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Review Article

A REVIEW ON VARIOUS TECHNIQUES AND PARAMETRS SIGNIFYING PURITY OF WATER

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ABSTRACT

Water is the source and basis of all life. Safe drinking water is essential to humans and other life forms even though it provides no calories or organic nutrients. Access to safe drinking water has improved over the last decades in almost every part of the world, At room temperature, it is a tasteless and odorless liquid, nearly colorless with a hint of blue. Many substances dissolve in water and it is commonly referred to as the universal solvent. Because of this, water in nature and in use is rarely pure and some of its properties may vary slightly from those of the pure substance. Drinking water must be purified. A brief idea regarding purification methods includes Distillation, Deionization, Reverse osmosis, Activated carbon filtration; Ultraviolet oxidation, Electro dialysis etc are described. Water has some unchanged parameters which can be use to check purity. It includes PH, turbidity, salinity, hardness etc. various analytical methods are now available to determine such parameters and checking of purity. Analytical methods include colourimetry, uv spectroscopy, titration, mass spectroscopy, titration and many more.

Keywords: analytical methods, parameters, purity, water,

INTRODUCTION [1-9]

Water is the source and basis of all life. It is essential for metabolism and is our most important foodstuff. It is widely used as solvent, analytical reagent and transporting agent it carries not only the vital minerals and nutrients, but also, increasingly, harmful pollutants, which bioaccumulate in aquatic or terrestrial organisms.[1] Water is an excellent solvent and the medium of most life processes on this planet. That is why water gets contaminated with just about everything it encounters and why microorganisms grow in it so well.[2]

IF water is polluted like raw sewage it might be obvious from its appearance or odor. It might be colored or turbid (cloudy), or have solids, oil or foam floating on water. It might have a rotten odor, or smell like industrial chemicals. A lot of dead fish floating on the surface of a lake would be a clear sign that something was wrong. But many harmful and beneficial materials in water are invisible and odorless. In order to go beyond the obvious, to determine what materials are in the water, and how much, we need to be able to conduct chemical or microbiological analyses. [3-7]

The five types of contaminants that may be found in water are:

- Particulates
- Dissolved inorganics (solids and gases)
- Dissolved organics
- Microorganisms
- Pyrogens [8]

There are many microscopic organisms that can contaminate water supplies and cause potentially serious, fatal, illnesses among wilderness travelers. The major danger from these infections is fluid loss due to diarrhea and vomiting, which can lead to hypovolemic shock and possibly death. In order to drink the water, you should be prepared to treat it. [9]

There are numerous methods of water purification.

Purification Methods[10-11]

Eight different methods are commonly used to purify water. These are:

- Distillation
- Deionization
- Reverse osmosis
- Activated carbon filtration
- Microporous filtration
- Ultrafiltration
- Ultraviolet oxidation
- Electrodialysis

At such low levels, sensitive equipment and careful technique are clearly necessary for accurate results. Avoiding contamination of the sample and using methods which prevent interferences from other substances in the water are crucial requirements for successful analyses. [10-11]

DISTILLATION [12-13]

If the analyte can be boiled out of the water, or along with the water, then the vapors can be cooled and re-condensed or trapped in a liquid form in a different container. This way the analyte can be removed from the interfering substances in the original water sample. Often the sample is made acidic or alkaline, or treated chemically in some other way before distillation, to convert the analyte into a volatile (easily evaporated) form, and to immobilize or neutralize interfering substances.

The equipment is relatively inexpensive, and it produces water of generally good quality. Distillation typically produces water of Type II or III quality, with a resistivity of about 1.0 megohm. Distillation has several drawbacks, so it is not as widely used as in the past. Distillation is not an on-demand process. therefore a quantity of water must be distilled and stored for later use. If the storage container is not made of an inert material, ions or plasticizers will leach out of the water container and recontaminate the water. Bacteria are known to grow well in standing water. And because of this the bottles may be sterilized and the collected water autoclaved.Once the bottle is opened, it is exposed to bacteria and contamination begins. Distillation has another drawbacks, including being highly wasteful of energy and water — typically only 5% of the water used in the process ends up as product water. Stills require regular cleaning due to build-up of mineral deposits from the feedwater.

DEIONIZATION [14-15]

It is commonly used in laboratories for producing purified water. Deionization systems have typically consisted of one to four cylindrical cartridges hooked up to plumbing lines and hanging on a wall near a sink. Deionization functions by exchanging hydrogen ions for cationic contaminants and hydroxyl ions for anionic contaminants in the feedwater. The deionization resins are tiny

spherical plastic beads through which the feedwater passes. After a period of time, cations and anions from the water displace all the active hydrogen and hydroxyl groups in the beads and the resin must be replaced o regenerated. Deionization has several advantages (over distillation) for the production of purified water. It is an on-demand process supplying purified water when needed. Nuclear grade deionization resin or polishing mixed bed resin removes almost all the ionic material in the water to a maximum resistivity of 18.2 megohm-cm (at 25° C).[14] Deionization alone, however, does not produce absolutely pure water. Tiny fragments of the ion exchange resin are washed out of the system during operation and stagnant water in the cartridges may allow excessive bacterial growth. Deionization also does not remove all dissolved organics from the feedwater, and in fact, dissolved organics can foul the ion exchange resin. Finally, deionization cartridges can be an expensive option for labs that choose to replace their cartridges rather than regenerate them. There have been many attempts to overcome the shortcomings of deionization and distillation. In some setups, distillation has preceded deionization — the cartridges last much longer, but the problems of bacterial contamination remain.[15]

REVERSE OSMOSIS[16-19]

Reverse osmosis can be explained better after understanding the natural process of osmosis. Osmosis is the process in which the movement of water across a semipermeable membrane from the lower concentrated side to the higher concentrated side. The flow is stopped when the concentrations reach equilibrium. Osmosis is the natural process by which water is flow into a plant's root, or moved from one cell to another in our bodies.[16-17] If a pressure higher than the osmotic pressure is applied to the more concentrated solution, using a high pressure pump, water molecules are pushed back across the membrane to the less concentrated side, yielding purified water. This is the process of reverse osmosis. Reverse osmosis removes 90-99% of maximum contaminants.[18] Reverse osmosis is a very cost effective technology because of its special purifying efficiency and is used to pre-purify tap water for further purification by another technologies. Since reverse osmosis removes a high percentage of micro-organism, it is usually combined with ion exchange to significantly prolong the life of the deionization "polishing" cartridges. In addition, a system which allows dispensing of the reverse osmosis water gives a source of high quality pre-purified water, which is suitable for various routine laboratory purposes.[19]

ACTIVATED CARBON FILTRATION [20]

It is the process to remove chlorine or low molecular weight organic material by chemisorption and dissolved organics by adsorption. It is often found at two places in a water purification system. Because thin film composite reverse osmosis membranes are very sensitive to chlorine, and to a smaller degree, fouling from dissolved organics, activated carbon is often placed before the RO membrane to remove these impurities. A granular activated carbon filter is also placed in the polishing loop of a water purification system to remove trace amounts of dissolved organics for water quality appropriate for HPLC work. This method can be avoided by using hot water sanitization.[20]

MICROPOROUS FILTRATION [21]

It is also known as a submicron filtration. It is uses a membrane or hollow fiber with an absolute pore size of 0.2 micron that prevents any contaminant greater than 0.2 micron from passing through it. The submicron filters retain carbon fines from the carbon cartridge, resin fragments from the deionization cartridges and any bacteria that may have entered the system. Microporous membranes are mostly considered to be indispensable elements of a water purification system, unless they are replaced by an ultrafilter. [21]

ULTRAFILTRATION [22]

It uses a membrane very similar to reverse osmosis systems except that the ultrafilter's pores are slightly larger. The ultrafilter is used to remove pyrogens or endotoxins and other long chain organic molecules such as RNase from the purified water. Ultrafiltration is an outstanding technology for ensuring very consistent ultrapure water quality. Ceramic ultrafilters are another molecular sieving technology. They may require higher operating pressures than membrane type ultrafilters. [22]

ULTRAVIOLET OR PHOTO OXIDATION[23-24]

It uses ultraviolet radiation at the wavelength of 254 nanometers to eliminate bacteria from the system. It also cleaves and ionizes certain organics at 185 nanometers for removal by the deionization and organic adsorption cartridges in the polishing loop. Control measures include regular inspection to detect bulb failure or film occlusions and regular bulb replacement. [23-24]

ELECTRODIALYSIS (ED)[25-27]

It removes impurities from water using an electrical current to draw ionic impurities through ion selective membranes (ion exchange resin in sheet form) and away from the purified water. Used to produce potable water from clean salty feed water, ED is cost competitive with reverse osmosis. To produce laboratory grade water, ED has several disadvantages and, as such, is hardly used in lab settings. [25]

The contaminants ED can remove are limited. ED cannot remove contaminants such as certain organics, micro-organism and elemental metals which have weak or nonexistent surface charges because they are not attracted to the membranes.

ED requires a skilled operator and routine maintenance. Large molecules which bear a significant charge such as certain colloids and detergents can plug the membranes' pores, reducing their ionic transport ability and requiring frequent cleaning. During operation, ED liberates caustic soda which may cause scaling, and hydrogen gas which is potentially dangerous. Finally, ED is relatively expensive. As ionic contaminants are removed from the water, its electrical resistance increases, so that higher electrical current is required to continue the purification process. Purification beyond the potable level is considered uneconomical due to the increased electrical consumption. Component materials such as platinum and stainless steel are also expensive.[26-27]

MEASUREMENT TECHNIQUES

Colorimetry and Spectrophotometry: [28-29]

By this method to measure the intensity of a color in a solution and relating it to the concentration of the analyte. While some materials of interest are already colored, most of these analyses require the analyst to add some chemical reagents (reacting chemicals) to a sample to produce a characteristic color. The simplest type of measurement is visual comparison of the intensity of the color to a set of color standards which represent various concentrations of the analyte. While this is method does not require any expensive equipment, color perception is rather subjective-- and many people have some degree of color-blindness. A more precise measurement can be made using a colorimeter.[28] A colorimeter is a device consisting of 1) a light source, which can be as simple as tungsten-filament light bulb; 2) some optics for focusing the light 3) a colored filter, which passes light of the color which is absorbed by the treated sample; 4) a sample compartment to hold a transparent tube or cell containing the sample, 5) a light-sensitive detector, like the light meter on a camera, which converts the light intensity into an electric current, and 6) electronics for measuring and displaying the output of the detector. Some colorimeters may be designed to read out directly in concentration units, while others may show the results in units of light absorbance which need to be compared to a calibration curve. If we want to get more precise and more interference-free measurements, we can use a spectrophotometer. This is very similar to a colorimeter, except that instead of using a filter to select the color of light to pass through the sample, we instead break the white light up into a rainbow (spectrum) of colors using a prism or a diffraction grating. The light is passed through a narrow opening (slit) before reaching the sample. By rotating the prism or grating, the color {"wavelength"} of light can be selected more precisely and we can better match the color with that

absorbed by the sample. The principle is shown in the diagram below.

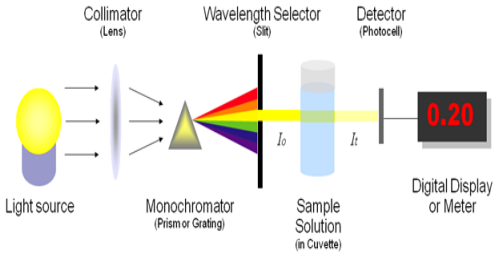

Figure 1: Spectrophotometer

Spectrophotometers cost more than colorimeters, and are likely to be more delicate and less portable. While many tests are done using visible light, some analyses also make use of the invisible ultraviolet or infrared portions of the spectrum. Scanning spectrophotometers can also be used to identify some types of analytes by the wavelengths or colors of the light they absorb.

There is a variation of this type of testing, usually referred to as atomic spectroscopy, which is used mostly for trace metal analysis. The sample is converted to a gas by one of several methods such as heating. Then the light from a lamp containing the same metal is passed though the gas and the absorbance measured just as with a liquid sample. Alternatively, the intensity of the light emitted from the heated atoms of the metal in the gas can be used as a way of measuring the concentration (atomic emission spectrophotometry). A very popular atomic emission method in use today is called inductively coupled plasma spectrometry. The sample is carried in a stream of argon gas surrounded by coils which emit radio frequency energy that converts some of the gas into a very hot, ionized form. An advantage of this method is that many elements can be measured simultaneously, or in rapid succession. [29]

Mass Spectrometry:[30-31]

Mass spectrometer converts molecules to ions so that they can be moved about and manipulated by external electric and magnetic fields. In this, an ionized vapor is passed between magnets or radio frequency coils which separate the ions by mass (actually by charge to mass ratio). The pattern produced is characteristic of the particular substance, which can be identified by comparison with computerized "libraries" of mass spectra. While the instrumentation can be used alone, for environmental analyses it is usually used in tandem with another technique. It is used with gas chromatography ("GC-MS"), it can positively identified components which have already been separated from a mixture. Another use with liquid chromatography, as well (LC-MS). As a detector for metal ions produced in an ICP it provides very high sensitivity and is being used to determine very low levels of metal in drinking water, and may be approved for wastewater effluents and receiving waters.

Chromatography: [32-34]

Chromatography is the technique which are used to separate and identification of the compound. Its name suggest "color picture", because it was first used to separate colored pigments from a single spot on a piece of paper or stationary phase. A solvent or mobile phase is allowed to move slowly across the paper, and the different components of the pigment travel at different rates. The result is a series of separated spots of different colors. They move at different rates because of differences in the pigments' relative attraction to the "stationary phase" and their solubility in "mobile phase". This principle is used in modern instrumentation to separate mixtures of organic chemicals or inorganic ions. The components can be identified by their retention times, i.e., how long it takes them to pass through the instrument and detectors can be used to measure the amount of each component.

In gas chromatography, the mixture of substances is injected into a narrow, coiled column, several feet long, made of an inert material like glass, silica or stainless steel. The sample has usually been extracted into an organic solvent and concentrated by evaporation as a pretreatment step. The column may be filled with an oil-coated, powdered mineral, which forms the stationary phase.[32] In the thinner capillary columns, the stationary phase is bonded directly to the wall of the tubing. The columns are usually contained in an oven, which may be programmable to increase the temperature at a controlled rate over time. Heating the column allows analysts to use this technique on many substances which are not gases at room temperature, including solvents and toxic chemicals like pesticides and PCB's. A continuous flow of an inert gas, such as argon, helium, or sometimes nitrogen, carries the evaporated mixture through the column. The substances are detected as they exit the column, usually by a technique that converts them into ions, although one method uses heat conduction. The ions are produced by means such as flames, ultraviolet light, or radioactive materials. They are detected by being attracted to charged plates, where they produce an electrical current proportional to the amount present. The output of the detector usually is shown as a chart of "peaks" vs. time, called a chromatogram, often with the retention time and the intensity of the peak printed out. The retention time is used to identify the substance, while the height or area of the peak is used to quantify its concentration. A more positive identification is possible using a mass spectrometer as the detector. For substances which cannot easily be vaporized because of high boiling point or instability at higher temperatures, there is a liquid version of this technique known as HPLC (High pressure or high performance liquid chromatography).[33] Organic solvents are used as the mobile phase. Ultraviolet (UV) light absorption is often used for detection. Another variation of LC is ion chromatography, (IC), where the target analytes are charged inorganic or organic substances. The mobile phase is an aqueous (water-based) solution, and the stationary phase is made up of an ion exchange resin. The detectors usually measure electrical conductivity, although UV absorption can also be used. This technique can be used to measure the concentrations of several important inorganic anions, such as fluoride, sulfate, phosphate, and nitrate all in one analysis.[34]

Titration: [35-36]

Titration depends on chemical reaction to measure the amount of a standard solution needed to react with certain amount of the unknown. A known volume, such as 100 mL, of sample is placed into a flask or beaker. The titrant is placed in a burette so the volume used can be measured. The "end point" of the reaction is usually determined by observing a color change after adding the indicator solution, which is added to the flask before the start of the titration. End points are also determined using electrochemical equipment. [35]Once we know how much of the standard reagent was used, we can calculate the amount of the analyte that is in the sample, because the reaction will always use the same proportion of the two materials. Karl fisher titration is used to check the content of water.[36]

Electrochemical: [37-38]

All atoms and molecules consist of electrons, and all chemical reactions involve interactions with these outer electrons and transfer. In this electricity and chemistry are interrelated, and that electrical measurements can be used to detect and determine some substances of interest. The procedures involve placing electrodesin a water sample and measuring either an electrical potential or voltage, in millivolts, or a current, in milliamperes, which is related to the concentration of analyte. In this electrodes are made of metals such as gold, silver, platinum, copper, etc.; or they may be elaborate systems with semi permiable membranes and several internal electrodes and filling solutions. The instrumentation may be capable of reading out directly in concentration units. Usually some type of calibration procedure is necessary, using one or more standard solutions of known concentration.[37-38]

Gravimetric analysis or, simply, weighing: [39-40]

Analytical balances regularly used for gravimetric analysis which are sensitive to one tenth of a milligram, or one ten-thousandth of a gram. Electronic balances are used with direct digital readouts. For a measurement of the milligrams per liter of solids in the water, a

measured volume of sample can be dried in a tared or pre-weighed dish; the dish plus solids are weighed after the water has evaporated off; the weight of solids is calculated by subtraction, and the concentration figured by dividing the weight of solids by the volume of the sample. For a filtered sample, the tared filter itself is dried along with the solids it captured, and the suspended solids calculated in the same way. In some chemical analyses, a precipitate is formed by reacting the analyte of interest with another chemical reagent (reacting chemical); then the precipitate can be filtered, dried, and weighed as a suspended solid. This type of analysis is more common with water solutions that are more concentrated than environmental samples, though, such as chemicals purchased for use in water or wastewater treatment.[39-40]

PARAMETERS

pH[41-43]

pH is a measure of the acidity or alkalinity of water. It is generally measured by using a colorimetric test - litmus paper changes colour with increased acidity or alkalinity and by pH meter. pH differs naturally within streams as a result of photosynthesis. Various materials, when dissolved in water, will produce an excess of (H+), either because they contain these ions and release them when they dissolve, or because they react with the water and cause it to produce the extra hydrogen ions. Substances which do this are called acids. Similarly, some chemicals, called bases or alkalis, produce an excess of hydroxide ions. While the pH measures the concentration of H+ or OH- in water, it may not measure the total amount of acid or base in the solution. Because of many acids and bases do not dissociate completely in water. It means, they only release a portion of their hydrogen or hydroxide ions. Because of Acidic pH corrosion is occurred in sewers systems and increase the release of toxic and foul-smelling hydrogen sulfide gas. This is also increase the release of metals, some toxic, from soils and sediments. Alkalinity is an important parameter because it measures the water's ability to resist acidification. In wastewater treatment, some many processes produce acidity. If there is not enough alkalinity to neutralize acidity, the pH of the process can drop and cause it to become inhibited. Alkalinity can be enhanced by chemical addition to avoid this. A normal pH range of freshwater is 6.5 – 8. [41-43]

TURBIDITY [44-46]

Turbidity is a measure of the ability of light to pass through water, that means, a measure of the water's cloudiness. Measuring cloudiness gives an evaluation of suspended solids in the water. Turbidity is measured by Nephelometric Turbidity Units (NTU's). Turbidity measurements take into account algae and plankton present in the water. Pollutants may bind with suspended solids and settle in bottom sediments where they may become concentrated.[44-45] Suspended sediments can also smother aquatic plants as they settle out in low flows, and clog mouthparts and gills of fish and aquatic macroinvertebrates. High turbidity affects submerged plants by preventing sufficient light from reaching them for photosynthesis. High turbidity also has the capacity to significantly increase water temperature. Though high turbidity is often a sign of poor water quality, clear water does not always assurance healthy water. Extremely clear water can signify very acidic conditions or high levels of salinity.[46]

SALINITY [47-48]

Salinity is a determine of the dissolved salts in the water. Salinity is generally highest during periods of low flows and increases as water levels decrease. Salinity is measured as either TDS (Total Dissolved Solids), which measures the amount of dissolved salts in the water, or as EC (Electrical Conductivity), which is the property of a substance which enables it to serve as a channel or medium for electricity. Salty water conducts electricity more readily than purer water. [47]While an appropriate concentration of salts is vital for aquatic plants and animals, salinity that is beyond the normal range for any species of organism will cause stress or even death to that organism. Salinity also affects the availability of nutrients to plant roots. High levels of salinity in water may have adverse effects upon fresh water flora and fauna, which are not salt tolerant. High levels of salinity may also affect when using water for stock watering. [48]

NUTRIENTS[49]

The three main plant nutrients are nitrogen, phosphorus and potassium. Other elements, such as iron, and magnesium, are also necessary for bacterial and plant growth. These nutrients are important in natural waters because it increase they can cause nuisance growth of algae or aquatic weeds. In wastewater treatment, a deficiency of nutrients can limit the effectiveness of biological treatment processes. In some plants treating industrial wastewaters, ammonia or phosphoric acid must be added as a supplement. It can be determined by an electrode method. Nitrogen can be determined by the Kjeldahl digestion methods which converts the nitrogen in those compounds to ammonia. Phosphate can be measured by ion chromatography.

The effects of consistently high levels of nutrient levels are:

- water bodies choked with vegetation or algae - often weed species;
- changes in aquatic flora and fauna composition. This is often a change to a monoculture, that is a change to a system dominated by a single plant species; increased fluctuations of dissolved oxygen levels. This places stress on aquatic fauna;
- an increase in total organic load, resulting in odours and reduced aesthetic quality. [49]

Chlorine: [50-51]

When chlorine is dissolved in water, most of it reacts to form hypochlorous acid (HOCl) and hydrochloric acid (HCl) which make the water more acidic. The HOCl dissociates and to form H+ and OCl-, called hypochlorite ion when the HCl dissociates completely. If there is enough base to react with the hydrogen ions produced and keep the pH around neutral, most of the chlorine will be in the form of hypochlorous acid and hypochlorite ion. Dissolved chlorine, hypochlorous acid, and hypochlorite ion, taken together, are all known as "free chlorine". Free chlorine can react with ammonia in solution to form compounds called chloramines, which are weaker disinfectants than free chlorine. Chlorine is the most commonly used disinfecting agent for drinking water and wastewater. It has some disadvantage like toxic and carcinogenic byproducts, such as chloroform, which are formed when it reacts with organic matter present in the water. Pure chlorine liquid or gas is also a storage and transportation hazard because of the possibility of accidental releases to the atmosphere. Some treatment plants are switching to hypochlorite solution because it is safer to handle. Others are eliminating it entirely and using UV light or ozone for disinfection. The indicator known as DPD (full name, N,N-diethylparaphenylenediamine) can be used to measure free or total chlorine both colorimetrically or as a titration indicator. "Amperometric titration" is a sensitive electrochemical method.[50-51]

Dissolved Oxygen (D.O.): [52-54]

Like solids and liquids, gases can dissolve in water. The amount of oxygen in water, to a degree, shows its overall health. Oxygen gas which exists in the form of O2 molecules, is not very water soluble. A saturated solution contains about 9 parts per million of D.O. by weight (9 mg/L) at room temperature and normal pressure. Lower temperatures or higher pressures increase the solubility, and visa versa.

Oxygen enters water as a result of two processes

Diffusion - diffusion of oxygen into water is accelerated when the water turbulence is increased and when there is a strong wind blowing. Additionally, oxygen will diffuse into cold water at a higher rate than it will into warm water.[52]

Photosynthesis - during daylight hours, aquatic plants use the sun's energy to create energy they can use for growth. A by-product of this process is oxygen which is released into surrounding water.

Dissolved oxygen is vital for fish to breathe and various microbial forms require it. The low solubility of oxygen in water means that it does not take much oxygen-consuming material to reduce the D.O. Sufficient D.O. is necessary for the proper operation of many wastewater treatment processes.

D.O. can be measured by a wet chemical procedure known as the Winkler titration. D.O. can be Measure more conveniently with electrochemical instrumentation. "D.O. meters" are subject to fewer interferences than the Winkler titration. They are portable and can be calibrated directly by using the oxygen in the air.[53-54]

Oxygen Demand: [55-56]

The biochemical oxygen demand (BOD) is a test to measure the amount of biodegradable organic material present in a sample of water. The results are expressed in terms of mg/L of D.O. which microorganisms will consume while degrading these materials. This method is a long-term bioassay test (5 days), a more rapid (2 hour) test is often used to estimate the BOD; it is known as the COD, or chemical oxygen demand test. An even more rapid test, known as the TOC, or total organic carbon test takes only a few minutes, but it requires expensive instrumentation.[55] The BOD test is done in a specially designed bottle with a widening cap which forms a water seal to keep out air. The COD test is carried out by heating a portion of sample in an acidic chromate solution, which oxidizes organic matter chemically. The amount of chromate remaining is measured by a titration, or the amount of reduced chromium produced is measured spectrophotometrically, is translated into an oxygen demand value. Both COD and TOC can frequently be correlated with BOD for a specific wastewater sample, but each wastewater is different. The COD of a raw domestic wastewater is about 2.5 times the 5-day BOD. [56]

Pathogenic microorganisms: [57-59]

Impure water or sewage contains various numbers of microbes which can cause illness in humans, including viruses, bacteria, fungi, protozoa and worms. While some of these can be measured directly by microscopic method. Wastewater treatment plants are often required to test their effluents for the group known as "fecal coliforms," which include the species E. coli, indicative of contamination by material from the intestines of warm-blooded animals. Water supplies test for a more inclusive group called "total coliforms", and in some cases, for general bacterial contamination (heterotrophic plate count, or HTP.) [57]

The two most commonly used methods of analysis for organisms are

The multiple tube fermentation technique

A number of tubes containing specific growth media are innoculated with different amounts of the sample and incubated for a specific time at a given temperature. The appearance of colors, fluorescence, or gas formation shows the presence of bacteria belonging to the target group. The number of organisms per 100 mL in the original sample is determined from most probable number (MPN) tables, which list the values of MPN for different combinations of positive and negative results in tubes which contained different initial volumes of the sample. Positive results must be confirmed by further innoculation of small amounts of material from the positive tubes into tubes containing a different media, which can extend the test to several days.

The membrane filter procedure

A known volume of sample through a membrane filter which has a small pore size to retain the bacteria. The filter is then placed in a dish of sterile nutrient media either soaked into an absorbent pad or in a gel such as agar and sealed. The dish is incubated for the given time and temperature. The media contain a colored indicator which will identify the target bacteria. Each bacterium in the original sample will result in a colony after incubation, which is large enough to see without a great deal of magnification. The concentration in the sample can be determined by direct count of the colonies, knowing the volume of sample used. Detection of HTP or of specific pathogenic bacteria, such as Salmonella, E. coli, or Enterococcus can be done by similar methods, but utilizing specific growth media for each type. Viruses are usually measured by concentration. Bacteria can be killed with disinfectants like hydrogen peroxide, hypochlorite, and formaldehyde. The ultrafiltration method is also used to remove pyrogens or endotoxins. DNA analysis is another recent innovation. [58-59]

Hardness [60]

Water hardness means to the level of unwanted minerals, like calcium and magnesium, found in water supply. Hard water is an aesthetic issue and a mechanical issue such as clogged pipes, expensive repairs, poor washing machine performance but it is not a health concern. Water hardness may be expressed in ppm - parts per million. Water hardness can be easily measured using a simple soap test.

Table 1

Soft water	0-17.1 mg/L of minerals
Slightly hard water	16.1-60 mg/L of minerals
Moderately hard water	61-120 mg/L of minerals
Hard water	121-180 mg/L of minerals
Very hard water	more than 180 mg/L of minerals

Determination of several parameters using different analytical techniques

Parameter	Method
pH value	pH measurement
Conductivity	Conductivity measurement
Anions, e.g. F–, Cl–, Br–, NO2 –, NO3 –, SO4 2–, etc.	Ion chromatography
Cations, e.g. Li+, Na+, K+, NH4+, Mg2+, Ca2+, etc.	Ion chromatography
Oxyhalides	Ion chromatography
Total hardness Ca, Mg	Titration
pH value	Titration and Ion Chromatography
Conductivity	
Anions	
Cations	
Zn, Cd, Pb, Cu, Tl, Ni, Co	Voltammetry

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