Authors: Damla BAYKAL

Gamze YÜCEL IŞILDAR

PURE-H2O DRINK PURIFIED H2O!

CHAPTER 3
QUALITY STANDARDS FOR DRINKING WATER TREATMENT PLANTS

3.1. Definition of Water Quality

Water has two closely linked dimensions: quantity and quality. Water quality is an important concept related to all aspects of ecosystems and human well-being such as the health of a community, food to be produced, economic activities, ecosystem health and biodiversity.

The quality of an aquatic environment can be defined as the set of concentrations, speciations, and physical partitions of inorganic or organic substances, the composition and state of aquatic biota in the water body and the description of temporal and spatial variations due to factors internal and external to the water body (http://www.who.int).

In other words, water quality refers to the condition of the water, including chemical, physical, and biological characteristics, usually relative to the requirements of one or more biotic species and/or to beneficiary use of water to any human need or purposes. Water quality helps ecological processes to sustain. Good water quality supports native fish populations, vegetation, wetlands and birdlife and poor water quality can pose health risk for people and for ecosystems. Besides, many human uses depend on water quality that is suitable for drinking, irrigation, recreation (swimming, boating), industrial processes, navigation and shipping, production of edible fish, shellfish and crustaceans, scientific study and education, etc.

Each freshwater body has an individual pattern of physical and chemical characteristics largely determined by the climatic, geomorphological and geochemical conditions of its drainage basin and the underlying aquifer. It should to be noted that water usually returns back to the hydrological system after its use and if discharged untreated, it can severely affect the environment. Thus, water quality is closely linked to the surrounding environment and land use. Water is affected by human uses such as agriculture, urban and industrial use, and recreation. Changes in water quality, including increases in levels of specific nutrients, can have serious adverse effects on aquatic life, thus in wildlife and eventually on human nature. Aquatic ecosystems play a crucial role in maintaining water quality. They are valuable indicators of water quality. If water quality is not maintained, the environment will suffer and the commercial and recreational value of our water resources will diminish, as well. Research studies indicate that worldwide water quality is declining mainly due to human activities. Increasing population growth, rapid urbanization, discharge of new pathogens and new chemicals from industries and invasive species are the main factors that contribute to the deterioration of water quality. In addition, climate change will further affect water quality.

From a management point of view, water quality is defined by its desired end use. Water for recreation, fishing, drinking, and habitat for aquatic organisms require higher levels of purity, whereas for hydropower, quality standards are much less important. It is important to know that different beneficial uses have different needs and thus, there is no single measure that constitutes good water quality. For example, while water that is suitable for drinking purpose can be used for irrigation, water used for irrigation may not meet drinking water standards. However, fish and wildlife have other requirements. Fish need water that contains enough oxygen and nutrients since they get all of their oxygen and food from water. Therefore depending on the beneficiary use, we use guidelines, and standards must be met accordingly. For instance, the first edition of guidelines for drinking water quality was published by World Health Organisation (WHO) in 1984-1985 and was intended to supersede earlier European and international standards.

The standards are also set by the national agencies based on their political and technical/scientific decisions about how the water will be used and referred to their international commitments where exist. There are also international standards such as regulations of International Organization for Standardization (ISO) which is covered in the section of ICS 13.060. The European Union has established a framework for Community Action in the field of water policy in the EU Water Framework Directive (Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000). The primary objective of the directive is to prevent further water deterioration and to implement the necessary measures to achieve "good water status" in all EU waters by 2015.

Water quality guidelines and standards provide basic scientific information about water quality parameters and ecologically relevant toxicological threshold values to protect specific water uses. The most common standards used to assess water quality are related to health of ecosystems, safety of human contact and drinking water. Drinking Water Regulations are health-related standards that establish the Maximum Contaminant Levels. Drinking water should not present a risk of infection, or contain unacceptable concentrations of chemicals hazardous to health and should be aesthetically acceptable to consumer. The control of the feacal pollution depends on being able to access the risk from any water source and to apply suitable treatment to eliminate the identified risks.

In order to describe and access water quality of a river, stream, lake, groundwater or marine environment, we need to have parameters that can be measured. Measurements of these parameters can be used to determine and monitor changes in water quality, and determine whether it is suitable for the health of the natural environment and the required uses. Water quality is measured by several factors, such as the concentration of dissolved oxygen, bacteria levels, the amount of salt (or salinity), or the amount of material suspended in the water (turbidity). In some water bodies, the concentration of microscopic algae and quantities of pesticides, herbicides, heavy metals, and other contaminants may also be measured to determine water quality. These parameters are mainly categorized under physical, chemical, and biological properties of water.

Water quality is determined by measurements on site and by in situ examination of water samples or in the laboratory. Thus, on-site measurements, the collection and analysis of water samples, the study and evaluation of the analytical results, and the reporting of the findings are the main elements of water quality monitoring. The results of analyses conducted on a single water body are only valid for the particular location and time at which that sample was taken. To gather sufficient data (by means of regular or intensive sampling and analysis) to assess spatial and/or temporal variations in water quality is therefore one of the purposes of a monitoring programme.

Physical measurements are those that include water temperature, depth, flow velocity and turbidity. These are all useful in analysing how pollutants are transported and mixed in the water environment, and can be related to habitat requirements for fish and other aquatic wildlife. For example, many fish have very specific temperature requirements, and cannot tolerate water that is either too cold or too hot.

With chemical measurements we measure concentrations of wide range of chemicals and chemical properties. Test results are defined as milligrams of chemical per liter of water (mg/l). Chemical water quality studies focus on the chemicals that are most important for the problem at stake, since even the purest water contains countless chemicals and it would be impossible to measure all of them. Therefore; while in agricultural areas, studies measure chemicals found in manure, fertilizers, and pesticides, in an industrial area studies focus on measuring chemicals used by the nearby industries.

With bacteriological analysis we measure the hygienic quality of water. The bacteriological quality of a water body is very important especially when we use the water body for drinking purposes.

To assess a water body in terms of quality, it is essential to gain a water quality data obtained in several intervals (monthly, seasonally, and annually) and monitor the changes of parameter values to point out the variations immediately after a specific intervention. The lack of water quality data and monitoring worldwide as well as lack of knowledge about the potential impact of natural and anthropogenic pollutants on the environment and on water quality is one of the major problems to define and solve water pollution problem. In many countries, the lack of prioritization of water quality has resulted in decreased allocation of resources, weak institutions and lack of coordination in addressing water quality challenges. Considering approximately 25% of the world's population has no access to potable water, water quality is at most importance in human health.

Monitoring the water bodies is particularly important to point out the reliability of source accessed for public use especially for drinking purposes. Water quality measurements for drinking purposes generally focus on health of the community and aestethic aspects. It should be ensured that the water intended for human consumption can be consumed safely on a life-long basis, and this represents a high level of health protection. Monitoring and control technologies provide the surveillance of source water quality and the detection of biological and chemical threats. They lead us to define the boundary conditions for the subsequent treatment and provide early warning in case of unexpected contaminations. They are mandatory for the high quality of finished water in treatment processes. Moreover, detection of changes in water quality during distribution and monitoring drinking water quality at consumers' tap is essential. Water quality deterioration in distribution systems, mainly caused by inappropriate planning, design and construction or inadequate operation and maintenance and water quality control, may be the cause of waterborne and water-related illness. Rapid urbanization, population growth and aging of infrastructure stress the distribution sysytems.

To ensure the water quality, the standards should be based on the latest scientific evidence and efficient and effective monitoring, assessment and enforcement of drinking water quality should be secured.

3.2. Physical and Chemical Quality of Water

Physical characteristics of water like temperature, colour, taste, odour and etc. can be determined by senses of touch, sight, smell and taste, together with adequate instruments. For example; by touching we can have an idea of its temperature, by smelling, its taste and odour, and we see the colour, floating debris, light penetration, turbidity and suspended solids. In general, the physical characteristics of water are not directly concerned for public health but they affect the aesthetic quality of the water. However, these affect the consumers' perception and behaviour. Dimensions of the water body, flow velocity, hydrological balance, etc. are other physical characteristics of water.

Chemical characteristics of water provides information on whether or not it is safe to use, for human health, as well as plants and animals that live in and around streams. Chemical assessment of water quality includes measurements of many elements and molecules dissolved or suspended in the water. Chemical measurements can be used to detect pollutants and toxicity. A significant number of very serious problems may occur as a result of chemical contamination of water resources. Most chemicals arising in drinking-water are of health concern only after extended exposure of years, rather than months. (The principal exception is nitrate). Water from sources that are considered to have a significant risk of chemical or radiological contamination should be avoided. To provide information whether this type of a problem exists or not, a selected series of physicochemmical parameters have to be measured. Assessment of the acceptabality of the chemical quality of drinking-water relies on comparison of the results of water quality analysis with guideline values.

The source of chemical constituents are;

- Naturally occuring (eg: rocks, soils and the effects of the geological setting and climate)
- Industrial sources and human dwellings (eg: mining (extractive industries) and manufacturing and processing industries, sewage, solid wastes, urban runoff, fuel leakages)
- Agricultural activities (eg: manures, fertilizers, intensive animal practices and pesticides)
- Water treatment or materials in contact with drinking-water (eg: coagulants, DBPs, piping materials)
- Pesticides used in water for public health (eg: larvicides used in the control of insect vectors of disease)
- Cyanobacteria (eg: eutrophic lakes)

Chemical parameters measured in natural waters mainly include pH, alkalinity, nitrates, nitrites and ammonia, ortho- and total phosphates, and dissolved oxygen and biochemical oxygen demand.

When the end use of a water body is for a community supply, additional measerements may include but may not be limited to, inorganics (metals, major ions, nutrients); and organics (total organic carbon, hydrocarbons and pesticides). Chlorination Disinfection By-Products (CDBPs), Trihalomethanes (THMs), Haloacetic Acids (HAAs) and Chlorine Residual Testing (Free and Total) should also be included to the parameters of monitoring of tap water. Treatment technologies play a significant role in safe water production from catchment to consumer. Each treatment step poses its own demands on the key-parameters to be monitored in order to guarantee an accurate and sustainable operation of the treatment process. Key-parameters for the monitoring of the quality of overall treatment effect/finished drinking water before entering distribution network, key-parameters for detection of quality changes during distribution, key-parameters for the monitoring of time related changes in water quality due to residence time in the distribution network and finally key-parameters for the monitoring of water quality at consumers' tap should be identified according to the characteristics of water body used and national regulations to provide safe water.

Detailed information on some of the physical and chemical parameters is given below;

3.2.1. Flow

Low flow in surface waters may lead to bacteriological degredation and higher concentrations of pollutants. During treatment, changes in flow can adversely affect coagulation and sedimentation processes. Besides, filtration rate and contact time with disinfectant are significant in the production of safe drinking water. Changes in flow rates within distribution systems can result in suspension of sediments and deterioration of supplies.

3.2.2. Temperature

Water temperature is an important physical property showing how hot or cold the water is. It is commonly measured on Celsius, Fahrenheit or Kelvin; but due to its universal use, water temperature is generally reported on the Celsius scale. The temperature of water can alter some of the important physical and chemical properties and characteristics of water: thermal capacity, density, specific weight, viscosity, surface tension, specific conductivity, salinity, solubility of oxygen and other dissolved gases, metabolic rates and photosynthesis production, compound toxicity, pH and etc. Besides, it can affect the metabolic rates and biological activity of aquatic organisms, i.e. the metabolic rates of aquatic organisms increase as the water temperature increases and, biological reaction rates increase with increasing temperature, as well. The temperature of water in streams and rivers throughout the world varies from 0 to 35°C. The existance of a fish species or an aquatic plant, besides other characteristics of water, depends on the temperature of that water body. In addition to this, high water temperatures can increase the solubility and thus toxicity of certain compounds including heavy metals and it can also affect the tolerance limit of organisms.

Dissolved oxygen concentrations in water bodies depend on temperature. Solubility of gases will decrease as temperature increases. The warmer the water, the less oxygen that it can hold. This is important for aquatic organisms to survive.

Water temperature plays a role in the shift between ammonium and ammonia in water. Ammonia is toxic at high pH levels, but temperature can also affect. For every 10°C increase in temperature, the ratio of unionized ammonia to ammonium doubles.

Moreover, water temperature can affect ionic activity and conductivity since it affects viscosity. An increase in temperature will decrease viscosity. Decrease in viscosity increases the mobility of ions in water, i.e. increases conductivity. Due to the increased mineral and salt ions, hot springs have high conductivity. Many salts are more soluble at higher temperatures. Thus in warm waters, the ionic concentration is often higher. These dissolved solutes are often called Total Dissolved Solids (TDS).

pH is also temperature dependent. pH is calculated by the number of hydrogen ions in solution. The hydrogen and hydroxyl ions have equal concentrations at a pH of 7 and it is neutral. However, the neutral concentration of 1 x 10-7 M only holds true at 25°C. As the temperature increases or decreases, the ion concentrations will also shift, thus shifting the pH without making it more acidic or basic.

Alteration in water temperature affects the density of water. Unlike most materials, the density of pure water decreases when it freezes. Pure water achieves its maximum density, 1.00 g/ml, at 4°C. This property ensures at least 4°C temperature at the bottom of a water body which sustains aquatic life. Freezing point and maximum density is also affected by salinity. They decrease as salinity levels increase. Pressure shifts the freezing, boiling and maximum density points but does not affect the temperature of the water itself.

Water temperature's impact on a variety of other parameters makes it an important factor in determining water quality.

Water temperature can be affected by many factors. Sunlight is the greatest source of heat transfer to water. It is a form of thermal energy that is then transferred to water's surface increasing the temperature of the water. This energy is absorbed until the sunlight is gone. The shallower water bodies tend to warm quicker than deeper water bodies. Like thermal energy from sunlight, atmospheric heat transfer occurs at the water's surface, as well. Warm water will transfer energy to the air and cool off when the air is cold and if the air is hot, cold water will receive the energy and warm up. Water temperature fluctuates more gradually than air temperature. Turbidity can also increase water temperature. Turbid water has high amount of suspended solids. The suspended particles in the water absorb heat from sunlight more efficiently than water. The heat is then transferred to water increasing its temperature. Moreover; groundwater, streams and rivers can change the temperature of the water body into which they flow. There are also men-made influences. Man-made influences on water temperature include thermal pollution (commonly comes from municipal or industrial effluents), runoff (from parking lots and other impervious surfaces), deforestation (when trees are removed, a water body can become unusually warm) and impoundments (such as dams; the temperature will shift if the dam release unusually cool or unusually warm water into the stream). Shallow and surface waters are more easily influenced by the above mentioned factors than deep water.

For drinking waters; an aesthetic objective of *15°C* has been established. However, it is not economical to change the temperature of the water in drinking water treatment plants. The temperature is hence largely determined by the selection of the raw water source and the depth at which the distribution system is buried.

3.2.3. pH

The pH of natural water can give important information about many chemical and biological processes. It can be indicative of a number of different impairments. A high organic content will tend to decrease the pH because as microorganisms break down organic material, the by-product will be CO_2 that will dissolve and equilibrate with the water forming carbonic acid (H_2CO_3). As a result of organic decomposition, some organic acids decrease pH. Besides, the acidity of natural waters can also be affected by mineral acids produced by the hydrolysis of salts of metals like aluminum and iron. Changes in pH indicate an industrial pollutant, photosynthesis or the respiration of algae that is feeding on a contaminant. Most ecosystems are sensitive to pH variations. pH is usually monitored to assess the health of aquatic ecosystem, recreational waters, irrigation sources and discharges, live stock, drinking water sources, industrial discharges, intakes, and storm water runoff.

In drinking water supply, disinfection with chlorine is highly dependent on pH. At pH above 8, disinfection is less effective. Generally, increasing pH values lead to decreased release of metals, due to decreased solubility at higher pHs. Therefore, raising the pH in water supplies has been used as a control measure to reduce lead concentrations.

3.2.4. Alkalinity

Alkalinity of water may be due to the presence of one or more number of ions. These include hydroxides, carbonates and bicarbonates. However, borates, phosphates, silicates, and other bases also contribute to alkalinity if present. Hydroxide ions are always present in water, even if the concentration is extremely low. However, significant concentrations of hydroxides may be present after certain types of treatment. Carbonates may also be found in the water after lime soda has been used to soften the water. Bicarbonates are the most common sources of alkalinity. Moderate concentrations of alkalinity are desirable in most water supplies to balance the corrosive effects of acidity. However, strong alkaline water has an objectionable "soda" taste.

Alkalinity can have varied impacts on the release of hazardous chemicals from materials and fittings. Higher alkalinities decrease corrosion and the release of iron from pipes (Pisigan & Singley, 1987; Cantor, Park & Vaiyavatjamai, 2000; Sarin et al., 2003) and lime from cement pipes (Conroy et al., 1994). In contrast, water utility and laboratory results show that higher alkalinities increase copper release (Edwards, Jacobs & Dodrill, 1999; Cantor, Park & Vaiyavatjamai, 2000; Shi & Taylor, 2007).

3.2.5. Hardness

Hardness is a measure of the concentration of divalent metallic cations (++ charged) dissolved in water and is generally expressed as the sum of calcium and magnesium concentrations expressed as equivalents of calcium carbonate. Other cations such as aluminium, barium, iron, manganese, strontium and zinc can contribute to hardness, but concentrations are usually much lower than calcium and magnesium. Hardness is most commonly expressed as milligrams of calcium carbonate equivalent per liter. Both calcium and magnesium are essential minerals and beneficial to human health in several respects. Excess calcium is excreted by the kidney in healthy people, however; the major cause of hypermagnesaemia is renal insufficiency associated with a significantly decreased ability to excrete magnesium. Drinking-water in which both magnesium and sulfate are present at high concentrations (above approximately 250 mg/l each) with continuous exposures can have a laxative effect. Hard waters can be problematic to low pressure and low flow watering systems due to the accumulation of insoluble calcium and magnesium carbonate deposits. Hard water can cause increased soap consumption as well. Producers located in karst regions should give additional consideration to hardness because elevated levels of calcium and magnesium are associated with limestone (karst) geology.

3.2.6. Sulfate

Sulfate is present in most water sources in the form of calcium, iron, sodium, and magnesium salts. High concentrations cause diarrhea and help development of polioencephalomalacia (a neurological disorder characterized by weakness, muscle tremors, lethargy, and even paralysis and death). The form of sulfur is important in determining toxicity. Sulphur bacteria may produce a dark slime or deposits of metal oxides that develop as a result of the corrosion of metal pipes. The slime or deposits can clog plumbing and stain clothing. Sulphates are discharged into the water body in wastes from industries that use sulphates and sulphuric acid, like mining and smelting operations, kraft pulp and paper mills, textile mills and tanneries. Salt water intrusion and acid rock drainage are also sources of sulphates in drinking water. Sulphate is one of the least toxic anions. The presence of sulphate in drinking water can also result in a noticeable taste.

3.2.7. Toxic Compounds

There hundreds of industrial and agricultural chemicals, including several known carcinogens, are posing risk in municipal water systems. The nation’s laws and enforcement programs have to keep pace with spreading contamination, posing significant health risks to millions. Those substances are; aluminium, antimony, arsenic, barium, benzo(a)pyrene, cadmium, chromium, copper, cyanide, disinfection by-products (including trihalomethanes, haloacetic acids and *N*-nitrosodimethylamine), fluoride, iron, lead, mercury, nickel, pesticides, petroleum hydrocarbons, selenium, silver, styrene, tin, uranium and vinyl chloride. Some risk factors are given below;

Lead - This poisonous metal can damage the blood, brain, and disrupt nervous system.

Mercury - Exposure to mercury can cause tremors, psychotic reactions, and suicidal tendencies.

Chlorine - Chlorine is a chemical element that is essential to human life. However, in anything other than trace amounts, it becomes a toxic gas that irritates the respiratory system.

PCB's - A class of organic compounds that cause skin, blood, and urine problems in humans.

Arsenic – It is an element that has been used for centuries as a deadly poison.

Fluoride - While this compound has many positive traits, such as the ability to clean our teeth, can also be quite toxic.

Cadmium - People who drink water containing cadmium well in excess of the maximum contaminant level (MCL) for many years could experience kidney damage.

Copper - Some people who drink water containing copper in excess of the action level may, with short term exposure, experience gastrointestinal distress, and with long-term exposure may experience liver or kidney damage.

Styrene - Some people who drink water containing styrene well in excess of the maximum contaminant level (MCL) for many years could have problems with their liver, kidney, or circulatory system problems.

MtBE - MtBE is a volatile, flammable, and colorless liquid that is used as an additive in gasoline.

DCPA - DCPA is an herbicide used on strawberries, melons, and cucumbers.

Hexachlorobenzene (HCB) – It is commonly used as a pesticide. HCB can cause cancer and disrupt the endocrine system and interfere with enzyme activity.
Dioxin – It is an organic compound which is known to increase the likelihood of cancer.
DDT – It is a deadly chemical used as an insecticide. It has been linked to diabetes and cancer.

3.2.8. Dissolved Oxygen

Oxygen is soluble in water. The oxygen that is dissolved in water is called dissolved oxygen (DO) and is essential for all forms of aquatic life and necessary for a healthy aquatic ecosystem. The need for DO depends on the species and life stage.

Surface water, near the water-atmosphere interface and with sufficient light for photosynthesis, is generally saturated or even supersaturated with oxygen. Deeper water receives oxygen through mixing by wind, currents, and inflows. Mixing and aeration also occur at waterfalls and rapids. Dissolved oxygen can be reduced to very low levels during the winter months when water is trapped under ice.

In general, the concentration of dissolved oxygen in a water body is the result of biological activity. Photosynthesis of some aquatic plants increases DO level in a water body during day time. On the other hand, they consume DO at nights. Organic material is consumed by microorganisms that mostly their process depends on DO. DO concentrations of unpolluted fresh water is close to 10 mg/l. In waters polluted with antropogenic discharges like fertilizers, suspended material, or petroleum waste, microorganisms such as bacteria will break down the contaminants. During this process DO may be consumed to such levels that the water may become anaerobic. Typically fish cannot live in DO levels less than 2 mg/l. DO is depleted through chemical oxidation, as well.

DO can vary in daily and seasonal patterns and it is also correlated with temperature, salinity and elevation.

DO can affect the solubility and availability of nutrients, which can be released from sediments under conditions of low dissolved oxygen.

Usually membrane electrodes are used as in situ DO sensors. Laboratory tests for assessing the DO is the biological oxygen demand (BOD - the amount of oxygen required to biologically break down a contaminant) and the chemical oxygen demand (COD - the amount of oxygen that will be consumed directly by an oxidizing chemical contaminant).

A high DO level in a community water supply is preferred because it makes drinking water taste better. However, high DO levels accelerate corrosion in water pipes.

3.2.9. Colour

Colour in water is one of the physical parameters which concern mainly the aesthetic aspects. People may think coloured water unfits to drink but that water may be perfectly safe for drinking purposes. On the other hand, colour can indicate the presence of organic substances, such as algae or humic compounds. A blue coloured water body indicates a transparent water body with low dissolved solids; some algea cause red colour in water bodies; reddish-orange water bodies may indicate the presence of iron precipitation or silt; brown-yellow water bodies may contain dissolved organic materials, humic substances from soil, peat, or decaying plant material; and the water body can be green due to the rich presence of phytoplankton and other algea. Recently, colour is also used for quantitative assessment of the presence of potentially hazardous or toxic organic materials in water bodies. Drinking water should ideally be colourless.

3.2.10. Taste and Odour

Taste and odour are other physical parameters which are direcly related to human perceptions of water quality. While relatively simple compounds produce sour and salty tastes, sweet and bitter tastes are produced by more complex organic compounds. People can detect odour more effectively than tastes.

Biologically derived contaminants (actinomycetes and fungi, cyanobacteria and algae, invertebrate animal life, iron bacteria), chemically derived contaminants (aluminium, ammonia, chloramines, chloride, chlorine, chlorobenzenes, chlorophenols, copper, dissolved oxygen, ethylbenzene, colour, hardness, hydrogen sulfide, iron, manganese, petroleum oils, pH and corrosion, sodium, styrene, sulfate, synthetic detergents, toluene, total dissolved solids, turbidity, xylenes, zinc) and temperature affect the taste and odour of water.

Taste and odor are more significant parameters when we use the water for drinking purposes. Some substances of health concern have effects on the taste, odour or appearance of drinking-water, however; concentration limits of these substances determined for the rejection of the water are generally lower than those of concern for health since there is such a wide range in the ability of consumers to detect them by taste or odour.

Taste and odour can originate from biological sources or processes (e.g. aquatic microorganisms - organic materials discharged directly to water bodies, such as falling leaves, runoff, etc., go in biodegradation process in those water bodies in which tastes and odour-producing compounds released) and from natural inorganic and organic chemical contaminants. They can also originate in water treatment and transmission/storage/distribution facilities; such as contamination by synthetic chemicals, corrosion or they can be produced as a result of problems with water treatment (e.g. chlorination). The cause of taste and odour problem in municipal water supply facilities should be investigated, especially if there is a sudden or substantial change.

3.2.11. Turbidity

As a general definition; turbidity is a measure of the light-transmitting properties of water, in other words; an optical determination of water clarity. Turbidity is significant for health and aesthetic considerations. Turbid water appears cloudy, murky or colored. Suspended solids and dissolved coloured material make the water body opaque, hazy or muddy and reduce water clarity.

Turbidity and **total suspended solids** are related. It is often used to indicate changes in the total suspended solids concentration in water body. The more solids present in the water, the less clear the water will be. Turbidity and water clarity are both visual properties of water based on light penetration. The clearer the water, the greater the potential for photosynthetic production is.

The clarity and transparency of natural water bodies are affected by human activities, organic matter such as algae, plankton and decaying material, suspended sediments such as silt or clay, and inorganic materials. Besides, turbidity can also include colored **dissolved organic matter,** fluorescent dissolved organic matter and other dyes. Chemical precipitates are also considered as a form of suspended solids. Salinity can be counted as one of the factors affecting water clarity. Salt ions collect and bind suspended particles together, thus their weights increase and settle to the bottom. Due to this mechanism, marine environment has a higher clarity (and lower turbidity) than fresh water.

Total suspended solids (TSS) are particles that are larger than 2 microns (both organic and inorganic) found in the water column. Particules smaller than 2 microns are considered as dissolved solid. Excessive total dissolved solids (TDS) can produce toxic effects on fish and fish eggs depending on their ionic properties. EPA, USPHS and AWWA recommend an upper limit of 500 mg/L TDS. TDS can also affect water taste, and often indicates a high alkalinity or hardness.

Turbidity and total suspended solids often overlap. Turbidity measurement can be used to estimate the total dissolved solids concentration but there are a few factors that only contribute to one or the other. Turbidity measurement does not include any settled solids or bedload. Moreover, they may be affected by colored dissolved organic matter which is not included in TSS measurements. Total suspended solids, on the other hand, is a specific measurement of all suspended solids, organic and inorganic, by mass. TSS is the direct measurement of the total solids, including settleable solids, and present in a water body. Therefore, sedimentation rates can be calculated by TSS, not by turbidity.

Presence of suspended solids in high concentrations can decrease water quality for aquatic and human life, hinder navigation and increase flooding risks. In addition to this, since they absorb additional heat from the sun, suspended solids can increase the temperature of water. This can also drop dissolved oxygen levels. Decrease in dissolved oxygen concentrations can be caused by blocked sunlight that inhibits photosynthesis. Without the necessary sunlight, plants below the water's surface will not be able to continue photosynthesis and may die. When the plants die, as photosynthetic processes decrease more and less dissolved oxygen is produced, ending up in the further reduction of dissolved oxygen levels in a body of water. The decomposition of the dead plants can drop dissolved oxygen levels even lower. And, with the loss of the underwater vegetation, it can cause population declines up the food chain since the amount of vegetation available for other aquatic life to feed on is reduced.

Suspended sediment present in water bodies mostly comes from runoff and erosion. An increase in turbidity can indicate erosion of stream banks. This may have a long-term effect on a water body.

Wastewater discharge increases turbidity. Pollutants such as dissolved metals and pathogens can attach to suspended particles and go into the water. Pollutants larger than 2 microns, they will also contribute to the total suspended solids concentration. This is why an increase in turbidity can also indicate potential pollution.

Turbidity and water flow are related. High flow velocities keep particles suspended instead of letting them settle to the bottom. So, rivers with high flow velocities are mostly turbid. Weather should be taken into consideration since it also affects water flow, which in turn affects turbidity.

Another important factor in increased turbidity and total suspended solids concentrations is inadequate land use. In construction, logging, mining areas and in other disturbed sites like agricultural areas exposed soil is increase and vegetation is decreased.

Turbidity is most often measured with a turbidity meter. Turbidity is reported in units called a Nephelometric Turbidity Unit (NTU), Jackson Turbidity Unit (JTU), Nephlometer Turbidity Units (NTU) or Formazin Nephelometric Units (FNU).

Total suspended solids can be measured by filtering and weighing a water sample and are reported in mg/L.

Water clarity, when not measured in terms of turbidity, is measured by Secchi depth. It measures how deep a person can see into the water. But this is used in shallow water.

Turbidity is significant in selection and efficiency of treatment processess. Turbidity can provide food and shelter for pathogens. If not removed, turbidity can promote regrowth of pathogens in the distribution system, leading to waterborne disease outbreaks.

3.2.12. Salinity

As a basic definition, salinity is dissolved salts content in water. Salinity is a strong contributor to conductivity. Generally, salinity is derived from the conductivity measurement, it is not measured directly. This Practical Salinity Scale is acceptable in most situations, however; a new method of salinity measurement was adopted in 2010. This method, called TEOS-10, determines absolute salinity. Absolute salinity can be used to estimate salinity not only across the ocean, but at greater depths and temperature ranges. It gives more accurate values than other salinity methods when ionic composition is known.

The units used to measure salinity vary depending on application and reporting procedure. While parts per thousand or grams/kilogram (1 ppt = 1 g/kg) can be used, in some freshwater sources, salinity is reported in mg/L. Lately, salinity values are reported based on the unitless Practical Salinity Scale (sometimes denoted in practical salinity units as psu) and as of an Absolute Salinity calculation was developed, it is reported in g/kg and is denoted by the symbol S.

Salinity affects dissolved oxygen solubility in water body. In high salinity levels, dissolved oxygen concentration lowers. That's why sea water has a lower dissolved oxygen concentration than freshwater sources.

Salinity influences organisms that can live in that area. In general, aquatic organisms can tolerate a specific salinity range.

Salinity also affects water density. One of the driving forces behind ocean circulation is the increase in density with salt levels.

Sodium levels in drinking water from most public water systems are unlikely to be a significant contribution to adverse health effects. There are aesthetic guideline levels for sodium.

3.2.13. Conductivity

Conductivity is a measure of water's capability to pass electrical flow. This is related to the ion concentrations in the water (electrolytes). The more ions present in water, the higher the conductivity. Therefore, we can simply say that sea water has a very high conductivity. It is an early indicator of change in a water system. Conductivity change can indicate pollution.

The standardized method of reporting conductivity is specific conductance. It is a conductivity measurement made at or corrected to 25°C, since the temperature of water will affect conductivity readings. Conductivity is correlated with temperature and salinity/TDS. The higher the water temperature, the higher the conductivity level will be.

Conductivity is generally reported in micro- or millisiemens per centimeter (uS/cm or mS/cm). Less commonly, it can be measured in micromhos or millimhos/centimeter (umhos/cm or mmhos/cm).

In streams and rivers, conductivity depends on the surrounding geology. Most of the salt in the seawater comes from runoff, sediment and tectonic activity. The factors that affect water volume such as heavy rain or evaporation affect conductivity, as well.

Resistivity, which is defined as reciprocal of conductivity, is a measurement of water's opposition to the flow of a current over distance.

Both total dissolved solids (TDS) and conductivity in drinking water indicate the total inorganic mineral content. Some water purification processes such as reverse osmosis can remove those inorganic contaminants from water.

3.2.14. Organic matter

Data of organic matter in treated water provide an indication of the potential for the regrowth of heterotrophic bacteria in reservoirs and distribution systems. Organic matter can be measured as Total Organic Carbon (TOC), BOD and COD. BOD is primarily used with wastewaters and polluted surface waters. TOC is the only parameter applicable to drinking water.

3.2.15. Nutrients

In aquatic ecosystems, nitrogen and phosphorus are the most important chemical elements that are essential to the growth and survival of living organisms.

3.2.15.1. Total Nitrogen (N_2)

Nitrogen is essential to all life. Nitrogen can go through many complex chemical and biological changes in a continuing cycle called the nitrogen cycle. Nitrogen is present in natural waters in different forms as nitrate (NO_3^-), nitrite (NO_2^-), and ammonia (NH_3). These three compounds are interrelated through the process of nitrification. It is the biological oxidation of ammonia to nitrate. Total nitrogen in natural waters refers to the sum of organic nitrogen containing compounds, and the inorganic nitrogen oxidation states present in solution. Total nitrogen can be calculated from the sum of the total kjeldahl nitrogen (organic and reduced nitrogen), nitrate and nitrite.

There are many sources of total nitrogen. Storm water runoff, livestock, fertilizers, waste water discharges, automobile exhausts finding way through precipitation into the water body contribute to the amount of total nitrogen. Natural break down of plant and animal material can be counted as natural sources of nitrogen.

Nitrogen as Ammonia (NH_3)

Ammonia is highly toxic and ubiquitous in surface water systems. Therefore, it is one of the most important pollutants. Sources of ammonia are industrial, municipal and agricultural waste waters. Ammonia also occurs as a result of natural processes as breakdown of nitrogenous organic compounds in water and soil and the breakdown of biota. Ammonia has a toxic effect on healthy humans only if the intake becomes higher than the capacity to detoxify. It is not of direct importance for health in the concentrations to be expected in drinking-water.

Nitrogen as Nitrate (NO_3^-)

Nitrate is the essential nutrient for many photosynthetic species and it is the growth limit nutrient. Nitrate is less toxic to people than ammonia or nitrite but nitrate will become toxic especially to infants at high levels. Symptoms include shortness of breath and blue baby syndrome. The primary health hazard from drinking water with nitrate-nitrogen occurs when nitrate is transformed to nitrite in the digestive system.

Excessive nitrate concentrations with the presence of other essential nutrient factors, eutrophication and algal blooms can become a problem. Nitrate levels over 5 mg/l in natural waters generally indicate antropogenic pollution. Where agricultural use of land increase and urban areas expand, nitrate monitoring is an important tool in accessing and preventing man made sources of nitrate.

Faulty septics tanks, nearby animal feedlots, agricultural or residential fertilizer use may be the source of high levels of nitrate in wells. Nitrate contamination in well water from human or animal waste indicates that microbial contaminants are also present.

Nitrogen as Nitrite (NO_2^-)

Nitrite is extremely toxic to aquatic life. Fortunately, since it is rapidly oxidized to nitrate it is usually present only in trace amounts in most natural freshwater systems. The source of nitrite in a water body may be the discharge of wastewater treatment effluent with impeded process of nitrification. Nitrification process in a treatment plant can be affected by several factors, including pH, temperature and dissolved oxygen, number of nitrifying bacteria and presence of inhibiting compounds.

Infants below six months who drink water containing nitrite in excess of the maximum contaminant level (MCL) could become seriously ill and, if untreated, may die. Symptoms include shortness of breath and blue baby syndrome/methemoglobinemia.

Nitrogen as Total Kjeldahl (TKN)

Total Kjeldahl nitrogen is the sum of organic nitrogen, ammonia (NH3), and ammonium (NH4+) in the chemical analysis of soil, water and wastewater. To calculate Total Nitrogen (TN), the concentrations of nitrate-N and nitrite-N are determined and added to the total Kjeldahl Nitrogen. Nitrogen mainly occurs in wastewater in this form. It is a term that reflects the technique used in their determination.

Nitrogen, Organic

Organic Nitrogen is the byproduct of living organisms. It may be in the form of a living organism, humus or in the intermediate products of organic matter decomposition. It usually occurs in only very small concentrations in most waters.

3.2.15.2. Phosphorus

Phosphorus is essential for plant growth and metabolic reactions in animals and plants. It typically occurs in nature as phosphate (PO_4^{-3}). Both organic phosphate and inorganic phosphate forms are present in aquatic systems and may be either dissolved in water or suspended. With even small amounts it can cause significant plant growth that has adverse affects on aquatic life such as algal blooms causing DO depletion. The main environmental impact associated with phosphate pollution is eutrophication. High levels of phosphorus will be quickly consumed by plant and microorganisms, impairing the water by depleting the dissolved oxygen and increasing the turbidities. These impairments will kill or harm fish and other aquatic organisms. Inorganic phosphate is often referred to as orthophosphate or reactive phosphorous. It is the form most readily available to plants, and thus may be the most useful indicator of immediate potential problems with excessive plant and algal growth.

Sources of phosphate include animal wastes, sewage, detergent, fertilizer, disturbed land, and road salts used in the winter. In unpolluted waters, phosphorous can enter a water system from the weathering of phosphorous baring rocks and minerals.

Phosphates do not pose a human health risk except in very high concentrations. However, phosphate levels greater than 1.0 may interfere with coagulation in water treatment plants. As a result, organic particles that harbor microorganisms may not be completely removed before distribution. Sometimes public water systems add phosphates to the drinking water as a corrosion inhibitor to prevent the leaching of lead and copper from pipes and fixtures. It is measured in mg/L.

3.2.16. Disinfectants

An automated drinking water system may contain residual disinfectants from the public drinking water supply. Chlorine is the most widely used disinfectant in water treatment. Proper measurement and control of disinfectant dose and contact time is obligatory. To maintain a minimal level of quality control of treated water disinfectant dose, residual obtained and time of contact should be measured. In addition to this, measurement of disinfectant residual concentration during and after disinfection is a required measurement in most water treatment plants. Residual concentration after contact should be continuously monitored.

3.3. Microbiological Quality of Water

Microbial quality is one of the primary indicators for the safety of a drinking water supply. Bacteriological examination of drinking water is made to determine whether the water consumed is contaminated, and microbial parameters can provide usefull information throughout the drinking water production process like catchment survey, source water characterisation, treatment efficiency and examination of distribution system.

Coliform organisms have been used to determine the biological characteristics of natural waters. Escherichia coli (E. coli) is generally used as an indicator organism. This organism is present in the intestine of warm-blooded animals, including humans. Therefore the presence of Escherichia coli in water samples indicates the presence of fecal matter and thus the possible presence of pathogenic organisms of human origin.

Faecal contamination is a common source of infectious microorganisms. These include bacteria, viruses and parasites that occur naturally in the gut of humans and other warm-blooded animals. The presence of waterborne disease causing microorganisms in drinking water may result in gastrointestinal illness or diarrhea and even lead to death. Microbiological contaminant parameters of EPA standards include Coliforms (total), Giardia lamblia, Heterotrophic Plate Count, Legionella, Pseudomonas sp., Pyrogens, Turbidity and Viruses).

Although treated, bacteria (Campylobacter jejuni/C. Coli, Esherichia coli, Vibrio cholerae, Salmonella typhi, Shigella, Legionella spp., Non-tuberculous Mycobacterium spp., Franciscella tularensis, etc.), viruses (Noroviruses, Rotaviruses, Enteroviruses, Adenoviruses, Hepatitis A, Hepatitis E, Sappoviruses, etc.), parasites (Cryptosporidium hominis/parvum, Entamoeba histolytica, Giardia intestinalis, Cyclosposa cayetanensis, Acanthamoeba, Naegleria fowleri, some invertebrates, including water mites, cladocerans and copepods, etc) and filamentous fungi and yeast (Aspergillus flavus, Stachybotrys chartarum, Psaudellescheria boydi, Mucor, Sporothrix, Cryptococcus, etc.) can be found in finished drinking-water, pipe biofilms and distribution systems. In a water distribution system faecal contamination may occur with an intrusion of faecal contaminant through broken mains and cross-connections or openings in storage tanks. In addition, construction, new pipe installation and repairs close to sewer lines can introduce contamination into the distribution system.

The presence of faecal pathogens is assessed by monitoring for indicator bacteria. The WHO Guidelines for Drinking-water Quality (WHO, 2011) recognize E. coli as the indicator of choice for faecal contamination, although thermotolerant coliforms (E. coli, Citrobacter, Klebsiella and Enterobacter) can be used as an alternative.

Although total coliforms are not a specific indicator group for contamination as for they can grow naturally in water and soils, they can be used to assess the cleanliness of distribution systems. Coliforms can arise from biofilm linings in pipes and fixtures or from contact with soil due to breaks or repair works. Testing for heterotrophic plate count bacteria is sometimes used for similar purposes. Total coliform numbers and heterotrophic plate count (also known as total or standart plate count) bacteria are used in operations as an indicator of system performance including a loss of disinfection efficiecy, intrusion of contaminants into drinking-water or the growth of biofilms that could support the presence of pathogens. The detection of any coliforms leads us a corrective action, such as increasing the chlorine dose at the water treatment plant, checking the operation of service reservoirs or pipe flushing and rechlorination of the affected area.

Standard plate count/HPC organisms are used for monitoring of efficiency of water treatment and disinfection processes or after growth in water distribution systems.

Total coliform bacteria (total coliforms) is used to evaluate quality of drinking water and related waters.

Fecal coliform bacteria (fecal coliforms) is used to evaluate the quality of wastewater effluents, river water, sea water at bathing beaches, raw water for drinking water supply and recreational waters.

Fecal streptococci (enterococci) are used in evaluation of treatment processes and recreational waters.

Clostridia (presumptive Clostridium perfringens) are used to indicate remote fecal pollution and to access efficacy of treatment and disinfection process.

Coliphages are used as indicators of the incidence and behaviour of human enteric viruses in the evaluation of drinking water. Also serves as an indicator of the presence of host bacteria.

Microbial pathogens including bacteria, viruses and protozoan parasites can be physically removed with other particles in treatment units such as coagulation / flocculation, clarification and filtration, or they can be chemically eliminated by disinfection. Since physical removal processes do not remove all microorganisms from the water, disinfection is important in maintaining the microbial quality of water. To control the microbial quality of water, the disinfectant residual that remains in the drinking water in the distribution system is important. It helps preventing bacterial re-growth after treatment and limiting the development of biofilms in the water pipes.

3.4. Characteristics of Pure Water

Webster defines pure water briefly as: "The liquid which descends from the clouds in rain, and which forms rivers, lakes, seas, etc. Pure ordinary water (H_20) consists of hydrogen (11.1888 %) by weight and oxygen (88.812 %). It has a slightly blue color and is very slightly compressible. At its maximum density at 39.2 °F or 4 °C, it is the standard for the specific gravities of solids and liquids. Its specific heat is the basis for the calorie and the B.T.U. units of heat. It freezes at 32 °F or 0 °C".

However; in reality "pure water" (H_20) occurs so rarely, that it can be called a non-existent liquid. Even the term "pure water" is vague having different implications to individuals in different fields. For example "pure water" is a sterile liquid for bacteriologists that do not contain any living bacteria in it. The chemist, on the other hand, might classify water as "pure" when it possesses no mineral, gaseous or organic impurities. Therefore, "pure water" as described is likely to be found only in laboratories and only under ideal conditions.

Environmental Protection Agencies (states/regional/territorial) and national regulatory bodies provide practical standards for water in terms of its suitability for drinking for aesthetic considerations in Water Regulations. In these regulations, the authorities commonly take into consideration adequate protection of water against the effects of contamination, both through natural processes and through artificial treatment. The standards in these regulations list requirements for bacterial count, physical and chemical characteristics.

Any source of water to meet basic requirements for a public water supply needs some form of treatment. In general, water to be used for public water supply;

- Should contain no disease-producing organisms.
- Should be colorless and clear.
- Should be good-tasting, free from odors and preferably cool.
- Should be non-corrosive.
- Should be free from gases, such as hydrogen sulfide and staining minerals, such as iron and manganese.
- Should be plentiful and low in cost.

A comparative table of both WHO and EU drinking water standards can be found below (Table 3.1);

Table 3.1. WHO and EU drinking water standards

	WHO standards 1993	**EU standards 1998**
Suspended solids	No guideline	Not mentioned
COD	No guideline	Not mentioned
BOD	No guideline	Not mentioned
Oxidisability		5.0 mg/l O2
Grease/oil	No guideline	Not mentioned
Turbidity	No guideline(1)	Not mentioned
pH	No guideline(2)	Not mentioned
Conductivity	250 microS/cm	250 microS/cm
Color	No guideline(3)	Not mentioned
Dissolved oxygen	No guideline(4)	Not mentioned
Hardness	No guideline(5)	Not mentioned
TDS	No guideline	Not mentioned
Cations (positive ions)		
Aluminium (Al)	0.2 mg/l	0.2 mg/l
Ammonia (NH4)	No guideline	0.50 mg/l
Antimony (Sb)	0.005 mg/l	0.005 mg/l
Arsenic (As)	0.01 mg/l	0.01 mg/l
Barium (Ba)	0.3 mg/l	Not mentioned
Berillium (Be)	No guideline	Not mentioned
Boron (B)	0.3 mg/l	1.00 mg/l
Bromate (Br)	Not mentioned	0.01 mg/l
Cadmium (Cd)	0.003 mg/l	0.005 mg/l
Chromium (Cr)	0.05 mg/l	0.05 mg/l
Copper (Cu)	2 mg/l	2.0 mg/l
Iron (Fe)	No guideline(6)	0.2
Lead (Pb)	0.01 mg/l	0.01 mg/l
Manganese (Mn)	0.5 mg/l	0.05 mg/l
Mercury (Hg)	0.001 mg/l	0.001 mg/l
Molibdenum (Mo)	0.07 mg/l	Not mentioned
Nickel (Ni)	0.02 mg/l	0.02 mg/l
Nitrogen (total N)	50 mg/l	Not mentioned
Selenium (Se)	0.01 mg/l	0.01 mg/l
Silver (Ag)	No guideline	Not mentioned
Sodium (Na)	200 mg/l	200 mg/l
Tin (Sn) inorganic	No guideline	Not mentioned
Uranium (U)	1.4 mg/l	Not mentioned
Zinc (Zn)	3 mg/l	Not mentioned
Anions (negative ions)		
Chloride (Cl)	250 mg/l	250 mg/l
Cyanide (CN)	0.07 mg/l	0.05 mg/l

PURE-H2O DRINK PURIFIED H2O!

Fluoride (F)	1.5 mg/l	1.5 mg/l
Sulfate (SO_4)	500 mg/l	250 mg/l
Nitrate (NO_3)	(See Nitrogen)	50 mg/l
Nitrite (NO_2)	(See Nitrogen)	0.50 mg/l
Microbiological parameters		
Escherichia coli	Not mentioned	0 in 250 ml
Enterococci	Not mentioned	0 in 250 ml
Pseudomonas aeruginosa	Not mentioned	0 in 250 ml
Clostridium perfringens	Not mentioned	0 in 100 ml
Coliform bacteria	Not mentioned	0 in 100 ml
Colony count 22°C	Not mentioned	100/ml
Colony count 37°C	Not mentioned	20/ml
Other parameters		
Acrylamide	Not mentioned	0.0001 mg/l
Benzene (C_6H_6)	Not mentioned	0.001 mg/l
Benzo(a)pyrene	Not mentioned	0.00001 mg/l
Chlorine dioxide (ClO_2)	0.4 mg/l	
1,2-dichloroethane	Not mentioned	0.003 mg/l
Epichlorohydrin	Not mentioned	0.0001 mg/l
Pesticides	Not mentioned	0.0001 mg/l
Pesticides-Total	Not mentioned	0.0005 mg/l
PAHs	Not mentioned	0.0001 mg/l
Tetrachloroethene	Not mentioned	0.01 mg/l
Trichloroethene	Not mentioned	0.01 mg/l
Trihalomethanes	Not mentioned	0.1 mg/l
Tritium (H3)	Not mentioned	100 Bq/l
Vinyl chloride	Not mentioned	0.0005 mg/l

(1) Desirable: Less than 5 NTU
(2) Desirable: 6.5-8.5
(3) Desirable: 15 mg/l Pt-Co
(4) Desirable: Less than 75% of the saturation concentration
(5) Desirable: 150-500 mg/l
(6) Desirable: 0.3 mg/l

(Ref:http://www.lenntech.com/who-eu-water-standards.htm)

To read more;

-Parameters of Water Quality, Interpretations and Standards, (Environmental Protection Agency (EPA)

-Guidelines for Drinking-water Quality FIRST ADDENDUM TO THIRD EDITION Volume 1 Recommendations, World Health Organisation (WHO)

PURE-H2O DRINK PURIFIED H2O!

-National Water Quality Management Strategy, Australian Drinking Water Guidelines 6, 2011, Version 3.1 Updated March 2015, Australian Government, Netional Health and Medical Research Council, Natural Resource Management Ministerial Council

-Assessing Microbial Safety of Drinking Water, Improving Approaches and Methods, Published on behalf oft he World Health Organisation for Economic Co-operation and Development (OECD) by IWA Publishing.

REFERENCES

Cantor AF, Park JK, Vaiyavatjamai P (2000). The effect of chlorine on corrosion in drinking water systems. Final report. Midwest Technology Assistance Center, University of Illinois and Illinois State Water Survey

(http://mtac.isws.illinois.edu/mtacdocs/CorrosionFinRpt/CorrosnFnlRpt00.pdf, accessed June 2013).

Chapra, S.C. (2008), *Surface Quality Modelling*, Waveland press, USA.

Conroy PJ, Kings K, Olliffe T, Kennedy G, Blois S (1994). Durability and environmental impact of cement mortar linings. Swindon, Wiltshire: Water Research Centre (Report No. FR 0473)

"Drinking Water Quality Management for Catchment to Consumer, A Practical Guide for Utilities Based on Water Safety Plans", Edited By Bob BREACH, IWA Publication.

Edwards M, Jacobs S, Dodrill DM (1999). Desktop guidance for mitigating Pb and Cu corrosion byproducts. J Am Water Works Assoc. 91(5):66–77.

"Guidelines for Drinking-water Quality" Third Edition Volume I Recommendations, World Health Organization, Geneva, 2004.

Popek, E.P. (2003), *Sampling and Analysis of Environmental Chemical Pollutants,* Academic Press, USA.

Pisigan RA, Singley JE (1987). Influence of buffer capacity, chlorine residual, and flow rate on corrosion of mild steel and copper. J Am Water Works Assoc. 79(2):62–70.

Sarin P, Clement JA, Snoeyink VL, Kriven WM (2003). Iron release from corroded, unlined cast-iron pipe. J Am Water Works Assoc. 95(11):85–96.

Shi B, Taylor JS (2007). Iron and copper release in drinking-water distribution systems. J Environ Health. 70(2):29–36.

Taylor, J.S., Hong, S.K. (2000), Potable Water Quality and Membrane Technology, Laboratory Medicine, 31, 10, 563-568.

Tebbutt, T.H.Y. , *Principles of Water Quality Control*, Pergamon Press, UK.

UNESCO, WHO, UNEP (2000) , *Water Quality Assessment: A guide to the use of biota, sediments and water in environmental monitoring*, Editor: Chapman, D. Chapman and Hall Publ., ISBN: 0-412 448 40 8, USA.

URL 1. https://en.wikipedia.org/wiki/Water_quality

URL 2. http://water.usgs.gov/owq/

URL 3. http://water.usgs.gov/edu/waterquality.html

URL 4. http://water.epa.gov/scitech/swguidance/standards/criteria/

URL 5. http://water.epa.gov/scitech/swguidance/standards/criteria/

PURE-H2O DRINK PURIFIED H2O!

URL 6. http://water.epa.gov/scitech/swguidance/standards/criteria/current/index.cfm
URL 7. http://water.epa.gov/scitech/swguidance/standards/criteria/aqlife/index.cfm
URL 8. http://pubs.usgs.gov/wri/wri014194/pdf/section-3.pdf
URL 9. http://www.cpcb.nic.in/Water_Quality_Criteria.php
URL 10.
http://www.unep.org/gemswater/Portals/24154/freshwater_assessments/pdfs/water_quality_management.pdf
URL 11. https://www.epa.ie/pubs/advice/water/quality/Water_Quality.pdf
URL 12. http://www.fondriest.com/environmental-measurements/parameters/water-quality/
URL 13. http://dnr.mo.gov/env/esp/waterquality-parameters.htm
URL 14. http://www.watershedcouncil.org/learn/water%20terminology/
URL 15. http://www.fosc.org/WQData/WQParameters.htm
URL 16. http://www.h2ou.com/h2wtrqual.htm
URL 17.
http://ww2.sabah.gov.my/mwg-internal/de5fs23hu73ds/progress?id=ITVAhvZdWRzFGQTUnGWWXIheT6j8vjq2IkdG_qSb7Ao,
URL 18. http://nocafos.org/waterquality.htm
URL 19.
http://www.who.int/mwg-internal/de5fs23hu73ds/progress?id=wVBjB6pncxSAW6lsl0OLWqekUnwE0Bxdm1tjFtsYn3A,
URL 20. http://www.who.int/water_sanitation_health/dwq/9241546301_chap2.pdf
URL 21. https://en.wikipedia.org/wiki/Drinking_water_quality_standards
URL
22.http://www.safewater.org/PDFS/PurposeofDrinkingWaterQualityGuidelinesRegulations.pdf
URL 23.
http://www.davidsuzuki.org/mwg-internal/de5fs23hu73ds/progress?id=sr2s8Q-BB5UP7satNeeizxLtSEnG5dLvRkn3_vTZMyo,
URL 24. http://www.who.int/water_sanitation_health/resourcesquality/wpcchap2.pdf
URL 25. http://ec.europa.eu/environment/water/water-drink/index_en.html
URL 26. http://ec.europa.eu/environment/water/water-drink/legislation_en.html
URL 27.
http://www.lenntech.com/applications/drinking/standards/eu-s-drinking-water-standards.htm
URL 28. http://www.irishstatutebook.ie/eli/2014/si/122/made/en/pdf
URL 29. http://www.lenntech.com/who-eu-water-standards.htm
"Water safety plans: Managing drinking-water quality from catchment to consumer" Prepared by Annette Davison, Guy Howard, Melita Stevens, Phil Callan, Lorna Fewtrell, Dan Deere and Jamie Bartram, World Health Organization Geneva 2005.

PURE-H2O DRINK PURIFIED H2O!

QUESTIONS AND ANSWERS FOR BOOK CHAPTER 3

Please choose "true" or "false" for the following sentence.

Q1. Water quality standards changes according to different beneficial uses of water.

a) True b) False

Q2. Write the names of the chemical parameters measured in natural waters?

Chemical parameters measured in natural waters mainly include pH, alkalinity, nitrates, nitrites and ammonia, ortho- and total phosphates, and dissolved oxygen and biochemical oxygen demand.

Q3. Which one of the following is not related with the **temperature** changes in water?

a) Dissolved oxygen concentrations

b) Flow

c) Metabolic rates and biological activity of aquatic organisms

d) Ionic activity and conductivity

e) pH

Q4. Hardness is a measure of the concentration of divalent metallic cations (++ charged) dissolved in water and is generally expressed as the sum of ___________and _________ concentrations expressed as equivalents of ___________________.

Hardness is a measure of the concentration of divalent metallic cations (++ charged) dissolved in water and is generally expressed as the sum of calcium and magnesium concentrations expressed as equivalents of calcium carbonate.

Q5. Dissolved oxygen concentrations does not depend on;

a) Taste

b) Salinity

c) Elevation

d) Availability of nutrients

e) Turbidity

Q6. Write the names of the most important and widely used indicator organism used for microbiological quality of water.

Escherichia coli (E. coli) and Fecal coliform bacteria (fecal coliforms) are generally used as an indicator organisms.

Q7. In drinking water supply, disinfection with chlorine is highly dependent on pH.

a) True b) False

Q8. ____________________ can promote regrowth of pathogens in the distribution system, leading to waterborne disease outbreaks since they can provide food and shelter for pathogens.

a) Calcium carbonate
b) Salinity
c) Turbidity
d) Cadmium
e) None

Q9. Which parameter is used to measure organic matter in drinking water?

a) DO
b) TOC
c) BOD
d) COD
e) None

Q10. Nitrate is extremely toxic to aquatic life.

a) True b) False

Q8. ___________________ can promote regrowth of pathogens in the distribution system, leading to waterborne disease outbreaks since they can provide food and shelter for pathogens.

f) Calcium carbonate
g) Salinity
h) Turbidity
i) Cadmium
j) None

Q9. Which parameter is used to measure organic matter in drinking water?

f) DO
g) TOC
h) BOD
i) COD
j) None

Q10. Nitrate is extremely toxic to aquatic life.

a) True b) False