.5 Stations will be classified as *Flux* stations where it is considered necessary to measure the mass of any substance carried by the flow. The frequency of sampling at such stations and analyses of constituents of interest may be increased to 12 or 24 times per year. measurement of discharge at such stations is necessary.

3.6 The recommended parameters for analysis for different categories of stations are given in Table 1.

Table 1 Parameters of analysis for surface water samples^a

Parameters	Initially	Baseline	Trend
General	Temp, EC, pH, DO, TDS	Temp, EC, pH, DO, TDS	Temp, EC, pH, DO
Nutrients	NH ₃ -N, NO ₂ + NO ₃ , total P	NH ₃ -N, NO ₂ + NO ₃ , total P	NH ₃ -N, NO ₂ + NO ₃ , total P
Organic matter	BOD, COD	None	BOD, COD
Major ions	Ca ⁺⁺ , Mg ⁺⁺ , K ⁺ , Na ⁺ , CO ₃ ⁻ , HCO ₃ ⁻ , Cl ⁻ , SO ₄ ⁻	Ca ⁺⁺ , Mg ⁺⁺ , K ⁺ , Na ⁺ , CO ₃ ⁻ , HCO ₃ ⁻ , Cl ⁻ , SO ₄ ⁻	Cl ⁻
Other inorganics	None	None	None
Metals	None	None	None
Organics	None	None	None
Microbiological ^b	Total coli.	None	Total and fecal coli.
Biological	None	None	None

a- based on 'Surface Water Quality Network Design, Guidelines and an Example', June 1997

b- depending on workload, analysis frequency may be reduced upto 2 samples per year

Other inorganics, metals, organics and microbiological parameters for analysis shall be determined as a part of special *survey* programmes, which may include some of the *Trend* stations where there is a need for determination of any of these groups of parameters.

3.7 The *survey* programmes shall ordinarily be of one year duration. The sampling frequency may be the same as that for Trend stations.

3.8 Special arrangements for sampling and transport of the samples will be necessary for the *survey* programmes and microbiological samples.

4. Sample Collection

4.1 The most important aspect in the surface water quality monitoring programme is the sampling. Location of sampling shall be so selected that the sample collected is representative of the water quality in that stretch indicating the health of the water body. More often than not samples are collected either from the bank or from the stagnant pool of water near the bank or just downstream of any polluting discharge into the water body, the quality of which is to be monitored. In all the above cases, the samples will not be representative for obvious reasons. The samples shall invariably be collected from the centre of the main stream of the flow/ river discharge from a depth of 30 cm from the water surface using a weighted bottle or by means of a Dissolved Oxygen (DO) sampler avoiding mixing of air into the water sampled. Hence, a location map of the sampling point is essential for the sampling personnel to arrive at the exact location.

4.2 In case of surveillance stations to monitor the impact of any polluted discharge into the water body, samples shall not be collected from immediate downstream or in near vicinity in the same bank where the pollutants are discharged. The ideal location will be sufficiently downstream where the pollutants discharged are thoroughly mixed/dispersed in the medium. Such a location is to be identified through a detailed survey.

4.3 Another extreme situation for sampling can be when the flow in the river is not enough to dip the DO-sampler, which is very common for Indian rivers. In such

conditions, samples shall be collected from just below the surface of the main flowing stream avoiding floating matters and mixing of air in the sample.

4.4 In case of any deviation in the sampling point, it shall be recorded in the Sample Identification Form to be filled for each sample, including local weather conditions at the time of sampling.

4.5 Sample containers shall be previously cleaned before coming to site. The container shall be rinsed with the sample at site three times before it is filled. A small air space shall be left inside the sampling bottle to allow mixing of sample at the time of analysis.

4.6 Sample containers shall be properly identified by attaching an appropriately inscribed tag or label. The sample code and the sampling date shall be clearly marked on the sampler or the tag. The sample 'Identification Form', as shown in Figure 1, shall be filled for each sample for each sampling occasion after doing the analysis for field parameters. If there are more than one bottle filled at a site, it is to be registered in the same form. Sample identification forms shall all be kept in a Master File at the level II or II+ laboratory.

4.7 Samples from reservoir site shall be collected from the out-going canal, power channel or water intake structure, in case water is pumped. When there is no discharge in the canal, sample shall be collected from the upstream side of the regulator structure, directly from the reservoir.

4.8 DO shall be determined in a sample collected in a DO bottle using a DO sampler. The DO must be fixed immediately after collection. DO concentration can then be determined either in the field or later, in a level I or level II laboratory.

Figure 1 Sample identification form for surface water samples

Sample code															
Observer					Agency				Project						
Date			Time		Station code										
Parameter code		Container				Preservation				Treatment					
		Glass	PVC	PE	Teflon	None	Cool	Acid	Other	None	Decant	Filter			
(1) Gen															
(2) Bact															
(3) BOD															
(4) COD, NH ₃ , NO ₃ ⁻															
(5) H. Metals															
o T (6)Tr. Organics															
Source of sample															
Waterbody		Point			Approach		Medium			Matrix					
o River		o Main current			O Bridge		o Water			o Fresh					
o Drain		o Right bank			O Boat		o Susp. matter			o Brackish					
o Canal		o Left bank			O Wading		o Biota			o Salt					
o Reservoir							o Sediment			o Effluent					
Sample type		o Grab o Time-comp o Flow-comp o Depth-integ o Width-integ													
Sample device		o Weighted bottle o Pump o Depth sampler													
Field determinations															
Temp		°C		pH		EC			µmho/cm			DO		mg/L	
Odour code		Odour free		Septic		Colour code			Light brown		Dark green				
		Rotten eggs		Aromatic					Brown		Clear				
		Burnt sugar		Chlorinous					Dark brown		Other (specify)				
		Soapy		Alcoholic					Light green						
		Fishy		(10)Unpleasant					Green						
Remarks															
Weather		o Sunny o Cloudy o Rainy o Windy													
Water vel. m/s		o High (> 0.5) o Medium (0.1-0.5) o Low (< 0.1) o Standing													
Water use		o None o Cultivation o Bathing & washing o Cattle washing o Melon/vegetable farming in river bed													

5. Sample Container, Preservation and Transport

5.1 The material of the container shall be such that it does not contaminate the sample due to leaching. Preservation of samples during transportation from site to the laboratory for analysis is also equally important. The type of container and the preservatives to be used are indicated in Table 2.

Table 2 Types of sample containers and preservation chemicals

Analysis	Type of Container	Preservation
General	Glass, PE	None
COD, NH ₃ , NO ₂ ⁻ , NO ₃ ⁻	Glass, PE	H ₂ SO ₄ , pH<2
P	Glass	None
DO	BOD bottle	DO fixing chemicals
BOD	Glass, PE	4 ⁰ C, dark
Coliform	Glass, PE, Sterilised	4 ⁰ C, dark
Heavy metals	Glass, PE	HNO ₃ , pH<2
Pesticides	Glass, Teflon	4 ⁰ C, dark

5.2 Samples shall be transported to concerned laboratory (level II or II+) as soon as possible, preferably within 48 hours.

5.3 Analysis of coliforms shall be started within 24 hours of collection of sample. If the time is exceeded, it shall be recorded with the result.

5.4 Samples containing microgramme / litre metal level, shall be stored at 4⁰C and analysed as soon as possible. If the concentration is of mg/l level, it can be stored for upto 6 months, except mercury, for which the limit is 5 weeks.

5.5 Left over samples shall be discarded only after primary validation of data.

6. Analysis and Record

6.1 Sample receipt register

There is a need for keeping record in the laboratory as the samples arrive and are distributed among the analysts/chemists. Each laboratory shall have a bound register, which is to be used for registering samples as they are received. An example of the headings and the information for such a register is given in Table 3.

Table 3 Sample receipt register

Date/Time received at lab.	Date/Time collected	Station code	Project	Collecting agency/collector	Preservation	Parameter code	Lab. Sample No.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
02.07.99/1400	01.07.99/1100	M 22	WQ monitoring	SW Div II/ Singh	No	1	28-1
02.07.99/1400	01.07.99/1700	M 24	WQ monitoring	SW Div II/ Singh	No	1	29-1
02.07.99/1400	01.07.99/1700	M 24	WQ monitoring	SW Div II/ Singh	Yes	4	29-4
05.07.99/1100	02.07.99/1300	S 44	Survey A	SPCB/ Bhat	Yes	5	30-5

The features of the above Table are as follows:

- Column (3) gives the station code conventionally followed by the monitoring agency.
- Column (4) gives the project under which the sample is collected.
- Column (7) corresponds to the parameter(s) code given in the sample identification form.

- Column (8) gives the laboratory sample number assigned to the sample as it is received in the laboratory. Note that the numbering has two parts separated by a hyphen. The first part is assigned in a sequential manner as samples are received from various stations. If two samples are collected at the same time from a station for different sets of analysis, the first part of the number is the same. The second part corresponds to the parameter code.
- The results of the analyses of all the samples having the same first part of the code would be entered in the data entry system as one sample having the same station code and time of sample collection.

6.2 Work Assignment and Personal Registers

For accountability and comparable distribution of work among analysts/chemist, the following procedure may be adopted:

- The laboratory incharge should maintain a bound register for assignment of work. This register would link the lab. sample number to the analyst who makes specific analyses, such as pH, EC, BOD, etc.
- An estimate of time needed for performing the analyses may also be entered in the register.
- Each laboratory analyst should have his/her own bound register, where all laboratory readings and calculations are to be entered.
- When analysis and calculations are completed, the results must be recorded in a register containing data record sheets described in the next section.

6.3 Analysis Record and Data Validation

- A recommended format for recording data is given in Figure 2. It includes all parameters, except heavy metals and trace organics, that may be analysed in the water quality monitoring programme currently envisaged. Ordinarily, a sample need NOT be analysed for all the listed parameters.

- Record of analyses for heavy metals and trace organics, which will be performed on a limited number of samples, shall be kept separately in a similar format.

- Columns (2) & (3) are to be filled from the entries in the Sample Receipt Register. Columns (4) – (9) pertain to the field measurements. This information will be available from the Sample Identification Forms. Columns (10) – (36) are to be filled in by the analyst(s) whom the work has been assigned (see Work Assignment Register).

- The format also includes primary data validation requirements in columns (37) – (53). The laboratory in-charge shall perform these validation checks as the analysis of a sample is completed. In case the analysis results do not meet any one of the validation checks, whenever possible, the analysis should be repeated. She/he would also fill in Columns (54) – (55).

- The results of the laboratory analyses shall be entered from these records in the data entry system.

7 Concluding Remarks

Water quality monitoring is a team work. Right from the preparatory work before proceeding for sampling till data validation and reporting to the District Data Centre, the activities are to be harmonised with a professional finish.

Collection of samples being the most crucial among the chain of activities, it shall not be left in the hands of un-skilled / casual staff as the entire monitoring programme and data generation hinges on representative sampling. The person collecting samples should have the application of mind in deciding, under the changing circumstances in the field, about the correct and representative point of sampling. Any variation in field conditions, which may have a bearing on the data generation and analysis, has to be recorded in the sample identification form with reasoning.

Figure 2 Data record and validation register

Data record

Laboratory / organisation

Laboratory code

Lab sample No	Station code	Date of collection	Field determinations						General				Nutrients			Org matter		Alkalinity		Hardness			Major ions						Other inorganics			Coliforms		Biol				
			pH	EC, μ mho/cm	DO, mg/L	Temp, $^{\circ}$ C	Colour, code	Odour, code	pH	EC, μ mho/cm	TDS, mg/L	TSS, mg/L	NH ₄ , mg N/L	NO ₂ +NO ₃ , mg N/L	Total P, mg/L	BOD, mg/L	COD, mg/L	Phen, mg CaCO ₃ /L	Total, mg CaCO ₃ /L	Total, mg CaCO ₃ /L	Ca ⁺⁺ , mg CaCO ₃ /L	Ca ⁺⁺ , mg/L	Mg ⁺⁺ , mg/L	Na ⁺ , mg/L	K ⁺ , mg/L	Cl ⁻ , mg/L	SO ₄ ⁻² , mg/L	CO ₃ ⁻² , mg/L	HCO ₃ ⁻ , mg/L	Si, mg/L	F, mg/L	B, mg/L	Total, MPN/100 mL	Faecal, MPN/100mL	Chlorophyll-A, μ g/L			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)	(30)	(31)	(32)	(33)	(34)	(35)	(36)			

Data validation

Lab sample No	Station code	Cations					Anions						Ion balance		EC bal	Carbon bal	CO ₃ ⁻² bal	Verification criteria	Checked by	Remarks	
		Ca ⁺⁺ , meq/L	Mg ⁺⁺ , meq/L	Na ⁺ , meq/L	K ⁺ , meq/L	Total cations	Cl ⁻ , meq/L	SO ₄ ⁻² , meq/L	CO ₃ ⁻² , meq/L	HCO ₃ ⁻ , meq/L	NO ₂ +NO ₃ ⁻ , meq/L	Total anions	$\frac{\{(41)-(47)\}}{\{(41)+(47)\}}$	$\frac{(39)}{(42)}$	$\frac{(12)}{(11)}$	$\frac{(18)}{(17)}$	If (10) < 8.3, is (19)=0 ?				
(1)	(2)	(37)	(38)	(39)	(40)	(41)	(42)	(43)	(44)	(45)	(46)	(47)	(48)	(49)	(50)	(51)	(52)	(53)	(54)	(55)	
																		(48) < 0.1 (49) = 0.8-1.2 (50) = 0.55-0.9 (51) > 1 (52) = yes			

PERIODIC REVIEW OF SURFACE WATER QUALITY MONITORING PROGRAMME

Er. S. C. Chadha*

1. Introduction

Surface water quality monitoring programme comprise several components and range of purposes, like (1) designing of the monitoring network following some rationale and categorisation of the monitoring stations depending upon quality requirements, (2) identification of the location for representative sampling, (3) finalising the frequency of monitoring and the parameters for analysis, (4) transportation of samples to laboratory after analysis of some of the field parameters and preservation of samples for analysis of the remaining parameters in the laboratory, (5) Standardising the analytical procedures, (6) data validation, (7) imposition of analytical quality control procedure for reliability in data generation, (8) data storage and interpretation, and (9) dissemination of information on water quality to data users for formulating action programmes to protect the wholesomeness of the water bodies and to meet the quality requirements to sustain various designated-best-uses. Hence, the functional elements are multi-disciplinary in nature and need to be harmonised for a concerted effort in generating reliable water quality data, so that the data user agencies are not at fault while drawing Action Plans for conservation of the quality of this scarce resource.

2. Need for Periodic Review of the Monitoring Programme

The river regime being an ever-changing dynamic system and so also being the land use

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pattern in a fast-developing country, like India, there is a need for periodic review of all the elements of the monitoring programme mentioned above. This is also necessary as the interpretation of the water quality data may reveal strengthening of monitoring programme in terms of more frequent sampling for surveillance, additional parameters for analysis, improved methods of analysis with state-of-the-art instruments for greater accuracy and precision to improve upon reliability in data generation etc. Besides, there may be necessities of having conjunctive studies on pollutant travel from surface to groundwater or vice-versa with the groundwater monitoring agencies and pollution control boards at the Central and State levels.

The “Hydrology Project” under the Ministry of Water Resources, Government of India, is for capability development of the Central and State Surface Water and Groundwater Agencies in water quality data generation as a part of the national “Hydrological Information System” (HIS) being developed under the Project, a mechanism has to be evolved for concerted effort in water quality monitoring programme through mutual discussion among the participating agencies for problem-solving and for sustenance of the programme even after the Project comes to an end.

3. Water Quality Monitoring and Co-ordination

Deliberations have already been held at the four regional level technical meetings on the recommendations of the State agencies participating in the Hydrology Project, and it was decided that the State-level Review Committees may discuss common problems/constraints for trouble shooting. The Committees will also review the locations of monitoring stations, need-based location-specific parameters and frequency of monitoring, co-ordination among State agencies to avoid duplication of efforts in WQ

monitoring, data analysis and interpretation, data management, faster communication and availability of data, analytical quality control among HP-laboratories etc. Data user agencies, within the scope of the Hydrology Project, have a provision under the Hydrological data user group meetings for interactions and feed back from user organisations. All project agencies are expected to formulate Hydrological Data User Groups (HDUG). A similar group for water quality may be essential. The memberships could comprise representatives from the following agencies:

- Central Water Commission (CWC)
- Central Ground Water Board (CGWB)
- Central Pollution Control Board (CPCB)
- State Pollution Control Board (SPCB)
- State level HP agencies
- Nodal Officers of the State
- Regional Data Centres of the State and CWC
- User agencies from educational and research institutes

The modalities of the membership, terms of reference, frequency of the meetings and scope may be discussed and finalised. The State level committees which may be statutory in nature, as recommended in the regional level meetings, may also be discussed.

4. Concluding Remarks

The proposal for constitution of the water quality data user group meetings and the State-level Committees is based on the premise that the monitoring agencies have understanding of the programmes of the member agencies through mutual exchange /dissemination of information besides having a unified procedure for monitoring in the

management of surface water quality. The member agencies could also initiate investigative studies of common interest to strengthen the monitoring programme without duplicating efforts for the common cause.

Such Committees can bring in transparency in the monitoring programme for the development of a reliable database on water quality through mutual help without being solely dependent on external technical support.

Note : The views expressed are for deliberations only and not of the Central Water Commission, Government of India.

Data Validation and Analysis

M. Villars*

1.1 Introduction

Validation of water quality data involves checking and assessment of the data to see if there have been any errors made during sampling or analysis of the water quality sample.

Definition

Water quality data validation consists of a series of checks to see if errors have been made in water sampling, sample analysis or data entry.

Standard checks should be applied to test the data. These usually involve the application of check readings for errors in time and magnitude. While many of the data validation checks can be made by hand, the checks are also built into the database software. The advantage of computer validation techniques are that they are objective and uniform. Data from all sources are subjected to the same scrutiny. The computer also allows the use of checking algorithms which can be tedious to apply manually.

One another important organizational aspect of validation is the possibility of splitting data validation tasks between field centres equipped with data entry microcomputers and the central data processing computer. Since most microcomputers have standard data entry software packages that incorporate data validation options, no software development effort is required. Fields validation checks could include absolute checks for dates and variable codes, and relative checks for range and rate of change. Tables and plots of input data could also be made for manual checking. Such a system would reduce considerably the error rate of data arriving at the centre where more elaborate validation, e.g., inter-station consistency checks, could be performed.

1.2 General Procedure for WQ Data Validation

Water quality data validation should be conducted in part by the chemist at a water quality laboratory, and in part by the water quality experts at the regional or district data centers.

The laboratory chemist will enter analytical results and field observations into the laboratory record sheet. This sheet includes a number of a validation checks to be conducted. In the future, the data will be entered into the computer database using the Data Entry Software (SW DES for WQ). This is currently under development. Most of the validation checks will be made by the database software.

Once the data has been checked, any signalled errors should be corrected if possible. This may require new analysis of some samples. The validated data will be sent by diskette from the laboratories to the regional data centre, where they will be added to the water quality data base.

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Further validation of data will take place at the data centre, where the latest data entries can be checked compared to the historical data.

1.3 Specific Data Validation Tests

A series of data checks should be carried out to identify any problems in the data. A number of tests is described below including:

- Absolute checking/Data entry
- Checking if data is within the detection limits of a particular method
- Checking if the data is within the expected ranges for a parameter
- Checking if there are too many (or too few) significant digits reported
- Checking if data are physically or scientifically possible (general checks)
- Checking correlation of parameters (Some conditional checks)
- Checking the correlation between EC and TDS
- Checking the cation-anion balance

Absolute checking/Data entry

Absolute checking implies that data or code values have a value range that has zero probability of being exceeded. Thus, geographical coordinates of a station must lie within the country boundary, the day number in a date must lie in the range 1-31, and in a numeric-coding system the value 43A cannot exist.

The limits used may take one of the following forms:

- A single absolute value or range;
- A set of ranges applicable in different areas and/or at different times
- Ranges applicable to many stations or ranges which are applicable only to individual stations.

Data failing these tests must be incorrect. It is usually a simple task to identify and remedy the error. The database software should be programmed to catch these types of errors during data entry.

Detection Limits

The water quality results reported cannot be less than the detection limit of the analytical procedure being used to measure the concentration. Thus all data should be checked compared to the expected detection limit. The detection limits of all analytical procedures must be known. If there are different procedures possible for making an analysis, the procedure that is used must also be known.

Checking WQ data against expected ranges

Water quality data can also be checked against expected ranges. For the parameters being measured in HP, typical ranges for surface water are known (Table 2).

Table 2 Some typical values for composition of surface water

Constituent	Unit	Concentration Range
Temp	°C	10-35
PH	-	6-9
EC	μS/cm	250-5000
Na ⁺	mg/l	5-75

Significant Digits

The number of significant digits to be reported for a water quality result depends on:

- the precision of the analytical procedure used
- the absolute value of the result compared to the range of expected results

General Checks

General checks are made to see if the water quality results are physically or scientifically possible.

A simple general check is that the totals of any variable must be greater than the component parts as in the following examples:

- Total coliforms must be greater than faecal coliforms
- Total iron must be greater than dissolved iron
- Total phosphorus must be greater than dissolved (ortho-)phosphorus
- Total iron must be greater than dissolved iron

General checks:

Total solids	≥ Total dissolved solids
Total solids	≥ Total settleable solids
COD	> BOD
Total Coli	≥ Faecal Coli
Total Iron	≥ Fe ⁺² , Fe ⁺³
Total P	≥ PO ₄ ⁻³
EC (μS/cm)	≥ TDS (mg/l)
Total oxidized nitrogen	≥ Nitrate, nitrite
Total oxidized nitrogen	= Nitrate + nitrite
Total hardness	= Ca hardness + Mg hardness

Some conditional checks: correlation of parameters

When there are known correlations between one or more water quality parameters these can be used to

Some of the more well known correlations between parameters are:

- Total dissolved solids and specific conductance
- pH and carbonate species
- pH and free metal concentrations
- Dissolved oxygen and nitrate

Conditional checks

If pH > 6 then Al⁺³ < detection limit
If pH > 6 then Mn⁺² < detection limit
If pH < 8.3 then CO₃⁻² = 0

If DO (mg/l) = 0 then NO₃⁻ = 0
If DO (mg/l) > 0 then NO₃⁻ > 0
If DO (mg/l) > 7 then Fe⁺² = 0

Correlation between EC and TDS

The numerical value of Electrical Conductivity (EC) in $\mu\text{S/cm}$ should be higher than that of Total Dissolved Solids (TDS) in mg/l. It is recommended that conductivity be plotted against TDS and values lying away from the main group of data be checked for errors. The relationship between the two parameters is often described by a constant (commonly between 0.55 and 0.7 for freshwaters).

Thus: TDS (mg/l) \sim 0.6 x EC ($\mu\text{S/cm}$)

The value of the constant varies according to the chemical composition of the water.

TDS and Conductivity

For freshwaters, the normal range of TDS can be calculated from the following relationship:

$$0.55 \text{ conductivity } (\mu\text{S/cm}) < \text{TDS (mg/l)} < 0.7 \text{ conductivity } (\mu\text{S/cm})$$

Typically the constant is high for chloride rich waters and low for sulphate rich waters.

Cation-Anion Balance

When a water quality sample has been analysed for the major ionic species, one of the most important validation tests can be conducted: the cation-anion balance.

The principle of electroneutrality require that the sum of the positive ions (cations) must equal the sum of the negative ions (anions). Thus a cation-anion balance can be written:

Cation-Anion Balance

$$\sum \text{cations} = \sum \text{anions}$$

where:

cations = positively charged species in solution (meq/l)

anions = negatively charged species in solution (meq/l)

If significant errors in any of the major ion analyses has been made there will be an error in the cation-anion balance. If this error is too large (>10%), it indicates that there has been a error made in at least one of the major anion analyses.

Percent Balance Error

$$\% \text{ balance error} = \frac{\sum \text{cations} - \sum \text{anions}}{\sum \text{cations} + \sum \text{anions}} \times 100$$

cations = $\text{Na}^+ + \text{Ca}^{+2} + \text{Mg}^{+2} + \text{K}^+$ (in meq/l)

anions = $\text{Cl}^- + \text{HCO}_3^- + \text{SO}_4^{-2}$ (in meq/l)

For GW and surface water, the % error should be less than 10%

Ion balance (example)

A laboratory measures the following concentrations:

Cation	Conc (mg/l)	Anion	Conc (mg/l)
Ca^{+2}	93.8	HCO_3^-	164.7
Mg^{+2}	28.0	SO_4^{-2}	134.0
Na^+	13.7	Cl^-	92.5
K^+	30.2		

1. First the concentrations of cations and anions must be converted from mg/l to meq/l.

(a) This conversion is made using the mg/meq value for each major ion species. This value is equal to the atomic weight of the species divided by the ion charge.

For Calcium (Ca^{+2}):

- atomic weight = 40
- ion charge = 2
- mg/meq = $40/2 = 20$

(b) Dividing the concentration (mg/l) by the mg/meq value for each species results in meq/l.

For Calcium (Ca^{+2}):

- Concentration (mg/l) = 93.8
- mg/meq = 20
- $93.8/20 = 4.69$ meq/l

(c) A table should be completed with all the values per species, and the sum of cations and anions.

Cation	Concentration		
	(mg/l)	(mg/meq)	(meq/l)
Ca ⁺²	93.8	20.0	4.69
Mg ⁺²	28.0	12.2	2.3
Na ⁺	13.7	13.7	0.60
K ⁺	30.2	39.1	0.77
Total Cations			8.36 meq/l

Anion	Concentration		
	(mg/l)	(mg/meq)	(meq/l)
HCO ₃ ⁻	164.7	61.0	2.74
SO ₄ ⁻²	134.0	48.0	2.79
Cl ⁻	92.5	35.5	2.61
Total Anions			8.14 meq/l

2. Check accuracy (% balance error)

$$\begin{aligned}
 \% \text{ balance error} &= \frac{\sum \text{cations} - \sum \text{anions}}{\sum \text{cations} + \sum \text{anions}} \times 100 \\
 &= \frac{8.36 - 8.14}{8.36 + 8.14} \times 100 = 1.3\%
 \end{aligned}$$

This is less than the allowed error, so the sample results can be accepted.
 If % error > 10% then check results, and possibly re-analyse samples.

Note: An accurate ion balance does not necessarily mean that the analysis is correct. There may be more than one error and these may cancel each other out.

1.4 Aspects of Data Analysis

The water quality data collected are the basis of the information that can be provided. However, the data themselves are not 'information'. If data are not in a form which can be used or understood by its intended recipients then they cannot be considered to be information. The process of data analysis involves abstracting, transforming, summarising and commenting on the data so that they will be useful to those to whom they are ultimately transmitted.

In order to make a conversion of data to information, the data need to undergo some form of analysis. Such analysis may be simple, for example, the calculation of elementary statistics or the production of graphical output, or may be more complex involving advanced statistics or mathematical modelling.

The specific analyses to be conducted depend on the water quality information desired, or the specific questions about water quality being asked. Water quality concerns are wide and varied, but probably the most commonly asked questions are:

1. What is the water quality at any specific location or area?
2. What are the water quality trends in the region: is the quality improving or getting worse?
3. How do certain water quality parameters relate with one another at given sites
4. For surface water (rivers): how do certain water quality parameters relate to stream discharge?
5. What are the total mass loadings of materials moving in and out of water systems, and from what sources and in what quantities do these originate?
6. Are sampling frequencies adequate and are sampling stations suitably located to represent water quality conditions in an area?

It is now possible to carry out many of the techniques described below on a computer running a proprietary statistical software package. However, it should be borne in mind that such an approach carries with it dangers for the inexperienced. With a computer package it is possible to generate any number of statistics from a set of data with no regard to their appropriateness. Care should be exercised if this method is contemplated, therefore.

1.5 Types of Data Analysis

It is often the case that those who receive, and may need to act upon, water quality data are non-technical people. Often managers, politicians or members of the public need to comment or make decisions based upon water quality data. Unless such people are technically qualified, data alone will not of any use to them; they need to know what the data means.

There are a number of ways that water quality data can be made more meaningful to a non-technical audience including the following:

- comparing the data with national water quality standards - this gives an insight into the scale of a particular data set (e.g., if the data show that a particular groundwater sample contains a higher concentration of pollutant than is allowed by a national drinking water standard, most people would assume that it may not be safe to drink this water)
- comparing the data to international standards - it may be useful to compare the data to standards used by other countries (e.g., the United States) or international organisations (e.g., the World Health Organisation or the European Union) particularly if standards for a particular pollutant have not been defined nationally
- calculating water quality indices, such as Water classification index or S.A.R.
- determining the water quality classification and comparing to desired classification
- comparing the data derived from one area to data from another similar area - for example, it is easy to see how two similar rivers compare in terms of their pollution load when their water quality data are presented together
- calculation of trends showing how water quality has changed at one or more sampling points either over time or due to a particular event (e.g., the construction of a power station on a river reach)

- calculating how much mass of a substance has travelled down a river (i.e. mass fluxes).

1.6 Water Classification Index for surface waters

In India, several water quality indices can be calculated which indicate the suitability of water for different uses:

- Water classification index for surface waters
- Sodium Absorption Ratio (SAR) for irrigation suitability
- Percent Sodium for irrigation suitability
- Residual Sodium Carbonate – for irrigation suitability
- Chloride – bicarbonate ratio
- Wilcox
- Pipers Tri-linear plotting

The a water classification index for surface waters has 5 categories and is used to indicate water quality required for different uses.

The Central Pollution Control Board has classified the inland surface waters into 5 categories - A to E on the basis of the best possible use of the water as shown in Table 1. The classification has been made in such a manner that the water quality requirement becomes progressively lower from class A to class E.

A water body may be subjected to more than one organised use. The use demanding the highest quality is the designated best use. A water body or stretch of river whose existing water quality does not meet the designated best use criteria requires action to mitigate the situation. Based on such analysis river action plans are formulated.

The results from the water quality monitoring should be used to calculate the water quality index, and to check with the designated use of that water body.

1.7 Graphical techniques

Many of the above techniques are considerably enhanced if the data are presented graphically. However, care should be taken to ensure that the graph type is chosen to clearly transmit the necessary information (see above).

There are a number of advantages associated with the data analysis using graphical techniques as follows:

- trends in the data are often easier to spot
- outlying data points are normally obvious
- many people find visually presented data more acceptable and more readily understandable

It is important when presenting data graphically that:

- all graphs are easy to read and understand - in particular the temptation to put too many data sets onto one graph should be avoided; it is better to present this information using more than one graph, if necessary.

Table1 Primary water quality criteria for various uses of fresh water

Designated best use	Class	Criteria
Drinking water source without conventional treatment but after disinfection	A	<ol style="list-style-type: none"> 1. Total coliform organisms MPN/100mL shall be 50 or less. 2. pH between 6.5 and 8.5 3. Dissolved oxygen 6 mg/L or more 4. Biochemical oxygen demand 2 mg/L or less
Outdoor bathing (organised)	B	<ol style="list-style-type: none"> 1. Total coliform organisms MPN/100mL shall be 500 or less 2. pH between 6.5 and 8.5 3. Dissolved oxygen 5 mg/L or more 4. Biochemical oxygen demand 3 mg/L or less
Drinking water source with conventional treatment followed by disinfection	C	<ol style="list-style-type: none"> 1. Total coliform organisms MPN/ 100mL shall be 5000 or less 2. pH between 6 and 9 3. Dissolved oxygen 4 mg/L or more 4. Biochemical oxygen demand 3 mg/L or less
Propagation of wild life, fisheries	D	<ol style="list-style-type: none"> 1. pH between 6.5 and 8.5 2. Dissolved oxygen 4 mg/L or more 3. Free ammonia (as N) 1.2 mg/L or less
Irrigation, industrial cooling, controlled waste disposal	E	<ol style="list-style-type: none"> 1. pH between 6.0 and 8.5 2. Electrical conductivity less than 2250 micro mhos/cm 3. Sodium absorption ratio less than 26 4. Boron less than 2mg/L 5. Percent Sodium less than 60

- the scale of the axes used is such that the data cover a large percentage of the graph
- all graphs are clearly titled and each axis, and if appropriate each data set, is clearly labelled

There are a number of types of graph which can be effective in presenting water quality data as detailed below. The choice of graph will depend upon a number of factors including the information required from the plot, the intended audience and clarity and ease of use considerations. It is often the case that the choice of graph can only be finally decided by actually plotting a number of different types of graph and assessing them for effectiveness.

Time Series Graphs

A graph in which water quality data (on the 'y' axis) are plotted against time (on the 'x' axis) in units which will depend on the frequency of sampling. This type of plot helps to identify trends or cyclic patterns in the data and is also a good way of identifying outlying data points.

Time series graphs are also useful for spotting connections between two or more water quality variables. If it is suspected, for example, that the biochemical oxygen demand in a river reach increases when the suspended solids load increases, an effective way of checking this can be to plot both of these variables on a time series graph. Visual inspection can then be used to see if peaks and troughs for the two variables coincide.

Histograms

Histograms or bar charts are effective at displaying the relative differences in data. That is, it is easy to show that a sampling point has twice the pollutant concentration of its neighbour by means of a histogram.

Histograms are also useful for displaying data for a non-technical audience as they are easily understood by the majority of people.

Pie Charts

Pie charts, which are circular diagrams divided into a number of segments, are less frequently used for water quality data. They are used when it is necessary to present information about the relative proportions of a particular parameter, however. For example, the relative proportions of a pesticide which were dissolved in water, bound to suspended solid particles or present in the bottom sediments of a river could be represented using a pie chart.

Profile Plots

A plot of water quality data down the length of a river (longitudinal profile) can be useful for observing changes which occur as the river flows downstream. Often such plots are annotated with the positions of major discharges and river tributaries so that the effect of these inputs is clearly visible on the graph.

If samples have been collected at various depths, a vertical profile of the data can be plotted. Such plots are often used to analyse how lake water or groundwater varies with increasing depth.

Geographical Plots

It is often useful to plot water quality data on a map base to show local and regional variations in water quality. Such a technique can be used to attempt to pinpoint a

pollution source from groundwater data or merely to show how one river or catchment compares to another in terms of its water quality or pollution load.

Advanced Techniques

In addition to those methods of data analysis given above there are also a number of more advanced techniques which can be used. Although, a complete description of such techniques is outside the scope of this document, there follows below a brief outline of some of the methods available:

- linear trend analysis - although this can be done simply by plotting data on a time series graph (see above), it is also possible to analyse trends through the use of sophisticated statistical analyses; trend analysis can be important for the analysis of water quality data as it can aid understanding of the variability of data and also allow predictions to be made of likely future water quality
- regression and correlation analysis - regression and correlation analysis are related techniques which are used to assess the association between two or more variables; both can be useful techniques for establishing the factors which regulate the variability of a particular water quality parameter.
- autocorrelation analysis: to assess the association between two or more measurements of the same variable at different times.
- hypothesis testing: Statistical analysis to check for relationships within the data (e.g. a step trend)
- mathematical modelling - a technique for representing and predicting, by means of mathematics, the behaviour of a system; mathematical models can be useful predictive and policy testing tools in that they allow operators to forecast the behaviour of a water body which will occur following some future change to the system

It is important to remember that the above techniques, whilst extremely powerful when used correctly, can lead to false conclusions and, therefore, poor management decisions if used by the inexperienced. It is often advisable, therefore, to use the simplest data analysis technique which will adequately perform the required task.

Design of Water Quality Yearbook

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Introduction

Data is a base for planning of any project. The process of collection of data has been in progress since time immemorial. The data has been collected for specific purposes, used for the purpose, changed in to reports & filed. At present the data is scattered in different organizations & laboratories. This has been quite expensive, as time and money has been spent on collection of same type of data. However old data can be of historical importance & a useful guide to understand the action of various forces, which may be responsible for present status.

Collection of data on the quality of water

Central Water Commission being a central organization under the Ministry of Water Resources has to think in terms of the national perspective on utilization of resources. The collection of hydrological data, by the default definition includes the data on quality of water. As is well known, the data collected by Central Water Commission is very thorough in respect of location, depth, time, velocity and distance from the reference point from the bank; a considerable amount of time and money is involved in this process of data collection. Keeping in view that quantity without quality may be meaningless, Central Water Commission is also collecting the data on the quality of water at all such important locations.

For collection of data on the quality of water, Central Water Commission has also established a large network of laboratories almost in all the states of India. Depending upon the level of data to be collected, these laboratories have been equipped with the adequate

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level of equipment and the laboratories have been designated as level I, level II and level III laboratories. The level I contains equipment suitable for observing the data on parameters which must be observed in situ i.e. without any time lag between the collection and analysis. The level II contains equipment suitable for observing the data on parameters which must be observed with more sophisticated equipment and can be done within 6-24 hour of collection of sample. For this purpose, the samples are kept under near freezing condition to keep the bacterial and other physico-chemical reactions at the minimum activity.

The level III contains equipment suitable for observing the data on parameters, which need sophisticated and state of art equipment. The equipment in such laboratories are quite costly and need expert personnel for their operation. In view of the cost involved and to observe economy at the national level, such laboratories are kept in Northern, Eastern and Southern Regions. Therefore such laboratories can also be termed as regional laboratories. Central Water Commission has already done this investment and the data is being collected on various parameters covering general physical, chemical and biological parameters. The data on trace metals and trace organic pesticide, herbicides and insecticides is also being collected.

Nature of data

The nature of data that can be stored can comprise of physical, chemical and biological nature. The parameters covering these aspects are given in annex 1. As the analysts are generally proactive, it is not necessary that all samples be analyzed for all parameters. That should depend upon the nature of sample and its immediate requirement.

Having established such a large network of collection of hydrological data, it goes without saying that a small part of time of the personnel employed at the basic data collecting centers can also be utilized for collection of information on factors which may have a bearing on the quantum of various parameters. Some of such factors have been listed below. (Details in annex –II)

1. Climate
2. Geology/Morphology

3. 10 year hydrology data (average of monsoon/non monsoon)
4. Agricultural practices
5. Various projects dams canals transfer inter basin.
6. Forest, semi arid, arid and mountain regions.
7. Population in villages, towns and cities.
8. Industries small, medium and large (In particular having solid and liquid wastes)
9. Quantum of water used & return flows
10. Health aspects on population – Hospital/Diseases.
11. Various flora and fauna – spatial distribution.
12. Reaches showing visible /invisible impacts.
13. Correlation with ground water quality with in 5 km radius.

As the qualified personnel having a very good academic and scientific background will collect the data on such aspects, the data will be very authentic and can be relied upon for doing modeling and other studies. The cost of collection of such data will also be very low in terms of manpower and other expenses

For examining the quality of water for various uses, the biological oxygen demand and bacterial presence or absence is also essential especially the coliform type as some of the coliforms are typically found in the intestines of animals including anthropoids. These are characterized by their prolific growth even at 45° Celsius. To examine the number of bacteria, these are allowed to grow in a special nutrient medium. When they form colonies, their number is counted under magnification. With powerful microscope, this can be done by isolation bacteria and staining them with suitable chemicals. The shape, size and their number can be easily recorded with very little extra effort. For this, equipment has already been procured in one of the Regional laboratories. As the information on the presence of various trace metals and other chemicals in trace quantities is being collected, it may not be difficult to link the presence of various tiny flora and fauna, including bacterial population with the trace metals chemicals and various factors connected with climate and ecology. Such correlation can be of immense help in linking degenerative and mutagenic changes in the life processes. It may not be out of place to mention that the changes take place faster in the species, which have a short life span and multiply rapidly under a given condition.

Quantum of data

However all these data with different frequencies, locations and timings will make it quite bulky even if taken for one year and individual values, except the extremes may not serve much purpose. However for reference one or two hard copies of daily data may be essential. For evolving any logical conclusion, the combination of some values and their statistical averages over different seasons may be useful. However some of the data such as odour, which cannot be converted into some numerical form for arriving at averages can be kept as such or attempt can be made to convert such information in to numerical forms.

Processing of data

Processing such large magnitude of data from hard copy (printed book) will also involve large number of man-hours. For wide circulation of data, it may be a fit case to present the averages and the trends, which can be statistically arrived, from the data. The demand from such users can be easily met if the data is properly stored in a format, which can be processed with suitable software to extract the relevant figures over a large time period. The general aspects can be summarized in one to two pages.

Users

The data of this type can be utilized for diverse purposes depending upon the immediate requirement of the user e.g.

- 1) Organizations needing the suitability of data for power plant (cooling purposes) need not be interested in colour/odour, climates, trace metals and pesticides, bacterial population etc.
- 2) Organizations for bathing need not worry on trace quantities of minerals and organics.
- 3) Water softening plants may not be very keen on bacteriological, suspended impurities and many other parameters except calcium & magnesium.

- 4) Recreational users may worry only on colour, odour, floating and suspended matter etc.
- 5) Agriculturist may more interested in Sodium Adsorption Ratio, Sodium Percentage & Electrical Conductance.
- 6) Municipal authorities may worry more about trace metals, organic and suspended impurities and bacterial population.
- 7) An environmentalist may be more keen an appearance of disappearance of flora and fauna and their numbers.
- 8) School & college students may be interested in general parameters.
- 9) Water storage authorities may be more interested in sulfate, chloride and BOD values.
- 10) Doctors may be more interested in sodium, nitrate and fluoride etc. which are not removed by the conventional treatment methods.
- 11) NGOs may worry about all aspects concerned with social life.
- 12) Pollution control agencies may concentrate on trends to prevent deterioration of quality

Publication of data

Presently Central Water Commission publishes such data on annual basis as Water Quality Yearbook on the lines of its Water Year Book and sediment Year Book. As most of the data was used in-house and the demands from other users were few and far between, these could be met easily, hence it was not thought necessary to give wide publicity to the data. However in recent years the demand from other users has increased and causes inconvenience in copying of data from the few published copies, it would be in the interest of Central Water Commission to publicize such data for the benefit of various users. It would also eliminate unnecessary repetition in collection of data or data with inadequate method of collection is minimized and the good quality data remains for reference. In doing so, the Central Water Commission can do a yeoman's service to the nation and may save a considerable cost on money and manpower. Various academic institutes and NGOs are incurring such costs on the pretext of providing Ph. D degrees and for bringing more awareness among general masses as well to gain publicity. The data collected by them is mostly not according to the standard methods. In many of such instances, it is observed that the conclusions drawn by them exceed all imaginations

The format for storing data on quality of water

The format for storing the data has to be worked out very carefully to ensure that most of the future demand on the data extraction can be easily met.

Each site should contain following information to cover.

1. General features of site, location, town, district, state, river- tributary, sub-tributary, longitude & latitude etc.
2. Basin map showing site in appropriate scale
3. Climate, geology, morphology of site.
4. Hydrological features / storage / Return flows
5. Agricultural practices,
6. Forests: flora & fauna.
7. Population
8. Location and spread of various industries.
9. Data: All parameters should be available for recording

The data can have the following formats

- | | |
|--------------------------------|------------------------------|
| a) Physical parameters | d) Trace metals and chemical |
| b) General chemical parameters | e) Microbiological |
| c) Biological | f) Computed indices |

All these details on a data should have identical value for the following variables

- Date of collection
- Time of collection
- Distance from the bank
- Depth of collection

For wide circulation of data, it may be a fit case to present the averages and the trends, which can be statistically arrived, from the data. The demand from such users can be easily met if the data is properly stored in a format, which can be processed with suitable software to extract the relevant figures over a large time period. The general aspects can be summarized in one to two pages. The details should be upgraded on annual basis to provide for various developmental activities.

The format for Water Quality Yearbook

The format for publication of averages and trends should include all such parameters that have bearing on general uses and also for special users. The following aspects can be included.

Maximum, minimum and average values with the number of observations for monsoon and non-monsoon seasons along with annual weighted average value in respect of following parameters:

- | | |
|----------------|---------------------|
| 1. Temperature | 9. Chloride |
| 2. Colour | 10. Nitrate |
| 3. Turbidity | 11. Sulphate |
| 4. pH | 12. Hardness |
| 5. EC | 13. SP |
| 6. DO | 14. RSC |
| 7. BOD | 15. Total Coliforms |
| 8. COD/TOC | 16. Total Planktons |

In respect of parameters such as trace metals, pesticides and special bacterial and micro flora and fauna; total sum of their values in terms of total loading can be given. This would require calculation of their mass from the values of concentration/ number and discharge for each season. Such a presentation would eliminate the risk of exposure of the classified data on discharge of rivers crossing national boundaries.

The format of Water Quality Yearbook is presented for consideration. A specimen is given at annex-III

Graphical presentation of data on concentration of above parameters for the last 5-10 years can also be given for the ease of understanding.

List of parameters

- | | | |
|---------------------|--------------------------|---|
| 1. Temperature | 25. Nitrite | 49. Phenolic compounds |
| 2. Colour | 26. Ammonia | 50. Zooplanktons |
| 3. Odour | 27. Kjeldahl Nitrogen | 51. Phytoplanktons |
| 4. Turbidity | 28. Organic phosphorous | 52. Organophosphorous pesticides |
| 5. pH | 29. BOD | 53. Organochlorine pesticides |
| 6. Conductivity | 30. COD | 54. Polycyclic hydrocarbons |
| 7. Dissolved Oxygen | 31. Total Organic Carbon | 55. Atrazine family pesticides |
| 8. Carbonate | 32. Iron II | 56. Total Coliform |
| 9. Bicarbonate | 33. Iron III | 57. Escherechia Coliform |
| 10. Sulfide | 34. Copper | 58. Other bacteria |
| 11. Calcium | 35. Mercury | 59. Radioactivity in water and sediment |
| 12. Magnesium | 36. Strontium | 60. Adsorbed chemicals on bottom sediments |
| 13. Sodium | 37. Nickel | 61. Adsorbed chemicals on suspended sediments |
| 14. Potassium | 38. Aluminum | 62. Total Hardness |
| 15. Chloride | 39. Manganese | 63. Sodium Percentage |
| 16. Sulfite | 40. Chromium III | 64. Residual Sodium Carbonate |
| 17. Sulfate | 41. Chromium VI | 65. Sodium Adsorption Ratio |
| 18. Fluoride | 42. Lead | 66. Classification |
| 19. Bromide | 43. Arsenic | |
| 20. Iodide | 44. Cadmium | |
| 21. Orthophosphate | 45. Zinc | |
| 22. Boron | 46. Silver | |
| 23. Silica | 47. Molybdenum | |
| 24. Nitrate | 48. Selenium | |

General features of Hydrological Observation station and its Basin

1. Type of soil & geological formation in the basin.
2. Nature & location of various ores in each Sub-basin basin and the nature of their prospecting activity.
3. Major minerals found in topsoil & subsoil say up to 100 M.
4. Nature of various major industries in various sub catchments of the basin.
5. Quantity and quality of surface flows in sub catchments.
6. Quantity and quality of water used for inter basin and inter sub basin transfers.
7. Nature of vegetative dispersion in the sub catchments.
8. Area under agricultural activity.
9. Area under assured irrigation.
10. Various crops grown in the sub catchments.
11. The respective area under each crop.
12. Nature & quantity of various insecticides and pesticides sold in each year season wise in each sub basin/basin.
13. Nature & quantity of various herbicides sold in each sub basin/basin.
14. Number of villages/towns/cities in each sub catchments.
15. Cattle population/ milch cattle population.
16. Total municipal water supply in each town and total quantity supplemented by private water harvesting.
17. Quantities of return flow from municipality & industries.
18. Treatment facility installed/ in operation.
19. Industry profile with respect to use of water and discharge of liquid and solid waste.
20. Disposal pattern of solid & liquid waste.
21. Source of collection of above information.
22. Names of hospitals in sub basin/basin.
23. Major and minor endemic & epidemic problems.
24. Major birds species found in the region with their eating habits & change in behavior & population (ornithologists)
25. Various type of water fauna in river & lake systems; seasons wise including major & minor variety, eating and reproductive habits.

26. Various type of bacterial population in different reaches. Season wise disease water borne on basins of illness.
27. Various water flora in the region; season wise.
28. Recreational activities in water bodies.
29. Partially or fully closed sub basins
30. Hydel generation/ thermal power generation units.
31. Nature of spatial distribution of rainfall.
32. Number of storage reservoirs in the sub-catchments with their capacity.
33. Water supplies arrangement of each municipality.
34. Activities on reuse of water by industry and municipality.
35. Impact on ground water quality where water is reused.

FORMAT OF WATER QUALITY YEAR BOOK
(Data part)

Parameter	Monsoon (Jun to Nov.)				Non-Monsoon (Dec to May)				Annual Mean	Weighted Mean
	Max.	Min.	Ave- rage	number of obs.	Max.	Min.	Ave rage	number of obs.		
Temp.	36	22	30.16	6	33.5	17	22.0	6	26.1	29.29
colour										
Turbidity										
pH	9.0	7.2	8.16	6	9.0	7.9	8.38	6	8.28	8.42
E.C	830	190	473	6	1050	310	546	6	510.00	431.16
D.0	7.6	0	2.4	5	12.0	0	4.6	6	3.51	3.37
Cl	91.8	8.2	54.9	6	167.7	8.2	56.3	6	55.58	72.10
S04	68.0	20.0	43	6	150.0	35.0	79.5	6	61.25	45.40
N03	6.2	0.5	2.7	6	5.0	1.0	3	6	2.91	2.99
B.O.D	21.04	1.96	1.3	6	60.6	7.1	21	6	19.03	240.71
T.O.C										
Hardness	249.6	174.8	217	6	483.2	164.2	270.4	6	243.69	3141.49
Sodium %	36.8	1.5	20	6	35.7	6.9	32.8	6	26.40	333.87
SAR	1.95	0.04	0.93	6	2.41	0.20	1.17	6	1.05	13.41
RSC	0	0	0		0	0	0		0	0
Coliform										
Plankton										

DISSEMINATION OF INFORMATION ON WATER QUALITY

Dr. Roop Narain⁺, Dr. M. C. Dutta⁺⁺, Dr. S. P. Chakrabarti*, and Dr. R. C. Trivedi**

1. Introduction

Data on quality of surface and ground water are most sought after by individuals, municipal bodies, students / scholars of academic institutions, pollution control authorities and social reformers. While an individual is keen to ascertain the quality for its potability before use, the municipal bodies are concerned to ascertain the degree of treatment necessary to render it suitable for safe public water supply. While the academicians look at it with interest for a variety of purposes, like establishing correlations among its constituent quality parameters, validating ionic balance, modelling of water quality for prediction of impact due to introduction of pollutants through innovative computer application techniques etc., pollution control agencies look for the trend for evolving strategy to maintain and restore quality of water resources by containment of polluting sources and prevention and control of pollutants being discharged into water bodies only after compliance with the standards. The non-governmental organisations (NGOs) and the Social Reformers serve as the ‘watch dogs’ for the protection of societal interest. Under this scenario, it is evident that there is a need for water quality data among various sections of the society, even if their interests could be conflicting at times.

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2. Water Quality Information

2.1 Water quality Data Generation

Water quality is being monitored by several agencies with specific objectives to meet the requirements of the respective agencies in accordance with their mandates. Although the Central and the State surface water (SW) Departments are concerned and are charged with the responsibility of developing water resources with no apparent concern about the quality aspect of the resources, it is inherently implied that the quality of the water resources developed is good enough to qualify for meeting the needs of various designated best-uses prevalent all along the river stretch. The Central and the State Pollution Control Boards are to observe that the wholesome quality of the natural waters are maintained or restored, if required, to sustain the prevalent uses. There is, therefore, an *unwritten* interdependency among the agencies involved in the task of water quality management, which can seldom be ignored. Hence, there is a sincere need for frequent interaction and sharing of information among the agencies.

2.2 Water Quality Database Development

Under the “Hydrology Project” taken up by the Ministry of Water Resources, the water quality database is being created at national and State levels as a part of the Hydrological Information System (HIS) being developed. After primary data validation at the laboratory, the data will be processed at the Sub-divisional / Divisional Data Processing Centres for secondary validation, following a designed format for data entry in a unified manner by all the agencies participating in the programme. and thereafter for storage at the State / Regional / National level to generate the database to be available for the user agencies.

2.3 Interpretation of Data for Information Generation

To render the validated data useful for the concerned agencies in planning of Action Programmes in a holistic manner and for their implementation, the data are to be analysed and interpreted for generation of information. This requires presentation of data in the form of charts. To meet the needs and purposes of the data user agencies and the society at large, it is imperative on the part of the generator(s) of data to publish “Annual Report on Water Quality” for dissemination of information in a simplistic manner, especially through graphic presentations or easy-to-read maps, with interpretations. Otherwise, it will remain stockpiled in individual organisations with no apparent use after incurring considerable expenses in collection, transportation, and analysis of samples in sophisticated instruments.

3. Annual Report on Water Quality

Annual Report on water quality, therefore, should contain river basin / water shed-wise information in terms of the following elements:

- Brief introduction of the basin with a map in appropriate scale indicating the location of monitoring stations with station code

- Water quality status: Desired quality to sustain designated-best-uses in various reaches;

If such information are not available with CWC, conjunctive efforts may be made with CPCB, to have a uniform database. The concept is already well-developed, and all major rivers with their principal tributaries have been classified into five

categories of designated-best-uses in consultation with the State agencies. The categories of designated-best-uses are as follows:

- Class A - Drinking Water Source after only disinfection
- B - Outdoor bathing and contact water sport
- C - Drinking water source after conventional treatment including disinfection
- D - Propagation of wildlife and fisheries
- E - Agriculture, industrial cooling & controlled wastewater disposal

- Existing water quality status as observed from monitoring in terms of the criteria parameters defined by CPCB for sustenance of the aforesaid uses; and
 - Critical parameters to be taken note of for protection of quality
-
- Analysis of data to establish spatial trend of water quality from preceding five years (say) in terms of Indicator parameters depicting the health of the river. This would require graphical presentation of the data for ease in understanding.
 - Development of correlations among parameters for better understanding of the quality and for validity checks in building up confidence in analysis and data reliability

- Identification of hot spots (stretch-wise) wherever the actual/existing quality falls below the desired quality. Such information will help the pollution control boards in planning strategies for strengthening their enforcement programmes.

4. Concluding Remarks

The surface water regime being a dynamic system, the monitoring programme needs periodic review atleast after every five years to decide on location of stations, parameters, frequency of sampling, instrumentation and method of analysis, training need for laboratory personal.

Interaction with concerned agencies involved in surface water quality monitoring is essential in view of rapid development in the field of instrumentation techniques in water quality analysis and also interdependency of the agencies in formulating Action Programmes with a holistic approach in a co-ordinated manner besides dissemination of information for the benefit of the society in providing quality water

Reference:

Water Quality Status & Statistics (1995), Monitoring of Indian National Aquatic Resources Series / MINARS / 12 / 1997, Central Pollution Control Board, Govt of India, 1997.

Quality Assurance Programme

A. K. Mitra*

1. Introduction

The objective of a water quality monitoring programme is to produce data and information on the quality of water resources, so that appropriate management can take place. All steps within the monitoring programme must be designed to produce the desired data and information, with sufficient quality.

The goal of a laboratory Quality Assurance Programme is:

- To ensure meaningful water quality assessment
- To have confidence in results, based on standardized procedures for all components of water quality monitoring

2. Components of Quality Assurance Programme

The QA programme for a laboratory or a group of laboratories should contain a set of operating principles, written down and agreed upon by the organisation, delineating specific functions and responsibilities of each person involved and the chain of command. The following sections describe various aspects of the plan.

Sample control and documentation: Procedures regarding sample collection, labelling, preservation, transport, preparation of its derivatives, where required, and the chain-of-custody.

Standard analytical procedures: Procedures giving detailed analytical method for the analysis of each parameter giving results of acceptable accuracy.

Analyst qualifications: Qualifications and training requirements of the analysts must be specified. The number of repetitive analyses required to obtain result of acceptable accuracy also depends on the experience of the analyst.

Equipment maintenance: For each instrument, a strict preventive maintenance programme should be followed. It will reduce instrument malfunctions, maintain calibration and reduce downtime. Corrective actions to be taken in case of malfunctions should be specified.

Calibration procedures: In analyses where an instrument has to be calibrated, the procedure for preparing standard solutions and making a standard curve must be specified, e.g., the minimum number of different dilutions of a standard to be used, method detection limit (MDL), range of calibration, verification of the standard curve during routine analyses, etc.

Quality control of the analytical data : Quality control may be either internal or external. External QC is also called as Quality assessments. All analysts must use some QC as an intuitive effort to produce credible results.

Data analysis : Data reduction, validation, and reporting are the final features of a QA programme. The reading obtained from an analytical procedure must be adjusted for such factors as instrument efficiency, extraction efficiency, sample size and back ground value,

before it becomes a useful result. Each result or a set of results must be accompanied by a statement of uncertainty.

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3. Quality Assurance in Water Quality Monitoring

The full set of activities for QA in WQM which should be documented are:

- monitoring network design,
- sample collection (including field measurements, bottle labelling, proformas, preservation, treatment and transport.
- sample control and documentation in the laboratory
- maintenance of equipment
- laboratory AQC
- Data validation, reduction, and reporting

3.1 Monitoring network

Monitoring network is to designed depending on the objective of the programme. It may be flexible.

3.2 Sample collection

Sample collection includes the following activities:

- collecting the sample in the correct manner, in the correct container
- field measurements of water quality: e.g. Temperature, pH, EC, DO
- labelling sample bottles and completing sample proforma
- preservation (if necessary) and transport to the laboratory

3.3 Collecting the sample

The person collecting the sample must know how to reach sampling site(s). A detailed location map for the site which should shows the sample collection point with respect to prominent landmarks in the area. In case there is any deviation in the collection point, record it on the sample identification form giving reason.

3.4 Field measurements

For all water quality samples of open dynamic systems such as rivers, field measurements must be made for : Temperature, pH, EC. and DO.

3.5 Labelling sample bottles and Completing Pro forma

Sample containers should be clearly and unambiguously marked. All details relevant to the sample should be recorded and connected with the sample container.

3.6 Preservation and Transport

Loss or transformation of the sample during sampling and transport needs to be controlled. Common measures are conservation, cooled storage, cooled transport and minimizing the time period between sampling and analysis (a maximum storage time before analysis can even be specified).

- Samples should be transported to concerned laboratory (level II or II+) as soon as possible, preferably within 48 hours.
- Analysis for coliforms should be started within 24 h of collection of sample. If time is exceeded, it should be recorded with the result.
- Samples containing microgram/L metal level, should be stored at 4°C and analysed as soon as possible. If the concentration is of mg/L level, it can be stored for upto 6 months, except mercury, for which the limit is 5 weeks.
- Discard samples only after primary validation of data.

3.7 Control Samples

- Field check samples to provide routine checks on sample stability. Checks can be done by dividing a real sample in two and making a known addition to one portion. The recovery is a check that conservation, sample transport and storage are satisfactory.
- Duplicate samples to provide checks on variability.

3.8 Sample control and documentation – Sample receipt register

- Each laboratory should have a bound register, which is used for registering samples as they are received.

3.9 Work Assignment and Personal Registers

- The laboratory incharge should maintain a bound register for assignment of work. This register would link the lab. sample number to the analyst who makes specific analyses, such as pH, EC, BOD, etc.
- An estimate of time needed for performing the analyses may also be entered in the register.
- Each laboratory analyst should have his/her own bound register, where all laboratory readings and calculations are to be entered.
- When analysis and calculations are completed, the results must be recorded in a register containing data record sheets described in the next section.

3.10 Maintenance of Equipment

Regular maintenance of laboratory equipment is key to making controlled analyses of water samples.

4. Recommendations

The primary goal of the Quality Assurance Programme in water quality monitoring is that the information obtained from the monitoring system meets the required quality criteria. Those using the data must have confidence in the data.

Important to Quality Assurance Programme is traceability. Traceability is concerned with defining and documenting the processes and activities that lead to the information and how the results are achieved. When the processes are known, activities can be conducted correctly, and if not, measures can be taken to improve these processes.

Quality management requires a system where there are documented procedures for all the relevant processes and products important in water quality monitoring and the responsibilities with regard to the distinguished procedures.

Standards methods and techniques are defined for, among others, sampling, transport and storage of samples, laboratory analysis, data validation, data storage and exchange, calculation methods and statistical methods as part of the requirements. All these steps are documented within the Hydrology Project. By following protocols, mistakes can mostly be avoided, and any mistakes that are made may be traced and undone.

If monitoring data from different monitoring networks are to be compared, it is important that the data be of comparable quality. Quality Assurance requires co-operation and participation of all personnel involved with water quality monitoring activities. Quality assurance of Water quality monitoring is the responsibility of the managers of the organisation and the device can be achieved by good managerial practices.

Management has to ensure that the analysts have the knowledge as well as skill of implementing analytical procedures. Any one can learn to turn knob and read galvanometers or digital reading, but assurance that a measurement has been made in the best possible system, must come from a Chemist.

Analytical Quality Control programme

Dr. A. K. Mitra

1. Introduction

Analytical Quality Control (AQC) is one of the main components of a complete Quality Assurance Programme for Water Quality Monitoring, wherein the quality of analytical data being generated in any laboratory is controlled through minimising or controlling errors to achieve a target accuracy. AQC is used to evaluate reliability of experiment data.

Why is it required?

Many studies have shown that analytical results are often subject to serious errors, particularly at the low concentrations encountered in water analysis. In fact, the errors may be so large that the validity of actions taken regarding management of water quality may become questionable.

An analytical quality control exercise (AQC) conducted by United States Environmental Protection Agency (US-EPA) showed a wide variation in results when identical samples were analysed in 22 laboratories:

Nutrient	Concentration, mg/L	Range of results, mg/L
Ammonia	0.26	0.09 - 0.39
	1.71	1.44 - 2.46
Nitrate	0.19	0.08 - 0.41
Total phosphorus	0.882	0.642 - 1.407

It is seen that the range of values reported are significantly large, $\pm 50\%$ for ammonia and $\pm 100\%$ for nitrates, compared to the actual concentrations.

2. Types of AQC

Two types of AQC schemes are practised: Intra laboratory and Inter-laboratory AQC.

Intra-laboratory AQC :

Intra-laboratory AQC focuses on achieving precision or 'reproducibility' of analyses within one laboratory. This can be achieved by following documented procedures for all analytical activities. Important components to identify errors are control charts and control samples.

Inter-laboratory AQC:

The focus of inter-laboratory AQC is to achieve comparability of results in all the participating laboratories by controlling the accuracy of each.

The main objectives of inter-laboratory AQC are:

- (a) To test for possible bias in measurements in a laboratory.
- (b) To provide direct evidence of comparability of results among laboratories in a common water quality-monitoring programme such as Hydrology Project.

3. Objectives of AQC

The objective of Analytical Quality Control is:

- To ensure meaningful water quality assessment
- To have confidence in results
- to assess the status of analytical facilities and capabilities of concerned laboratories.
- to identify the serious constraints (random & systematic) in the working environment of laboratories.
- to provide necessary assistance to the concerned laboratories to overcome the shortcomings in the analytical capabilities.
- to validate the water quality monitoring data.
- to promote scientific and analytical competence of the concerned laboratories to the level of excellence for better output.

4. Basic statistics in AQC

True value – A value is accepted as being true when it is believed that uncertainty in the value is less than the uncertainty in something else with which it is being compared.

Error – The term error refers to the numerical difference between a measured value and true value.

Determinate errors or systematic errors – Determinate errors are generally unidirectional with respect to true value, and in many cases they can be predicted. Examples are incorrectly calibrated instrument, an impurity in a reagent or distilled water, a side reaction in a titration and heating a sample at a temperature different from that required.

Bias is a measure of determinate errors.

Indeterminate errors – These types of errors cannot be attributed to any known cause. They are random in nature and lead to both high and low results with equal probability. They cannot be eliminated and are the ultimate limitation on the measurement.

Accuracy – An accurate result is one that agrees closely with the true value of a measured quantity.

Precision – The term precision refers to the agreement among a group of experimental results; it implies nothing about their relation to the true value.

Frequency distribution: Relation between the values of results of repetitive analyses of a sample and the number of times (frequency) that a particular value occurs.

Mean: Mean is the central value of results of a set of repetitive analyses of a sample. It is calculated by summing the individual observations and dividing it by the total number of observations. Mean, (\bar{x}) , of a set of data is calculated by adding all the observed values of variable (results of analyses) and dividing it by the total number of observations:

$$\bar{x} = (x_1 + x_2 + \dots + x_n) / n$$

where x_1, x_2, \dots, x_n are the observed values and n is the total number of observations.

Standard deviation: Standard deviation is a measure of spread of results of repetitive analyses of a sample around its mean value. It is a measure of precision of the analytical method. It is calculated by taking square root of sum of squares of deviation of the observations from the mean divided by the number of observations minus one. Standard deviation, s , is calculated as:

$$s = \sqrt{\{(x_1 - \bar{x})^2 + (x_2 - \bar{x})^2 + \dots + (x_n - \bar{x})^2\} / (n - 1)}$$

A small value of s signifies that most of the observations are close to the mean value.

A large value indicates that the observed values are spread over a larger range.

Precision and standard deviation

The most important parameter to evaluate in the results is the precision. The statistical term to evaluate precision is standard deviation. The numerical value of the standard deviation depends on the average concentration (standard deviation also has the unit of concentration).

Normal distribution

Normal distribution is a frequency distribution, which is symmetrical around the mean. In a normal distribution 95.5% and 99.7% of the observations lie in \pm two times standard deviation and \pm three times standard deviation range around the mean, respectively.

Control Limits

Two sets of control limits are usually set: inner limits at about $\pm 2s$ (UWL & LWL) to warn of possible trouble and outer limits of $\pm 3s$ (UCL & LCL) demanding a corrective. It has been observed that 99.7% of a group of results should fall within the $\pm 3s$ limits unless a definite cause is operating on the analysis. If the method is under control, approximately 4.5% of results may be expected to fall outside the UWL & LWL lines. This type of chart provides a check on both random and systematic error gauged from the spread of results

5. Components of an AQC Programme

5.1 Intra-Laboratory AQC

Types of Control Samples

Good Analytical Quality Control includes control samples such as :

- standard solutions
- recovery of known additions,
- analysis of reagent blanks, and
- analysis of duplicates

A control sample is a sample whose analytical results are used to check the procedures being used and results being produced in the analytical laboratory. Different types of control samples help to detect different types of error. Control samples should be representative of the samples routinely analysed in terms of the determinant concentration. Examples of some control samples and their characteristics and use are given below:

Standard Solution

Standard solutions are samples of known concentration which are prepared independently of calibration standards from pure materials. They are used to check on calibration error (random and systematic). A standard solution should be made of a chosen concentration which is representative of the range being routinely analysed. The correct analysis of the standard solution should be independent of analytical techniques.

Recovery of known additives (spiked solutions)

The technique of recovery of known additions is adopted to evaluate matrix effect and suitability of analytical method. In a spiked sample, a real sample is first analysed and then a known amount of the constituent being determined is added. The difference between the analytical results for samples with and without the added constituent gives the recovery of the amount of added constituent. If the recovery is satisfactory, the confidence in the accuracy of the procedure is enhanced. The amount of known additives should be between 5 and 50 times the Minimum Detection Level (MDL), or between 1 and 10 times the ambient level, whichever is greater.

Running parallel determinations (duplicates)

Analysis of individual control samples or sets of samples (to obtain mean values) from same control standard to check random error. A duplicate analysis of a single sample serves as a check on the result, and indicates the precision of the analysis. Good agreement between duplicate results does NOT mean that the results are correct (accurate): a constant error may be present (i.e. bias). This technique is adopted for control charts.

Running a blank determination (reagent blank)

This consists of carrying out a separate analysis of reagent blanks to monitor purity of chemicals and reagent water. A 'blank' sample (e.g. distilled water) using the same procedures and under the same experimental conditions as used for a real sample is analysed. This means that the 'blank' has been treated with the same reagents as a real sample. The object is to find out the effect of the impurities introduced through the reagents and equipment. Ideally, the measured concentration of a blank should be nil. A large reading for a blank is undesirable because the exact value then becomes uncertain.

Additionally the intra-laboratory programme may include:

- **Calibration of instruments/equipment/measuring glass wares.**
- **analysis of sample blanks to evaluate sample preservation, storage and transportation;**

Preparation of reagent grade water is most important to obtain the statistically acceptable data in a laboratory

The important components of intra-laboratory AQC is the maintenance of control charts (e.g. Shewhart control charts).

The control chart method has proved useful in keeping track of the performance of analytical methods in laboratories where same type of samples are repeatedly analysed day after day over long periods of time. The method tends to distinguish with a high degree of efficiency definite trends or periodically recurring anomalies from random fluctuations.

Control charts may be employed to help the laboratory personal keep track of the precision of an analytical method.

Method for making Control charts:

- Analyse three replicates of a standard solution on each day for eight days over a 12 day period. (The number of replicate analyses should thus be 24 carried out over a 12 day period).
- Calculate the mean, (\bar{x}), and the standard deviation (s) of the 24 replicate analyses. Use the mean to calculate the warning limits and control limits.
- Construct the control chart by plotting the mean, the upper and lower warning limits (UWL and LWL) and the upper and lower control limits (UCL and LCL). These values are drawn as lines. Individual points of these analyses should not be plotted.
- Repeat the analysis of the standard solution 2 to 3 times per week for the next 7 weeks and plot the individual measurements on the charts. You should have 14-20 samples. Check if the samples fall within the limits, and if the procedure was under statistical control.
- Recalculate the mean and limits of the chart after combining the two sets of values.

5.2 Inter-Laboratory AQC

Inter-laboratory programmes are designed to evaluate laboratory bias.

The method for this is to identify a coordinating laboratory which will prepare test samples that are to be analyzed by a number of laboratories. Typically, there are 2 test samples (A and B), which have known concentrations of a number of parameters. Each participating laboratory receives samples containing the same concentration of the parameters. The laboratories must analyze samples A and B for the specified parameters, and send analysis results to the coordinating laboratory within a limited time period.

The results of all the participating laboratories are compared to the known concentrations. An 'acceptable range' for the concentration of each parameters is calculated for sample A and sample B, based on the reported concentrations of all the laboratories and the standard deviation of these results.

The results of inter-laboratory AQC are plotted in a Youden 2-sample plots. For each parameter, the plot shows the value for sample A against that of sample B as reported by a laboratory. Thus there is one data point per laboratory for the two samples. The acceptable limits for the two samples are also drawn on the plot as two parallel horizontal lines for the sample values plotted on the Y-axis and two parallel vertical lines for the sample values plotted on the X-axis. The centre of the rectangular block created by the two sets of parallel lines is the reference value for the parameter. Results close to this point are considered to represent a high degree of accuracy.

It may be added that for various parameters all of the AQC actions listed may not be necessary. Further, these are not one time exercises but rather internal mechanisms for checking performance and protecting laboratory work from errors that may creep in. Laboratories who accept these control checks will find that it results in only about 5 percent extra work.

5.3 Identification of errors

- The values outside the warning limit indicate gross analytical errors e.g., in preparation of standards, incorrect calibration, impurities etc.,

- The pattern of seven sequential results lying above or below the mean indicate e.g., problem with standards – new standards of different quality is being used.
- Seven values showing an increasing or decreasing trends indicate e.g.,, evaporation of a solvent or degradation of the standard sample with age, improper temperature control of the reaction.

Sources of error in specific analyses

Examples of specific sources of error for the determination of EC are given below:

Error may be in the instrument:

- condition of the conductivity cell
- sensitivity of instrument
- age of instrument

Error may be in accuracy of preparation of KCl calibration solution (0.01M KCl):

- drying of KCl powder
- weighing (defective balance)
- quality of the de-mineralised water used for the calibration solution
- glassware used (volumetric flask vs. measuring cylinder)

Error may be in measurement procedure:

- calibration of the instrument (cell constant adjustment)
- measurement of the sample temperature and temperature correction
- decontamination of the probe

Error may be in other general procedures:

- cleaning of glassware
- wrong labelling of sample
- calculation and reporting errors

Standard Methods recommends the following actions that may be taken based on analysis results in comparison to the standard deviation.

Control limit: If one measurement exceeds the limits, repeat the analysis immediately. If the repeat is within the UCL and LCL, continue analyses; if it exceeds the action limits again, discontinue analyses and correct the problem.

Warning limit: If two out of three successive points exceeds the limits, analyse another sample. If the next point is within the UWL and LWL, continue analyses; if the next point exceeds the warning limits, discontinue analyses and correct the problem.

Standard deviation: If four out of five successive points exceed one standard deviation, or are in increasing or decreasing order, analyse another sample. If the next point is less than one standard deviation away from the mean, or changes the order, continue analyses; otherwise discontinue analyses and correct the problem.

Central line: If six successive points are on one side of the mean line, analyse another sample. If the next point changes the side continue the analyses; otherwise discontinue analyses and correct the problem.

6. Good analytical practices

1. The primary criteria of obtaining data quality is the preparation of distilled water / reagent grade water to be used for dilution, preparation of reagents and for blank. The quality of water required is related directly to the analysis being made. Reverse osmosis, distillation and deionization in various combination can produce reagent grade water when used in the proper sequence.
2. A sound method must be selected.
3. The technique is simply to carry a sample to number of manipulations without accidental losses and without introducing foreign material.
4. Common sense plus awareness of the danger spots is the main requirement of an analyst.
5. Don't mix up samples, add the wrong reagents, or spill solutions and break glass-ware.
6. No analysis should ever be performed using anything but clean glass-ware.
7. Glass- wares used for volume measurements should be cleaned with hot detergent solutions.
8. If the glass surface does not drained uniformly use cleaning solutions (25 g of Sodium dicromate + 50 ml distilled water + 450 ml 1 : 1 Sulphuric Acid). Cleaning solution is usually avoided in biological work because many micro organisms are sensitive to traces of chromium which remain on the glass even on thorough rinsing.
9. After cleaning, apparatus should be rinsed several times with tap water, then small portions of distilled water and finally to allow to drain.
10. Neatness in the laboratory must be maintained. Neatness includes stewardship over the more permanent laboratory fixtures, such as ovens, hotplates, hoods, sinks, and the work-benches.
11. Use reagents of AR grade and LR grade depending on the requirement. Only AR grade chemicals are used as primary standards.
12. Chances of contamination increase when a reagent bottle placed in the laboratory for use of large number of analyst. It is most important that analyst carefully adhere the certain rules –
 - (a) The reagent shelf should be clean and orderly
 - (b) Any spilled chemicals must be cleaned up immediately
 - (c) The stopper of the reagent bottles should not be placed on shelf or laboratory bench. Stoppers may be placed on clean watch glasses, however, it is best to hold them between two fingers while reagents are being withdrawn
 - (d) The mouth of the reagent bottles should be kept clean.
 - (e) Pipettes, droppers or other instruments should never be inserted into reagent bottles. Rather, a slight excess of reagent should be poured in to a cleaned beaker from which the pipetteing is done and the excess discarded, not returned to the bottle.
 - (f) Fingers, spatulas, or other implements should not be inserted into bottles of solid reagents.
13. The pipette is to be filled by gentle suction to above 2 cm above the ETCH line, using an aspirator bulb.
14. The tip of the pipette should be kept well below the surface of the liquid during the filling operation. Any hanging droplets of the solution are removed by touching the tip of the pipette to the side of the glass-ware and the stem is wiped with the piece of tissue paper to remove the drops of solution from the outside surface. After delivery the tip of the pipette is touched to the inner side of the receiving vessel at the liquid surface.
15. Discard Pipette with damaged tips.
16. Burettes must be cleaned to ensure a uniform drainage of solutions down the inner surface.
17. Make sure the small openings of the stopcock and the barrel is not plugged with grease.
18. When not in use the burette should be filled with distilled water and cap.

19. Before a titration is started, it must be ascertained there are no air bubbles in the tip of the burette.
20. When a solution is delivered from a burette, the liquid running down the inner wall is somewhat detained. After the stopcock has been closed, wait a few seconds for this drainage before taking a reading.
21. When solutions made up in volumetric flask, make a practice of mixing the solutions thoroughly before the final volume has been adjusted, and mixing again after flask has been filled to the mark.
22. Solution is never be heated in volumetric flask.
23. When a solid is dissolved in a volumetric flask, the final volume adjustment should not be made until all the solid is dissolved.
24. Alkaline solution cause ground glass stoppers to freeze and should never be stored in flask equipped with such stoppers.
25. Some instruments contain fragile components which may be injured by improper handling.
26. Some times a carefully worked out calibration may be ruined by manipulation of the wrong knobs.
27. No analytical instrument should ever be touched by a person unfamiliar with the direction for its proper use and the precautions against damaging it.
28. An instrument should never used by a person who has not thought through its advantages and limitations for the job at hand, who does not have a proper estimate of the reliability of the data obtained and who cannot interpret correctly the significance of the instrumental measurements and apply it with intelligence.

7. Concluding Remarks

One should not think that analysis of samples is a hopeless undertaking. The checks and safe-guards to be built into the operation must be stringent and comprehensive than those most analyst are accustomed to.

ACCREDITATION OF TESTING LABORATORIES

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What is Laboratory Accreditation?

- Laboratory accreditation is the formal recognition, authorization and registration of a laboratory that has demonstrated its capability, competence and credibility to carry out specific test or types of tests claimed by the laboratory. Accreditation of laboratories creates a transparent situation in the world of quality assurance and a powerful tool in developing and establishing confidence and credibility between parties in the market. The accredited laboratory is authorized to issue calibration/test reports and reports of chemical analysis which are recognized and accepted internationally.

Why Laboratory Accreditation?

- There are many reasons for laboratories to opt for accreditation. These include :-
 - (i) Provides recognition of technical competence including quality system management of the laboratories based on external (third party) assessment.
 - (ii) External verification of efficiency, correctness and accuracy of the processes in the laboratory.
 - (iii) (International) acceptance of test reports issued by the accredited laboratories.
 - (iv) Improved customer confidence in the test reports issued by the accredited laboratories.
 - (v) Potential for increased business through greater user confidence.
 - (vi) Time and money saved through elimination of multiple assessment.
 - (vii) Increased confidence of personnel in their work.
 - (viii) Improved protection against liability.
 - (ix) Clients can locate and identify the laboratories, appropriate to their need from compendium of Accredited Laboratories.

Criteria for Laboratory Accreditation

- A laboratory seeking accreditation must be able to demonstrate that it is meeting all the requirements of National Accreditation Board for Testing and Calibration Laboratories (NABL) accreditation criteria Doc. 101 (1994). NABL-Doc. 101 is consistent with the provisions of ISO/IEC - Guide 25 and European Standards EN 45001.
- The criteria set out in the NABL-Doc. 101 covers all the aspects of a laboratory's activities and include its legal identity, organization and management, quality system, personnel, accommodation and environment, facilities and equipment, measurement traceability, calibration, test procedures, sample handling and identification and the recording and reporting of results. It also include quality system audit, review and quality control which ensures that quality system is fully implemented and in practice.
- A laboratory applying for accreditation should prepare a Quality Manual which documents the quality system (the operating procedures, standard test methods and work instructions, training records etc.) adopted by it for assuring compliance with the NABL criteria.

Preparation of Laboratory Accreditation

☛ Internal Preparation

- (i) There must be a commitment from the top management to establish a quality assurance system which is real and visible.
- (ii) Obtain all relevant NABL documents and get fully acquainted with requirements of NABL criteria at all levels.
- (iii) Make a definite plan of action for obtaining accreditation.
- (iv) Establish a core group to review the progress of preparedness of accreditation.
- (v) Nominate a Technical Manager and a Quality Manager to co-ordinate all activities related to seeking accreditation. Such persons should be familiar with laboratory's existing quality system.
- (vi) Define and declare the laboratory Quality Policy which must be communicated and understood at all levels.
- (vii) Assess existing quality system and technical competence (documented procedures, records etc.) and identify gap/weak areas and make action plan to fill up the gaps.
- (viii) Define the scope for accreditation i.e. the range of sample types to be tested or analyzed and types of tests (parameters).

- (ix) Prepare a Quality Manual.
- (x) Develop next level documents like Quality Procedures, Test Procedures & Quality Record formats.
- (xi) Implement Quality Manual, Operational Procedures, Test Methods and prepare/maintain records.
- (xii) Train laboratory staff at all levels specifically those who perform functions which may affect the quality of output.
- (xiii) Arrange internal quality audit training for selected staff to be used for internal audit of laboratory.
- (xiv) Establish/conduct internal quality audit using the trained staff and repeat few cycles.
- (xv) Conduct management review to assess the effectiveness of the quality system implemented and take corrective actions.
- (xvi) Prepare the accreditation application in prescribed proforma enlisting tests (parameters) conducted with detection limits and accuracy and also test methods being followed.
- (xvii) Laboratories are required to submit ten sets of applications in appropriate application form for each field alongwith two copies of the Quality Manual.

External Preparation

- (i) On receipt of application, NABL appoints a Lead Assessor to examine the Quality Manual for its adequacy.
- (ii) If the Quality Manual is not acceptable, NABL informs the laboratory for amending the Quality Manual.
- (iii) If NABL feels that Quality manual has adequately addressed all the requirements of NABL Doc. 101, it informs the applicant laboratory and fixes preliminary visit to laboratory by the Lead Assessor.
- (iv) The Lead Assessor makes a preliminary visit to the laboratory and collects information on size of the laboratory, nature of the testing, experties and number of Assessors required for assessment.
- (v) A team of minimum two Assessors visits the laboratory to make an on the spot assessment of the compliance of the laboratory to the NABL Criteria (1994).

- (vi) Lead Assessor submits his final assessment report to NABL which is being presented to relevant Committee (s).
- (vii) The Committee examines the findings of the assessment team and determines whether recommendations in the report are consistent both with NABL's requirements and claims made by the laboratory in their application.
- (viii) On recommendations of the Committee, the result of the accreditation is communicated to the laboratory by NABL.
- (ix) Accreditation certificate is issued by the NABL which is valid for three years.
- (x) A surveillance audit is carried out every year by NABL but prior intimation to the laboratory.
- (xi) Request for renewal of accreditation is made to NABL in advance (six months).

RECOGNITION OF ANALYTICAL LABORATORY

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1. Introduction

The Water (Prevention and Control of Pollution) Act, 1974 provides under Sections 24 and 25 of the Act for granting of 'Consents' to industries by the State Pollution Control Boards, prior to establishment of the industry and also later on at the time of its commissioning, on compliance with the standards for discharge of only treated effluent into environment.

For granting of 'Consent to establish', the industry is required to submit its plans for installation of pollution control devices to comply with the standards for each of its outlet along with the application in the prescribed format. This 'Consent' is required only once unless the manufacturing process or raw material or the production capacity is changed.

For granting of 'Consent to operate', the industry is required to apply before commissioning in the prescribed format along with the report on chemical analysis of its effluent from a laboratory recognised by the concerned State Government in consultation with the State Pollution Control Board. The consent is granted if the test results indicate compliance with the standards for discharge prescribed by the Board. This 'Consent' is renewable at a frequency to be prescribed by the Board depending upon the type of the industry and the

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characteristics of the effluent in terms of its toxicity and hazard potential. The Consent renewable frequency may be even once every year.

2. Recognition of laboratory

Section 51/52 of the Water Act states that the Central/State Government may, by notification in the Official Gazette, establish a Central/State Laboratory, or specify any laboratory/any State laboratory or institute as a Central/State Water Laboratory to carry out the functions entrusted to the Central/State Water Laboratory under this Act. The Central/State Government in such cases makes rules in consultation with the Central/State Pollution Control Board prescribing the functions of the Central/State Water Laboratory and the procedures for submission of water and wastewater samples for analysis, the form of the laboratory report and the fees payable in respect of such report.

Under Section 53 of the Water Act, the Central/State Government may, by notification in the Official Gazette, appoint such persons as it thinks fit and having the the prescribed qualifications to be Government Analyst for the purpose of analysis of water and wastewater sent for analysis to any laboratory established or specified under the Act.

Similar provisions are there under Sections 12 and 13 of the 'Environment (Protection) Act, 1986 for recognition of laboratories or institutes as Environmental Laboratories to carry out functions entrusted to an environmental laboratory, and appointment/recognition of persons fulfilling qualification requirements as Government Analyst through Official Gazette Notification.

2. Benefits of Recognition

There are several direct / indirect and consequential institutional benefits in getting recognition of laboratory as Central/State Water Laboratory or as Environmental Laboratory. These are summarised as follows:

- The laboratory gets continuously upgraded during fulfilment of the requirements for getting recognition, and renewal thereafter at regular intervals.
- Precision in analysis, accuracy in analysis result and the reliability in data generation improve during fulfilment of procedural requirements.
- It serves as morale-boosting for the laboratory personnel conducting the analysis that his services are being utilised at the country's interest.
- The observations/reports of the laboratory will be upheld in the Court of law.
- The scientist/chemist gets recognition through the Central/State Government's Official Gazette notification as Government Analyst.
- The services rendered by the recognised laboratory generate revenue in terms of sample analysis fee to support/supplement the annual budget of the laboratory.

4. How to get Recognition ?

According to the provisions of the "Water (Prevention and Control of Pollution) Act, 1974", the "Environment (Protection) Act. 1986" and the rules framed thereunder, a laboratory seeking recognition as a Central/State Government laboratory has to apply in the prescribed format to the Ministry of Environment and Forests, Government of India or the concerned State Government. On receipt of the application, a team of Scientists from the

Central / State Pollution Control Board inspect the laboratory's capability in respect of availability of qualified man-power, instrument/equipment, infrastructure facilities etc. Based on the fulfilment of requirements, the laboratory is recognised by the concerned government as the Government Laboratory and the Scientist as Government Analyst through Official Gazette notification. There could be more than one Government Analyst in a laboratory.

3. Concluding Remarks

In view of the direct and indirect benefits of recognition of laboratories mentioned, a laboratory should seek recognition of the Government in the quest for capability development and generation of reliable water quality database. The Central / State Pollution Control Boards conduct Analytical Quality Control (AQC) exercises at regular intervals to keep the laboratory in tune. Analysis of environmental water samples, where constituent chemicals are sometimes present in traces and the analysis suffer from interferences unless those are shielded, indirectly helps the analyst in the pursuit of knowledge about the state-of-the-art instrumentation in laboratory analysis.