Chapter 2
Water Quality Standards, Its Pollution and Treatment Methods

**Sheenam Thatai, Rohit Verma, Parul Khurana,
Pallavi Goel and Dinesh Kumar**

Abstract Water is not only the most essential source of our day-to-day life, but the development of this natural resource also plays a crucial role in economic and social development processes. Waste disposal has become a worldwide problem for increased environmental awareness, for more rigorous environmental standards and dewatering challenges. Therefore, water quality management is a great work controlled by monitoring of discharge and various effluents. World health organization has issued guidelines for drinking water quality, its contaminants and how to handle water supplies in small rural communities. Qualitative and quantitative measurements are needed from time to time to constantly monitor the quality of water from the various sources of supply. This chapter highlights different water quality assessments, several sources of water pollutions and the methods used for treating water for various purposes such as for drinking, industrial water supply, irrigation, water recreation or many other uses.

Keywords Water · Quality · Pollution · Standard · Treatment

S. Thatai (✉) · R. Verma (✉) · P. Goel
Amity Institute of Applied Sciences, Amity University, Noida, Uttar Pradesh, India
e-mail: messageforsheenam@gmail.com

R. Verma
e-mail: rverma85@amity.edu

P. Goel
e-mail: pallavigoel85@gmail.com

P. Khurana
Department of Chemistry, G. N. Khalsa College of Arts, Science and Commerce,
Mumbai University, Mumbai, India
e-mail: messageforparul@gmail.com

D. Kumar
Department of Chemistry, Central University of Gujarat, Gandhinagar, India
e-mail: dsbchoudhary2002@gmail.com

1 Introduction

Water is one of the prime elements responsible for life on earth. Water is used every day for various purposes and involved in all the bodily purposes. An average body consists of 42 l of water. Safe water availability is important for public health. UN general assembly recognized the right of humans to clean water and sanitation. Since 1990, 2.6 billion people have gained access water quality standard to improved drinking water (Pathak 2013). 97% of water available on earth is saline and only 3% of water is freshwater. Of the 3% freshwater, 68.7% is available in glaciers and icecaps and 30.1% is available as ground water. And the remaining 0.3% is available as surface water. Out of this 0.3% of surface water, 87% is present in lakes, 11% in swamps and 2% in rivers (Pontius 1990).

India is ranked among the top ten water rich countries with 4% of world's freshwater resources. Surface water sources in India include rivers, lakes or fresh water wetlands. India has 12 major river systems. The perennial Himalayan Rivers in the north include Ganga, Yamuna, Indus and Brahmaputra. The south has rivers Krishna, Godavari and Cauvery while rivers Narmada, Tapti and Mahanadi drain central India. The Bay of Bengal receives 70% of total drainage while the Arabian Sea receives 20% of the total drainage. Rivers are the lifeline of growth. They provide drinking as well as raw water for industrial use. Lakes also serve as a source of water for agriculture, drinking and industries. They also act as recharge zones for groundwater. Lakes are a source of livelihood for many people. Indian cities such as, Ahmedabad, Bangalore and Hyderabad have a number of lakes. Some of the lakes are Dal Lake, Loktak Lake, Ropar Lake, etc. Water sources within aquifers are known as ground water resources. The assessment of ground water resources of the country is carried out by Central Ground Water Board. Ground water contributes to 85% of drinking water, 58% of irrigation water and about 50% of industrial requirements (Durfor and Becker 1964; Kumar et al. 2017).

A World Health Organization (WHO) report also suggests that about 1.8 billion people rely on sources of drinking water which are contaminated. Water pollution is the most serious ecological threat that the world faces today. Water pollution is defined as the condition in which one or more toxic substances accumulate in water bodies and degrade the quality of water. The Economist report in 2008 stated that in India each day over 1000 children die of diarrheal sickness. Water is polluted by both natural and manmade activities. Let, us now discuss the major causes that lead to the pollution of water.

2 Causes of Water Pollution

There are several causes of water pollution. The main causes are as follows.

2.1 Urbanization

The population of urban dwellers has risen to 285 million from 25.8 million people in 1901. With population growth the demand for housing, food and cloth has also increased. This rapid urbanization has led to various issues such as inadequate water supply, production of wastewater in large amount, its disposal and treatment. Water is supplied from rivers, lakes, ponds for domestic and industrial use. After the work is done, this water is released out as wastewater, which is left untreated most of the times. Thus, causing large scale surface water pollution. Due to rapid population growth, the use of water for domestic purposes and use of soaps and detergents going to sink has also increased. But the facility of sewerage lags far behind. Only 22% of the waste water from class 1 cities is collected through sewerage. Thus wastewater in large amount is left uncollected. According to the CPCB 2003 report, wastewater about 22,900 million liter per day (mld) was generated. Out of which, only 5900 mld which accounts to only 26% is treated while the remaining wastewater, which is about 17,100 mld is left untreated (http://greencleanguide. com/earths-water-distribution-and-indian-scenario/). It has been found that permanent treatment facility is available only in 27 cities while the rest forty-nine cities have access to only primary and secondary facility for treatment of water. Table 1 explains the trend of population, water supplied, wastewater generated and the amount of wastewater treated and untreated in class I cities and class II towns.

Table 1 Water supply trend and sanitation status in class I cities and class II towns

Parameters	Class I cities			Class II towns		
Year	1978–79	1989–90	1994–95	1978–79	1989–90	1994–95
Number	142	212	299	190	241	345
Population (millions)	60	102	128	12.8	241	23.6
Water supply (mld)	8638	15,191	20,607	1533	1622	1936
Wastewater generated (mld)	7007	12,145	16,662	1226	1280	1650
Wastewater treated (mld)	2756 (39%)	2485 (20.5%)	4037 (24%)	67 (5.44%)	27 (2.12%)	62 (3.73%)
Wastewater untreated (mld)	4251 (61%)	9660 (79.5%)	12,625 (76%)	1160 (94.56%)	1252 (97.88%)	1588 (96.27%)

The numbers in round brackets show the percentage of the treated and untreated water (mld stands for million liters per day)
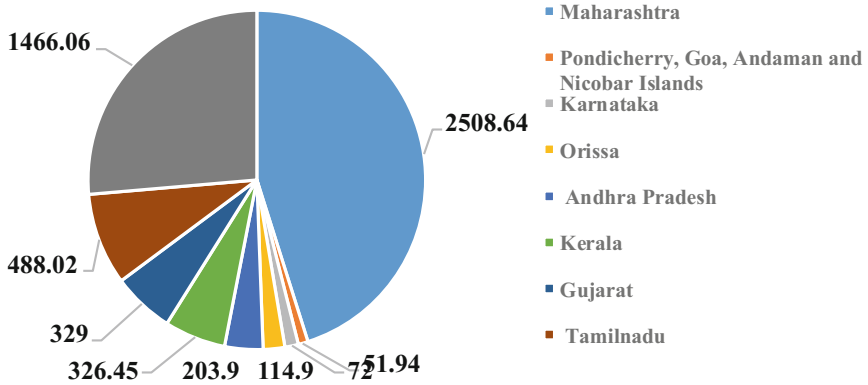
Chart 1 Municipal wastewater generated in coastal cities of India
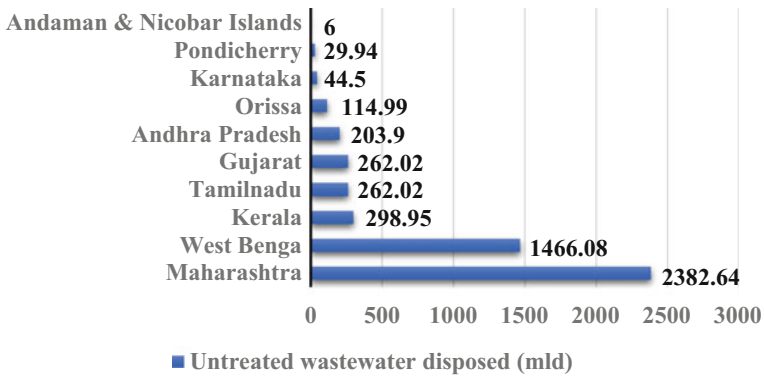
Chart 2 Untreated municipal wastewater disposed in the coastal cities of India

From the above table, it is evident that the amount of wastewater treated in comparison to the amount generated is very less. Thus, large amount of wastewater is left untreated and released into the water bodies leading to pollution of water and causing harmful effects on marine life, plants, and humans who consume this polluted water.

Large amount of wastewater is generated and left untreated in the coastal cities. India has an 8118 km long coastline. Cities near the coastline generate 5560.99 mld of wastewater and 90.62% of the total wastewater generated is released into the coastal water untreated. Chart 1 shows the amount of wastewater generated in different coastal cities. And it has been found that Maharashtra generates the highest amount of wastewater, followed by West Bengal (Aral 2009).

While Chart 1 depicts the amount of wastewater generated and Chart 2 depicts the amount of wastewater which is left untreated. Maharashtra, which generates the

largest amount of wastewater also disposes most of its wastewater untreated, followed by West Bengal and Kerala.

Another survey shows that during 2015, 61,754 mld wastewater was generated in India and about 38,791 mld of untreated sewage was discharged directly into water bodies (http://cpcb.nic.in/).

2.2   Industries

Most of the fresh water sources like rivers are contaminated by toxic wastes produced by industries. A water pollution control programme was launched by the Central Pollution Control Board (CPCB) in 1992 for industries. This program identified 1551 industries which did not comply with the pollution standards. CPCB gave them a time period for compliance with prescribed standards. It has been estimated that the major industrial sources generate around 83,048 mld of waste water. The major waste water generating industries in terms of volume are engineering industries and electroplating units. Steel plants, paper mills, textile and sugar industries also contribute significantly to waste water. Table 2 shows the wastewater generated by different industrial sectors (http://www.sulabhenvis.nic.in).

Both large and small scale industries contribute to water pollution. In 1995, only 59% of large and medium industries had adequate effluent treatment plants. There are about 3 million small scale industries in India which cannot afford ETP's of their own. Such small scale industries contribute to 40% of industrial water pollution (Murty and Kumar 2011).

2.3   Agriculture

Agriculture is the largest user of freshwater resources. It is also a major cause of surface and ground pollution of water. Very large parts of total land area are under

Table 2 Wastewater generated by different industrial sectors

Industrial sector	Annual waste water discharge (million cubic meters) (%)
Thermal power plants	27,000.9
Engineering	1551.3
Pulp and paper	695.7
Textiles	637.3
Steel	396.8
Sugar	149.7
Others	241.3
Total	30,729.2

agriculture. Agricultural runoffs contain pesticides and fertilizers which pollute the ground and surface water resources. A 40 km long drain in Haryana, pours 250,000 kg/day of chlorides into Yamuna. Thus, raising the concentration of chlorides in Yamuna to 150 mg/l. Majority of chlorides are from agricultural return flow. Nutrients which are derived from farming lead to enrichment of water. These principally include nitrogen and phosphorous and their various forms, which often lead to eutrophication. Also, the transfer of soil from agricultural land into water resources affects the amount of light entering the water and fish spawning. Irrigation is also a major cause of surface and ground pollution of water. Runoff of salts leads to salinization of surface water and runoff of fertilizers and pesticides to surface water leads to bioaccumulation in aquatic organisms. Other agricultural activities such as aquaculture and silviculture also deteriorate the quality of surface and ground water (Memon and Schröder 2009; Agarwal et al. 1997).

These were the major causes of water pollution. From the above discussion, it can be concluded that large amount of wastewater is disposed off in water bodies untreated. For treatment of this wastewater, techniques have been designed in accordance with the pollutants present in wastewater. In order to determine the degree of treatment required, water is tested for various characteristics which are discussed below.

3 Characteristics of Water Tested for Water Quality Assessment

Water contamination is caused due to chemicals, pathogens, heavy metals, pesticides, fertilizers, etc. which are a product of agricultural and industrial activities (Arora et al. 2011). Such activities have become a hazard to human health. It is necessary to characterize the various characteristics of water in order to develop treatment plans.

The following characteristics are tested for water quality.

1. **pH**: pH is defined as the measure of acidic or basic nature of a solution. It is determined by the concentration of hydrogen ion (H^+) activity in a solution. Mathematically,

$$pH = -\log(H^+)$$

2. **Temperature** The metabolism of the aquatic system is regulated by the temperature of the water. Under high water temperature the ability of water to hold dissolved gases such as oxygen reduces. Thus, leading to killing of fishes due to reduced availability of oxygen in water.

3. **Hardness** Hardness is the defined as the measure of the water capacity to precipitate soap. It is also defined as the sum of concentration of calcium and magnesium (Memon and Schröder 2009).

4. **Nitrate and Nitrite** Nitrates and nitrites are a part of the nitrogen cycle. Excessive use of fertilizers, pesticides, sewage disposal, discharge from industries, domestic effluent, water from decayed vegetables and atmospheric precipitation, have led to increase in concentration of nitrate in drinking water. Excessive concentration of nitrate causes heart and lung diseases. Excessive nitrites leads to production of methemoglobin in warm blooded animals leading to the condition of methemoglobinemia (Memon and Schröder 2009).

5. **Chlorides** Combination of chlorine (Cl) gas with a metal results in formation of inorganic compounds known as chlorides such as sodium chloride (NaCl). Chlorine is used as a disinfectant and is highly toxic in nature. Surface water is contaminated by chlorides through several sources such as agricultural run-off, wastewater from industries, and effluent waste from water treatment plants and also from rocks containing chlorides. High level of chlorides in freshwater and lakes affects the health of aquatic organisms. Chlorides also affect the taste of food products and corrode metals (Memon and Schröder 2009; Agarwal et al. 1997).

6. **Fluoride** In 20 states of India, the fluoride levels in ground water are higher than permissible limits (Memon and Schröder 2009). This means more than 60 million people consume water which has fluoride greater than 1 mg/l. High concentration of fluoride in drinking water leads to severe conditions such as dental and skeletal fluorosis. Consumption of high levels of fluoride in drinking water also reduces the absorption of iron which further leads to iron deficiency and related problems. The fluoride endemic states in India are Andhra Pradesh, Kerala, Maharashtra, Gujarat, Karnataka, Punjab, Tamil Nadu, Rajasthan, Haryana, Jammu and Kashmir and Delhi (Memon and Schröder 2009).

7. **Arsenic** Arsenic is an odourless metalloid. The most toxic form of arsenic is Arsenite. Ground water is contaminated by arsenic during weathering of rocks and minerals. Exposure sources of arsenic also include anthropogenic sources such as agrochemicals, burning of fossil fuels, industrial sources, wood preservatives, etc. Ground water arsenic contamination was first observed in West Bengal in the year 1983 (Memon and Schröder 2009; Arora et al. 2011). High levels of arsenic leads to the condition called arsenicosis which refers to arsenic poisoning. Arsenic causes skin damage, skin cancer, and internal cancers and also damages the vascular system. The crops grown using arsenic contaminated water are transported to other unaffected places. Thus, affecting the habitants of the unaffected region and posing new dangers (Memon and Schröder 2009; Arora et al. 2011).

8. **Lead** Natural sources contribute to presence of lead in tap water to some extent but primarily household plumbing systems contain lead and thus contaminate tap water. Lead compounds present in PVC pipes can be leached from them and contribute to high concentration of lead in water. Lead poisoning has several health hazards such as anemia, lower IQ and hyperactivity in children, stunted

growth of the fetus in pregnant women, reproductive problems, and cardio-vascular effects and reduced kidney function in adults (Memon and Schröder 2009; Bushra et al. 2015; Mittal et al. 2016; Nabi et al. 2009).

9. **Phosphorous** Phosphorous is one of the most important elements for growth of biotic things. Phosphate a compound formed from phosphorous exists in three forms, orthophosphate, metaphosphate, and organically bound phosphate. Excessive growth of phosphate leads to rapid growth of algae and aquatic plants. Thus, choking up the water and reducing the availability of water, leading to the condition of eutrophication. Rapid growth of aquatic vegetation causes death and decay of vegetation and deteriorates the quality of aquatic life by reducing the availability of dissolved oxygen in water (Atwater and Polman 2010).

10. **Iron** Iron is the second most abundant metal and it is most commonly found in form of its oxides. According to WHO, the minimum requirement of iron ranges between 10 and 50 mg/day. Iron is a vital element required in the oxygen transport mechanism in the blood. Consumption of iron doses as low as 40 mg/kg of body weight have resulted in deaths. Increased iron absorption in the body results in chronic iron overdose. Iron present in domestic water supply leads to staining of laundry and porcelain. Excessive iron in drinking water gives it a bitter and astringent taste (Metcalf et al. 2003).

11. **Dissolved Oxygen** Dissolved oxygen refers to the amount of free oxygen dissolved in an aqueous solution. Dissolved oxygen has influence on aquatic organisms and thus is a very important parameter to access the quality of water. Dissolved oxygen enters water through air by diffusion and as a byproduct of photosynthesis. The amount of dissolved oxygen depends on temperature, pressure and salinity. As temperature decreases the solubility of oxygen decreases. Dissolved oxygen decreases with increase in salinity and increases with increase in pressure. With the increase in concentration of dissolved oxygen the fish mortality rate increases. High level of dissolved oxygen can result in gas bubble disease in fishes (http://nptel.ac.in/courses/105105048/M13L16.pdf).

12. **Biological Oxygen Demand (BOD)** BOD is defined as the amount of oxygen required for decomposing the organic matter by microorganisms. It also measures the chemical oxidation of organic matter. The amount of dissolved oxygen in water sources is directly affected by biological oxygen demand. Greater the value of BOD, more rapid will be the depletion of oxygen in water sources. Thus reducing the amount of oxygen available for aquatic organisms in the water. For raw sewage the general range of BOD is 100–400 mg/l. Dead plants and animals, animal manure, water treatment and food processing plants and effluents from paper mills are the major sources of biological oxygen demand.

The water quality monitoring results obtained during 1995 and 2011 with respect to biological oxygen demand show that the quality of water has degraded gradually. Chart 3 shows the number of observations having
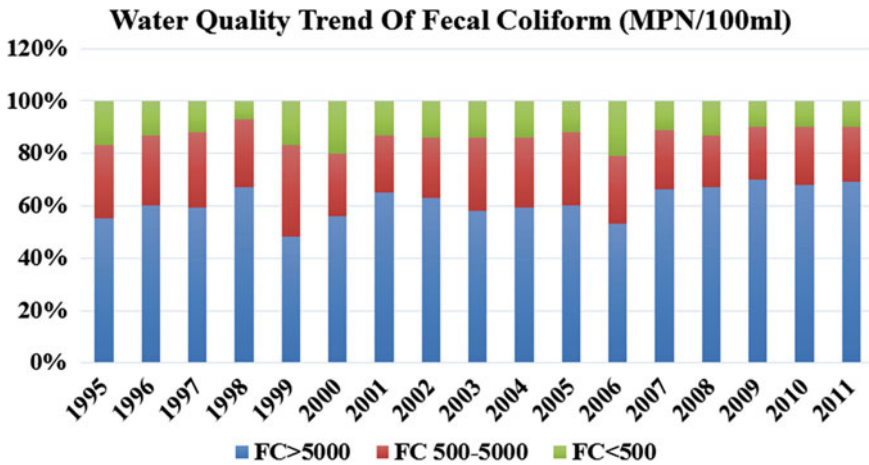
WATER QUALITY TREND OF BOD (MG/L)
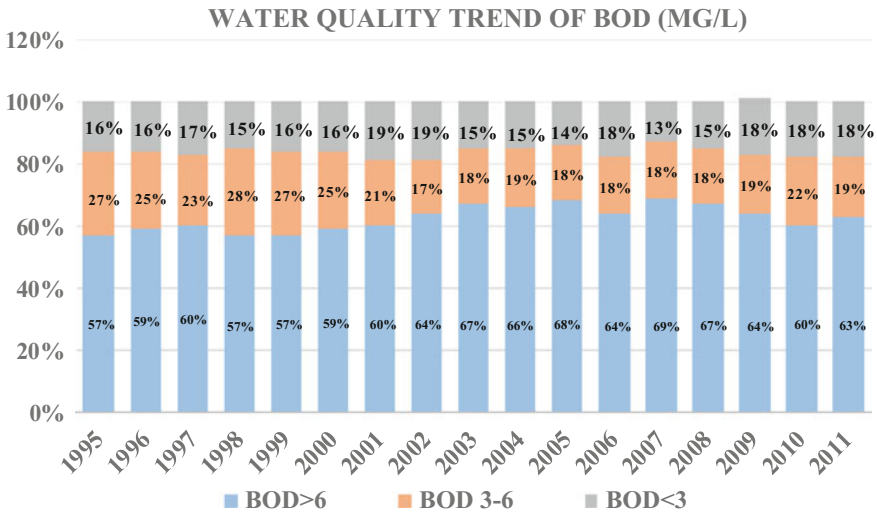
Chart 3 Water quality trend of biological oxygen demand (BOD)

biological oxygen demand in different ranges for the period 1995–2011. A gradual decrease was observed in the number of observations having BOD < 3 and the highest value of 69% was observed in the year 2007. Similarly there was a gradual decrease in the number of observations having BOD between 3 and 6 mg and the highest value of 28% was observed in the year 1998. But the number of observations having BOD > 6 was maximum in the year 2001 and 2002 and then decreased gradually. While in the year the 2011 maximum value of 18% was observed (http://nptel.ac.in/courses/105105048/M13L16.pdf; Drinan 2001).

13. **Fecal Coliform Bacteria** Fecal coliform serves as indicators of fecal pollution in the water. Fecal coliform present in water suggests that the water has been polluted by the fecal material. Absence of coliform organism indicates that the water is free from disease spreading organisms. Coliform bacteria reside in the intestine of human beings. *Escherichia coli* is the most common member of this group. Typhoid fever, hepatitis A and viral are some of the most common pathogenic diseases. Chart 4 shows the water quality monitoring results obtained during the period of 1995–2011 with respect to the indicator of fecal coliform bacteria. During the year 1995–2011 the numbers of observed fecal coliform values of 500 MPN/100 ml was found to be between 48 and 70% and that of fecal coliform values of the ranges 500–5000 MPN/100 ml was between 20 and 35%. In the former case maximum value of 70% was observed in the year 2009 while in the latter case the maximum value of 35% was observed in the year 1999. For the third case, i.e. for fecal coliform values >5000 MPN/100 ml, the numbers of observed values was between 7 and 21% in the year 1995–2011 and the maximum value of 21% was observed in the year 2006 (http://cpcb.nic.in/water.php).

Water Quality Trend Of Fecal Coliform (MPN/100ml)

Chart 4 Water quality trend of fecal coliform

In the above section of the chapter, we have discussed the causes of water pollution, major trends associated with it and the important characteristics which are tested for treatment of contaminated water. Now, in the upcoming section, we will describe the harmful effects of polluted water on human health. Contaminated water leads to various chronic diseases, killing millions of people each year. The various water related diseases are discussed below.

4   Water-Related Diseases

Water related diseases lead to death of millions of people each year and a large proportion of about 2.3 million people suffer from water related diseases (http://cpcbenvis.nic.in). Different water related diseases have different nature, transmission methods and harmful effects.

4.1   Water-Borne Diseases

Diseases are caused by water which is contaminated by animals, humans and chemical wastes. Typhoid, polio, hepatitis A, hepatitis E, cholera and meningitis come under the water-borne diseases. Improper sanitation facilities lead to various water borne diseases majorly diarrhea. About 4 billion cases of diarrhea are reported every year. Presence of toxic substances such as fertilizers, chemicals, pesticides, industrial wastes, etc. can give rise to chronic diseases such as cancers. Presence of pesticides such as DDT also has harmful effects on human health. They lead to cancers and are also responsible for reduced sperm count and neurological diseases.

4.2   Water-Based Diseases

These diseases are caused by aquatic organisms that live both in water and as parasites of animals. They can reside in polluted as well as unpolluted water. Various organisms such as flukes, worms, helminths, etc. cause these diseases. Some examples of water based diseases are bilharzia, paragonimiasis and guinea worm.

4.3   Water-Related Vector Diseases

Vectors or insects are those which breed near polluted and unpolluted water, transmit infections and cause diseases such as malaria, dengue fever, filariasis, sleeping sickness, etc. A rapid increase has been observed in water related vector diseases. Mosquitoes are developing resistance to insecticides such as DDT. Other factors such as climate change, migration, creation of new breeding sites, etc. has also contributed in the increase of such diseases (http://cpcbenvis.nic.in). Table 3 shows the water related diseases along with the respective causative organism (http://cpcbenvis.nic.in).

Now, that we have discussed the harmful effects of contaminated water on human health, we must explain about the steps involved to reduce water

Table 3 Water related diseases and their causative organism

Disease	Causative organism
Water-borne diseases	
Bacterial	
Typhoid	*Salmonella typhi*
Cholera	*Vibrio cholera*
Paratyphoid	*Simonella parayphi*
Bacterial dysentery	*E. coli*
Viral	
Hepatitis	Hepatitis-A
Diarrheal diseases	Rota-virus
Water-washed diseases	
Scabies	Skin-fungus species
Bacillary dysentery	*E. coli*
Water-based diseases	
Guinea worm	Guinea worm
Schistosomiasis	Schistosoma sp.
Infection caused due to water related vectors	
Malaria	*Plasmodium*
Sleeping sickness	*Trypanosoma*

contamination. One of the most important steps in this regard is standardization of water quality. The water quality standards set for various purposes are discussed below.

5 Water Quality Standards for Various Purposes

Drinking water is used for various purposes such as drinking, cooking, etc. Water is a basic human need and a prime resource. Therefore, the provision of safe drinking water is a matter of high priority. According to the Bureau of Indian Standards (BIS)-10500, drinking water shall comply with the requirements given in the Table 4 (http://cpcbenvis.nic.in):

According to the Central Pollution Control Board (CPCB), under the National Water Quality Monitoring Programme (NWMP), the classification of surface waters in India on the basis of their usage and the respective water quality criteria is discussed in Table 5 (http://cpcbenvis.nic.in):

According to the World Health Organization (WHO) guidelines, drinking water shall comply with the requirements discussed below in the Table 6 (http://cpcbenvis.nic.in/water_pollution_main.html).

Now, as we are aware of the water quality standards for various purposes, let us discuss about the treatment methods involved. Contaminated water has to be treated in order to meet the quality standards. Treatment of wastewater involves various techniques and processes which are used according to the type of pollutants present in the wastewater.

6 Treatment of Wastewater

Various treatment techniques are used for removal of pollutants from water. We have already discussed the various characteristics for which water is tested. Let's talk about the techniques involved in testing of the discussed parameters.

6.1 Techniques for Testing of Various Parameters in Wastewater

Drinking water is tested for various parameters (http://cpcbenvis.nic.in; http://cpcbenvis.nic.in/water_pollution_main.html). The methodology for measurement of various parameters is as follows.

Table 4 Water quality standards

S. No.	Parameter	BIS, Indian Standards (IS 10500:1991)		BIS, Indian Standards (IS 10500:1991)	Risk or effects	Sources
		Desirable unit	Permissible unit			
1.	Color	5 Hazen Units	25 Hazen Units	Visible tint, acceptance decreases	Tannins, Iron, Copper, Manganese, natural deposits	**Color**
2.	Odour	Unobjectionable	Unobjectionable	Rotten egg, Musty, Chemical	Chlorine, Hydrogen Sulphide, Organic matter, Methane gas	**Odour**
3.	pH	6.5–8.5	No relaxation	Low pH: corrosion, metallic taste High pH: bitter/soda taste, deposits	Natural	**pH**
4.	**Total Dissolved Solids**	500 mg/l	2000 mg/l	Hardness, staining, salty or bitter taste, corrosion of pipes	Livestock waste, septic system, landfills, nature of soil, dissolved minerals, iron and manganese	**Total Dissolved Solids**
5.	**Hardness**	300 mg/l	600 mg/l	Soap scums, scale in utensils and hot water system	Calcium and magnesium from soil	**Hardness**
6.	**Alkalinity**	200 mg/l	600 mg/l	Low alkalinity leads to deterioration of plumbing	Plumbing fixtures, pipes, landfills	**Alkalinity**
7.	**Iron, Fe**	0.3 mg/l	1.0 mg/l	Discoloration of beverages, brackish color and bitter and metallic taste	Leaching of pipes in water distribution system	**Iron, Fe**
8.	**Manganese, Mn**	0.1 mg/l	0.3 mg/l	Black stains on laundry, bitter taste and brownish color of water	Deposits in rocks and soil	**Manganese, Mn**
9.	**Sulphate, SO₄**	200 mg/l	400 mg/l	Rotten—egg odor, bitter and medicinal taste	Sewage, industrial waste and natural deposits	**Sulphate, SO₄**

(continued)

Table 4 (continued)

S. No.	S. No.	Parameter	BIS, Indian Standards (IS 10500:1991)	BIS, Indian Standards (IS 10500:1991)	Risk or effects	Sources
10.	Nitrate, NO_3^-	45 mg/l	100 mg/l	Blue baby disease in infants	Fertilizers, waste water from households, manure lagoons	Nitrate, NO_3-
11.	Chloride, Cl	250 mg/l	1000 mg/l	High blood pressure, corrosion of pipes and appliances, blackening of stainless steel	Fertilizers, minerals and waste from industries	Chloride, Cl
12.	Fluoride, F	1.0 mg/l	1.5 mg/l	Coloration of teeth and damage to the bones	Industrial waste	Fluoride, F
13.	Arsenic, As	0.05 mg/l	No Relaxation	Depression, skin and nervous system toxicity	Improper waste disposal, rocks, pesticides	Arsenic, As
14.	Chromium, Cr	0.05 mg/l	No Relaxation	Nasal ulcer, lung tumors, Damage to nervous and circulatory system	Industrial discharge and mining	Chromium, Cr
15.	Copper, Cu	0.05 mg/l	1.5 mg/l	Anemia, damage to liver and kidney, staining of plumbing fixtures		Copper, Cu
16.	Cyanide	0.05 mg/l	No Relaxation	Thyroid, Damage to nervous system	Fertilizers	Cyanide
17.	Lead, Pb	0.05 mg/l	No Relaxation	Mental retardation, hearing loss, hypertension and blood disorders	Paint, discarded batteries, leaded gasoline	Lead, Pb
18.	Mercury, Hg	0.001 mg/l	No Relaxation	Vision and hearing loss, nervous system disorders	Electrical equipment, fungicides	Mercury, Hg
19.	Zinc, Zn	5 mg/l	15 mg/l	Metallic taste	Paints, dyes and leaching of galvanized pipes	Zinc, Zn

1. **Temperature** Temperature is measured by dipping the bulb of a thermometer in the river for about 2–3 min. Then the mercury level in the thermometer is read.
2. **pH** pH is measured with the help of a pH meter at the Divisional Laboratory (Level-2). The instrument is standardized before measuring the pH value.
3. **Electrical Conductivity** Electricity conductivity (EC) is measured by an electrical conductivity meter. An EC meter is used to measure the resistance of water between two platinized electrodes.
4. **Magnesium** It is measured by complex metric titration using the standard solution of EDTA under the buffer solution which is prepared from ammonium chloride and ammonium hydroxide of pH 10.0. Value of the EDTA solution gives the sum of calcium and magnesium concentration.
5. **Sodium** A flame photometer is used to measure sodium. Sample emits radiation which is measured through yellow filters.
6. **Potassium** A flame photometer is used to measure potassium. Potassium solution is used to standardize the instrument. A flame photometer work on the principle of measuring the radiation emitted by the atoms of potassium.
7. **Carbonate** Presence of carbonate is indicated when pH touches 8.30. It is measured with the help of process of titration with HCl and phenolphthalein as an indicator. As the value of pH exceeds 8.3 phenolphthalein becomes pink.
8. **Sulphate** Sulphate is measured with the help of nephelometric method. In this method the concentration of turbidity is measured with respect to the known sulphate solution.
9. **Chloride** For measuring chloride, a sample is titrated against silver nitrate solution. A potassium chromate solution in water is used as an indicator.
10. **Dissolved Oxygen** Dissolved oxygen is measured using the Winkler's method. It must be measured at the river site as it changes with time.
11. **Biochemical Oxygen Demand** Winkler's method is used to measure dissolved oxygen which is left in the sample. The difference between the initial and final values of dissolved oxygen gives the amount of oxygen consumed by bacteria during the incubation period. The value is calculated for one liter of sample.
12. **Total coliform** The bacteria which are present in water grow rapidly when placed in a nutritive medium. The movement of the bacteria growing under these special conditions is restricted and thus the number of bacteria is confined to the sample. Various colonies of bacteria together give the total number of coliform in the sample (http://cpcbenvis.nic.in).

Now, let us discuss a wastewater treatment plant and the different methods which are involved.

6.2   Methods Involved in a Wastewater Treatment Plant

A wastewater treatment plant involves use of different treatment methods (http://cpcbenvis.nic.in; http://cpcbenvis.nic.in/water_pollution_main.html; Camp 1963). These methods are classified into the following categories.

6.2.1   Preliminary Treatment

Preliminary treatment involves removal of floating material and settleable inorganic and organic solids from raw water. Preliminary treatment involves processes such as screening and grit removal.

Screening is the first operation in a wastewater treatment plant. It is used for removal of large floating objects such as plastics, clothes, paper, dead animals, etc. A set of inclined parallel bars are fixed at a certain distance in a channel. Screens are designated as hand cleaned and mechanically cleaned based on the method of cleaning. On the basis of the size of the opening, screens are differentiated into coarse and fine screens. Coarse screens consist of parallel bars with bar spacing of 50–150 mm.

Fine screens are mechanically cleaned and the opening size ranges from 0.035 to 6 mm. They are specifically used for pretreatment of industrial wastewater. They are also used for removing solids from primary effluents to prevent clogging of filters (http://cpcbenvis.nic.in).

Grit removal technique is used for removing heavy inorganic materials such as sand and ash. Working of grit chambers is based on the process of sedimentation due to gravitational forces. Grit chambers are very similar to sedimentation tanks, as they are also used for separation of heavier materials and to pass on the lighter materials. The velocity of water through the grit chamber is maintained very high in order to prevent the organic solids from settling. This velocity is known as the "differential sedimentation and differential scouring velocity". The critical velocity of flow "V_c" should always be less than the scouring velocity of grit. Because beyond the critical velocity of flow, already settled particles can be reintroduced in the flow (http://cpcbenvis.nic.in/water_pollution_main.html).

6.2.2   Primary Treatment

Primary treatment involves removal of organic and inorganic solids by physical processes such as sedimentation and floatation. In primary treatment a quiescent condition is maintained and the velocity of flow is reduced such that the denser material settles down and the lighter one floats to the surface. During primary treatment, about 50–70% of total suspended solids and 65% of oil and grease is removed. Chemicals that are used to precipitate insoluble substances are added in water in order to promote sedimentation. These chemicals are known as flocculants.

Flocculation leads to aggregation of small pollutants. Thus, forming large floc so that they can settle down fast. The solids that settle down are known as primary or raw sludge.

A sedimentation tank usually has 4 zones; inlet zone, settling zone, sludge zone and outlet zone (Camp 1963).

Based on shape the primary sedimentation tank is divided into three types.

- Rectangular tank: These are the most widely used tanks. Cost of maintenance is very low in case of rectangular tanks. Also, these are suitable for large capacity. Rectangular basins are least likely to short circuit. In a rectangular tank, the flow takes place lengthwise.
- Circular tank: These type of sedimentation tanks are preferred for continuous vertical flow type of sedimentation tanks. Circular tanks have high clarification efficiency but they are uneconomical as compared to rectangular tanks.
- Hopper bottom tank: In this type of tank, a deflector box which is placed at the top deflects the incoming influent downwards with the help of a central pipe. The collected sludge is disposed using a sludge pump (http://cpcbenvis.nic.in/water_pollution_main.html).

6.2.3 Secondary Treatment

After primary treatment, the wastewater is directed towards secondary treatment, which degrades the biological content of sewage by removing nutrients and remaining solids. Secondary treatment involves use of biological processes. Aerobic microorganisms perform biological treatment in presence of oxygen. These microorganisms consume the organic matter and produce more microorganisms and inorganic end-products. Secondary treatment involves use of sedimentation tanks known as secondary clarifiers. During secondary sedimentation, biological solids called as secondary or biological sludge are removed. Processes involved in secondary treatment include activated sludge process, trickling filters and aerated lagoons and oxidation ponds (http://cpcbenvis.nic.in; http://cpcbenvis.nic.in/water_pollution_main.html; Camp 1963).

Activated Sludge Process

Activated sludge plant involves the following steps

- Wastewater aeration in presence of microorganisms.
- Separation of solids and liquids.
- Discharge of clarified effluent.
- Wastage of extra biomass.
- Remaining biomass is returned to the aeration tank.

Table 5 Classification of surface water and respective water quality standard

Beneficial use	Criteria
Drinking water source without conventional treatment	1. Dissolved Oxygen 6 mg/l 2. BOD (5 days 20 °C) 2 mg/l 3. pH between 6.5 and 8.5 4. Total coliform organism MPN/100 ml must be 50 or less
Outdoor bathing	1. Dissolved Oxygen 5 mg/l 2. BOD (5 days 20 °C) 3 mg/l 3. pH between 6.5 and 8.5 4. Total coliform organism MPN/100 ml should be 500 or less
Source of drinking water after conventional treatment	1. Dissolved Oxygen 4 mg/l 2. BOD (5 days 20 °C) 3 mg/l or less 3. pH between 6 and 9 4. Total coliform organism MPN/100 ml should be 5000 or less
Propagation of wildlife and fisheries	1. Dissolved Oxygen 4 mg/l 2. pH between 6.5 and 8.5
Irrigation and waste disposal	1. pH between 6.0 and 8.5 2. Maximum boron 2 mg/l 3. Maximum sodium absorption ratio 26

In this process, wastewater is aerated in an aeration basin. Microorganisms are added in the waste water, which metabolize the organic matter present in wastewater and form floc. Also, these microorganisms multiply to produce new microorganisms. Wastewater from the aeration tank is transferred to the settling tank, where these stable solids (floc) settle down. This settled organic matter consists of numerous activated microorganisms and is called activated sludge. A part of this settled activated sludge is returned to the aeration tank and the remaining waste activated sludge is removed from the tank and fed to sludge digestor (Camp 1963).

Trickling Filter

Trickling filter is an aerobic treatment process. In this process, the microorganisms which are used for treatment are attached to a medium in order to remove organic matter form wastewater. Microorganisms are attached to material such as rock, sand, redwood and various synthetic materials. Microbes such as bacteria, fungi and algae grow on the filtering medium and are called biological slime. During the process, wastewater is sprayed in the air and is allowed to trickle through the medium. During this the organic matter which is present in the wastewater is metabolized by the biological slime attached to the medium. Thickness of the biological slime increases as the organic matter present in wastewater is synthesized into new cellular material. Eventually, the biological slime layer becomes very thick

Table 6 WHO water quality standards

S. No.	Parameter	WHO guideline (maximum allowable concentration)
1.	Color	15 True Color Units
2.	Turbidity	5.0 NTU
3.	pH	6.5–8.5
4.	Total hardness	500 mg/l
5.	Chlorides	250 mg/l
6.	Dissolved solids	1000 mg/l
7.	Sulphate	400 mg/l
8.	Nitrate	10 mg/l
9.	Fluoride	1.5 mg/l
	Micro pollutants	(Heavy metals and pesticides) (mg/l)
10.	Zinc	5.0
11.	Iron	0.3
12.	Manganese	0.1
13.	Copper	1.0
14.	Arsenic	0.05
15.	Cyanide	0.1
16.	Lead	0.05
17.	Chromium	0.05
18.	Aluminium	0.2
19.	Cadmium	0.005
20.	Selenium	0.01
21.	Mercury	0.001
22.	Sodium	200
23.	Aldrin and dieldrin	0.03
24.	DDT	1.0
25.	Lindane	3.0
26.	Methoxychlor	30.0
27.	Benzene	10.0
28.	Hexachlorobenzene	0.01
29.	Pentachlorophenol	10.0

and gets detached from the surface. This phenomenon of detachment of slime layer is known as sloughing. This detached slime layer and treated wastewater is collected through underdrainage and is passed to a settling tank for separation of solids and liquids (http://cpcbenvis.nic.in/water_pollution_main.html).

6.2.4   Tertiary Treatment

Tertiary treatment is also known as the final or advanced treatment. Tertiary treatment involves removal of organic matter left after secondary treatment. Tertiary

treatment involves removal of different types of pollutants such as suspended solids, nutrients, pathogens, organic matter and heavy metals which are not removed by secondary treatment. In tertiary treatment, the methods/processes used depend on the characteristics of the secondary effluent.

Removal of Nitrogen

The most reduced nitrogen compound found in wastewater is ammonia. Under aerobic conditions, ammonia nitrogen is oxidized biologically to nitrate. Air stripping and biological nitrification and denitrification are the two most common processes used for removal of ammonia.

Air Stripping

This process involves conversion of ammonia to gaseous form and then dispersion of the liquid in air. Thus, leading to transfer of ammonia from wastewater to air. This process is well suited for wastewater with ammonia levels between 10 and 100 mg/l. It depends on the temperature of air and pH of the wastewater. This is a controlled process and produces no backwash. Also, the process is unaffected by toxic compounds (Camp 1963).

Biological Nitrification and Denitrification

Nitrogen is removed biologically by bacteria in a two-step process involving nitrification followed by denitrification.

Nitrification

It is defined as the biological conversion of ammonium to nitrate nitrogen. Nitrification involves two steps. In the first step, bacteria *Nitrosomonas* converts ammonia to nitrite, which in the second step is converted into nitrate by another bacteria called *Nitrobacter.* Nitrification requires long retention rate, sufficient alkalinity and low food to microorganism ratio. The process is also affected by the wastewater temperature and pH.

Denitrification

This process is carried out by heterotrophic bacteria under anaerobic conditions. These bacteria use dissolved oxygen or nitrogen as an oxygen source for oxidation of organic matter. For reduction of nitrogen to occur, the level of dissolved oxygen must be near zero and enough carbon supply must be available to the bacteria. The process is conducted in an aerobic filter.

Removal of Suspended Solids

Removal of suspended solids can be achieved using two techniques, namely micro straining and coagulation and flocculation.

Micro Straining

In a micro strainer, a very fine screen made of stainless steel or plastic is supported by a rotating drum. The wastewater fed into the drum is filtered outwards through the screen. And solids accumulate on the screen inside the drum. These accumulated solids are flushed in a removal trough by a backwash system (http://cpcbenvis.nic.in; http://cpcbenvis.nic.in/water_pollution_main.html; Camp 1963).

Coagulation and Flocculation

Suspended particles vary in size, source, charge and shape. Coagulation process aims at altering the particles in such a way that they adhere to each other. A coagulant neutralizes the charge of suspended particles allowing them to combine together to form large particles. The commonly used coagulant is alum. Once the floc formed has gained appropriate strength and size, the solution is transferred to a settling tank for the process of sedimentation (Camp 1963).

References

Agarwal V, Vaish AK, Vaish P (1997) Groundwater quality: focus on fluoride and fluorosis in Rajasthan. Curr Sci 9:743–746

Aral MM (2009) Water quality, exposure and health: purpose and goals. Water Qual Expo Health 1:1–4

Arora P, Sindhu A, Dilbaghi N, Chaudhury A (2011) Biosensors as innovative tools for the detection of food borne pathogens. Biosens Bioelectron 1:1–12

Atwater H, Polman A (2010) Plasmonics for improved photovoltaic devices. Nat Mater 9:205–213

Bushra R, Naushad M, Adnan R et al (2015) Polyaniline supported nanocomposite cation exchanger: synthesis, characterization and applications for the efficient removal of Pb^{2+} ion from aqueous medium. J Ind Eng Chem 21:1112–1118. https://doi.org/10.1016/j.jiec.2014.05.022

Camp TR (1963) Water and its impurities. Reinhold, New York, p 355

Drinking water—specification, Bureau of Indian Standards (Second Revision of IS 10500). www.mdws.gov.in/sites/default/files/Drinking_water_quality_standards

Drinan JE (2001) Water and wastewater treatment: a guide for the non engineering professionals. CRC Press, US

Durfor CN, Becker E (1964) Public water supplies of the 100 largest cities in the United States. US Geog. Sur. water supply paper 1812, p 364

http://cpcb.nic.in/

http://cpcb.nic.in/water.php

http://cpcbenvis.nic.in

http://cpcbenvis.nic.in/water_pollution_main.html

http://greencleanguide.com/earths-water-distribution-and-indian-scenario/

http://nptel.ac.in/courses/105105048/M13L16.pdf

http://www.sulabhenvis.nic.in

Kumar S, Meena HM, Verma K (2017) Water pollution in India: it's impact on the human health: causes and remedies. Int J Appl Environ Sci 12:275–279

Memon AR, Schröder P (2009) Implications of metal accumulation mechanisms to phytoremediation. Environ Sci Pollut Res 16:162–175

Metcalf and Eddy, Tchobanoglous G, Burton FL, Stensel HD (2003) Wastewater engineering: treatment and reuse, 4th edn. Metcalf & Eddy, Inc. Tata McGraw-Hill

Mittal A, Naushad M, Sharma G et al (2016) Fabrication of MWCNTs/ThO$_2$ nanocomposite and its adsorption behavior for the removal of Pb(II) metal from aqueous medium. Desalin Water Treat 57:21863–21869. https://doi.org/10.1080/19443994.2015.1125805

Murty M, Kumar S (2011) Water pollution in India—an economic appraisal. India Infrastructure Report, pp 286–298

Nabi SA, Naushad M, Bushra R (2009) Synthesis and characterization of a new organic—inorganic Pb^{2+} selective composite cation exchanger acrylonitrile stannic (IV) tungstate and its analytical applications. NANO 152:80–87. https://doi.org/10.1016/j.cej.2009.03.033

Pathak AK (2013) Water pollution and treatment. Int J Environ Eng Manage 4:191–198

Pontius FW (1990) Water quality and treatment, 4th edn. McGraw-Hill Inc., New York