

ASSESSMENT OF WATER QUALITY AND THE RELATED INSTRUMENTAL TECHNIQUES

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ABSTRACT

To assess and monitor the quality of water/water bodies, required observations range from simple colour, odour, presence of suspended matter to complicated physical analysis of spectral image for surface mapping of natural water bodies for colour and temperature and chemical analysis for natural and man-made organics, inorganics and radio nuclides. The routine instruments to meet the above requirement comprise of pH meters for acidity and alkalinity measurements, nephelometers for turbidity, conductivity meters for salt content, spectrophotometers for nutrients and major elements, atomic absorption spectrophotometers for metals including toxic ones, ion selective electrodes for oxygen and halides, gas chromatography for organic contaminants/traces, scintillation and Geiger-Mueller counters for radio nuclides measurements. Analytical methods pertaining to the water quality analysis and the instruments employed were briefed.

Water is a vital component for the existence of life on earth. It is immensely used for drinking, cooking, agriculture including aquaculture, transport and recreation. It is believed that large bodies of natural water systems such as lakes, rivers, estuaries, and coastal waters would not be affected by man. Suitability of this water, for the above mentioned purposes, depends on its nature of dissolved and particulate substances. The impact of over-exploitation of living and non-living resources coupled with various types of pollutants causes many changes and destruction in the aquatic environment and in the consequent food chain. To

safeguard human health and maintain sustainable aquatic ecosystem several countries have now decided to have national legislation for maintaining the critical levels of specific substances not only in drinking water but sewage and industrial effluents as well (Tables 1 and 2). In this paper we brief on the physico-chemical and biological parameters to assess the water quality and related instrumental techniques.

Physical Parameters

The physical parameters considered to be of significance in water quality assessment are colour, odour, conductivity (total salt content), temperature and suspended materials (APHA, 1980). Most of these parameters can be measured and monitored in large areas simultaneously by remote sensing techniques.

Colour and Odour

For drinking purpose water should be free from coloured materials and odour causing impurities. The routine method employed for the colour measurement is the visual comparison which involves the comparison of colour of the sample with a known concentration of a coloured solution by naked eye. Odour is measured as 'odour threshold' by diluting the sample with odour-free water till the individual's least perception of the odour. However, this might involve a bias in the measurement as this perception varies from person to person.

Conductivity (Total salt content)

Natural waters contain some amounts of dissolved substances that are essential for the biota. If the total quantity of these is increased the

resultant higher concentration of minerals might affect the physiology of the biota. The total content of inorganic substances in water can be measured by argentimetric titration or by conductivity technique. In the argentimetric technique, which is widely used, the water sample is titrated against a standard solution of silver nitrate which gives the total halides present in the sample. This quantity, known as chlorinity, could be converted to the total dissolved solids or salinity (Grasshoff, 1976). In the conductimetric technique the conductivity of the sample due to the current carried by dissolved cations and anions is measured and compared with a standard solution of known conductivity. For the measurement of the conductivity a conductivity cell and Wheatstone bridge are used. The highly sensitive conductivity meters such as AUTOSAL salinometer, manufactured by Guildline Instruments, are exclusively used for estuarine and marine environmental studies (Anonymous, 1984). The current signal sensed is proportional to the conductivity of the sample in which the sensing head is immersed. In AUTOSAL only 50 ml sample is sufficient to measure to an accuracy of 1 ppm.

Temperature

Heat is discharged into the water bodies at the vicinity of nuclear power plants, ocean thermal energy plants, industrial cooling operations, etc. Thermal pollution has both a positive and negative impact on the ecology of the aquatic biota. A sudden shut down of the above operations causes a serious damage to the ecosystem. At the source region of thermal effluents temperature is monitored with thermometers whereas, in the sink region of water body, bucket type thermometers, portable CTD profilers

and Expendable Bathy Thermographs (XBT) are advantageous since the temperature gradient is wide spread in the surface as well as with depth. Bucket thermometer is an ordinary thermometer placed in a hollow thermally insulated cylinder which is completely sealed at one end to retain some water at the sensitive portion of the thermometer in order to measure the temperature. XBT consists of an expendable probe in which is embedded a thermistor which senses the temperature when launched into sea water at the discharge point. The changes in the thermistor's resistance is proportional to the temperature variations and is converted to equivalent voltage and recorded on a strip chart recorder of deck unit (Anonymous, 1990) as a temperature-depth profile. Thermo-Salinographs are used from ships for continuous monitoring for both temperature and salinity of sea surface waters. Surface sea water is pumped and air-bubble freed in a special chamber and then the electrical conductivity (and hence salinity) and temperature are accurately recorded on a strip-chart recorder as a function of time.

Suspended material

The suspended solids in unpolluted waters comprise of mineral and organic materials of different sizes. To this the industrial effluents add hydrophilic and hydrophobic colloidal particulates. The amount of suspended solids can be quantified by conventional filtration/gravitational settlement and nephelometric methods. The impact of suspended particles on light transmission in water bodies is assessed with irradiameter.

In the conventional filtration method the water sample is filtered through a filter paper of specified porosity under vacuum. The turbidimetric technique involves the measurement of amount of light absorbed whereas the nephelometric technique involves the measurement of scattered light. The amounts of light absorbed and scattered, respectively, will be proportional to the amount of particles.

Irradiameter senses and measures the light filtered (of a specified bandwidth) through its teflon sphere or hemisphere. By making measurements of light intensity at different depths and that of ambient at surface of a water body the attenuated light/attenuation coefficient can be measured (Anonymous, 1977).

Physical parameters' assessment by Remote sensing techniques

In passive remote sensing infrared or microwave radiations emanating from sea surface are received by sensors on board satellites. Whereas in active remote sensing technique microwave pulses (radar) of typical wave length are transmitted from aircrafts or satellites. The reflected signals will be sensed by high resolution sensors. The CZCS sensors are used in mapping of the sea surface colour (due to luxuriant growth of phytoplankton out of nutrient pollution and also due to natural productivity). AVHRR, MSS and SAR sensors are used in detection and mapping of oil slick movement and tracing of thermal plumes by mapping of sea surface temperature. Analysis of images provide information on the above surface phenomena of water bodies (Barrett and Curtis, 1982).

Chemical Parameters

In the measurement of chemical substances in natural waters proper sampling procedure should be adopted followed by analysis of the sample by suitable means.

Sampling

The precautions in the collection of water samples are to be strictly observed; lest the sample may be contaminated or substances may be lost from the sample. Samples should be collected in precleaned glass or plastic bottles. For trace metals teflon bottles are preferred. For dissolved oxygen, samples are collected in air tight BOD bottles. Water samples are collected from different depths in large water bodies such as lakes and the marine

environment. In such cases Nansen, Niskin, Gofflow and Vandorn bottles of various capacities are fixed to the hydrographic wire driven by winches in open condition and deployed to the predetermined depths. By means of messenger operation sample bottles are closed at specified depth (Sverdrup et al, 1942).

Analysis

Proper analytical technique and instrument are to be employed to get meaningful results as most of the dissolved substances in natural waters are present at trace concentrations. In case the samples are not analyzed immediately, they are to be stored at very low temperatures or by adding a suitable preservative. Some of the important parameters to be studied for monitoring water quality are pH, Oxygen, Biochemical Oxygen Demand (BOD), Chemical Oxygen Demand (COD), nutrients (nitrite, nitrate, ammonia, phosphate and silicates), sulphide, cyanide, fluoride, chloride, residual chlorine, hardness of water, metal ions, organics such as petroleum hydrocarbons, oils and grease, phenolic compounds and pesticides, and radioactive substances. The analytical methodology for these parameters and the related instrumental techniques were dealt in detail elsewhere (APHA, 1980; Ewing, 1960; Grasshoff, 1976; Rump and Krist, 1988 and Vogel 1978).

pH

pH is defined as the negative logarithm of hydrogen-ion activity which is considered to be a master variable in natural water systems. The pH is measured by using indicator electrode and a reference electrode. The indicator electrode consists of a bulb filled with reference hydrochloric acid of 0.1 N in contact with the silver-silver chloride electrode. The potential generated due to the difference in the hydrogen activity between the test solution and the reference solution in the bulb will be measured by a potentiometer. This instrument has to be calibrated through the use of appropriate buffer solutions prior to the

sample measurement.

Oxygen, Biochemical Oxygen Demand and Chemical Oxygen Demand

The water in aquatic bodies on land and surface sea water is continuously in exchange with atmosphere. If the water quality deteriorates the oxygen content would be decreased because of after-effects of eutrophication and large amounts of organic wastes. BOD is a measure of the amount of oxygen required by the micro-organisms to stabilize the organic material. COD is defined as that oxygen needed to oxidize the total organic material present by a strong oxidant such as permanganate. Both BOD and COD are indicators of extent of organic pollution.

Oxygen can be measured through Winkler's titration and also a selective electrode. In Winkler's titration the oxygen in the sample is fixed through precipitation of Mn(IV)-oxyhydroxide in alkaline iodide solution and later dissolved in acid to liberate iodine. The liberated iodine is titrated against thiosulphate using starch as indicator. Equivalents of thiosulphate used is proportional to the oxygen present.

In the ion-selective electrode technique the oxygen is sensed by an electrode consisting of polyethylene or teflon membranes with specificity of permeability to oxygen only. The oxygen diffused through the membrane generates electric current and so the current generated will be proportional to the oxygen content in the sample.

The BOD and COD are measured as differences in oxygen content at the time of collection and after a stipulated period of incubation, usually five days.

Nutrients

Nutrients, mostly nitrates, ammonia and phosphates, are widely used in industry and agriculture. These nutrients (including silicates) occur in dissolved and particulate forms in natural waters. The amounts of nutrients in dissolved forms can be

found more precisely by colorimetric or spectrophotometric techniques. In this technique a nutrient (nitrite) is allowed to form a coloured compound (an azo dye in this case) the colour of which will be proportional to the nutrient present in the sample. The intensity of colour is proportional to the amount of light absorbed at a wavelength specific to the compound and free from interferences from other dissolved ions/compounds in solution. The spectrophotometer consists of a light source, usually of tungsten and deuterium lamps for the visible and ultra-violet ranges of the spectrum, respectively. A prism or grating is used to split the incident light into monochromatic light beams of different wavelengths. The monochromatic light that passes through the coloured sample solution reaches a detector which is normally a photocell or photomultiplier, which senses and multiplies the signal that is transmitted to display unit. Colorimeters contain filter in place of prism or grating and hence are less precise in yielding specific wavelengths. For instance, good spectrophotometers give a wavelength resolution less than 1 nm whereas a good colorimeter could give the same within 20-30 nm. Modern instruments have facilities with double beam arrangement to eliminate the background noise in the colour measurement of the sample.

The nitrate is first reduced to nitrite and the analysis performed for the latter. Phosphate is found through the formation of phosphomolybdenum blue, ammonia as indophenol blue and silicate as silicomolybdenum blue. Thus analyzed nutrients without any sample treatment yield only the reactive ions present. Some of these nutrients are also present in organic forms and these can be made reactive only by the digestion of the sample with strong oxidizing agents such as hydrogen peroxide with UV radiation, perchloric acid and/or persulphate.

Sulphide

Sulphide is present in natural waters only in anoxic or suboxic conditions

formed largely due to decomposition of organic matter when sulphate acts as a source of oxygen. Sulphide is highly toxic for biota. Qualitative test for the presence of sulphides in water treatment is done by lead acetate test involving exposure of hydrogen sulphide vapors to the lead acetate paper which turns black, due to the formation of lead sulphide. The quantitative measurement of sulphide by spectrophotometric determination involves formation of methylene blue complex when the sulphide containing sample is treated with dimethyl-P-phenylenediamine in the presence of ferric chloride.

Cyanides

Cyanides are highly toxic to aquatic fauna. Most of the metal cyanides are sparingly soluble and HCN (hydrogen cyanide) forms from their hydrolysis. The analytical methodology of cyanides involves the conversion of cyanides into HCN by acidification and distilled HCN is estimated either by argentimetric titration using P-dimethylaminbenzylrhodamine indicator or spectrophotometrically in which it reacts with chloramine-T and pyridine-barbituric acid reagent forming a red blue dye.

Chloride

Chloride is the major anion in natural waters. Salty taste of the potable water is due to the high content of chlorides. The estimation of chloride is done argentimetrically as is discussed in total solids section.

Residual chlorine

Chlorine in the form of elemental chlorine or hypochlorite is added to the water as disinfective agent. Most part of it is present as free available chlorine. If the treatment is excessive it produces adverse effects. The available free chlorine is known as residual chlorine and is estimated by iodometric titration when the sample is devoid of oxidizing and reducing agents. Chlorine in the sample solution liberates iodine stoichiometrically from potassium

iodide. The liberated iodine is titrated with standard sodium thiosulphate solution. When the sample is turbid and impurities are present amperometric titration is advantageous for residual chlorine estimation.

In amperometric measurements the current produced due to difference in potentials between a reference and working electrodes will be measured. This measured current will be proportional to the residual chlorine present in the sample. The residual chlorine is titrated against phenylarsine and the amperometric cell consists of a nonpolarizable reference electrode and a readily polarizable noble-metal working electrode. The reference electrode will be in contact with salt solution while the working electrode will be in contact both with the reference salt solution and the sample solution. This titration has to be carried out between pH values 6.5 and 7.5.

Fluoride

Insufficient or over consumption of fluoride by humans leads to health hazards. The fluoride in water can be estimated through spectrophotometric and ion selective electrode techniques. The spectrophotometric technique consists of the colour development by fluoride reaction with lanthanum-alizarin complex-one and subsequent measurement of the absorbance.

Similar to the measurement of pH, fluoride also can be measured by use of specific ion-electrodes. The fluoride ion-selective electrode is generally made of solid state membrane containing lanthanum fluoride crystals. The potential developed because of the difference in fluoride concentration between the test solution and the reference solution in the selective electrode is a measure of the fluoride content in the test solution. The potential has to be measured against an external reference electrode such as calomel electrode.

Hardness of water

Hardness of water is due to the presence of excess carbonates and

sulphates of calcium and magnesium and is undesirable for boilers as these form scales. The extent of hardness can be found from estimating the calcium and magnesium ions. These ions can be found either by complexometric analysis or spectroscopy. In complexometry, these ions are titrated with a complexing agent such as ethylenediamine tetra-acetic acid (EDTA) by using suitable indicators for finding the end point. The amount of EDTA consumed during the titration would be proportional to the concentration of these ions. In the atomic spectroscopy for these ions, two types of techniques could be used. One is flame photometry and the other atomic absorption. A flame photometer consists of a burner/sample chamber, a filter to allow the monochromatic light to pass and a detector unit. The sample solution is sprayed into air-acetylene flame in the burner chamber where some of the calcium and magnesium ions get excited to higher orbital levels. When the excited ions come back to the ground state, energy is released in the form of light whose wavelength will be specific to the element in question. The use of filter before the photocell detector unit is to allow only the emitted monochromatic light for the detection. This sensed signal will be passed to the display unit. The intensity of the light emitted will be proportional to the concentration of the element in solution.

The atomic absorption spectrophotometer is similar to a spectrophotometer described in the section on nutrients and comprises of a source light, a sample compartment (here consists of burner/atomizer) and a detection unit. The source light here is that emitted from a hollow cathode lamp which consists of a metal of an analyte element. This hollow cathode lamp will be filled with an inert gas which gets charged and facilitates the emission of a particular resonance line. When the sample is sprayed into the air-acetylene flame in the burner, atomization of the ions takes place. These atoms present in the flame absorb the incident monochromatic

radiation from the hollow cathode lamp. The remaining incident light reaches the detector. The absorbed amount of the radiation will be proportional to the concentration of element in the sample solution.

Metal ions

Although some of the metal ions are essential for biochemical reactions the presence of high concentrations of these will adversely affect the physiology of the organisms. Some of the toxic metals are mercury, lead, zinc, arsenic, selenium, chromium, copper, nickel and cadmium. The common analytical techniques for detecting the metals are spectroscopy and polarography. In the analysis of metals in natural waters a preconcentration step is necessary since these are present in trace amounts. The preconcentration step normally involves co-precipitation, solvent extraction and/or ion exchange. These techniques will be decided based in the level and nature of the dissolved metal. After preconcentration the sample can be analyzed by atomic absorption spectroscopy.

In polarography technique, a mercury pool in contact with the sample solution is used as the anode and a hanging mercury drop is the cathode. When external voltage is applied the metal ions in solution diffuse towards the cathode, at a specific potential which is characteristic of the metal, and this diffusion current is proportional to the concentration of the metal ion. The advantage of this technique is that the sample does not require any preconcentration, particularly in regard to Anodic Stripping Voltammetry (an offshoot of Polarography).

Organic compounds

In natural waters presence of dissolved organic substances is common but the increased use of natural and synthetic organics for human needs results in the introduction of petroleum hydrocarbons, oils and grease, phenolic compounds and pesticides into the adjacent aquatic bodies.

a) *Petroleum hydrocarbons*:- The presence of petroleum hydrocarbons can be estimated by fluorescence spectroscopy. In this technique the substances present are activated by supplying energy through a higher wavelength radiation which is called as excitation. The substance is excited to higher wavelength radiation which is called as excitation. The substance is excited to higher states on absorption but comes down to ground state while emitting radiant energy at a relatively lower wavelength to that of excited wavelength. As this involves the measurement of emitted radiation or fluorescence the detector would be placed at right angles to that of the incident radiation. The emitted radiation would be proportional to the concentration of petroleum hydrocarbons in the sample.

b) *Oils and grease*: Oils and grease give undesirable odour to the potable water. In natural water bodies these interfere with energy and mass transfer of gases across the surface. Oils and grease consist of a wide range of compounds such as mineral hydrocarbons, fatty acids of plant and animal sources, chlorophylls etc which dissolve in trichlorofluoromethane (APHA, 1980). Oils can be estimated by weighing the dried residue after extracting the sample with the above solvent. Grease is estimated by treating the sample with acid followed by filtration, after extraction with trichlorofluoromethane residue gives the grease content of the sample.

c) *Phenolic compounds*:- Phenols are hydroxy derivatives of benzene and its condensed nuclei. Their distribution is widespread in natural waters. In coastal waters and estuaries, condensed phenolic substances along with other dissolved organic matter forms gelbestoff which interferes with light attenuation and also deterrent to certain biota. During chlorination process phenols form toxic substances in drinking water. The analytical methodology of phenolic compounds involves the separation of these compounds by distillation followed by reaction with 4 - aminoantipyrine in the presence of potassium ferricyanide

to form a coloured antipyrine dye. The intensity of this dye is measured spectrophotometrically.

d) *Pesticides*:- The pesticides in water are to be preconcentrated because of their low concentrations. The analysis of pesticides is done by Gas Chromatography. In this technique pesticides are first partitioned between the stationary phase (usually a liquid) and the carrier gas in a column which will be later eluted by the inert carrier gas. The retention time of a specific compound will depend on the partition characteristics of the compound between the stationary phase in the column and mobile gas phase. The eluant will be subjected to measurement in an electron capture detector (ECD). The peak areas will be proportional to the concentration of pesticides in water.

Radionuclides

Natural waters contain some amount of radioactivity associated with the source of those waters and the terrain they originate from. This activity could be seen in the form of alpha, beta and gamma radiations. To this natural radioactivity, man induced nuclides contribute significantly thus warranting the regular monitoring of these bodies. Some of the harmful radionuclides include ^3H , ^{90}Sr , ^{131}I , ^{137}Cs and ^{226}Ra , whose maximum permissible levels in drinking water as per EPA regulations are 2,00,000, 8,3,200 and $^3\text{pCu}/1$ respectively. The radioactivity can be measured by use of different counters. Among these the scintillation counters are simple since they depend on the photomultiplier measurement of light emitted when the radioactive particle hits the surface of a solid (like anthracene or sodium iodide) or a liquid (such as 1,4-bis-2-(5-phenyl-oxazolyl) benzene (POPOP)). Isotopes such as ^{14}C and ^3H are commonly measured with this technique. The ionization counters or the Geiger-Mueller counters are used to measure the beta and gamma radiations since the air gap and mica sheets used between the sample and the detector

cut off the alpha and feeble beta radiations.

Biological Parameters

The most important biological parameter to be checked for stringent quality control of drinking water is *Coliform* (bacterial and pathogenic organisms) count responsible for water-borne diseases. This aspect is also essential for sewage disposal water quality. Bioassay or toxicity test for organisms is one of the basic techniques for controlling the quality of industrial effluents for disposal.

Coliform count

The popular methodology for counting the *Coliforms* are multiple tube fermentation technique and membrane filter technique. The former technique involves the counting of coliforms under microscope after incubation of the sample with a culture medium. The results are reported as most probable numbers (MPN). The later technique comprises of the filtration of sample through 0.45 μm membrane filter, incubation with culture medium followed by counting with a microscope.

Bioassay test

In this test a target organism is exposed to the polluted medium for a particular time to assess the pollutant effect on the organism. The results are expressed as LC 50 referring to the mortality of 50% of the target organisms within specified time.

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References

APHA, 1984. Standard Methods for the Examination of Water and Waste Water. American Public Health Association, Washington, DC.

Anonymous. 1974 a. Indian standard. Tolerance limits for Inland Waters Subject to Pollution. IS: 2296. ISI. New Delhi.

Anonymous. 1974 b. Indian Standard. Tolerance Limits for Industrial Effluents Discharge into Inland Surface Waters. IS:2490 (Part I). ISI. New Delhi.

Anonymous. 1977. Manual for Radiometric Underwater Irradiometers. Khal Scientific Instrument Corporation. California, USA. 1977.

Anonymous. 1984. Manual on AUTOSAL Laboratory Salinometer. M/S. Guidline Instruments Corporation. Ontario, Canada.

Anonymous. 1990. XBT manual. Plessey-Sippican Corporation. Marion, MA. USA.

Barrett, E.C. & L.F. Curtis. 1982. Introduction to Environmental Remote Sensing. Chapman and Hall, London.

Ewing, G.W. 1960. Instrumental Methods of Chemical Analysis. McGraw-Hill Book Company, New York.

Grasshoff, K. 1976. Methods of Seawater Analysis. Verlag Chemie. Weinheim.

Hunt, D.T.E. & A.L. Wilson. 1986. The Chemical Analysis of Water. General Principles and Techniques. The Royal Society of Chemistry. London.

Krishnama Charyulu, R.J. & L.V.G. Rao. 1985. Temperature Measurements in the Sea. Research and Industry. 30:429.

Rump, H.H. & H. Krist. 1988. Laboratory Manual for the Examination of Water, Waste Water and Soil. Longman Inc., New York.

Sverdrup, H.U., M.W. Johnson & R.H. Fleming. 1942. The Oceans: their Physics, Chemistry and General Biology. Prentice Hall Inc., Englewood

Vogel, A.I. 1978. A Text Book of Quantitative Inorganic Analysis including Elementary Instrumental Analysis. Longman Inc., New York. Cliffs.

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Ten of the tallest dams in India

No	Name of the Dam	Ht (in m)	Length (in m)	Volume Content (10^3 m^3)	Gross Storage Capacity (10^3 m^3)	Year of Commencement	Year of Completion	River	State	Purpose
1.	Bhakra	226	518	4130	9,621,000	1948	1963	Sutlej	Himachal Pradesh	Irrigation & Hydro Power
2.	Idukki	169	366	460	1,996,000	1966	1974	Periyar	Kerala	Hydro Power & Flood Control
3.	Srisailem	143	512	1953	8,722,000	1965	1984	Krishna	Andhra Pradesh	Hydro Power
4.	Bens	133	1950	35,500	8,570,000	1963	1974	Beas	Himachal Pradesh	Irrigation & Hydro Power
5.	Ramganga	128	743	11,013	2,442,600	1964	1978	Ramganga	Uttar Pradesh	Irrigation & Hydro Power
6.	Nagarjuna Sagar	125	4865	7960	11,550,000	1957	1974	Krishna	Andhra Pradesh	Irrigation & Hydro Power
7.	Sholayar	105	1282	2496	160,660	1961	1971	Sholayar	Tamil Nadu	Irrigation & Hydro Power
8.	Koyna	103	808	1555	2,796,500	1956	1961	Koyna	Maharashtra	Hydro Power
9.	Rihand	93	934	1680	10,600,000	1952	1962	Rihand	Uttar Pradesh	Hydro Power
10	Kodayar	88	166	163	98,680	1963	1972	Kodayar	Tamil Nadu	Hydro Power

Table I - Tolerance limit for inland surface waters for use as raw water for public water supply as per Indian standard Anonymous, 1974 a)

Characteristic parameter	maximum (* - minimum) tolerance limit
1. Coliform organisms (monthly average MPN per 100 ml)	Not more than 5000, with less than 5% of the samples with value > 20,000, and less than 20% of the samples value > 5000
2. pH value	6.0 to 9.0
3. Fluoride (as F), mg/l	1.5
4. Chlorides (as Cl), mg/l	600
5. Cyanides (as CN ⁰), mg/l	0.0
6. Selenium (as Se), mg/l	0.05
7. Lead (as Pb), mg/l	0.1
8. Total Chromium (as Cr), mg/l	0.5
9. Arsenic (as As), mg/l	0.2
10. Dissolved oxygen	* 40% saturation value or 3mg/l whichever is higher
11. Biochemical oxygen demand (5 days at 20 °C), mg/l	3
12. Phenolic compounds (as C ₆ H ₅ OH), mg/l	0.005
13. Alpha emitters, uc/ml	10-8
14. Beta emitters, uc/ml	10-8
15. Nitrates (as NO ₃), mg/l	50
16. Oils and grease, mg/l	0.1
17. Insecticides	* absent

Table II - Tolerance limits for industrial effluents discharged into inland surface water as per Indian standard (source Anonymous 1974 b)

Characteristic parameter	Max. tolerance limit
1. Total suspended solids, mg/l	100
2. Particle size of total suspended solids	shall pass 850 μ sieve
3. pH	5.5 to 9.0
4. Temperature	shall not exceed 40 C in any section of the stream within 15 metres downstream of the effluent outlet
5. Biochemical oxygen demand for 5 days at 20 °C, mg/l	30
6. Oils and grease, mg/l	10
7. Phenolic compounds, mg/l	1.0
8. Cyanides (as CN), mg/l	0.2
9. Sulphides (as S), mg/l	2.0
10. Radioactive materials:	
a) Alpha emitters, uc/ml	10 ⁻⁷
b) Beta emitters, uc/ml	10 ⁻⁶
11. Insecticides	absent
12. Total residual Chlorine, mg/ml	1
13. Fluorides (as F), mg/l	2.0
14. Arsenic (as AS), mg/l	0.2
15. Cadmium (as Cd), mg/l	2.0
16. Hexavalent chromium (as Cr), mg/l	0.1
17. Copper (as Cu), mg/l	3.0
18. Lead (as Pb), mg/l	0.1
19. Mercury (as Hg), mg/l	0.01
20. Nickel (Ni), mg/l	3.0
21. Selenium (as Se), mg/l	0.05
22. Zinc (as Zn), mg/l	5
23. Ammonical nitrogen, mg/l	50
24. Chemical Oxygen Demand, mg/l	250