MINISTRY OF JAL SHAKTI
Department of Water Resources,
River Development & Ganga Rejuvenation

WATER QUALITY ACTIVITIES IN CENTRAL WATER COMMISSION

CENTRAL WATER COMMISSION
R.K. Puram, Sector -1 , New Delhi

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WATER QUALITY ACTIVITIES IN CWC

Central Water Commission is a premier Technical Organization of India in the field of Water Resources and is presently functioning as an attached office of the Department of Water Resources, River Development and Ganga Rejuvenation, Ministry of Jal Shakti, Government of India. The Commission is entrusted with the general responsibilities of initiating, coordinating and furthering in consultation of the State Governments concerned, schemes for control, conservation and utilization of water resources throughout the country, for purpose of Flood Control, Irrigation, Navigation, Drinking Water Supply and Waterpower Development. It also undertakes the investigations, construction and execution of any such schemes as required.

Mandates and objectives of water quality monitoring

Being the apex national body for development of water resources in the country, its mandate is assessment of water resources in general. This would include the following objectives in regard to water quality monitoring:

- Establishment of baseline water quality
- Assessment of suitability of water for various uses
- Detection of trends in water quality changes.
- Dissemination of water quality information upon request

1. INTRODUCTION

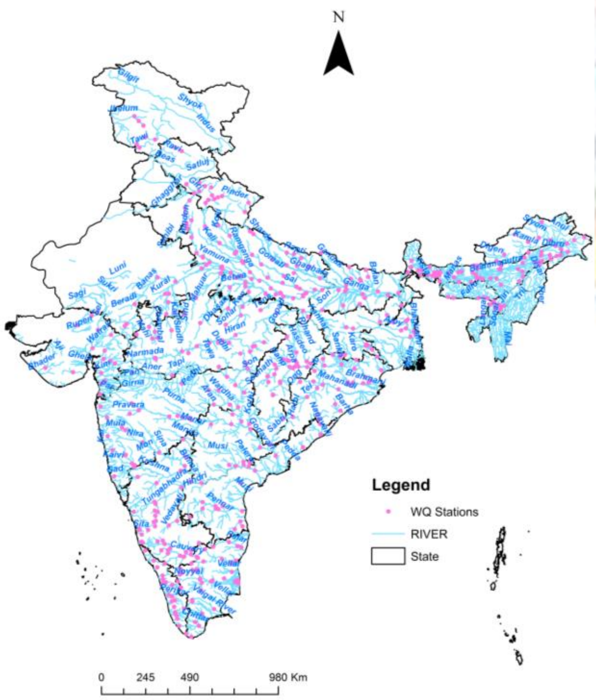
Central Water Commission has a well-established 'Water Quality Monitoring Network' consisting of monitoring stations at 552 key locations covering all the major river basins of India. The water quality monitoring network consists of 295 field laboratories called the level-I laboratories located at field water quality monitoring stations on various rivers of India for monitoring of 6 in-situ parameters, eighteen (18) level-II laboratories for the analysis of 25 physico-chemical plus bacteriological parameters, and five (05) level-III/II+ laboratories for the analysis of 41 parameters including heavy metals / toxic parameters and pesticides.

Water Quality Monitoring Network in CWC at present

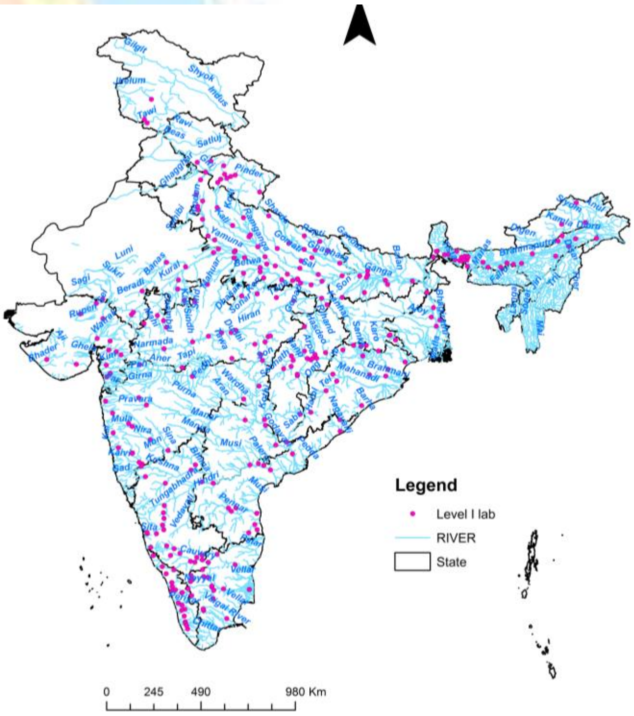
At present, Central Water Commission follows a three tier laboratory system for providing analytical facilities for the analysis of river water samples collected from 552 water quality monitoring stations belonging to the Water Quality Monitoring Network and covering all the major river basins of India.

The three tier laboratory system consists of:

1. **Level-I Laboratories:** These are the field laboratories which are located at field water quality monitoring stations on various rivers of India where in-situ values of six, five physical parameters and one chemical parameter (Dissolved Oxygen) of river water are monitored. There are a total number of 295 level-I laboratories located at field water quality monitoring stations on various rivers of India.
2. **Level-II Laboratories:** There are 18 level-II laboratories located at division offices to analyse 25 physico-chemical and bacteriological parameters of river water. The list of level-II laboratories in CWC is given at **(Table-1).**
3. **Level-III/II+ Laboratories:** There are five (05) regional level-III / II+ laboratories for analysis of 41 parameters including heavy metals / toxic parameters and pesticides. The list of level-II+/III laboratories in CWC is given at **(Table-1).**
4. **National River Water Quality Laboratory (NRWQL), New Delhi**
   The level-III laboratory at New Delhi under Yamuna Basin Organisation is the National Laboratory named as "National River Water Quality Laboratory (NRWQL), New Delhi".



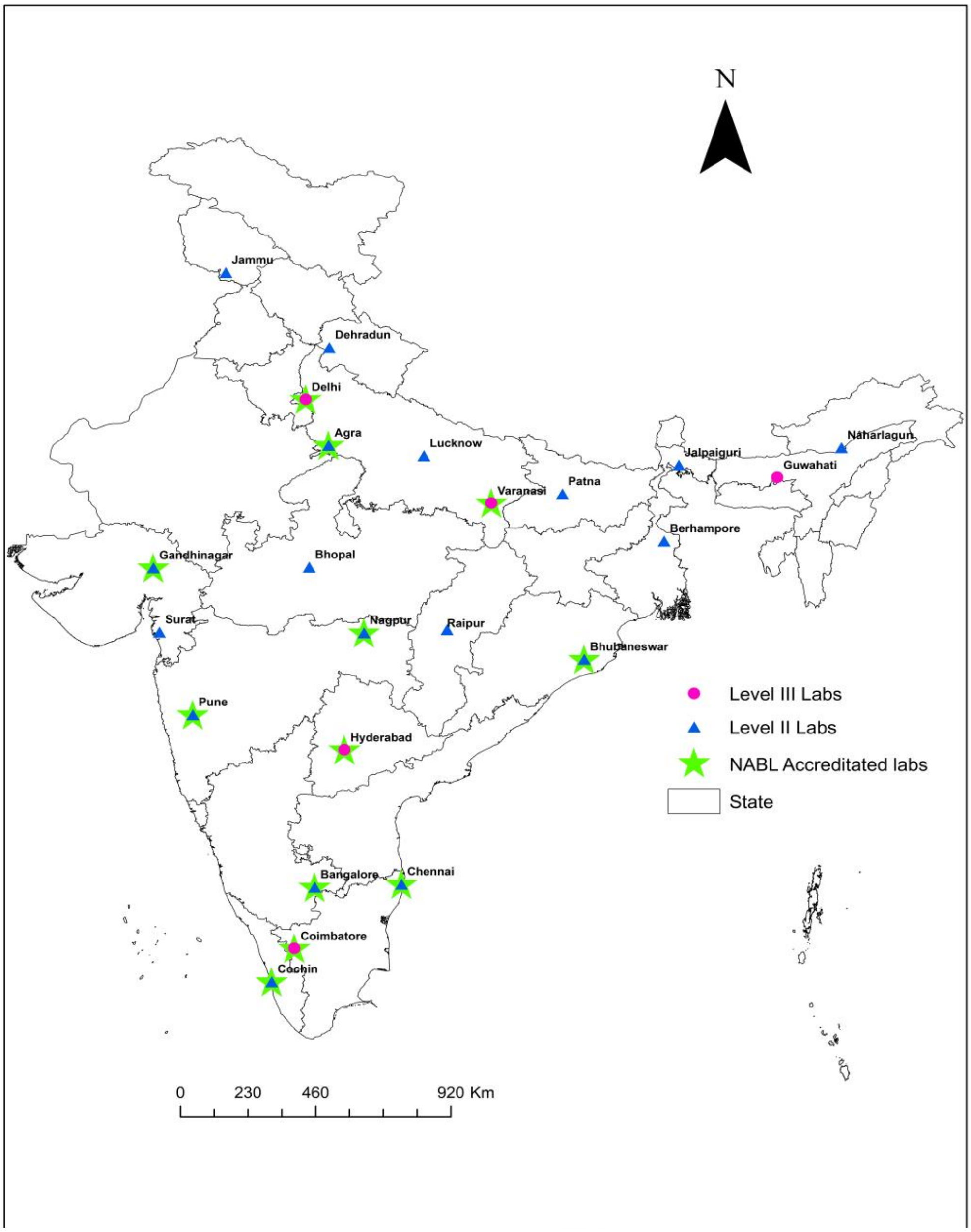
552 WQ Stations in CWC



295 Level 1 WQ Laboratories

Table : 1 - List of Water Quality Laboratories in CWC			
S. No.	**Location of laboratory**	**Level of Laboratory**	**Organisational Jurisdiction**
1	National River Water Quality Laboratory (NRWQL), New Delhi	III	YBO, New Delhi
2	Lower Cauvery Water Quality Laboratory (LCWQL), Coimbatore	II+	C&SRO, Coimbatore
3	Upper and Middle Ganga Water Quality Laboratory, Varanasi	III	UGBO, Lucknow
4	Krishna and Godavari River Water Quality, Hyderabad	II+	K&GBO, Hyderabad
5	Upper Cauvery Water Quality Laboratory, Bangalore	II	C&SRO, Coimbatore
6	South Western Flowing Rivers Water Quality Laboratory (SWFRWQL), Kochi	II	C&SRO, Coimbatore
7	Upper Krishna Division Water Quality Laboratory (UKDWQL), Pune	II	K&GBO, Hyderabad
8	Mahi Division Water Quality Laboratory (MDWQL), Gandhinagar	II	NTBO, Gangdinagar
9	Lower Yamuna Water Quality Laboratory, (LY-WQL), Agra	II	YBO, New Delhi
10	Eastern Rivers Water Quality Laboratory (ERWQL), Bhubaneswar	II	M&ERO, Bhubaneswar
11	Hydrology Division, Chennai	II	C&SRO, Coimbatore
12	WainGanga Division, Nagpur	II	Nagpur
13	Middle Brahmaputra Division, Guwahati	III	B&BBO, Shillong
14	Lower Brahmaputra Division, Jalpaiguri	II	B&BBO, Shillong
15	U.B. Division, Dibrugarh	II	B&BBO, Shillong
16	Chenab Division, Jammu	II	IBO, Chandigarh
17	Lower Ganga Division, Berhampore	II	LGBO, Patna
18	Middle Ganga Division -V , Patna	II	LGBO, Patna
19	Mahanadi Division, Raipur	II	M&ERO, Bhubaneswar
20	Narmada Division, Bhopal	II	NBO, Bhopal
21	Tapi Division, Surat	II	NTBO, Gangdinagar
22	Himalayan Ganga Division, Dehradun	II	UGBO, Lucknow
23	Middle Ganga Division -I , Lucknow	II	UGBO, Lucknow

NABL accredited Water Quality Laboratories in CWC



- **National River Water Quality Laboratory, New Delhi**
- **Krishna & Godavari River Water Quality Laboratory, Hyderabad**
- **Upper & Middle Ganga Water Quality Laboratory, Varanasi**
- **Lower Cauvery Water Quality Laboratory, Coimbatore**
- Upper Cauvery Water Quality Laboratory, Bangalore
- Lower Yamuna Water Quality Laboratory, Agra
- West Flowing Rivers Water Quality Laboratory, Kochi
- Upper Krishna Division Water Quality Laboratory, Pune
- Mahi Division Water Quality Laboratory, Gandhinagar
- Eastern River Water Quality Laboratory, Bhubaneswar
- East Flowing Rivers Water Quality Laboratory, Chennai
- WainGanga Division, Nagpur

2. CLASSIFICATION OF WATER QUALITY MONITORING STATIONS:

In accordance with the definition given in the “Uniform Protocol on Water Quality Monitoring Notification” 2005, subsequently updated during 2017, available at CPCB website (http://cpcb.nic.in/wqm/Guidelines_Water_Quality_Monitoring_2017.pdf) water quality monitoring stations are classified as follows:

1. **Baseline stations:**

   Baseline stations mean the monitoring location where there is *no influence of human activities* on water quality.

   Frequency of sample collection in CWC is once every two months.

2. **Trend stations:**

   “Trend station” means the monitoring location designed to show how a particular point on a watercourse varies over time due, normally, to the influence of man’s activities.

   Frequency of sample collection in CWC is once every month.

3. **Flux stations or Impact stations:**

   “Flux stations or Impact stations” means the location for measuring the mass of particular pollutant on Main River stem for measuring the extent of pollution due to human interference or geological feature at any point of time and is necessary for measuring impact of pollution control measures adopted.

   Frequency of sample collection in CWC is thrice every month.

The “Uniform Protocol on Water Quality Monitoring Notification” issued by the Water Quality Assessment Authority, Ministry of Environment & Forests dated 17th June, 2005 and the updated guideline during 2017, both are available at CPCB website. (Annexure-1&2)

3. PARAMETERS ANALYSED IN THE THREE LEVELS OF LABORATORIES:

The list of parameters analysed in the three levels of laboratories is given in **(Table-2)**.

Table : 2 List of water quality parameters analyzed by CWC in Level II / II+ / III

S. No.	**Water Quality Parameter**	
1.	Temperature	Level I Laboratory
2.	Colour	
3.	Odour	
4.	Electrical Conductivity / TDS	
5.	pH	
6.	Dissolved Oxygen (DO)	
1.	Temperture	Level II Laboratory **(1 to 26)**
2.	pH	
3.	Electrical Conductivity	
4.	Total Dissolved Solids (TDS)	
5.	Turbidity	
6.	Sodium	
7.	Calcium	
8.	Magnesium	
9.	Potassium	
10.	Carbonate	
11.	Bicarbonate	
12.	Chloride	
13.	Sulphate	
14.	Fluoride	
15.	Boron	
16.	Silicate	
17.	Ammonia (Nitrogen)	
18.	Nitrate	
19.	Nitrite	
20.	Phosphate	
21.	Dissolved Oxygen (DO)	
22	Biochemical Oxygen Demand (BOD)	
23.	Chemical Oxygen Demand (COD)	
24.	Total Coliform	
25.	F. Coliform	
26.	Arsenic	Level II^+ / III Laboratory **(1 to 41)**
27.	Cadmium	
28.	Chromium	
29.	Copper	
30.	Iron	
31.	Lead	
32.	Nickel	
33.	Mercury	
34.	Zinc	
35.	Alpha Benzenehexachloride (BHC), Beta BHC, Gama BHC	
36.	OP-Dichlorodiphenyltrichloroethane (OP DDT), PP-DDT	
37.	Alpha Endosulphan, Beta Endosulphan,	
38.	Aldrin, Dieldrin,	
39.	Carbaryl (Carbamate),	
40.	Malathian, Methyl Parathian,	
41.	Anilophos, Chloropyriphos	

4. WATER QUALITY PARAMETERS & ITS IMPORTANCE

Water in its chemically pure form occurs rarely in nature. In fact, water is commonly found to carry a variety of constituents. When water in its precipitate form reaches the surface of the earth, it has already collected a number of substances and properties that characterise natural water. Gases have been absorbed or dissolved, dust particles have been picked up, and it has obtained a certain temperature. In case of a high radioactive washout or high acidity pickup, atmospheric water may not even be clean in the general sense and may not be suitable for some uses.

Atmospheric water is subject to further changes of quality both upon reaching the earth's surface and during its travel underground. The ability to dissolve salts is gained in the topsoil where carbon dioxide is released by bacterial action on organic matter. The soil water becomes charged with carbon dioxide resulting in formation of carbonic acid. Under the acidic conditions that develop many soil and rock constituents are dissolved.

Man's influence on the quality of water is quite apparent and is now a major concern. Mixing with municipal and industrial waste waters may result in drastic changes in the water quality of natural waters. Agriculturally oriented activities such as irrigation, use of fertiliser, pesticides, herbicides, etc., may lead to diffuse pollution of both surface waters and ground water. Irrigation return waters also tend to increase total salts in the receiving water. Construction schemes, such as those connected with river training, flood control, low flow augmentation, etc., considerably influence the quality regime. Mining activities often cause substantial water quality changes.

There is a great range of water quality parameters that can be used to characterise waters. Largely the water quality measurement objectives and the previous history of the water body will determine selection of parameters. It is true, however, that some parameters are of special importance and deserve frequent attention.

GENERAL

The parameters belonging to this group give a general picture of the quality of the water body. Except for the solids determination, analysis for the rest of the parameters can be performed in the field also. These are, therefore also called field parameters.

1. TEMPERATURE

The temperature of a surface water body depends on its location, season and time of the day. The temperature of tropical and sub-tropical rivers may vary from 10 to 30°C. Temperature of rivers receiving water from snow melt in their upper reaches may be even lower than 10^{o}C. Warm temperatures result in:

- decrease of solubility of gases in water, such as, O_2, CO_2 and N_2
- increase in the metabolic and growth rates of the aquatic organisms
- increase in volatilisation and chemical reaction rates of substances
- increase the die-away rate of micro-organisms, which are not normal inhabitant of the aquatic environment

Considering the above factors, it is seen that the warm water environment, along with organic pollution, would lead to a greater stress on the oxygen resources of the stream. In the case of addition of nutrients, it would also lead to eutrophication of the water body.

2. COLOUR

Ordinarily, surface waters do not have any true colour. Naturally present minerals and humic acids in dissolved state may impart their characteristic hues. Presence of suspended matter may give an apparent colour. Green, yellow-brown or red colour may be the result of presence of different microorganisms, particularly, algae. Presence of suspended, inorganic matter may also result in an apparent colour. Water Quality Standards specified by Bureau of Indian Standards (Tolerance Limits) are defined below:

3. ODOUR

Fresh water is odour free. Presence of odour suggests higher than normal biological activity due to the presence of decomposable organic material contributed by human or industrial wastes or excessive growth of algae and other plants. Odour is caused by production of volatile organic compounds and inorganics, such as, NH_3 and H_2S. It is more pronounced when the dissolved oxygen in water is less than about 25% of its saturation value. Industrial wastes can also create odours directly.

4. SOLIDS

Suspended solids in water may consist of silt, clay and other fine inorganic and organic particles. Planktons may also contribute to the suspended solid load. Normally, the particles range from 10 nm to 0.1 μm in diameter. Their concentration depends on the location of the water body and changes from season to season. During rainy season, it may change hourly during a rainfall event. It is greatly influenced by the catchment area characteristics.

Turbidity, which is a related parameter, is interference to the passage of light or scattering of light by suspended particles in a column of water. It is measured in nephelometric turbidity units (NTU). It may range from 1 to 1000 NTU.

5. TOTAL DISSOLVED SOLIDS

Total dissolved solids (TDS) refers to the residue left after evaporation of a known volume of water at 105°C, which has been filtered through a standard filter. It is approximately equal to the total content of dissolved substances in a water sample since approximately half of the bicarbonate ion, which is one of the dominant ions in waters, is lost as CO_2 during evaporation process. The TDS value for river waters depends largely on the ratio of the contribution of the overland flow to the subsoil flow. It may vary from less than 50 mg/L to a few thousand mg/L. Surface evaporation in arid climates and agricultural return waters increase the TDS considerably.

6. CONDUCTIVITY

Conductivity or electrical conductivity (EC) of natural water is due to the presence of salts, which dissociate into cations and anions. It is the ability of a solution to conduct current. The units of EC are µmhos/cm or µS/cm and is expressed at 25^oC. Even in cases where the chemical composition of water is represented almost exclusively by inorganic ions, the correlation between their content and EC may change considerably since different ions conduct electricity to different extents.

The value of EC may serve as an approximate index of the total content of dissolved substances in water samples. TDS, mg/L may be obtained by multiplying EC, µmhos/cm, by a factor ranging between 0.55 and 0.9. A commonly used value is 0.67. In order to increase the accuracy of the evaluation of the mineral content of waters from EC measurements, it is necessary to establish such correlations, for each body of water. The conductivity of most fresh waters ranges from 10 to 1000 µmhos/cm. It is, at times, used as an indication of ingress of sea water in estuarine region of a river.

7. pH

The hydrogen ion concentration in water is expressed in terms of pH. It is defined as the logarithm of inverse of hydrogen ion concentration in moles/L. The pH value of natural waters mostly depends on free carbon dioxide, bicarbonates and carbonate ions. The equilibrium condition may be changed by the intensity of photosynthetic process (which consumes carbon dioxide) and the biochemical oxidation of organic substances (which produces carbon dioxide), as well as chemical conversions of some mineral substances, such as reduction-oxidation reactions of ammonia, sulphur containing minerals, iron, etc. The pH value is also affected by the presence of naturally present humic substances and various acids and alkalis, which may be discharged into the body of water through wastes.

Alkalinity and *acidity* are related parameters, which reflect the capacity of a water sample to neutralise acid or alkalinity, respectively. Measurement of these parameters along with pH may be required when solubility and ionic equilibria of various chemical species are under investigation.

8. DISSOLVED OXYGEN

The dissolved oxygen (DO) saturation concentration of water varies with temperature, salinity and atmospheric pressure. In fresh waters, at sea level, it ranges from 15 mg/L at 0°C to 7.5 mg/L at 30°C. In water samples, it may be expressed in absolute terms as mg/L or as percent of saturation value.

Deviation in the concentration of DO from the saturation equilibrium value in a surface water body may exist due to aerobic biochemical oxidation of organic matter and photosynthetic activity of plants in water. These reactions, combined with atmospheric reaeration may result in establishing a different equilibrium concentration at a location, which may be below or above the saturation value. Oxygen content of fresh, unpolluted water bodies, having normal biological activity, ranges from 80% to 100% of saturation DO level. Lower levels indicate presence of organic pollution. DO in grossly polluted waters may be less than 25% of the saturation value. At this level, a drastic shift from the biological community of fresh waters may be expected. The water also becomes turbid and foul smelling.

In the main current of a stream the DO is usually the same at all depths because of mixing. However, in still water areas there may be stratification. This is particularly true for lakes. In eutrophic waters, the variation in DO with depth is very pronounced. Further, it is important to record the time of sampling since wide variation in DO at a location may occur over a 24-hour period.

NUTRIENTS

Nitrogen and phosphorus are essential for the growth of plants and animals. For this reason these elements are often identified as nutrients, or bio stimulants when present in surface waters. It should be noted that both the organic and inorganic forms of these constituents are of importance.

1. NITROGEN COMPOUNDS

Concentrations of nitrogen compounds referred to in the following discussion are always expressed in terms of mg/L as N (sometimes also written as mg N/L).

Organic nitrogen

In nature, nitrogen is cycled between its organic and inorganic forms. Bacteria and plants are responsible for the production of organic compounds containing nitrogen (proteins) from inorganic forms of nitrogen. Animals, including humans, cannot utilise nitrogen from atmosphere or from inorganic compounds to produce proteins but must obtain nitrogen in organic form. Bacteria also break down organic nitrogen in animal and plant wastes and convert it into inorganic forms. Organic nitrogen in unpolluted fresh waters is very low. Further, organic nitrogen is easily deaminated to produce ammonia. It is, therefore, not a routine parameter for characterisation of waters. However, in grossly polluted waters and where nutrient budgets are studied, organic nitrogen may be measured.

Ammonia

Proteins are broken down by bacterial activity to ammonia and urea, the latter in turn is also hydrolysed to ammonia and carbon dioxide. Ammonia may also be discharged into water bodies through industrial wastes. In water, it exists both as molecular specie, NH_3 and in ionic form, $NH_0{}^+$.

Total ammonia, or simply ammonia refers to the sum of the two. At pH 7 nearly all of the ammonia exists in the ammonium form. At higher pH values, the ionic form is converted to the molecular specie and may be lost from the aqueous phase through volatilisation. Total ammonia concentration in surface waters typically range between 0.1 and 2 mgN/L. Higher values may indicate pollution. Concentrations of undissociated ammonia upto 1 mgN/L may be tolerated by most fishes. However, toxicity varies greatly from specie to specie.

Oxidised Nitrogen

In aerobic environment, ammonia is biochemically converted to nitrite (NO_2^-) and then to nitrate (NO_3^-) by nitrifying bacteria. The total of nitrite and nitrate nitrogen is called oxidised nitrogen. The rate of conversion of nitrite to nitrate is much faster than the formation of nitrite from ammonia. Therefore, nitrite concentration is usually much lower compared to nitrate. Nitrates may also be contributed to fresh waters through igneous rocks, land drainage and agricultural runoff. Under anaerobic conditions, nitrates may be converted to nitrogen gas and would be lost from the aquatic system.

In fresh waters nitrate nitrogen concentration seldom exceeds 0.1 mg N/L. Higher concentrations indicate the effect of human activity. Concentrations greater than 5 mgN/L indicate a significant level of pollution. Though many factors influence eutrophication phenomenon, waters having oxidised nitrogen in excess of 0.2 to 0.5 mgN/L are prone to algal blooms provided other requirements for the growth of algae are met.

2. PHOSPHORUS COMPOUNDS

The phosphorus containing compounds of interest with respect to water quality include orthophosphates ($PO_4{}^{3-}$), polyphosphates ($P_3O_{10}{}^{5-}$, $(PO_3)_5{}^{3-}$, $P_2O_7{}^{4-}$) and organically bound phosphate. The concentration of phosphates is always expressed as P and not as PO_4^{3-}. The sources of phosphorus are mainly the drainage from phosphate bearing rocks, agricultural run-off and decomposing organic matter. Considerable amounts may be added through pollution from municipal and industrial wastes. Orthophosphates and polyphosphates, which are the dissoved forms, are often the limiting factor in the process of photosynthesis. They are converted to organic forms during the growth of plants and are utilised to a point where insignificant, small concentrations are left. The main users of organic phosphorus are zooplanktons and bacteria. They are also responsible for recycling of the organic form into the soluble form. As a result there can be a seasonal change in the concentration of soluble phosphorus in surface waters.

Concentrations of phosphorus compounds should be expressed in terms of mgP/L. In most natural surface waters the concentration of dissolved phosphorus may be 0.02 mgP/L or less, often as low as 0.001 mgP/L. Higher concentrations indicate presence of pollution and may result in the eutrophication of the water body.

ORGANIC MATTER

The content of organic matter in water is one of the most important parameters of the quality of water. The parameters discussed in the following section measure the aggregate organic substances. Usually the measurement includes both the suspended and dissolved forms. It serves as a useful pollution index of a body of water. Determination of individual organic compounds of interest, such as phenols, humic acids, pesticide, etc., is carried out through specific tests.

BIOCHEMICAL OXYGEN DEMAND

Micro-organisms utilise waste organic matter as food. In aerobic environment, the organic matter is biochemically converted to carbon dioxide and water. The biochemical oxygen demand (BOD) test measures the oxygen consumed in the reaction. The standard test is carried out under controlled laboratory conditions, at a constant temperature and over a specified time. Since not all organic matter is biochemically decomposable, the test measures the oxygen equivalence of the degradable matter only. Compounds such as cellulose, lignin and many synthetic petrochemicals are very resistant to biological breakdown. Nitrification is the term applied to the biological oxidation of ammonia to nitrate. The oxygen consumed during the process is differentiated from that required for the oxidation of organic matter. It is called the nitrogenous BOD.

The BOD of unpolluted waters is usually less than 2 mg/L. Higher values indicate organic pollution from municipal or industrial wastes. The BOD of domestic and municipal wastes ranges between 150 and 400 mg/L. In slow moving streams, values greater than 8 mg/L indicate the possibility of on set of anaerobic conditions in the stream since the oxygen demand may exceed the supply of oxygen through atmospheric reaeration. Ammonia, if discharged with organic wastes, is oxidised only after the stabilisation of the major portion of the organic matter. The BOD test is used extensively in the modelling of oxygen concentration in rivers and streams subjected to pollution.

CHEMICAL OXYGEN DEMAND

The chemical oxygen demand (COD) test measures the oxygen equivalent of the organic matter using potassium dichromate, which is a strong oxidant. The oxidation is carried out at a high temperature in an acidic medium, in the presence of a catalyst, to ensure complete oxidation of all organic matter. Only aromatic hydrocarbons and pyridines are not oxidised.

One of the chief limitations of the COD test is its inability to differentiate between biologically oxidisable and biologically inert organic matter. In addition it does not provide any information regarding the rate at which the oxidation of biodegradable matter would proceed in nature. The COD test is used extensively in surveys where industrial wastes are discharged in streams. In conjunction with the BOD test, the COD test is helpful in indicating toxic conditions and the presence of biologically resistant organic matter. Compared to the BOD test, it has better precision and can be completed in a shorter period of time.

The COD of unpolluted surface waters is typically lower than 20 mg/L, which is mainly due to the presence of humic substances and the normal biota of the water body. The COD value of domestic and municipal wastes ranges between 400 and 800 mg/L.

TOTAL ORGANIC CARBON

For smaller amounts of organic carbon, the instrumental, total otganic carbon (TOC) method has proved to be satisfactory. In one form of this test, first the acidified sample is purged to remove the inorganic forms of carbon. Then a small amount of sample is evaporated and oxidised catalytically at high temperature to carbon dioxide which is measure with an infrared analyser. The TOC value of unpolluted surface waters is usually less than 10 mg/L. Note that while the COD and BOD tests measure the oxygen equivalence of carbon, the TOC test measures the carbon content. In most samples COD > BOD > TOC.

MAJOR IONS

All-natural waters contain dissolved ionic constituents. Analyses of surface and groundwaters from various sources has shown that the following species represent the principal chemical constituents. Typically, the ionic species are derived from the contact of water from various mineral deposits. The occurrence of these ions and the consequences, if they exceed certain limits, with respect to water quality and use, are discussed in Section 2.9, of this volume.

OTHER INORGANICS

1. SILICA

Silicon is widespread in earth’s crust. Degradation of silica containing rocks results in the presence of silica in natural waters. It occurs as suspended particles, in a colloidal or polymeric state and as silicic acids or silicate ions. The silica content of natural waters ranges between 1 and 30 mg/L. Silica is an essential element for aquatic plants, principally diatoms. Silica is also undesirable in industrial waters as it forms scales, which are difficult to remove.

2. FLUORIDES

Fluorides appear in unpolluted natural water as the result of the interaction of the water with fluorine containing minerals. Natural surface water contains fluorides in amounts which usually do not exceed 1 mg/L. Fluorides may also be contributed to surface waters through industrial wastes, such as, from glass industry and some ore enriching plants.

Fluoride, in concentration range between 1.5 and 2 mg/L in drinking water, results in mottling of teeth. Higher concentrations may cause bone diseases.

3. BORON

Boron may occur in natural waters through weathering of rocks, soil leaching, or find its way into a watercourse through industrial waste effluents. Many cleaning compounds contain boron. Concentrations in unpolluted waters do not exceed 0.1 mg/L and seldom reach 1 mg/L level. Boron in excess of 2.0 mg/L in irrigation water is deleterious to plants. Some sensitive crops may be adversely affected by concentrations as low as 0.5 mg/L. Drinking waters should not contain more than 1.0 mg/L.

4. TRACE ELEMENTS

In addition to the major and minor ionic species found in natural waters, a variety of inorganic species, principally heavy metals, of anthropogenic origin may also be found. These constituents are of concern because of their toxicity to microorganisms, plants and animals. Typically, the presence of these constituents is due to improperly processed industrial wastes.

Because of the long list of the parameters in this category, a few are included in monitoring programmes on priority basis. In case one or more of these may be found, samples for others may be analysed. Metals in waters can exist in dissolved, colloidal and suspended forms, as precipitates or adsorbed on other particles. Speciation and partitioning of the metals in a natural aquatic environment is a rather complicated and poorly understood phenomenon. Specification studies should be carried out only under specially designed surveys. Further, as dissolved metals occur in very low concentrations, it is recommended that metals are measured as the total metal concentration in a water sample. As a rule, the ionic form of a metal is the most toxic form. However, there are exceptions, such as methylmercury formed by aquatic organisms. The concentration of different metals in unpolluted waters varies over a wide range,0.001 – 0.1 µg/L.

ORGANIC CONTAMINANTS

Thousands of organic compounds have been synthesised by man. This section briefly discusses those classes of organic compounds that have found their way into natural waters and whose presence is of concern from ecological standpoint. Of greatest concern are those organic compounds that may be carcinogenic and may cause mutations in humans and other living forms at extremely low concentrations.

1. PESTICIDES

Pesticides are toxic substances, primarily used for the control of diseases and pest organisms in agriculture. These chemicals can be grouped based on their molecular structure: chlorinated hydrocarbons, organophosphates, carbamates and derivatives of urea. The major source of these chemicals in surface water is agricultural runoff.

Pesticides and herbicides belonging to the chlorinated hydrocarbon group are most widely spread. They have been in use longer compared to others and have greater resistance to breakdown from natural processes. Organophosphorus pesticides have relatively lower chemical and biological stability and decompose in the environment within a month.

Most of the pesticides are insoluble in water but highly soluble in hydrocarbons and fats. The have the ability to accumulate in fatty tissues of organisms, reaching a much higher concentration in certain aquatic biota compared to the surrounding water and sediments. Concentration of pesticides in water bodies may range from 10-5 to 10-2 mg/L.

2. OTHER ORGANIC CONTAMINANTS

The classes of compound discussed above, by no means, comprehensively include all types of toxic organic contaminants. There are many compounds which are known carcinogens. These are used in industrial processes and emitted in waste products. To name a few, polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAH), benzene, toluene, dichloromethane carbon tetra chloride, trichloroethane 1, 1, 1, whose presence in the aquatic environment has been recorded. The above compounds are not included in monitoring programmes, routinely. It is difficult and expensive to monitor the presence of such micro pollutants, which may occur in concentrations of a few ng/L in water. Special survey programmes may be undertaken for their monitoring around the suspect sites.

BIOLOGICAL

1. COLIFORMS BACTERIA

Microorganisms are a valuable parameter of water quality in relation to drinking water quality. Although tests are available for specific pathogenic organism, there is no way of knowing which pathogenic organism is present in a sample. Also the cost of testing for all the pathogenic organisms is prohibitive. The sanitary quality of drinking water is therefore routinely measured on the basis of the presence or absence of indicator bacteria.

Since most of the common disease, such as typhoid, cholera, dysentery, infectious hepatitis, etc., affect the gastrointestinal tract, faeces of the affected persons contain large number of the causative agents of the diseases. Non-pathogenic bacteria are also excreted in even higher numbers in faeces of all persons. Some of these bacteria have been shown to be present exclusively in faecal matter. Presence of these indicator bacteria in water therefore can be taken to indicate the certain presence of faecal matter and the possible presence of pathogenic bacteria. *Escherichia coli* and some related bacteria, together called ‘faecal coliforms’, which originate only from faeces are used as an indicator bacteria. The faecal coliforms are a part of a larger group known as ‘total coliforms’.

Other members of the total coliform group originate from soil and decaying plant matter. As a general rule the faecal coliforms are about 20% of the total coliform concentration, although a wide spread exists depending on the general sanitary conditions in the area of monitoring. In polluted waters, the die-away rate of faecal coliforms usually parallels that of most of the pathogenic organisms. However, it is possible, that some pathogens may survive for longer periods of time compared to faecal coliforms. Therefore, often the drinking water quality is judged on the basis of the presence or absence of total coliforms. This provides an additional factor of safety. The count of coliform bacteria is determined statistically on the basis of analysis of different volumes of the same sample. The result is expressed in terms of most probable number (MPN) per 100 mL. The total count of coliforms in unpolluted stretches of rivers may vary between 10 to100 MPN/100 mL. In polluted reaches the count may increase to 103 MPN/100 mL or even 106 MPN/100 mL, depending on the extent of pollution.

5. SAMPLE COLLECTION

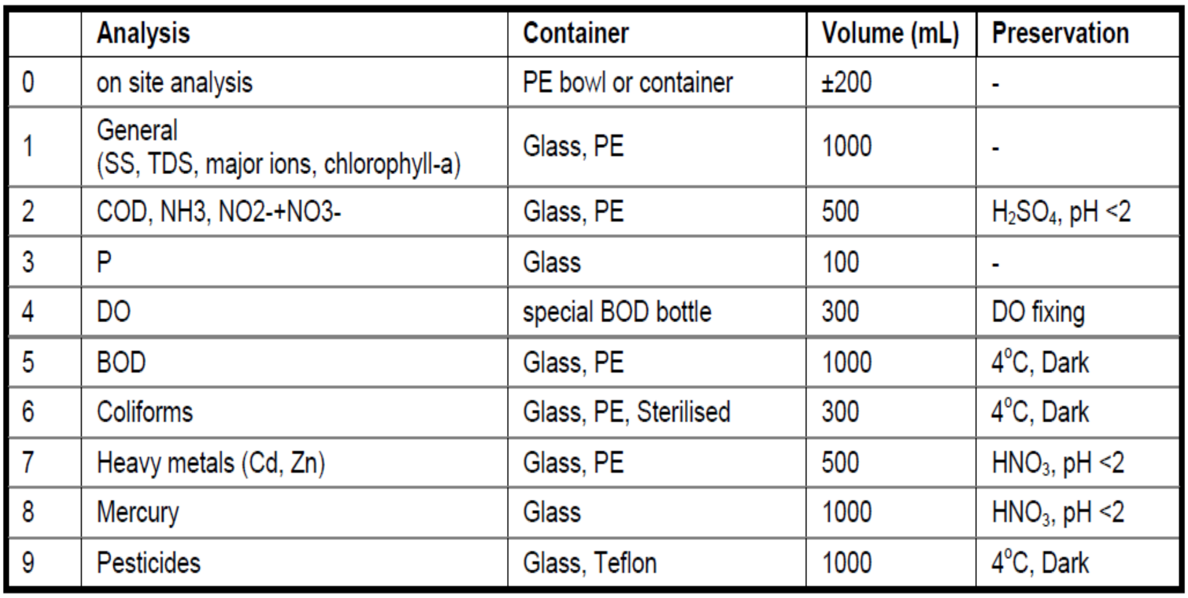
i). Sample collection for baseline and trend stations shall be collected from well mixed section of the river or main stem 30 cm below the water surface using a dissolved oxygen sampler or weighted bottle.

i). Sample for Impact stations shall be collected 30cm below the water surface from the point of interest, such as bathing ghats, downstream of point discharge, water supply intakes and other sources.

ii). The dissolved Oxygen in the sample shall be fixed immediately after collection and DO analsysis shall be done wither in the field or in laboratory.

6. SAMPLE CONTAINERS

The sample containers needed for a sampling campaign are prepared by the laboratory and given to the person collecting samples. An overview of the types of containers and preservation is given in Table.3



	Analysis	Container	Volume (mL)	Preservation
0	on site analysis	PE bowl or container	±200	-
1	General (SS, TDS, major ions, chlorophyll-a)	Glass, PE	1000	-
2	COD, NH3, NO2-+NO3-	Glass, PE	500	H_2SO_4, pH <2
3	P	Glass	100	-
4	DO	special BOD bottle	300	DO fixing
5	BOD	Glass, PE	1000	$4^{o}C$, Dark
6	Coliforms	Glass, PE, Sterilised	300	$4^{o}C$, Dark
7	Heavy metals (Cd, Zn)	Glass, PE	500	HNO_3, pH <2
8	Mercury	Glass	1000	HNO_3, pH <2
9	Pesticides	Glass, Teflon	1000	$4^{o}C$, Dark

7. Quantity of Sample to be Collected

Samples for chemical & bacteriological analysis should be collected separately as the method of sampling and preservation is completely different from each other. The interval between collection and analysis of the sample should be shortest possible.

- Quantity of sample for General Analysis: 1 or 2 litre (non-acidified).
- Quantity of sample for Bacteriological Analysis: 250 ml in sterilized bottles.
- Quantity of sample for BOD Analysis: 300 ml in glass bottles.
- Quantity of sample for Metals Analysis: 1000 ml acidified sample for metal analysis.

8. SAMPLE PRESERVATION AND TRANSPORTATION

SAMPLE PRESERVATION

As a general rule, all water quality samples should be stored at a temperature below 4^0C and in the dark as soon after sampling as possible. However, this might not be practical for a large sampling campaign. If it is not possible to keep all samples cooled and dark, then at least samples for BOD, coliforms, pesticides and other organics that are likely to volatilize MUST be kept at 4^0C, and dark. In the field, this usually means placing them in an insulated cool box together with ice or cold packs. Once in the laboratory, samples should be transferred as soon as possible to a refrigerator. Cooling serves the purpose of reducing the reaction rate of all bio-chemical reactions taking place in the sample and thus slowing down undesired changes in the quality of the sample.

When a sample is being collected for dissolved oxygen analysis by the ‘Winkler’ method, it is important that, because the dissolved oxygen concentration in the sampling bottle can change rapidly from its original value, the sample is chemically ‘fixed’. This ensures that the dissolved oxygen concentration determined is as near as possible to that which prevailed in the water body. Chemical fixing of dissolved oxygen is carried out by adding 1 ml of manganous sulphate solution, 1 ml of alkaline iodide-azide solution and 1 ml of concentrated sulphuric acid to a 300 ml water sample and mixing. The analytical determination may then be carried out up to 8 hours later with no loss of accuracy.

If samples collected for chemical oxygen demand (COD) analysis cannot be determined the same day they are collected they should be preserved below pH = 2 by addition of concentrated sulphuric acid. This procedure should also be followed for samples for ammoniacal nitrogen and total oxidised nitrogen analysis. Samples which are to be analysed for the presence of metals should be acidified to below pH = 2 with concentrated nitric acid. Such samples can then be kept up to six months before they need to be analysed. Mercury determinations should be carried out within five weeks, however.

SAMPLE TRANSPORTATION

Normally, a motor vehicle with a reasonable weight carrying capacity, such as a light van or car, should be used for water quality sampling. This is because a one (or more) day sampling campaign encompassing a number of sampling points can mean that many bottles of water are collected. This is particularly the case where a range of parameters are to be determined each of which requires a different type of sample bottle.

Transporting samples by public transport like bus or train is possible but the weight of the cool-box containing several filled sample bottles and ice will easily exceed a weight of 10 kg and may not be easy to handle.

For economic reasons and the necessity of analysing the collected samples as soon as possible (some preferably within a day) it is best to plan a sampling campaign such that it can be completed in one day. Ideally, this will entail visiting a number of sampling points in a logical order and ending the day's journey at the laboratory where the samples can be analysed or at least refrigerated until the following day. If samples cannot be analysed until the following day, such sampling campaign should not be carried out the day before a laboratory staff holiday. Initially all sample containers are sent to the laboratory that is involved in organising the monitoring campaign. If needed samples, may be forwarded from there only for advanced analyses in a higher-level laboratory.

9. Anlytical Quality Control

Analytical Quality Control The basic objective of a water analysis laboratory is to produce accurate data describing the physicalchemical characteristics of water samples under study. Quality assurance is the total programme for assuring the reliability of analytical data. Guidelines discussed in this document can all be considered as contributing to the overall programme of quality assurance. Another essential component of a quality assurance is analytical quality control which refers to the routine application of procedures for controlling the measurement process.

Internal quality control or statistical quality control is the most important component of any laboratory quality control programme. Experience indicates that 10-20% of the resources of a laboratory should be devoted to such work. Suitable approaches to internal quality control should be followed. External quality control is best applied after incorporating internal quality control practices in the laboratory and consists in the periodic analysis of reference samples. These reference samples may not be different from the control samples which the laboratory has been preparing for its own.

10. Safety measures to be followed in Laboratory

Precautions with Hazardous Chemicals:

- All containers must be clearly labeled and read before opening. If dispensing into another container, put label along with warning.
- Minimal stocks not exceeding 500 ml of corrosive or flammable solvents only may be kept in work room. Keep rest of the volume/quantity in safe place.
- Glacial acetic acid must be regarded as a flammable solvent.
- Ether and low boiling point flammable liquids must not be kept in fridge.
- Large containers of corrosive or flammable liquids should never be put on high shelves or where they can be knocked down or fall. Also, never put liquids that react violently together closely.
- Never carry bottles by neck alone. Open bottles with care.
- When diluting concentrated sulphuric acid or other strong acids, it should be added to water in heat resistant vessel. Gloves and safety glasses should be used at such times.
- Paint circles on shelves for keeping bottles in the right places.

Spillage of Hazardous Chemicals:

- If amount/volume of spillage is small, dilute with water or detergent.
- If amount is large, protective aprons, rubber gloves and boots should be worn and treatment carried out according to wall chart showing how to manage chemical spillage.
- Hydrochloric acid and sulphuric acid can be neutralized with anhydrous sodium carbonate then shovel into a plastic bucket which is subsequently diluted by water and run to waste.
- Ammonia solution, ethanol, methanol and formalin are best treated by diluting with water, collection and running to waste. Windows must be opened.
- Phenols must be diluted with at least 20 times the volume of tap water before draining.

Avoidance of Hazards of Equipment

- Only trained staff should operate the equipment.
- Operating instructions should be available for each instrument.
- Check the autoclave filled with water to correct level before loading.
- If fire breaks out, nearby electrical equipment should immediately be switched off and disconnected.
- When not in use, switch off and withdraw plug from socket.
- Avoid use of multi-adaptors. If necessary, to use they must be fitted with fuses.

Using Fire extinguishers

- Water extinguishers are suitable for fires involving ordinary combustible materials e.g. wood, paper, textile, upholstery. Never use on electrical fires or liquids that will catch fire.
- Dry powder extinguishers or sand are suitable for liquids on fire, electrical fires and burning metals.

First Aid

- First Aid Chart should be mounted on a nearby wall in the laboratory.
- First Aid box must always be equipped and should be accessible to Laboratory Staff. An emergency eye wash bottle with a bottle of sterilized water should be readily available.
- A Universal poison antidote is useful. Activated aluminum oxide or a tin of evaporated milk should be readily available. A tin opener and some waterproof dressing material should also be readily available.

Additional safety/hygiene requirements:

- Safety instructions and precautions to be followed in laboratory must be displayed inside the laboratory.
- BIS specifications (IS 10500:2012)-Drinking Water Specification, IS 3025 -Method of Sampling & Test-Physical & Chemical, IS 1622- Methods of Sampling & Microbiological examination of water) and APHA Manual should be made available in each laboratory.
- Date of preparation of reagent solutions and date of expiry for each solution prepared should be clearly mentioned on bottles wherein chemical solution is kept.
- Under no circumstances, sanctity of the laboratory should be violated. Unauthorized persons should not enter into laboratory. Eating should not be allowed in laboratory space meant for analysis.
- A clean and well-maintained toilet MUST be attached to the laboratory with hand washing facility and soap.

11. NATIONAL RIVER WATER QUALITY LABORATORY & IT'S ACTIVITIES

National River Water Quality Laboratory (NRWQL), New Delhi is the highest-level laboratory in CWC. It is a referral laboratory and besides its regular functions, it also caters to the training needs of various college students and scientific personnel working in the field of 'Water Quality Monitoring & Assessment' in India.

NRWQL provides one-stop solutions to Water Quality and offers a wide range of services – laboratory analysis to environmental management.

- The National River Water Quality Laboratory at Delhi has sophisticated equipment supported by automation.
- It has been made as the 'Referral Laboratory' to ensure uniformity in physico-chemical and biological analysis of surface waters in India.
- The laboratory has facilities and capabilities to determine water quality constituents including major and minor ions, trace elements and bacteriological parameters.
- Conduct the Training programmes and Workshops
- Preparation of the Status Reports of Indian Rivers
- Research Work on Water (Water Pollution, Fluoride and defluoridation)
- Special Study assigned by Ministry of Water Resources

National River Water Quality Laboratory is well-equipped with state-of-art equipment to identify and quantify physical, chemical and bacteriological parameters in rivers, lakes, reservoirs, wells etc.

BASIC EQUIPMENT/INSTRUMENTS

NRWQL is well furnished laboratory. The laboratory is divided into several units e.g., physical, chemical, bacteriological, preparation room, etc. (Analytical area, Balance room, Instrument room, Microbiology room, Sample room-sample receipt and sample storage, Conference room-cum-library, Staff office, Store room). The National River Water Laboratory has separated the chemical and physical analysis work from microbiological analysis. The performance and capabilities of a laboratory depend heavily upon instrumentation, equipment, staff and other facilities. National River Water Quality laboratory have the following equipment / Instruments for analysis of Physico-chemical, microbiological and metals:

Instruments:

Atomic Absorption Spectrometer (AAS) with graphite furnace & VGA

pH Meter
Turbidity meter
Dissolved Oxygen Meter
Ion Meter
Flame Photometer
Quartz Distillation Unit
Digital Burette
Microscope
Bacteriological Incubator

Electrical Conductivity Meter
Nephelometer
Colorimeter
Visible Spectrophotometer
Analytical Balance
Milipore Water Purification system
Monopan Digital Balance, Chemical
Laminar Flow
Biosafty cabinet

Equipment

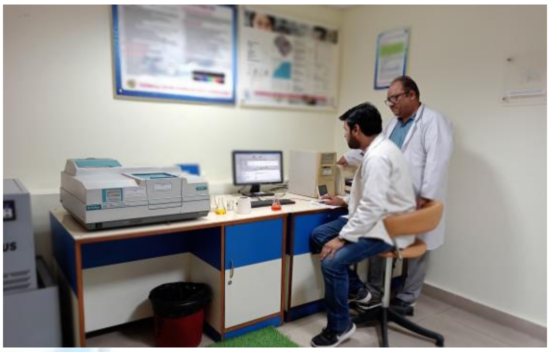
Microwave Oven
Magnetic Stirrer
Autoclave
Incubators 370C and 440C
Colony Counter
Hot Plates
Water Bath
BOD Incubator
Electronic Pipettes

Muffle Furnace
Oven
Membrane Filter Assembly
Centrifuge
Vacuum Pump
Physical Balance
Desiccators
Rotary Shaker
Bottle top Dispenser

Others

Deep Freezer
Fuel Gas cylinder
Safety Equipments
PC with printer
Ice Box

Refrigerator
Burners
UPS Generator
Air conditioner



12. CAPACITY BUILDING:

National River Water Quality Laboraotry of Central Water Commission aims to provide professional and need based training with a wide outreach in environment, water quality related topic. Hands-on training is provided in the laboratory, where participants can improve their skills in analyzing water and wastewater samples. NRWQL provides hands-on training for PG students/ research scholars of Universities. The following training programmes were organized by NRWQL during recent past:

- **Water Quality Monitoring of level –II parameters– 2007**
- **Analysis of Biological parameters (ABP-2008)**
- **Analytical Quality Control (AQC-2009)**
- **Chemical Analysis of Drinking Water (CADW-2010)**
- **Water Quality Management (WQM-2012)**
- **Water Quality Monitoring and Assessment (WQMA-2014)**
- **Water Quality Monitoring and Assessment (WQMA-2015)**
- **Water Quality Monitoring and Assessment (WQMA-2016)**
- **Two day workshop on "Trend Analysis of River Water Quality of India" 2016**
- **Analytical Quality Control (2017)**

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