Consortium for Educational Communication

Module on

WATER TESTING

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Text:

Introduction:

Water is important to the food processing industry because it is not only present in all foods, but, is also extensively used in most food plants as a processing aid and for cleaning operations. When water is used as a food ingredient, its quality (e.g. impurities) can affect the properties of foods including texture, shelf stability, appearance, aroma and flavour. As a processing aid, water may be used for conveying, heating, cooling, rinsing, dissolving, dispersing, blanketing, diluting, separating, steam generation and other activities. In each case, purity of the water will affect its performance. For example, hardness (minerals in water) may deposit on equipment surfaces in an evaporative cooler or reduce water's ability to dissolve and disperse food ingredients. Cleaning activities in the food industry involve the use of water as a carrying agent, dispersant, solvent and diluent. However, everyone is aware about the difficulties in handling of hard water for making the detergent suspensions.

Critical agents that deteriorate the water quality, when talking about food industry, can be distinguished in microbiological contaminants, chemical contaminants and physical contaminants. The risks associated with the use of water contaminated by one or more of such agents in different foods may include:

- Presence of the pathogens of faecal or non-fecal origin that cause food-borne illnesses. It may include following:

a) Bacterial pathogens, e.g. *Vibrio cholerae*, *Salmonella typhi*, *Shigella* spp. *Campylobacter* spp. and pathogenic strains of *E. coli.*

b) Viruses, especially enteroviruses (including Rotavirus, Norwalk, Small Round, Calciviruses, Adenoviruses, Hepatitis A).

c) Protozoa, especially *Giardia* spp., *Cryptosporidium* spp., *Cyclospora* spp. and *Entamoeba histolytica* and;

d) Algae that are chiefly responsible for the eutrophication.

- Presence of the harmful chemicals.
- Presence of chemicals that are not harmful but have a concentration above their allowable daily intake (ADI).

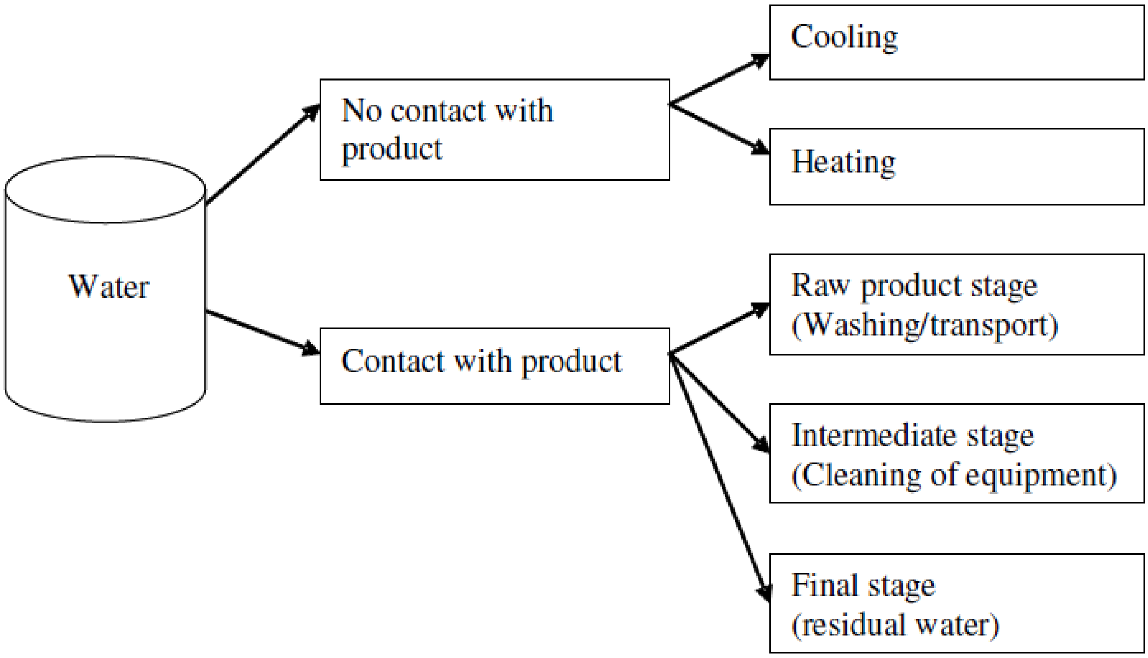
In order to minimise such risks an approach of formalising quality assurance programmes for drinking water supplies has recently emerged. It included the approaches based on testing the generic quality (ISO 9001 Quality Standard) and application of the Hazard Analysis and Critical Control Point (HACCP) principles (Havelaar, 1994) which were formally codified by The National Advisory Committee on Microbiological Criteria for Foods (NACMCF, 1998). In this scenario, testing the quality of water plays the main role for hazard identification and for taking the corrective measures.

Water quality requirements in food industry:

Food industry has a high demand for clean and fresh water. Access to an abundant source of high quality water is one of the essential factors in designing a food plant. Water is often a direct ingredient in food and drink. The quality of water can have significant impact on the safety, quality and taste of products. The principal concerns related to water quality in the food and beverage industries are:

- Microbiological control and product safety;
- Reducing the formation of scale and deposits;
- Maintaining product integrity;
- Lowering overall production costs.

Due to the importance of consumer health, microbiological control and product safety has an especially high precedence among the other criteria of water quality, while reducing the formation of scale and deposits is generally a well-documented issue for protection of machinery and pipelines. On the other hand, product integrity best demonstrates the quality of a food product in terms of its organoleptic characteristics. In general, the uses of water in different sectors of food industry can be classified into two main categories depending on whether the water comes into contact with food product(s) or not. The examples where water has no direct contact with the foods include the use in heating/cooling and for the generation of "non-food steam". On the other hand, the instances where water has contact with foods may be at the raw product stage (e.g. washing or transport), at intermediate stages (e.g. cleaning of equipment), or in the final product itself (i.e. residual water or as an ingredient) as shown in figure (Fig A)



below:

Fig A: Diagrammatic representation of the types of applications of water in food industry.

Precisely, quality parameters of water for the different production systems can be discussed under four subheadings which describe its most intended applications. These include the uses of water as a food ingredient, as bottled water, for washing and rinsing, for blanching and, for culinary steam. The quality criteria of water for these five categories of applications are briefly discussed below:

1. **Water used as a food ingredient:**

Water is often a direct ingredient in food and drink. The quality of water can have significant impact on the safety, quality and taste of products. When water is used as an ingredient in food, it must be free from undesirable taste, odour, color and impurities that could be harmful to consumers and product quality. In addition, it must be free from physical, chemical and microbiological hazards. Ordinary tap water that is meeting the safe drinking water standards may not achieve these qualifications. In general, the off-odour or off-flavour in water may be due to excess chlorination treatment, algal growth, effluent discharges and oil spillages. Sometimes, astringent tastes can also be caused by the presence of excessive amounts of metals or dissolved salts. It is observed that organoleptic taste problems arise most commonly from algae and from phenols after chlorination. Decaying algal masses can release trace organic compounds (including phenolic substances) to the water which produce offensive tastes after chlorination treatment.

Raw water can be contaminated with pathogens, usually as a consequence of human or animal faecal material or run-off contaminated with faecal material. It can also be contaminated with a wide range of chemicals, both natural and anthropogenic, which are of concern under some circumstances depending on the concentrations present. The chemical and microbiological hazards in water generally arise from the disposal of untreated sewage containing high microbial load and toxic chemical residues in the water bodies by various industries and the agricultural sector. Water can serve as a vehicle for transmission of microbial contamination and chemical pollutants with endocrine-disrupting activity (Burger & Nel 2008) posing a serious health risk to humans and animals. The former include *Escherichia coli, Shigella spp., Salmonella spp*. and protozoan parasites such as *Cryptosporidium hominis* and *Giardia lamblia* species. Most of these are important pathogens since they can cause diarrhoea in humans and animals, which may result in the death of immune compromised individuals, children with malnutrition, transplant recipients, patients receiving chemotherapy for cancer and patients with immunosuppressive infectious diseases (Fayer et al. 2000).

2. Bottled Water

Bottled water is generally required to be bacteria-free. In order to achieve this, many bottled water processors use ozonation to disinfect the water, since it has a little effect on taste. Ultra-violet treatment may also be used and is frequently included as a backup measure. Reverse osmosis (RO) removes 99.9 percent of all viruses, bacteria and pyrogens and is more energy efficient compared to distillation processes. However, its drawbacks include removal of "good" minerals, low speed and wasting of two to three parts of water for every part purified (Everpure, 2012).

3. Water for washing and Rinsing

Washing is one of the major stages in the food industry that involves the selective removal of unwanted compounds from a substance using a solvent. For washing to be successful the unwanted materials must be more soluble in the solvent than in their current state. Water is the common solvent used in industrial washing processes. Washing and rinsing requires clean and soft water. Mild taste and odour issues are probably not as important as they are for the former cases. Its hardness should be removed along with the mineral content that could affect the additive performance. This is especially important for the better performance of soaps, cleaners and sanitizers.

4. Water for blanching

Blanching is a mild heat treatment given to fruits and vegetables for a short time with either steam or water, and is an essential step before canning, drying or freezing of food. It is given to fresh horticultural commodities to inactivate certain enzymes that would otherwise adversely affect the nutrient content, colour, flavour or texture during subsequent processing and storage. One of the most widespread commercial methods of blanching involves passing fruits and vegetables through a bath of hot water. Water used for this purpose is required to be free from thermophilic bacteria. It must satisfy the adequate hygienic standards for both the product and equipment. Knowledge of the added chemicals to blancher water can also contribute in determination of acceptable quality for the process, for example, sodium carbonate (0.125 % w/w) or calcium oxide is often added to blancher water to protect chlorophyll and to retain the colour of green vegetables.

5. Water for generation of culinary steam

Culinary (or sanitary) steam is safe for direct injection into a product or more precisely for the contact with product. Water for culinary steam may be one of the most difficult treatment cases in the food industry. Boiler feed water should be thoroughly treated to prevent problems in boilers and associated piping, valves and processing equipment. Corrosive components, like oxygen and carbon dioxide, may be removed by deaeration. In addition the pH adjustment is essential for this application. Boiler water pH should be maintained at about 8.5 (Cleanboiler.org, 2012) and may require the addition of chemicals.

Quality requirements for boiler feed makeup water are actually dependent upon the pressure at which the boiler is operated. Generally the higher the pressure, the higher the quality of water required. Very high-pressure boilers require makeup water of distilled quality. In general, even potable water must be treated to reduce the hardness of the boiler-feed water close to zero. Removal or control of insoluble salts of calcium and magnesium and control of silica and aluminium are required since these are the principal causes of scale build-up in boilers. In addition, high alkalinity may contribute to foaming, resulting in deposits in super heater, re-heater and turbines. Bicarbonate alkalinity under the influence of boiler heat, may also lead to the release of carbon dioxide, which is a source of corrosion in steam-using equipment.

Need for water testing:

Food producers, processors and caterers need to ensure that the use of water in their premises is maintained to the highest possible standards. Water is used for many operations and all operatives and contractors must be adequately trained in appropriate water usage and the controls needed, in order to ensure that water does not become a source of contamination. It is, therefore, vital to minimise the risks and avoid unnecessary harm by ensuring that the necessary control measures are put in place, e.g. water safety plans and Hazard Analysis and Critical Control Point (HACCP).

Water quality requirements are a function of the type of food, processing conditions and methods of final preparation in home (cooked/uncooked). They are also dictated by the use of water within a particular process or processes. If the water is potable, then it is probably acceptable for all food contact uses. Potable water also known as drinking water or improved drinking water may be defined as "the water that is safe to drink or to use for food preparation without the risk of health problems." This water should meet the requirements of local standards for safe drinking water as recommended by WHO or BIS. In order to ensure the safety and quality standards of water for the specific applications, its testing is highly essential for every sector and subsector of food industries.

Different types of te,sts conducted: Different types of tests conducted to assess the water quality include:

1. **Bacteriological examination**

The principal risk associated with water is that of infectious disease(s) related to faecal contamination. Hence, the microbiological examination of drinking-water emphasizes the assessment of hygienic quality of the supply. This requires the isolation and enumeration of organisms that indicate the presence of faecal contamination. In certain circumstances, the same indicator organisms may also be used to assess the efficiency of drinking-water treatment plants, which is an important element of quality control. Other microbiological indicators, not necessarily associated with faecal pollution, may also be used for this purpose. Commonly used methods for bacteriological examination of water include multiple-tube method, membrane-filtration method, presence–absence test and single-application (disposable) test kits.

a) **Membrane-filtration method**

In the membrane-filtration (MF) method, a minimum volume of 10 mL of the sample is introduced aseptically into a sterile or properly disinfected filtration assembly containing a sterile membrane filter (of 0.2 or 0.45 micrometer diameter). A vacuum is applied and sample is drawn through the membrane filter. All indicator micro-organisms are retained on or within the filter, which is then transferred to a suitable selective culture medium in a Petri dish. Following a period of resuscitation, during which the bacteria become acclimatized to the new conditions, the Petri dish is transferred to an incubator at the appropriate selective temperature where it is incubated for a suitable time to allow the replication of the indicator micro-organisms. Visually identifiable colonies are formed and counted, and the results are expressed in numbers of "colony forming units" (CFU) per 10 ml of original sample. This technique is inappropriate for waters with a high level of turbidity that would cause the filter to become blocked before an adequate volume of water had passed through.

b)Multiple-tube method

The multiple-tube method depends upon the separate analysis of a number of volumes of the same sample. Each volume is mixed with culture medium and incubated. The concentration of microorganisms in the original sample is then estimated from the pattern of positive results (the number of tubes showing growth in each volume series) by means of statistical tables that give the "most probable number" per 100 ml of the original sample. Therefore, it is also referred to as the most probable number (MPN). This test is essential for highly turbid samples that cannot be analysed by membrane filtration. The technique is used extensively for drinking-water analysis. However, the multiple tube method may be more sensitive than membrane filtration.

c) Presence–absence tests

Presence–absence tests are qualitative tests that indicate only the presence or absence of the indicator microorganism sought. The use of such tests is appropriate only where positive results are known to be rare as these are not meant to quantify the degree of contamination. Consequently, presence-absence tests have a very little use particularly in countries or situations where contamination is common and the purpose of analysis is to determine the extent of contamination rather than whether or not the contaminant is present. These are not recommended for use in the analysis of surface waters, untreated small-community supplies, or larger water supplies that may experience occasional operational and maintenance difficulties.

d) Single-application (disposable) test kits:

Disposable test kits provide the results of qualitative as well as quantitative microbial contamination very rapidly. These are both widely marketed and increasingly used in developed countries. However, their reliability may vary widely and should be properly assessed by a reference laboratory.

e) Heterotrophic plate count (HPC):

Heterotrophic Plate Count, formerly known as 'standard plate count', 'total viable count', 'total count', 'plate count', ''total bacterial count', 'water plate count', 'colony count' or 'aerobic mesophilic viable count', is a technique used for estimating the viable heterotrophic bacterial population in the sample of water. It includes testing and enumerating the presence of aerobic as well as facultative anaerobic bacteria. The term "heterotrophic bacteria" includes all bacteria that use organic nutrients for growth. Heterotrophic plate count (HPC) bacteria, on the other hand represent those microbes isolated from water by a particular method, whose variables include media composition, time of incubation, temperature of incubation, and means of medium inoculation.

The general principle of this method is that a sample of water is put on the petri plate that contains nutrient media required by bacteria for growth and survival. The nutrient media that is most often used for this test is called R2A Agar, which is a gelatine-like substance, best suited to the needs of water bacteria. After 5-7 days of incubation, the number of small spots on the plate, called colonies, is counted and a measure of how many bacteria are present in each millilitre of water is determined. The HPC results are generally reported as Colony Forming Units per millilitre or CFU/mL. Each colony-forming unit represents an initial single, live bacterium that was capable of multiplying until it could be observed on the plate. It is important to understand that the colony count alone does not allow one to draw conclusions about the risks to public health. However, it currently serves as a relatively easy way to measure filtration and disinfection efficiency, as well as the estimated numbers of bacteria in areas that have the potential for increased contamination. Some important concepts about heterotrophic plate count are given below:

a) **Media and methods:** Based on decades of research with a variety of HPC media and methods, the following observations have been made:

- All media used for HPC determinations, along with respective time and temperature conditions, are ''selective'' for those bacteria that can grow under those specific conditions.
- There is no single medium or method that will recover or enumerate all bacteria in the water being analyzed.
- Many heterotrophic bacteria that are present in water are not culturable at present.
- Both high-nutrient and low-nutrient media can be used for HPC determinations. However, low-nutrient media are better for enumeration of water-based bacteria (autochthonous) found in aquatic systems, including drinking water. The most commonly employed heterotrophic medium is R2A. It was designed specifically as a low-nutrient, low-ionic strength formulation to isolate bacteria that have a water-based, rather than mammalian lifestyle (Reasoner, 1990).

b) **Time and temperature of incubation:** These are very significant variables for HPC. High-temperature incubation (35–37 □C) and short incubation time (34–48 h) favors the growth of bacteria from animals and humans while low-temperature incubation (20–28 □C) and longer incubation time (5–7 days) favor the growth of water-based bacteria.

c) **Standard methods:** There are three different standard methods of bacterial enumeration in HPC, i.e., pour-plate, spread plate and membrane filtration methods. The pour plate method generally yields lower bacterial counts regardless of medium or time of incubation and is generally limited to 0.1 to 1.0 mL sample volume. The spread plate method generally yields higher counts than other methods but is limited to a 0.1 to 1.0 mL sample volume. The membrane filtration method is more flexible because it allows for the analysis of sample volumes greater than 1.0 ml.

d) **HPC genera found in drinking water:** There is a significant body of information in the literature on genera that comprise HPC populations enumerated in drinking water using different methods. The average upper range of HPC populations in drinking water is estimated to be 5000–10,000 CFU/mL (Reasoner, 1990). Some commonly found genera include *Acinetobacter, Methylomonas, Actinomycetes, Micrococcus, Alcaligenes Mycobacterium, Aeromonas, Morexella, Nitrosomonas, Proteus, Pseudomonas, Corynebacterium, Enterobacter, Serratia, Escherichia coli, Sphingomonas, Flavobacterium, Staphylococcus, Streptococcus, Gallionella* and *Klebsiella pneumonia*. Different bacteria pose various risks to public health. Micro organisms recovered through HPC tests generally include those that are a part of the natural (typically non-hazardous) microbial flora found in water. Some predominant bacterial species detected in drinking water, as well as the doses that would need to be ingested to cause an infection are outlined in the table below:

Bacterial species	Infectious Dose (Ingested)
Pseudomonas aeruginosa	10^8-10^9 CFU
Aeromonas hydrophila	>10^{10} CFU
Mycobacterium avium	10^4-10^7 CFU
Xanthomonas maltophila	10^6-10^9 CFU

A higher risk exists for those people with a depleted immune system, such as the elderly and infants, or those with HIV. Those people on antibiotics also seem to be at an increased risk for infection following ingestion. Some of the HPC bacteria found in drinking water can cause other problems such as skin and wound infections in the consumers.

2. Physicochemical analysis

a) Chlorine residual

Chlorine is the principal disinfecting agent used for water treatment in most countries due to the advantages like relative cheapness, efficacy, and ease of measurement, both in laboratories and in the field. However, the presence of free chlorine which forms the most reactive species like hypochlorous acid and the hypochlorite ion in water must be monitored. The method recommended for the analysis of chlorine residues in drinking water employs *N*,*N*-diethyl-*p*-phenylenediamine, more commonly referred to as DPD. The addition of DPD to the water causes the generation of colour which can be measured spectrophotometrically. Most commonly colour generated is matched against the standard coloured discs or tubes. The method can be used by staff without extensive specialized training. In addition, analysis can also be made using starch–potassium iodide which is not specific for free chlorine, but measures directly the total of free and combined chlorine. It is, therefore, not recommended except in countries where it is impossible to obtain or prepare DPD.

b) pH

It is important to measure pH of water besides the chlorine residues since the efficacy of disinfection with chlorine is highly pH-dependent. In case the pH of the treated water exceeds 8.0, disinfection is less effective. To check that the pH is in the optimal range for disinfection with chlorine (less than 8.0), simple tests may be conducted in the field using comparators such as those used for chlorine residues. With some chlorine comparators, it is possible to measure pH and residual chlorine simultaneously. Alternatively, portable pH electrodes and pH meters are now available that provide the reproducible and precise information about the pH of the sample. However, if these are used in the laboratory, they must be calibrated against fresh pH standards at least daily and immediately before each test.

c) Turbidity

High levels of turbidity can protect microorganisms from the effects of disinfection, stimulate the growth of bacteria, and exert a significant chlorine demand. Where disinfection of water is practised, the turbidity must always be low, e.g. below 5 nephelometric turbidity units (NTU) or more specifically below 1 NTU for effective disinfection. Measurement of turbidities lower than 5 NTU will generally require the electronic meters while those above 5 NTU can be measured by simple extinction methods, which are far cheaper and require no consumables. In the monitoring of small community water supplies in developing countries, such methods may be more preferable.

d) Alkalinity

Alkalinity is a chemical measurement of the ability of water to neutralize acids. In natural waters, alkalinity is due to the presence of weak acid salts, carbonate and bicarbonate species with the set of chemical equilibria as shown below:

$$CO_2 + H_2O \Leftrightarrow H_2CO_3^*$$
$$H_2CO_3 \Leftrightarrow HCO_3^- + H^+$$
$$HCO_3^- \Leftrightarrow CO_3^{2-} + H^+$$

In addition, strong bases that contribute the hydroxyl ions (OH^-) and salts of weak acids, such as borate, silicates, ammonia, phosphates, and organic bases from natural organic matter, may be present in small amounts in alkaline water. The major sources of alkalinity to water is partitioning of CO_2 from the atmosphere and the weathering of carbonate minerals in rocks and soil. Therefore, alkalinity, by convention, is reported in terms mg/L $CaCO_3$.

There is no health based standard for the hardness of drinking water. However, The World Health Organisation Guidelines (2004) has identified that water with the hardness value of 200 mg/L or higher will produce scale and soft water with a value of 100 mg/L or less will have a low buffering capacity and, will be more corrosive to pipes. Where water companies artificially soften water before putting it into supply, it is recommended that they maintain a minimum total hardness of 150 mg/L (as calcium carbonate). This is because there is some limited evidence of a relationship between water hardness and cardiovascular health which may be related to the beneficial properties of magnesium and calcium in the diet. In spite of that, knowledge of alkalinity of water may be important because:

(1) The alkalinity of a body of water provides information about how sensitive that water body will be to acid inputs such as acid rain.

(2) Turbidity is frequently removed from drinking water by coagulation and flocculation. This process releases H^+ ions into the water. Alkalinity must be present in excess of that destroyed by the H^+ ions released for effective and complete coagulation to occur.

(3) Hard waters are frequently softened by precipitation methods. The alkalinity of the water must be known in order to calculate the lime ($Ca(OH)_2$) and soda ash (Na_2CO_3) requirements for precipitation.

(4) Knowledge of alkalinity is important to control corrosion in piping systems.

(5) Bicarbonate and carbonate in alkaline water may complex with other elements and compounds, altering their toxicity, transport, and fate in the environment.

To determine the alkalinity, a known volume of water sample is titrated with a standard solution of strong acid to a pH value in the approximate range of 4 to 5. Titrations can distinguish between three types of alkalinity i.e., carbonate, bicarbonate, and total alkalinity. Carbonate alkalinity is determined by titration of the water sample to the phenolphthalein indicator endpoint, or approximately a pH of 8.3. Total alkalinity is determined by titration of the water sample to the endpoint of the methyl orange indicator, or an approximate pH of 4.5. The difference between the two is the bicarbonate alkalinity.

3. Aesthetic parameters

Aesthetic parameters of water include colour, taste and odour. They are important in monitoring community water supplies because they may cause the water supply to be rejected. Some aesthetic quality parameters of water include:

a) Colour

Colour in drinking-water may be due to the presence of coloured organic matter, e.g. humic substances, metals such as iron and manganese, or highly coloured industrial wastes. Drinking-water should be colourless. For the purposes of surveillance of community water supplies, it is useful simply to note the presence or absence of observable colour at the time of sampling. Changes in the colour of water and the appearance of new colours serve as indicators that further investigation is needed.

b) Taste and odour

Generally, the taste buds in the oral cavity detect the inorganic compounds or metals such as magnesium, calcium, sodium, copper, iron, and zinc. As water should be free of objectionable taste and odour, it should not be offensive to the majority of the consumers. If the sampling officer has a reason to suspect the presence of harmful contaminants in the supply, it is advisable to avoid direct tasting and swallowing of the water. Under these circumstances, a sample should be taken for investigation to a central laboratory.

An important test related to the odor detection of contaminated water is determination of Threshold Odor Number (TON). Threshold Odor Numbers are whole numbers that indicate how many dilutions by fresh water are required to make the contaminated water odor-free. Contaminated water that has the detectable odor is made odor-free by sufficient dilution with fresh water. It is the most widely used sensory test in the water industry for about 50 years. According to the US Environmental Protection Agency, TON of the contaminated water should not exceed '3'.

4. **Other analyses of relevance to health**

Although, the great majority of quality problems with community drinking-water are related to faecal contamination, a significant number of serious problems may occur as a result of chemical contamination from a variety of natural and man-made sources. In order to establish whether such problems exist, chemical analyses must be undertaken. However, it would be extremely costly to undertake the determination of a wide range of parameters on a regular basis, particularly in the case of supplies that serve small numbers of people. Some of these health-related parameters include fluorides, nitrates, lead, chromium, arsenic and pesticides. If these or any other chemicals of health significance are thought to be present, they should be monitored and examined in the light of the WHO guideline values or any relevant national standards already established. These parameters may be measured by means of portable test kits based on conventional titrations, comparators, or photometers. If this is done, the reagents must be of high quality and carefully standardized. Other parameters require conventional laboratory analysis by spectrophotometry, atomic absorption spectroscopy, or chromatography, using standard methods.

Some basic concepts:

- **Determination of threshold odour number (TON)**: The current procedure in *Standard Methods* (1998) uses odor-free water to dilute the water sample to be tested. As described in Standard Methods for the Examination of Water and Wastewater, the test involves two steps. In step one, 200 mL, 50 mL, 12 mL, and 2.8 mL of test sample (contaminated water) is taken in four separate 500 mL flasks. The test water in each flask is diluted by odor-free water to create a total volume of 200 mL. A blank is also taken in another flask filled with only odor-free water. The flasks are heated to 40-60°C with stirring. Starting with the odor-free water and proceeding from lowest to highest concentration of sample water, each flask is smelled to detect the odor. In step two, the first dilution in which the odor was detected is determined and TON is calculated using the formula given below:

$$\text{Threshold Odor Number} = \frac{A + B}{A}$$

Where, A = the volume of sample water and B = the volume of odor-free water. Since A + B is always going to equal 200 mL, the calculation can be restated as:

$$\text{Threshold Odor Number} = \frac{200\text{ mL}}{\text{Sample Volume, mL}}$$

For example, if the first dilution in which the odor could be detected contained 5 mL of the sample water, the TON would be (195 mL + 5 mL) divided by 5 mL, or TON = 40. It is important to note that the TON is not a measure of odor intensity, but a measure of an odorous compound's persistence upon dilution.

- **Amenity use:** Certain criteria have been established in some countries that aim at the protection of the aesthetic properties of water. These criteria are primarily orientated towards visual aspects. They are usually narrative in nature, for example, waters must be free of floating oil or other immiscible liquids, floating debris, excessive turbidity, and objectionable odours.
- **Green water:** It refers to rainfall used by agricultural crops, pasture, forestry and natural vegetation. The majority of agricultural production worldwide is based on consumption of green water.
- **Blue water:** It refers to water abstracted from rivers, lakes, reservoirs and groundwater which is used in agriculture for irrigation of

agricultural crops, agricultural operations and watering livestock.

- **Common tests used for quantitative analysis of water:**

Quantitative water analysis	Purpose	Scale	Normal value
pH	Relative acidic or basic level of the solution. [hydrogen ion concentration]	0 to 14 with a pH of 7 as neutral; 0 more acidic; and 14 more basic. The scale is logarithmic, meaning that a pH of 9 is 10 times more basic than a pH of 8.	Surface water: 6.5 to 8.5 Groundwater: 6 to 8.5
Total Solids (TS)	Sum of total dissolved solids (TDS) and suspended solids (TSS) in water.	Measured in weight per volume of water; e.g. mg/l	up to 500 mg/l (WHO, 2003)
Conductivity (Ionic Contamination)	Measurement of total dissolved solids (TDS)	Conductivity meter, which measures electrical conductivity of water in Seimens/m	Drinking water: 0.005 to 0.5 S/m (www.lenntech.com)
Resistance (Ionic Contamination)	Measurement of ionic contamination	Resistivity meter, which measured electrical resistivity of water in ohms·cm (resistance is the inverse of conductivity)	1.8 to 200 Ω/m
Total Bacterial Count	Measure of total viable (can proliferate) organisms in water	Colony forming units (CFU) of organisms per volume of water	100 CFU/ ml
Pyrogens	Amount of substances that can produce a fever in mammals (normally produced by bacteria)	Endotoxins units (EU) per volume of water	Water for injection: 0.25 EU/ml (USP, 1995)
Total Organic Carbon (TOC)	A measurement of the organic material contamination present in water	Measured weight per volume of water (e.g. mg/l)	0.05 mg/l (USEPA, 1991)
Biochemical Oxygen Demand (BOD)	Amount of dissolved oxygen needed to meet the demand of aerobic microorganisms in water	Measured in weight of dissolved oxygen per volume of water (e.g. mg/l)	1 mg/l
Chemical Oxygen Demand (COD)	Amount of dissolved oxygen required to cause chemical oxidation of the organic material in water	Measured in weight of dissolved oxygen per volume of water (e.g. mg/l)	10 mg/l (hannainst.com)

- **Quality criteria and standards for drinking water:** Various agencies like United States Environmental Protection Agency (USEPA), World Health Organization (WHO), Bureau of Indian Standards (ISI), Indian Council of Medical Research (ICMR) and Central Pollution Control Board (CPCB) have provided different recommendations regarding the quality criteria and standards for drinking water. Some of them are listed below:

Parameters	USEPA	WHO	ISI	ICMR	CPCB
pH (mg/L)	6.8-8.5	6.8-8.5	6.8-8.5	6.5-9.2	6.8-8.5
Turbidity NTU	-	-	10	25	10
Conductivity (mg/L)	-	-	-	-	2000
Alkilinity (mg/L)	-	-	-	-	600
Total hardness (mg/L)	-	500	300	600	600
Iron (mg/L)	-	0.1	0.3	1.0	1.0
Chlorides (mg/L)	250	200	250	250	1000
Nitrates (mg/L)	-	-	45	45	100
Sulphates (mg/L)	-	-	150	150	400
Residual free chlorine (mg/L)	-	-	0.2	0.2	-
Calcium (mg/L)	-	75	75	200	200
Magnesium (mg/L)	-	50	30	-	100
Copper (mg/L)	1.3	1.0	0.05	1.5	1.5
Fluoride (mg/L)	4.0	1.5	0.6-1.2	1.5	1.5
Mercury (mg/L)	0.002	0.001	0.001	0.001	No relaxation
Cadmium (mg/L)	0.005	0.005	0.01	0.01	No relaxation
Selenium (mg/L)	0.05	0.1	-	-	No relaxation
Arsenic (mg/L)	0.05	0.05	0.05	0.05	No relaxation
Lead (mg/L)	-	0.05	0.10	0.05	No relaxation
Zinc (mg/L)	-	5.0	5.0	0.10	15.0
Chromium (mg/L)	0.1	-	0.05	-	No relaxation
E. coli (MPN/100 mL)	-	-	-	-	No relaxation