

The Islamic University of Gaza- Environmental Engineering Department
Water Treatment (EENV- 4331)

Lecture 2: Water Quality Parameters

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Water quality parameters

- Chemical, microbiological and Physical properties
- Water quality is determined according to purpose of use (**drinking, agriculture or industrial**)
- Water used for certain purpose is compared with standards for that type of water
- Standards put into account not to affect negatively **public health, plant growth, or industrial processes**

1. General physical parameters:

Color (g.pt/m³)

Turbidity (JTU, FTU, NTU, ppm, SiO₂)

Odor and taste

Temperature

pH = -log H⁺

Conductivity (μs/cm or μs/m)

Dry solids content (mg/l or g/m³)

Color: is due to the presence of natural organic matter (humic substance giving the yellow color).

The color may also be caused by certain industrial waste and by some metallic complexes.

Color is measured by the concentration of standard Platinum, pt-Co solution that produces an equivalent effect and expressed in (g.pt/m³)

EPA Secondary Drinking Water Recommendation is for color of less than 15 Platinum Cobalt Units (PCU)

1 unit - the color of distilled water containing 1 milligram of platinum as potassium chloroplatinate per liter

Color is reduced or removed from water through the use of coagulation, settling and filtration techniques

Turbidity: is related to the presence of finely suspended particles of inorganic or organic origin.

is the capacity of a water for absorbing or scattering light and is measured by the concentration of a standard like fine silica or formazine that produces an equivalent effect.

Measurements of turbidity do not give complete information about the size, number, mass or type of particles that scatter or absorb light.

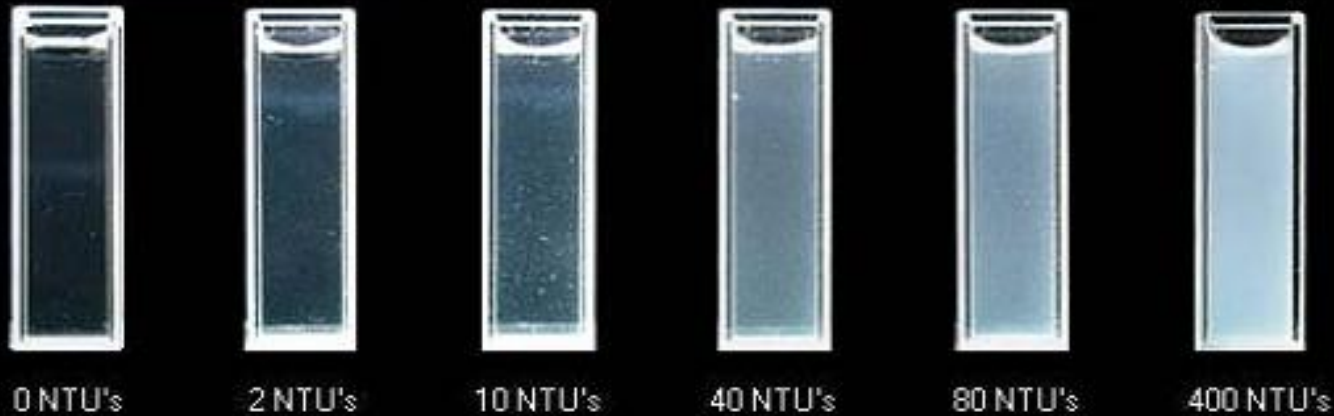
Jackson Turbidity Units (JTU): Turbidity unit based upon the visibility of the flame of a candle through the water.

FTU: Standard formazine, which gives a reproducible turbidity to water.

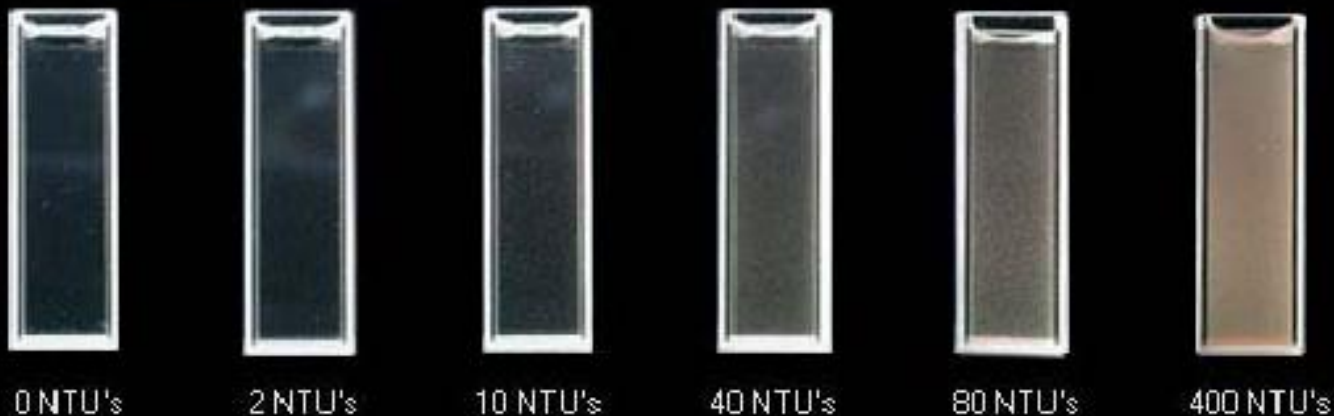
Nephelometer Turbidity Units (NTU): Different standard are used.

Nephelometer Turbidity Units (NTU)

Formazine turbidity standard



Turbidity of suspended clay



Odor and Taste: is often due to dissolved organic impurities, such as phenols, chlorophenols, sewage component.

They are subjective properties which are difficult to measure.

Algae can produce severe taste and odor problems.

Temperature: is an important parameter because many physical, chemical and biological processes, which can occur in water are temperature –dependent.

Temperature affects a number of water quality parameters Such as dissolved oxygen which is a chemical characteristic

Conductivity: is a measure of water capacity to convey an electric current.

Most inorganic acids, bases and salts are good conductors

The standard unit of electrical resistance is the **ohm**, the standard unit of electrical conductance is its inverse, the **mho** or recently **Siemen**.

Total Solids (TS): The total of all solids in a water sample

Total Suspended Solids (TSS): The amount of filterable solids in a water sample, filters are dried and weighed

Total Dissolved Solids (TDS): Non-filterable solids that pass through a filter with a pore size of 2.0 micron, after filtration the liquid is dried and residue is weighed EPA Secondary Drinking Water Recommendation is for TDS of less than 500mg/L

Volatile Solids (VS): Volatile solids are those solids lost on heating to 550 degrees C - rough approximation of the amount of organic matter present in the solid fraction of wastewater

pH: The intensity of acidity or alkalinity of water is measured on the pH scale
Which actually measures the concentration of hydrogen ions present

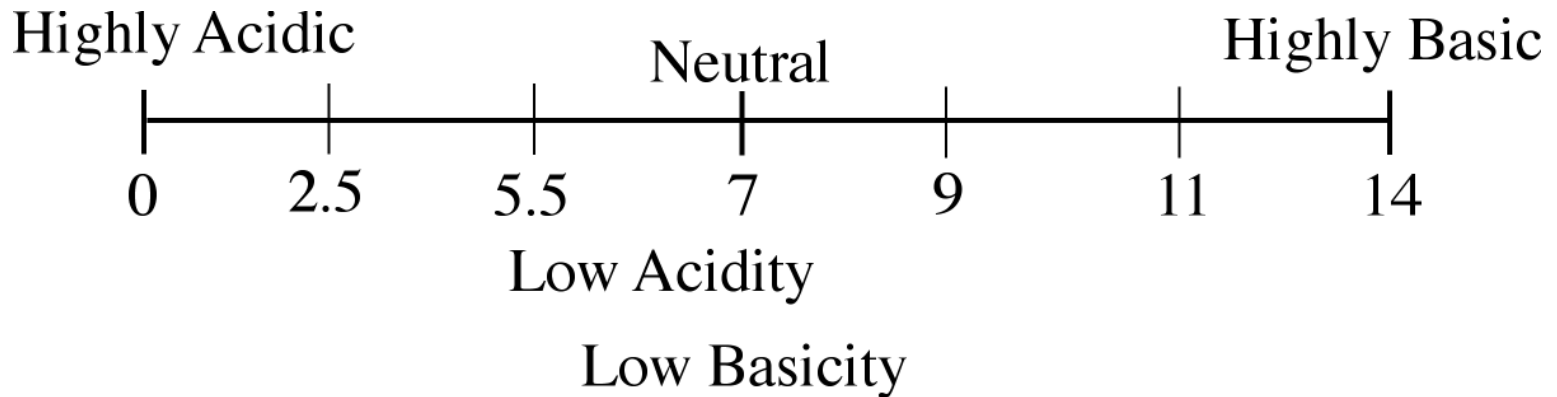
pH example, H^+ is measured to be 2.4×10^{-9} moles/liter:

$$pH = -\log_{10}[H^+], \text{ where } pH = -\log_{10}[2.4 \times 10^{-9}]$$

This gives us a pH value of 8.62.

Alkalinity and pH

- Alkalinity is a measure of the buffering capacity of a solution, or the capacity of bases to neutralize acids.
- pH is a measure of the activity of hydrogen ions (H^+) in a solution.
- Most substances have a pH range between 0 and 14. Some extremely acidic or basic solutions can have a $pH < 0$ or $pH > 14$.
- The pH scale below illustrates these ranges.



Effects of pH on Various Buffers

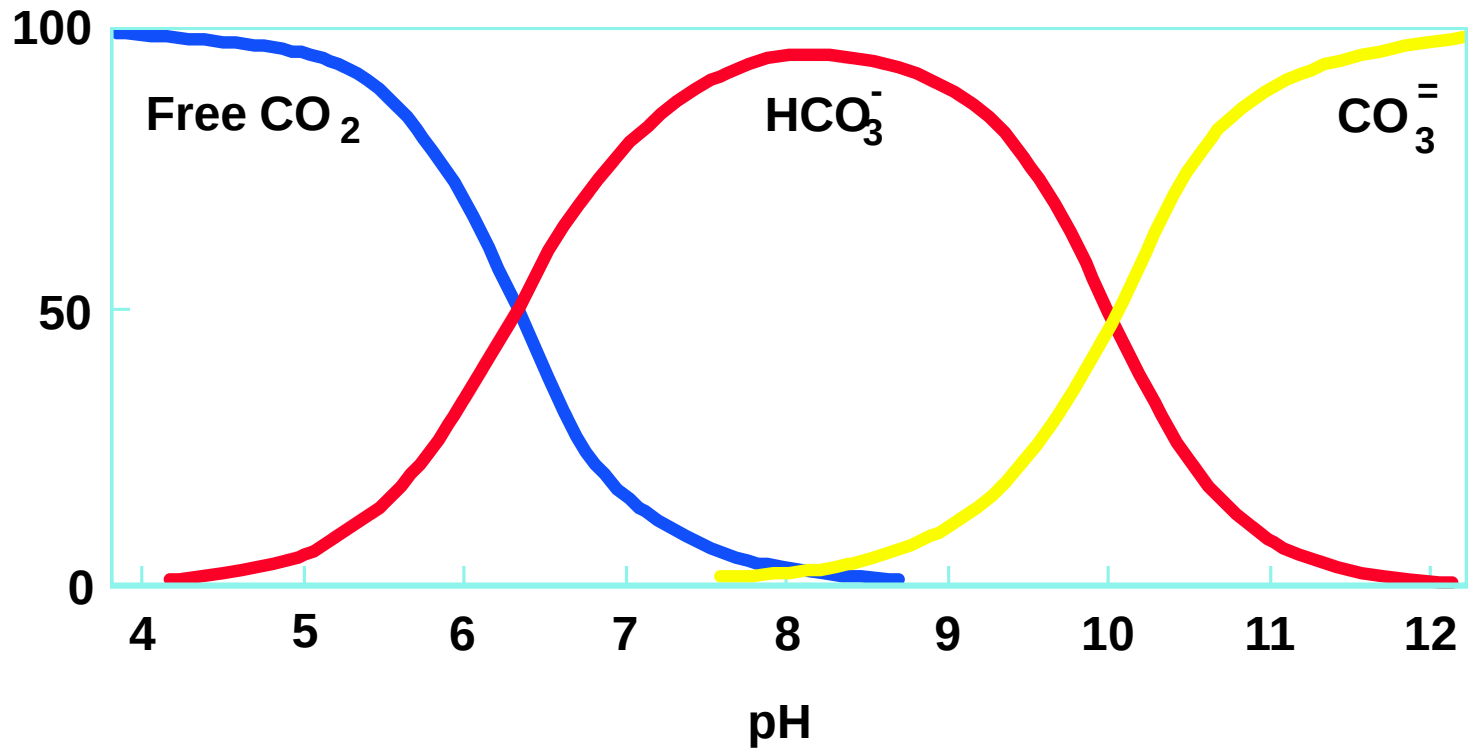
Mixture of an acid (or base) and its conjugate base (or acid)

chemical equilibrium:



Effects of pH on Various Buffers

Percent of Total CO_2



OH^- is a strong base.

HCO_3^- is a weak acid

more OH^- than HCO_3^- , it completely neutralizes it and just have OH^-
more HCO_3^- than OH^- , then it partially neutralizes it and detect only
 HCO_3^-

- Water with low alkalinity are very susceptible to changes in pH.
- Water with high alkalinity are able to resist major shifts in pH.
- As increasing amounts of acid are added to a water body, the pH of the water decreases, and the buffering capacity of the water is consumed.

2. Chemical parameters:

Cations: Na^+ , K^+ , NH_4 , Ca , Mg^{2+} , Fe^{2+} (Fe^{3+}), Mn^{2+} (Mn^{4+}), Al^{3+}

Heavy metals: AS, Cd, Cr, Zn, Hg

Anion: HCO_3^- , Cl^- , F^- , NO_3^- , NO_2^- , SO_4^{2-} , CO_3^{2-} , HPO_4^{2-} , H_2PO_4^- , HS^-

Gases: O_2 , CO_2 , H_2S

Total Hardness = Ca^{2+} hardness + Mg^{2+} hardness + other divalent cations

Carbonate Hardness:

- Ca^{2+} , Mg^{2+} associated with HCO_3^- , CO_3^{2-}
- Often called "temporary hardness" because heating the water will remove it.
- When the water is heated, the insoluble carbonates will precipitate and tend to form bottom deposits in water heaters.
- The amount of hardness in excess of this is called noncarbonate hardness.

Non-Carbonate Hardness:

- Ca^{2+} , Mg^{2+} associated with other ions, Cl^- , NO_3^- , SO_4^{2-}

Example 1: From water analysis:

	mg/l	meq/l
Ca^{2+}	140	$140/20 = 7$
Mg^{2+}	24	$24/12.15 = 2$
HCO_3^-	305	$305/61 = 5$
CO_2		
Total hardness = $\text{Ca}^{2+} + \text{Mg}^{2+} = 7+2 = 9$ meq/l		
Carbonate hardness = 5 meq/l		
Non- Carbonate hardness = 4 meq/l		

Note: total hardness more than carbonate hardness

Solution 1:

	mg/l	meq/l
Ca^{2+}	80	$80/20 = 4$
Mg^{2+}	12	$12/12.15 = 1$
HCO_3^-	305	$305/61 = 5$
CO_2		
Total hardness = $\text{Ca}^{2+} + \text{Mg}^{2+} = 4 + 1 = 5$ meq/l		
Carbonate hardness = 5 meq/l		
Non- Carbonate hardness = 0 meq/l		

Note: total hardness equals carbonate hardness

Continue example 1.:

	mg/l	meq/l
Ca ²⁺	70	70/20= 3.5
Mg ²⁺	6	6/12.15= 0.5
HCO ₃ ⁻	305	305/61= 5*
CO ₂		
Total hardness = Ca ²⁺ + Mg ²⁺ = 3.5 + 0.5 = 4 meq/l		
Carbonate hardness = 4 meq/l		
Non- Carbonate hardness = 0 meq/l		

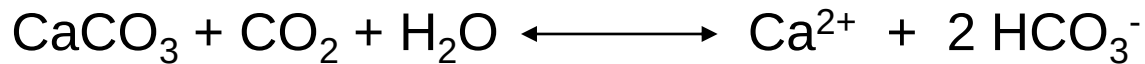
Note: total hardness less than carbonate hardness

* 1 eq HCO₃⁻ / l is related to Na⁺, K⁺ etc

Aggressive CO₂

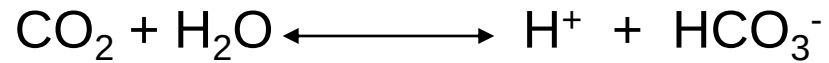
In contact with CaCO₃ water containing CO₂ can be aggressive resulting in a dissolution انحلال of CaCO₃

Between CaCO₃, HCO₃⁻ and CO₂ there exist an equilibrium:

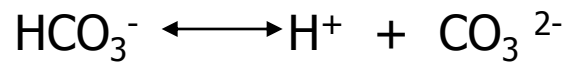


In this respect the concentration of CO₂, Ca²⁺ and HCO₃⁻ in water are very important. These compounds are interrelated by the following equations:

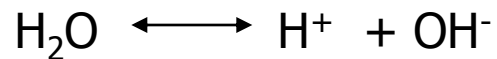
Aggressive CO₂



$$K_1 = \frac{(\text{H}^+)(\text{HCO}_3^-)}{(\text{CO}_2)}$$



$$K_2 = \frac{(\text{H}^+)(\text{CO}_3^{2-})}{(\text{HCO}_3^-)}$$



$$K_w = (\text{H}^+)(\text{OH}^-)$$



$$K_s = (\text{Ca}^{2+})(\text{CO}_3^{2-})$$

The Langelier Index- A method to determine the aggressivity of water

Let us consider the following reaction with their K-values.



Rearrange of K_s -relation

$$(\text{CO}_3^{2-}) = \frac{K_s}{(\text{Ca}^{2+})}$$

Substitute in the K_2 relation gives:

$$K_2 = \frac{(\text{H}^+) * K_s}{(\text{Ca}^{2+})(\text{HCO}_3^-)}$$

Rearrange

$$[\text{H}^+] = \frac{K_2}{K_s} [\text{Ca}^{2+} [\text{HCO}_3^-]]$$

$$\text{Log } H = \text{Log } K_2 - \text{Log } K_s + \text{Log } Ca + \text{Log } \text{HCO}_3$$

$$\text{pH}_s = \text{p } K_2 - \text{p } K_s + \text{p } Ca + \text{p } \text{HCO}_3$$

The pH here is the pH of the CaCO_3 Saturation.

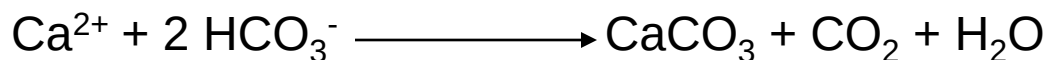
Langelier defined the saturation index: $I = \text{pH} - \text{pH}_s$

$I < 0$ $\text{pH}_{\text{actual}} < \text{pH}_s$ $(\text{CO}_2)_{\text{actual}} > (\text{CO}_2)_s$ aggressive CO_2

$I = 0$ $\text{pH}_{\text{actual}} = \text{pH}_s$ $(\text{CO}_2)_{\text{actual}} = (\text{CO}_2)_s$ in equilibrium

$I > 0$ $\text{pH}_{\text{actual}} > \text{pH}_s$ $(\text{CO}_2)_{\text{actual}} < (\text{CO}_2)_s$

The actual CO_2 is lower than the corresponding equilibrium value. In nature there is a tendency towards equilibrium so the following reaction take place



So the water has a tendency to precipitate CaCO_3

Example 2: Lab analysis:

$$\text{HCO}_3 = 95 \text{ mg/l}$$

$$\text{CO}_2 = 18 \text{ mg/l}$$

$$\text{Ca} = 85 \text{ mg/l}$$

$$K_1 = 3.4 \times 10^{-7}$$

$$K_2 = 3.24 \times 10^{-11}$$

$$K_s = 7.05 \times 10^{-9}$$

Use Langelier saturation index to identify the water condition
(Aggressivity)

Solution 2:

$$pK_2 = 10.5, \quad pK_s = 8.15 \quad K_1 = \frac{(H^+)(HCO_3^-)}{(CO_2)}$$

$$H = \frac{K_1(CO_2)}{(HCO_3^-)} = \frac{(3.4 * 10^{-7}) * \frac{18}{44} * 10^{-3}}{\frac{95}{61} * 10^{-3}} = 0.96 * 10^{-7} \text{ moles / l}$$

$$pH = -\text{Log } 0.96 * 10^{-7} = 7.0$$

$$\begin{aligned} pH_s &= p K_2 - p K_s + p Ca + p HCO_3 \\ &= 10.5 - 8.15 + \{-\text{Log } (85/40) * 10^{-3}\} + \{-\text{Log } (95/61) * 10^{-3}\} \\ &= 10.5 - 8.15 + 2.7 + 2.8 = 7.85 \end{aligned}$$

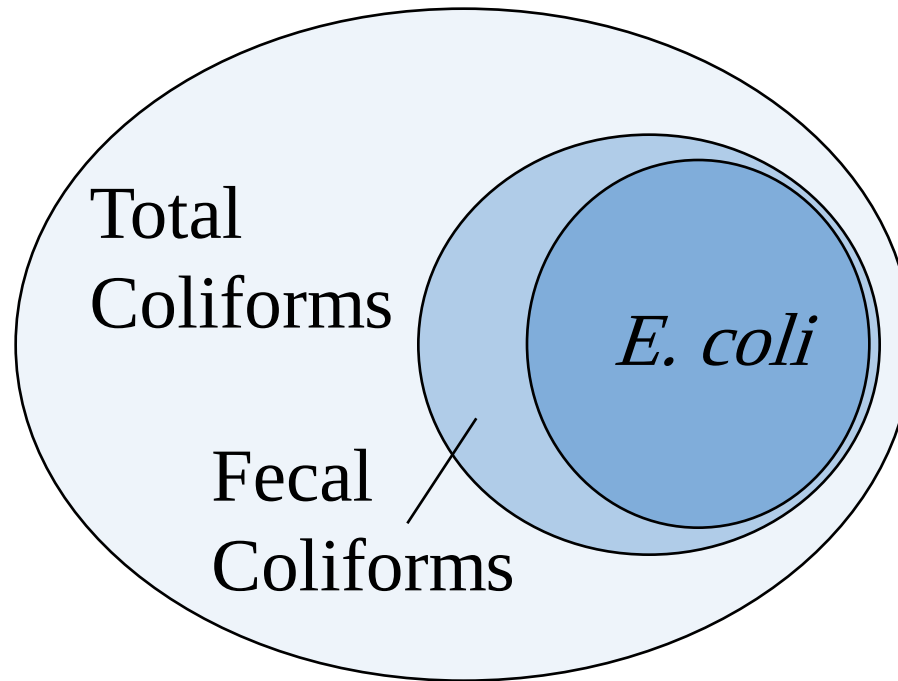
$$I = pH - pH_s = 7.0 - 7.85 = -0.85 < 0 \quad \text{so water is aggressive}$$

3. Parameters for microbial quality

Indicator organisms

E-Coli, coliforms

Faecal streptococci



Common Indicator Bacteria

Criteria for ideal indicator

- should be a member of the intestinal microflora of warm-blooded animals
- should be present when pathogens are present
- should be present in greater number than the pathogen
- should be equally resistant as the pathogen to environmental insults
- should not multiply in the environment
- should be detectable by means of easy, rapid, and inexpensive methods
- should be non-pathogenic

Waterborne Diseases

- Water –and sanitation-related diseases are major causes of illness and death among people in both rural and urban areas in many developing countries.
- The health and well being of people cannot be improved without understanding these diseases and knowing how they are transmitted from one person to another.
- Such diseases are caused by living organisms that must spend much of their life in or on a human body.

- They include viruses so tiny that they can pass through the finest filter, bacteria and protozoa that can be seen only with the aid of a microscope, tiny mites that are barely visible to the eye and worms that may be a meter long.
- The transmission of all of these diseases is related in some way to water supply and sanitation, usually to inadequate disposal of human wastes and to contaminated water supplies.
- The disease are transmitted through contact with or consumption of water, contact with infected soil, the bites of insects that breed in or near water and poor personal and family hygiene.
- Man is usually the source of the organisms that cause the diseases and human activity is an important factor in the diseases and human activity is an important factor in the transmission of them.

- One of the WHO surveys in the field of water quality and health has reached the following facts:

Each day some 30000 people die from water–related diseases.
In developing countries 80 percent of all illness water– related.

A quarter of children born in developing countries will have died before the age of 5, the great majority from water-related disease.

At any one time there are likely to be 400 million people suffering from gastroenteritis **الالتهاب المعوي**, 160 million with malaria. All environmental factors may also be important.

Because of this and due to the possibility that other contaminants may have a negative impact on human health, it is important that the relationship between water quality and health be fully appreciated by the engineers and scientist concerned with water quality controls.

Characteristic of diseases

All diseases require for their spread a source of infection, transmission route, and the exposure of a susceptible living organism.

This shows that control of a water-related disease is based on breaking the transmission route and protecting the susceptible population.

Engineering, measure are concerned with breaking the transmission route and medical measures are concerned with the other two parts of the infection chain.

When a disease is always present in a population at a low level of incidence it is termed **endemic** المرض المستوطن. When it has widely varying levels of incidence the peak levels are called **epidemics** الأوبئة, and world-wide outbreaks are termed **pandemic** الوباء.

Classification of transmission mechanism

It is known today that water-related diseases are transmitted in four distinct mechanisms.

These include **water-born, water-washed, water-based and water-related insect vector.**

- 1. Water-born mechanism:** this refers to the situation when the pathogen is in water which is drunk by a person or an animal which may then become infected. Infections in this group include cholera, typhoid, infectious hepatitis, diarrheas and dysenteries.
- 2. Water-washed mechanism:** this includes diseases that can be significantly reduced if the water volume used is increased. Thus quantity rather than quality is important in this category. The relevance of water to these diseases is that it is an aid to hygiene and cleanliness.

This category includes types: Intestinal tract infection, such as diarrhea diseases like cholera, bacillary dysentery. Thus are all faecal-oral in their transmission route and therefore can be water-washed or water born.

Skin or eyes infections: bacterial skin sepsis, scabies, fungal infections, trachoma are examples.

3. Water-based mechanism: a water-based disease it one in which the pathogen spends a part of its life cycle in a water snail or other aquatic animal.

All these diseases are due to infection by parasitic worms which depends on aquatic intermediate host to complete their life cycle. Important examples are schistosomiasis, and Guinea worm (*Draculus medinensis*).

4. Insect vector mechanism. In this case, insects breed in water or bite near water. Examples include Malaria, Yellow fever, and onchocerciasis.

Guidelines for Drinking-water Quality

THIRD EDITION
INCORPORATING THE FIRST AND SECOND
ADDENDA
Volume 1
Recommendations



World Health
Organization

Geneva
2008

Chemical Standards

(Compounds affecting health and water suitability)

Element/Compound	Symbol	Acceptable Level (mg/l)	MCL (mg/l)
Total Dissolves Solids	TDS	500	1500
Total Hardness	TH (CaCO ₃)	100	500
Detergents	ABS	0.5	1
Aluminum	Al	0.2	0.3
Iron	Fe	0.3	1
Manganese	Mn	0.1	0.2
Copper	Cu	1	1.5
Zinc	Zn	5	15
Sodium	Na	200	400
Nickel	Ni	0.05	0.1
Chloride	Cl	200	400
Fluoride	F	1	1.5
Sulfate	SO ₄	200	500
Nitrate	NO ₃	45	70
Silver	Ag	0.01	0.05
Magnesium	Mg	50	120
Calcium	Ca	100	200
Potassium	K	10	12

Chemical Standards (Toxic elements)

Parameter	Symbol	MCL (mg/l)
Lead	Pb	0.01
Selenium	Se	0.01
Arsenic	As	0.05
Chromium	Cr	0.05
Cyanide	Cn	0.05
Cadmium	Cd	0.005
Mercury	Hg	0.001
Antimony	Sb	0.005
Nickel	Ni	0.05

Palestinian drinking water quality standards

Element/Compound	Symbol	MCL (mg/l)
Total Dissolves Solids	TDS	1500
Total Hardness	TH (CaCO ₃)	600
Alkalinity		400
Detergents	ABS	0.5
Sodium	Na	200
Chloride	Cl	600
Fluoride	F	1.5
Sulfate	SO ₄	400
Nitrate	NO ₃	70
Nitrite	NO ₂	0.1
Ammonium	NH ₄	0.5
Magnesium	Mg	150
Calcium	Ca	100- 200
Potassium	K	12
Residual chlorine		0.2- 0.8

Effects of Exceeding MCL

Aluminium (Al): Related to Alzheimer's

Arsenic (As): Accumulate in the body. Carcinogenic

Cadmium (Cd): Accumulate in the body. Highly toxic. adverse changes in arteries of human kidneys. linked with certain human cancers

Calcium (Ca)

form harmful scales in boilers, pipes, and cooking utensils

CaCO_3 contributes to the total hardness of water

Iron (Fe)

cause staining of laundry and porcelain

bittersweet taste

is detected at levels above 1 mg/l

Magnesium (Mg)

Important contributors to the water hardness forming scales in boiler. have a cathartic مسهل and diuretic مدر للبول effect

Effects of Exceeding MCL

Manganese (*Mn*): cause objectionable stains to laundry

Mercury (*Hg*): Accumulate in the food chain
very toxic and not allowed to exist in the environment or water

Selenium (*Se*): toxic to animals and may be toxic to humans

Silver (*Ag*)

cause argyria, a permanent blue-gray discoloration of the skin and eyes that causes a ghostly appearance
pathological changes in the kidneys, liver, and spleen الطَّحَال
of rats

Toxic effects on fish in fresh water have been observed at
conc. as low as 0.17 ug/l

Effects of Exceeding MCL

Sodium (*Na*)

Ratio of sodium to total cations (SAR) is important in agriculture and human pathology

Soil permeability may be harmed by a high sodium ratio

Persons afflicted with certain diseases require water with low sodium concentration

Vanadium (*V*)

It plays a beneficial role in the prevention of heart disease

In New Mexico, with low heart disease cases, water contained 20-150 ug/l

In a state where heart disease is high, water did not contain vanadium

Vanadium pentoxide dust causes gastrointestinal and respiratory disturbances

Effects of Exceeding MCL

Zinc (*Zn*)

It is essential and beneficial element in plant and animal growth

Concentrations above 5 mg/l can cause bitter taste and an opalescence تَلَأْلُؤ in alkaline waters

Effects of Exceeding MCL



Chloride (Cl^-)

High conc. of Cl^- may harm: metallic pipes and structures and growing plants.

- Cyanide CN^-

Highly toxic

- Fluoride F^-

Fluorosis

- Nitrate NO_3

Blue baby syndrome (methemoglobinemia)

- Sulfate SO_4

$\text{Na}_2(\text{SO}_4)$ and MgSO_4 have cathartic effects.

Physical Standards

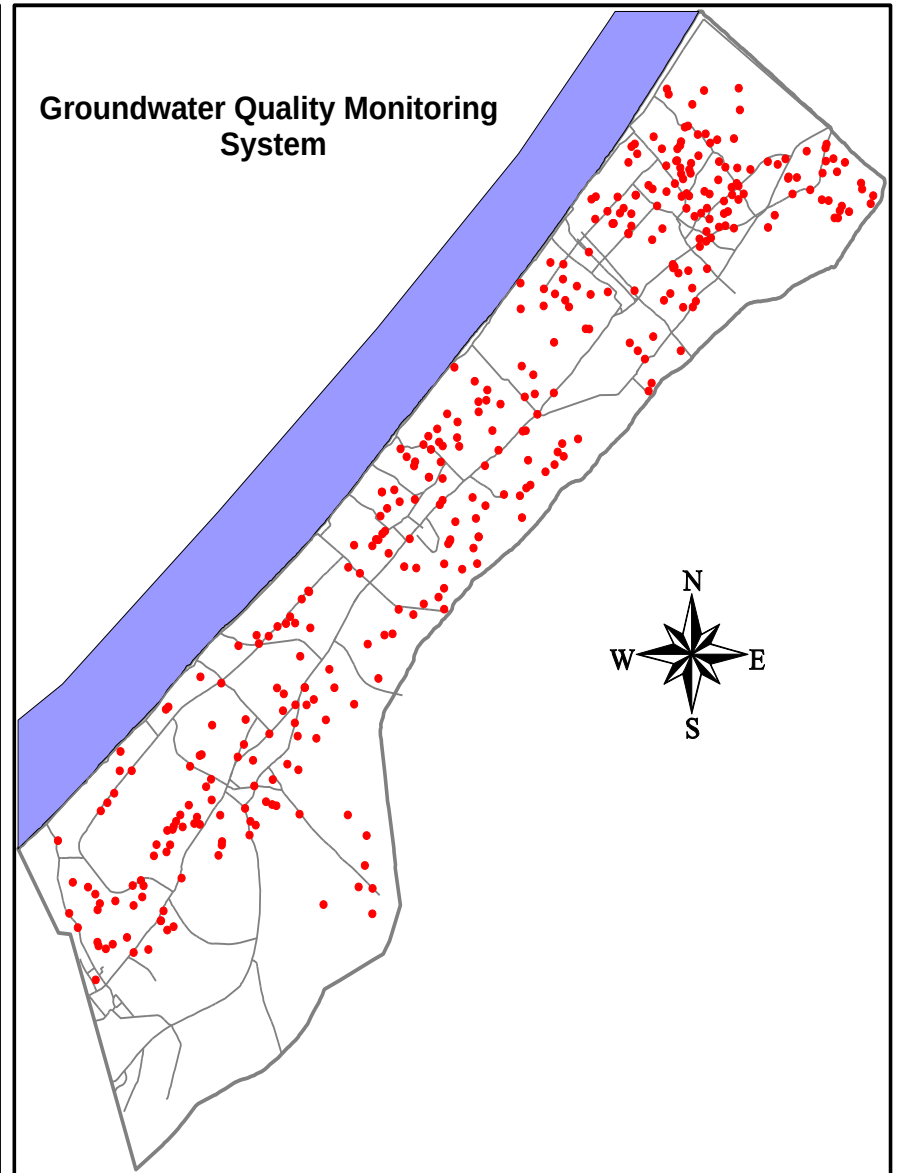
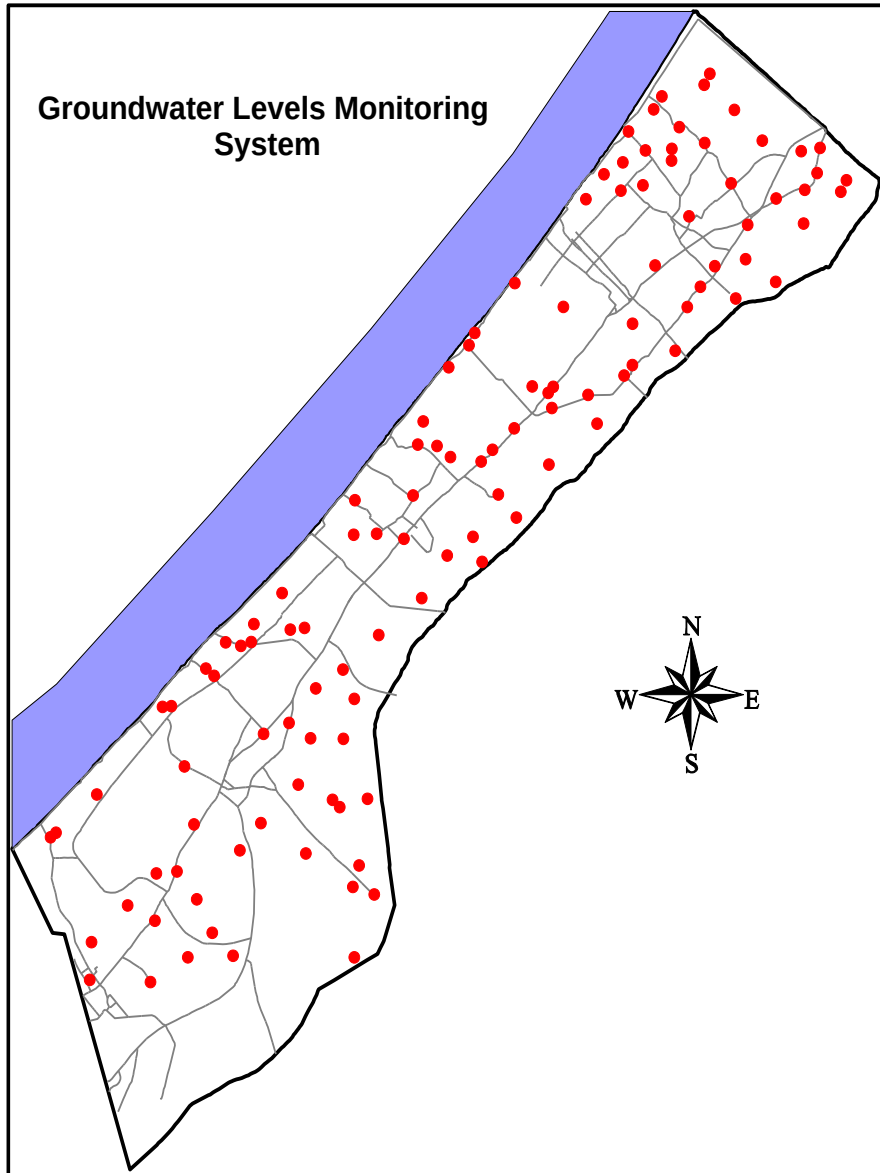
Drinking water should have **turbidity**, **color** and **odor** within the MCL standards

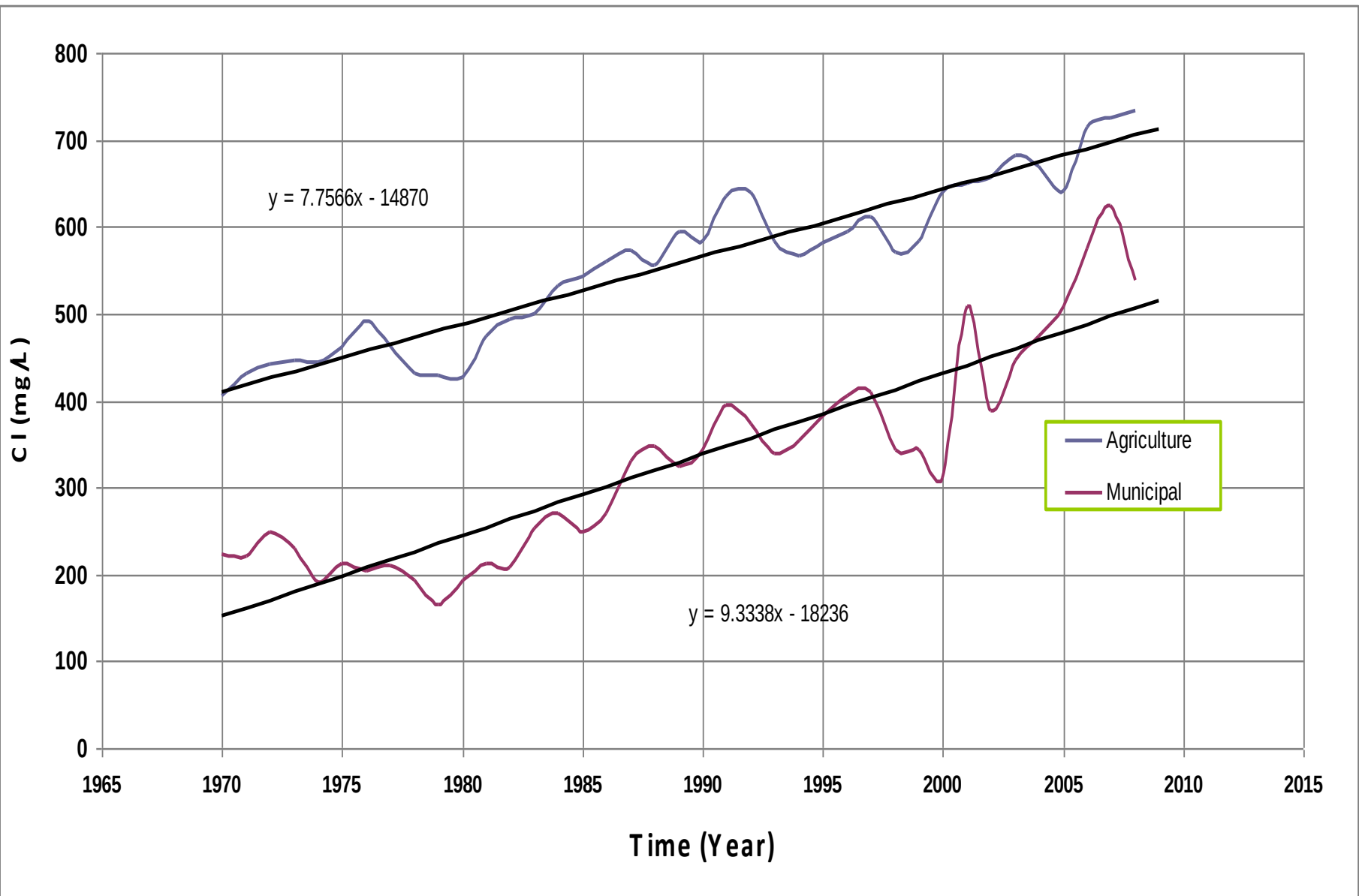
Using local marketed filters could reduce the objectionable turbidity, color, and odor.

Physical Standards

Property	Accepted level	Max. Cont. Level (MCL)
Taste (20C)	Accepted to majority of consumers	
Odor	Accepted to majority of consumers	
Color	10 units (platinum cobalt)	15 units
Turbidity	1 NTU	5 NTU
pH	6.5-8.5	9.5
Temperature	8-25C	

Groundwater quality in the Gaza Strip



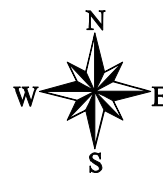


**Average Chloride Concentration
1970 (mg/l)**



**Area of Groundwater with
Cl >1000 mg/l**

**Average Chloride Concentrations
2007 (mg/l)**



1000

1000

1000

1000

Water Pollution

Pollution:

Any changes in water composition or water properties that adversely affect the environment.

Water pollution:

Anything that adversely affects water and makes it:

1. unsafe for domestic purposes
2. unsafe for irrigation purposes
3. unsafe for husbandry.

Types and degree of pollution:

this needs: chemical, physical and microbiological tests.

Why these tests?

- 1- to evaluate whether water is safe or not for drinking, industrial, agricultural or tourism purposes
- 2- to evaluate the type and degree of treatment necessary to eliminate pollutants
- 3- to evaluate the efficiency of water treatment

Sources of Water Pollution:

1. Municipal wastewater
2. Ground water over pumpage
3. Industrial pollution
4. Solid waste (leachate)
5. Agricultural activities

When pollutants gain access to water resources :

- (i) increase in nitrate concentration
- (ii) increase in total coliforms
- (iii) increase in fecal coliforms

Factors that determine groundwater suitability for drinking purposes:

- 1- presence of coliform bacteria
- 2- increase of Cl^- concentration
- 3- increase of NO_3^- concentration
- 4- increase of heavy metals concentration