



ANALYSIS OF WATER QUALITY

¹K.Sreelatha, ²A.Nirmala Jyothsna, ³M.Saraswathi, ⁴P.Anusha, ⁵A. Anantha Lakshmi

^{1,2,3,4,5} Lecturer

¹Department of Physics,

¹Ch.S.D.St. Theresa's College, Eluru, Andhra Pradesh, India

Abstract: Water is perhaps the most precious natural resource after air. Though the surface of the earth is mostly consists of water, only a small part of it is usable, which makes this resource very limited. This precious and limited resource, therefore, must be used with prudence. As water is required for different purposes, the suitability of it must be checked before use. Nowadays fresh water cannot be used directly for drinking purposes due to contamination and pollution. So treatment is used before it is used for drinking or for industrial processes. Also, sources of water must be monitored regularly to determine whether they are in sound health or not. Poor condition of water bodies are not only the indicator of environmental degradation, it is also a threat to the ecosystem. In industries, improper quality of water may cause hazards and severe economic loss. Thus, the quality of water is very important in both environmental and economic aspects. Thus, water quality analysis is essential for using it in any purpose. The quality of water depends upon its source of history. The history of water signifies the terrain through which water is flowing, its origin and most important the extent to which it is contaminated on its way by impurities, sediments and industrial waste. The solubilisation and fragmentation of the terrain through which it flows determines its quality. The extent of dissolved solid materials present in water decides its quality. Such quality is also decided by the solubility of the geological deposits, contact of water with sediments, time of interaction and special factors related to environment. To ascertain suitability of water for consumption, it is necessary to undertake examination of quality of water. Major information on the quality of water is obtained by physical examination. Such examination includes the study of colour, conductivity, odour, turbidity and hardness.

Index Terms -Water quality- monitoring, assessment, analysis and Physical examination - Colour, Conductivity, Odour, Turbidity and Hardness.

I. INTRODUCTION

The total amount of water on surface of earth is 3.5×10^{20} gallons of which 97% is found in sea while fresh water is only 37 million km^3 . Of this 0.8% occurs in polar ice water which percolates in ground is called 'ground water' and it emerges on surface of earth as river or lake water. Due to hydrological cycle on water, earth is in constant circulation by evaporation, precipitation, percolation and run off. There is natural balance between evaporation and precipitation. The ground water i.e., aquifers is mainly used for drinking. Limnology is the study of fresh water. The knowledge on chemistry of natural water has developed enormously with development of chemical sciences. In ancient times whole civilization had disappeared due to water scarcity by climatic variations. In olden days the water-born diseases like cholera and typhoid killed several people. The increase in population has resulted in large amount of the consumption of water. The microorganisms are indicators of the quality of water. The study of water is called 'hydrology'. The main supply of water from earth is called 'hydrological cycle'. Hydrosphere and lithosphere (earth) interaction is of great significance. The human consumption relates to fresh water and ground water. There is however nonuniform distribution of water. Water has excellent characteristics such as good solvent properties, high dielectric constant and surface tension; transparent appearance, maximum density at 4°C , high heat of evaporation with higher heat of fusion of ice and higher heat capacity. In such water the marine organisms thrive very well. Unfortunately this fresh water does not remain pure but gets polluted by several agencies. Sewage and oxygen demanding waste is main culprit. In addition infections agents, plant nutrients, exotic organic chemicals, inorganic materials and compounds sediments and heat totally spoil the quality of water. The important sources of water pollution are domestic waste, industrial waste, agricultural and shipping waste. To ascertain suitability of water for consumption, it is necessary to undertake examination of quality of water. Such quality is ascertained by examination including i) Physical examination of water, ii) Chemical characterisation of water and iii) Biological investigation of water.

What is Water Quality?

Water Quality can be defined as the chemical, physical and biological characteristics of water, usually in respect to its suitability for a designated use. Water can be used for recreation, drinking, fisheries, agriculture or industry. Each of these designated uses has different defined chemical, physical and biological standards necessary to fulfil the respective purpose. For example, there are stringent standards for water to be used for drinking or swimming compared to that used in agriculture or industry.

What is Water Quality Analysis?

After many years of research, water quality standards are put in place to ensure the suitability of efficient use of water for a designated purpose. Water quality analysis is to measure the required parameters of water, following standard methods, to check whether they are in accordance with the standard.

Why Water Quality Analysis is required?

Water quality analysis is required mainly for monitoring purpose. Some importance of such assessment includes: (i) To check whether the water quality is in compliance with the standards, and hence, suitable or not for the designated use.

(ii) To monitor the efficiency of a system, working for water quality maintenance

(iii) To check whether upgradation / change of an existing system is required and to decide what changes should take place

(iv) To monitor whether water quality is in compliance with rules and regulations.

Water quality analysis is of extremely necessary in the sectors of:

- Public Health (especially for drinking water)
- Industrial Use

PROCEDURES OF WATER QUALITY ANALYSIS

The steps for water quality analysis in general is mentioned in Figure-1.

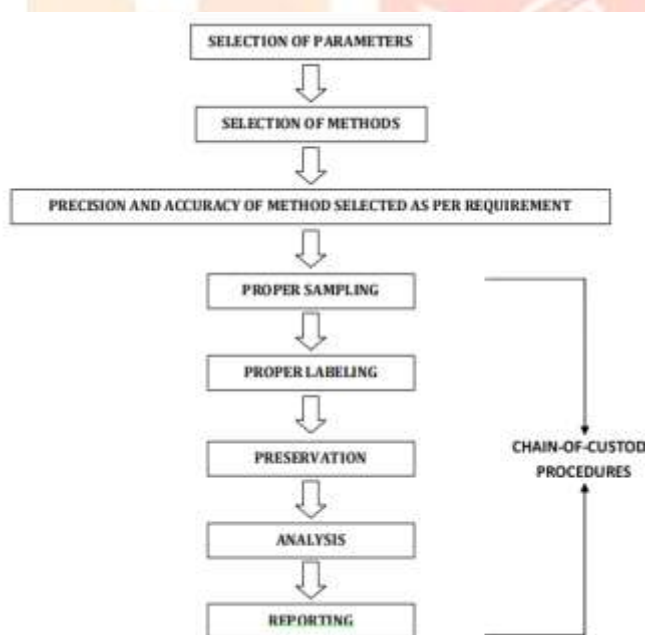


Figure -1: Steps for Water Quality Analysis

Chemical Characteristics		Physical properties	Biological Investigations
Major: Ca^{2+}	Minor: Al	Colour	Total coliforma
Mg^{2+}	Ba	Conductivity	Faecal coliforma
Na^+	B	Temperature	Faecal streptococci
K^+	F	Odour	Crenothrix
Cl^-	NO_3	Turbidity	Plankton, Diatmalgae
SO_4^{2-}	NO_2	Hardness	Algae, Protozoa
CO_3^{2-}	PO_4		Nitrosomonas; E coli
HCO_3^{2-}	Fe		
	Mn		

Table :1 Physical, Chemical and Biological examination of water:

Selection of Parameters

The parameters of water quality are selected entirely according to the need for a specific use of that water. Some examples are: (1)**Drinking:** As per WHO/CPCB Standards (2)**Irrigation** (3)pH (4)Conductivity (5)Sodium & Potassium (6)Nutrients (7)Specific compounds

Industries: As per specific requirement

Domestic Consumption: As per BIS Standards

Water Bodies: As per CPCB guidelines

However, some of the most common parameters assessed for checking potability and industrial use in India are in Figure-2.

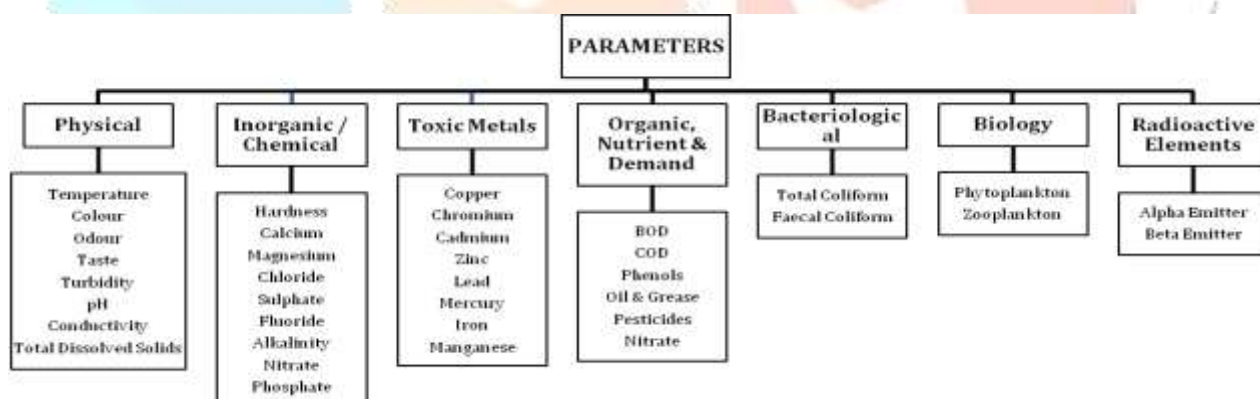


Figure -2: Parameters for Water Quality Analysis

Colour: The colour of the water is due to presence of metallic ions, peat and humus materials from decaying vegetable matter. Industrial waste also contributes to colour of water. This colour is classified into two categories, viz., true colour and apparent colour. True colour is the real colour of water. Such colour does not depend upon background when viewed. While apparent colour is colour due to reflection of sky, e.g., blue colour of sea or reflection of trees as green colour of well water. The classical method of measurement of colour consisted of the comparison of colour with one prepared by dissolving known weight of dipotassium hexachloroplatinate or cobalt chloride. This is called as the platinum-cobalt method of comparison. The unit of colour is one produced by 1 mg platinum/litre in the form of chloroplatinate ion. Thus, 1.25gm of K_2PtCl_6 and 1 gm of $\text{CoCl}_2 \cdot 6\text{H}_2\text{O}$ are dissolved in 100 ml of water and concentrated hydrochloric acid and made upto one litre with distilled water. The resulting stock solution has colour of 500 units. This method of analysis involves personal error. The spectrophotometric method is the most reliable method, wherein the absorbance of water is measured between 400 and 700 nm.

The colour may be due to metallic ions also. It is sometimes necessary to remove turbidity before colour measurement, but is not always advisable as many a times filtration remove colour hence centrifugation is considered to be best method for removal of turbidity. Cobalt-platinum method is valid only for potable water and not for industrial waste water. It is always necessary to specify pH when colour is measured. The colour is identified in terms of (e.g., red/green/yellow) in terms of the dominant wavelength and degree of

brightness by luminance. Tristimulus calorimeter with three filters is also used to measure the transmittance of sample of water.

Conductivity: The equivalent conductance of various ions is listed. The conductance is the measure of concentration of mineral constituents present in water. It gives a rapid method to get an idea about dissolved solids in water. The conductance is reciprocal of resistance, which is measure usually between two electrodes kept one cm apart, with area of cross-section as one cm². The value depends upon presence of total concentration of ions. It also checks quality of distilled water. The average value should be less than 2 μ ohms. The self-contained conductivity instruments are available for such measurements. In conductivity cell, first it is necessary to evaluate cell constant. Usually, conductivity is measured at a fixed temperature.

The conductivity is numerical index of ability of an aqueous solution to carry an electric current. This ability depends upon the presence of ions in the sample of water as well as on their total concentration, mobility, valance and temperature. The values used to assess degree of mineralization, variation in dissolved mineral levels, or estimate total dissolved solids. Since conductivity depends upon temperature latter must be kept fixed. KCl is used as the standard during such measurements.

S.No	Parameters
1	Acidity – no definite data
2	Alkalinity – 10-500 mg/litre as CaCO ₃
3	Colour – 50 platinate units
4	Hardness – 5-1000 mg/litre CaCO ₃
5	pH 6.0-9.0
6	Specific conductance 30–1000 microohms or sieman
7	Temperature 0-30°C
8	Turbidity 0-1000 JU
9	Odour – 3 TON

Table : 2 Physcial characteristics of typical sample of water

S. No	HardnessCaCO ₃ mg/litre	Remarks
1	0-40	Soft
2	40-100	Moderately hard
3	100-300	Hard
4	300-500	Very hard
5	500-1000	Extremely hard

Table : 3 Classification of Turbidity

Range	Value, NTO	Range	Value, NTO
0-10	0.05	100-400	10
10-40	1.0	400-1000	50
40-100	5.0	1000 above	100

Table : 4 Classification of Hardness

Temperature:

It is measured immediately after collecting the water sample preferably on the site itself. This parameter is useful for calculating various factors such as alkalinity or acidity of water. The elevated temperature has adverse ecological consequences on water. All thermometers must be calibrated before measurement. The depth temperature is required for limnological studies, which may be measured with a reversing thermometer or thermophone or thermistor. The last devise, viz., thermistor is the most reliable amongst measuring instruments.

Odour and Taste: The volatile compounds produce odour. The dilution of sample at which odour is just perceptible is a measure of its intensity. The odour is qualitatively described as medical (phenolic) and fishy (due to algae), earthy (decaying matter) or chemical (chlorine). Odour is quality factor influencing acceptability of potable water.

In spite of advancement of science and technology no instrument has so far been developed for the measurement of odour. Such measurement largely depends upon contact of a stimulating substance with appropriate human receptor cell. Such stimuli are chemical in nature and hence termed as chemical sense. The details of odour, its sampling measurement and control is very well described elsewhere in this book. The odour of water is measured in terms of TON i.e., threshold odour number, indicating the number of times the dilution one should carry out with odour free water, (in order to get no perceptible odour) e.g., TON = 4.0 indicate if we dilute with water in the ratio of 1:4, no odour will persist. Obviously, smaller the value of TON, better is its quality. Accepted average value of TON = 3. The chemical senses are used to characterize odour and taste. Food, beverage and pharmaceuticals preparations necessarily need odour free water. The odour is measured at 60⁰ or 40⁰C. Odour free standard water can be obtained by passing water over activated charcoal. For good results panel of at least 5 and not more than 10 members is needed for smelling. Threshold odour number (TON) is the dilution ratio at which odour is just detectable. Now taste refers to sensation by tongue to soft palate as flavour needs nose for comparison. The profile threshold test (FTT), flavour is needed for comparison. The flavour threshold (FTT) flavour rating assessment (FRA) profile analysis (FPA) are used in food industry. FRA is used to assess mineral contents. FPA is used to ascertain offensive flavour against background of recorded sensory quality which is an judged acceptable.

Turbidity:

It is a measure of the light absorbing properties of the water sample. It can be measured either with nepheloturbidimeter or by conventional Jackson candle Turbidimeter. Usually, turbidity is caused by suspended matter. It is an expression of optical quantity of water. The standard method for determination of turbidity has been based on Jackson candle turbidimeter, but lower turbidity measurement, a candle turbidimeter (similar to measuring cylinder with reverse graduations) is kept on ground glass. The candle is lighted and held below the cylinder. Water is then continuously poured in turbidimeter and the flame is viewed from top. When flame disappears reading on the cylinder is noted. The units on cylinder indicates turbidity units of water. Alternatively, it is very easy to measure turbidity of water by nephelometer in terms of NTU units. The instrument permits measurement from 100 NTU, while Jackson model permits 25 to 1000 JU limits. The turbidity is bad for water used for human consumption. The process of coagulation and sedimentation can remove turbidity. It is caused by clay, silt, finely divided organic and inorganic contents. Turbidity is also an expression of the optical property of water which causes light to be scattered and absorbed rather than transmitted. The main cause for the variation in turbidity analysis results of the use of suspension of different types of matter having different optical properties, refractive indices and varying particle size. The hydrazine sulphate or methylene tetramine are used to prepare standard turbid solution for comparison. The mixture of 1 gm hydrazine and 10 gm hexamethylene tetramine in 100 ml sample of water gives a turbidity of 400.

Hardness: The total hardness is defined as the sum of calcium and magnesium concentration expressed both as the calcium carbonate hardness in milligram per litre. It is greater than the sum of bicarbonate and carbonate alkalinity. This is termed as carbonate hardness. The calculated hardness is obtained from amount of calcium and magnesium present while hardness is experimentally evaluated by titration technique. The heavy metal interferences in complexometric titration. They are eliminated by use of CDTA as inhibitor. Various indicators like erichrome black T, calmagite, murexide are used in EDTA titration for determination of calcium and magnesium.

Classification of hardness:

As a matter of fact hardness should have been classified as the chemical property of water. Hardness of water is caused due to the presence of sulphates and chlorides of calcium and magnesium. Hardness sometimes is attributed due to sulphates or chlorides of iron, manganese and aluminium. This causes what is called the permanent hardness, while temporary hardness is caused due to the presence of bicarbonates of calcium and magnesium and can be eliminated by mere boiling of water. In order to ascertain the hardness of water, one has to use soap test. Water will form soft and beautiful lather with soap if water is soft. However, if water is hard than Ca and Mg will combine with stearates of form soap to form curd or insoluble lather of calcium-stearate or magnesium-stearate. Alkali metal stearates are soluble. Usually, hardness is expressed in terms of CaCO₃/litre.

Thus, water with 25mg/litre CaCO₃ is considered soft water, while water with 500mg/litre of CaCO₃ is termed as hard water. The usual method for analysis of hardness is titration method, one involving KMnO₄ titration, while another method is involving the use of EDTA for the purpose, latter is more popular.

The indicator used is Eriochrome black T, where pH is maintained at 10.0. EDTA combines first with Ca from water; then magnesium can be first precipitated as $Mg(OH)_2$. So titration value gives the amount of calcium only. Solochrome dark-blue can also be used instead of murexide indicator, with equal efficiency for calcium. When erichrome black-T is used, one gets reading for both Ca and Mg. Usually, EBT is grounded with solid NaCl in the ratio of 1:1, and is used during titration. A new indicator called Patton Reeder indicator is best for determination of calcium in hard water. It permits simultaneous analysis of both calcium and magnesium in water.

So far we have considered physical properties of water. Such as colour, conductivity and turbidity. However, physical properties alone cannot give definite information on quality of water. Most of the methods so far discussed are largely physical with few exceptions like hardness based upon the physiochemical properties. Similarly, acidity/alkalinity or salinity is classified in chemical composition of the water.

Chain-of-Custody Procedures

Properly designed and executed chain-of-custody forms will ensure sample integrity from collection to data reporting. This includes the ability to trace possession and handling of the sample from the time of collection through analysis and final disposition. This process is referred to as “chain-of custody” and is required to demonstrate sample control when the data are to be used for regulation or litigation. Where litigation is not involved, chain-of-custody procedures are useful for routine control of samples. A sample is considered to be under a person’s custody if it is in the individual’s physical possession, in the individual’s sight, secured and tamper-proofed by that individual, or secured in an area restricted to authorized personnel. The following procedures summarize the major aspects of chain of-custody:

- i. **Sample Labels:** Labels are used to prevent sample misidentification as well as to identify the collector, if required. In other words, labeling ensures the responsibility and accountability of the collector.
- ii. **Sample Seals:** Sample seals are used to detect unauthorized tampering with samples up to the time of analysis. So, it is essential to seal a sample before leaving the custody of the collector. Sealing must be done in such a way as one have to break the seal to access the sample.
- iii. **Field Log Book:** All the useful information related to a field survey or sampling should be recorded in a Log Book. At least the following data should be in the log book:
 - a. Purpose of sampling
 - b. Location of sampling point
 - c. Name and address of field contact
 - d. Producer of material being sampled and address, if different from location
 - e. Type of sample
 - f. Method, date, and time of preservation.
- iv. **Sample Analysis Request Sheet:** The sample analysis request sheet accompanies samples to the laboratory. The collector completes the field portion of such a form that includes most of the pertinent information noted in the log book. The laboratory portion of such a form is to be completed by laboratory personnel and includes: name of person receiving the sample, laboratory sample number, date of sample receipt, condition of each sample (i.e., if it is cold or warm, whether the container is full or not, color, if more than one phase is present, etc.) and determinations to be performed.
- v. **Sample Delivery to the Laboratory:** Sample(s) should be delivered to laboratory as soon as possible after collection, typically within 2 days. Where shorter sample holding times are required, special arrangements must be made to insure timely delivery to the laboratory. Where samples are shipped by a commercial carrier, the waybill number to be included in the sample custody documentation. Samples must be accompanied by a complete chain-of-custody record and a sample analysis request sheet.
- vi. **Receipt and Logging of Sample:** In the laboratory, the sample custodian inspects the condition and seal of the sample and reconciles label information and seal against the chain-of-custody record before the sample is accepted for analysis. After acceptance, the custodian assigns a laboratory number, logs sample in the laboratory log book and/or computerized laboratory information management system, and stores it in a secured storage room or cabinet or refrigerator at the specified temperature until it is assigned to an analyst.
- vii. **Assignment of Sample for Analysis:** The laboratory supervisor usually assigns the sample for analysis. Once the sample is in the laboratory, the supervisor or analyst is responsible for its care and custody.

- viii. **Disposal:** Samples are held for the prescribed amount and duration for the project or until the data have been reviewed and accepted. Samples are disposed usually after documentation. However, disposal must be in accordance with approved methods.

Proper Sampling

Proper sampling is a vital condition for correct measurement of water quality parameters. Even if advanced techniques and sophisticated tools are used, the parameters can give an incorrect image of the actual scenario due to improper sampling. The proper sampling should fulfill the following criteria:

- I. **Representative:** The data must represent the waste water or water body being sampled. So, the following factors must be well planned for proper sampling:
 - (a) Process of Sampling (b) Sampling size/volume (c) Number of Sampling Locations
 - (d) Number of Samples (e) Type of Samples (f) Time Intervals
 During sampling, these factors must also be taken care of:
 - Choosing of proper sampling container, Avoiding contamination, Ensure the personal safety of the collector
- ii. **Reproducible:** The data obtained must be reproducible by others following the same sampling and analytical protocols.
- iii. **Defensible:** Documentation must be available to validate the sampling procedures. The data must have a known degree of accuracy and precision.
- iv. **Useful:** The data can be used to meet the objectives of the monitoring plan.

Proper Labeling

Proper labeling prevents sample misidentification and ensures the responsibility and accountability of the collector. The sample container should be labeled properly, preferably by attaching an appropriately inscribed tag or label. Alternatively, the bottle can be labeled directly with a water proof marker. Barcode labels are also available nowadays. Information on the sample container or the tag should include at least:

- i. Sample code number (identifying location)
- ii. Date and time of sampling
- iii. Source and type of sample
- iv. Pre-treatment or preservation carried out on the sample
- v. Any special notes for the analyst
- vi. Sampler's name

Preservation

Usually a delay occurs between the collection and analysis of a sample. The characteristics of the sample can be changed during this period. Therefore proper preservation is required in the way to laboratory after collection, and in the laboratory upto when analysis starts. Complete and unequivocal preservation of samples, whether domestic wastewater, industrial wastes, or natural waters, is a practical impossibility because complete stability for every constituent never can be achieved. At best, preservation techniques only retard chemical (especially, hydrolysis of constituents) and biological changes that inevitably continue after sample collection. No single method of preservation is entirely satisfactory; the preservative is chosen with due regard to the determinations to be made. Preservation methods are limited to pH control, chemical addition, the use of amber and opaque bottles, refrigeration, filtration, and freezing.

Analysis

The samples, after reaching laboratory, are analyzed, according to the requisite parameters, following standard methods and protocols.

Reporting

The ultimate procedure of water analysis is to prepare a proper report against the submitted requisition. The report must be authenticated before handing over the authority. All data should be kept in the laboratory log and preferably in laboratory database. An alternative way to present the overall quality of water is to express it in the form of Water Quality Index (WQI). WQI is a concise numerical representation of overall water

quality of a water body, which is convenient to interpret and used widely. WQI expresses the overall quality of water with a single digit, instead of many digits for all the WQP. Thus, it is readily conceivable for common people.

CONCLUSION

Assessment of water quality is essential to check the suitability of a water source for the designated use. Several water quality parameters are assessed and compared with their standard values to determine the acceptability of the water to be used. Water is such an important commodity that we cannot afford to pollute it. In order to ascertain such pollution the physical, chemical and biological examination is necessary. The physical examination covers, colour, conductivity, temperature, odour, and taste turbidity and hardness. In the last decades environmental pollution has grown by leaps and bounds needing immediate attention from mankind. To understand this problem one needs basic knowledge of environmental chemistry and specially of environmental chemical analysis. The impact of man on the environment and interaction with various sphere of environment originated pollution. The ecology and environment are closely related. In last one decade pollution has reached a level in alarming proportion all over the world. The transportation is the main culprit leading to photochemical smog. The water pollution was known to man since ages with reference to the quality of drinking water. Most of the rivers are highly polluted. Waste water generated after use of water in industry causes serious problem of the pollution. It depends upon the source of the effluent. Pollution due to sewage is rampant in India. In India since 1962 Maharashtra was the first state to enact Water Pollution Act, followed by preparation of the draft proposal for Air Pollution Control in 1980. Fortunately the central government is aware of the problems. It passed comprehensive environmental protection bill in 1986 to include legislation on abatement of noise pollution. We have now state boards for abatement and control of air and water pollution in every state of India, including union territories. However, these control measures shall not be effective, unless environmental education is imparted from primary school to college and university level. We have the department of Environment and Forest of the Central Government under the Ministry of Environment. Agencies to control environmental pollution which will be effective only if we properly monitor pollution. No doubt future is certainly bright for India, provided we are alert.

REFERENCES

- [1] D. C. Adriano, Trace elements in Terrestrial Environment, Springer-Verlag, New York.
- [2] K. Grasshoff, Methods of Sea Water Analysis, Verlag-Chemi, Weinheim.
- [3] Mayuri Gandhi and S.M. Khopkar, Indian Journal Of Environmental Protection.
- [4] Water Treatment Handbook, 5th Ed., Degremont.
- [5] K.J. Irgolic and A.E. Martell – Environmental Inorganic Chemistry, VCH Publishers Inc. USA
- [6] American Public Health Association and American Water Works Association 1999 Standard Methods for the Examination of Water and Wastewater. 20th Ed, Washington, D.C., USA
- [7] Brown R. M., McClelland N. I., Deininger R. A., Tozer R. G. 1970 A water quality index- do we dare? Water and Sewage Works, October 1970, 339-343
- [8] Bureau of Indian Standards 2012 Indian Standard Drinking Water Specification (Second Revision)
- [9] Deshpande L. undated Water Quality Analysis: Laboratory Methods. National Environmental Engineering Research Institute (NEERI), Nagpur, Council of Scientific & Industrial Research, New Delhi, Govt. of India
- [10] Kori R., Parashar S., Basu, D.D. undated Guide Manual: Water and Wastewater Analysis. Central Pollution Control Board, Ministry of Environment and Forest, India
- [11] Metcalf E., Eddy H. 2003 Wastewater Engineering: Treatment and Reuse. Tata McGraw-Hill Publishing Co Ltd, India.
- [12] Roy R. 2018 An Approach to Develop an Alternative Water Quality Index Using FLDM. In: Majumder M. (eds) Application of Geographical Information Systems and Soft Computation Techniques in Water and Water Based Renewable Energy Problems. Water Resources Development and Management. Springer, Singapore, 51-68
- [13] Roy R., Majumder M. 2017 Comparison of surface water quality to land use: a case study from Tripura, India. Desalination and Water Treatment, 85, 147-153
- [14] Roy R., Majumder M. 2018 A Quick Prediction of Hardness from Water Quality Parameters by Artificial Neural Network. International Journal of Environment and Sustainable Development, 17(2/3), 247-257
- [15] Tyagi S., Sharma B., Singh P., Dobhal R. 2013; Water Quality Assessment in Terms of Water Quality Index. American Journal of Water Resources, 1(3), 34-38 [11] World Health Organization 2004 Guidelines for Drinking-Water Quality (3rd edition)