

GENERAL CHARACTERISTICS OF WATER

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Summary

Water is among the abundantly available substances in nature, covering 75 per cent of the earth's surface. It is also an essential ingredient of animal and plant life due to its unique physical, chemical and biological properties. Natural water is never completely pure. During precipitation water passes over and through the ground, acquiring a wide variety of dissolved or suspended impurities that profoundly affect its usefulness. Chemical properties of water refer to the properties of aqueous solutions of a variety of substances, namely those found as impurities in natural water, added to water during treatment, picked up during the flow of water through pipes and conduits, and added to water by manifold uses that convert it to household, municipal, or industrial waste water.

The substances of interest range from dissolved gases through numerous inorganic materials to the complex organic compounds that impart color to natural waters, which are characteristic of sewage and other waterborne waste.

Water treatment is carried out to produce water for potable use, domestic use (washing utensils, clothes, etc.) and industrial use, i.e. cooling towers, steam production in boilers, and water fit for pharmaceutical and electronic industries, etc. Water is treated either to remove harmful substances from polluted water completely or partially to prevent deterioration of the ground water supply.

From energetic viewpoint water is a valuable resource. From biological viewpoint, water is a main life support to all known living systems. However, some living systems are pollutants or life-threatening with respect to other living systems.

1. Pure Water

The anomalous properties of pure water are as follows.

- (a) The high specific heat of water prevents extreme ranges in temperature and heat transfer by water movements is very large. Water tends to maintain uniform body temperature.
- (b) A high latent heat of fusion results in a large thermostatic effect at freezing point during absorption or release of heat.
- (c) A high latent heat of evaporation results in a large thermostatic effect at boiling point temperature. It is extremely important in heat and water transfer within the atmosphere.
- (d) Fresh water and dilute seawater have a maximum density at temperatures above the freezing point. The maximum density of normal seawater is at the freezing point.
- (e) Highest surface tension is important in cell physiology as it controls certain surface phenomena and the formation and behavior of droplets.
- (f) The dissolving power of water has obvious implications in both physical and biological phenomena.

A high dielectric constant of water is important in the behavior of inorganic dissolved substances because of the resulting high dissociation. Water is a neutral substance, yet it produces both H^+ and OH^- ions due to its very small dissociation. Water is largely transparent to sunlight. The absorption of radiant energy in water is large in infrared and ultraviolet regions. In the visible portion of the energy spectrum there is relatively little selective absorption by water. Hence, water is colorless in small amounts. The characteristic absorption of radiant energy by water is important in physical and biological phenomena.

The high heat conductivity of liquid water is important on a small scale such as in living cells. Water has low viscosity at comparable temperatures, hence it readily equalizes pressure differences. The maximum density of freshwater is 1 g cm^{-3} at 3.98°C and seawater has a maximum density at its freezing point, i.e. -1.9°C . Light can travel a maximum of a few hundred meters through water. Sound can travel thousands of kilometers through water. Water is essential to life.

2. Natural Waters

Natural waters acquire their characteristics due to dissolution as well as chemical reactions with different materials they come into contact with during the hydrological cycle. Dissolved mineral matter in the natural waters comes from the crust materials of the earth, which the water disintegrates and dissolves by weathering. The interaction of carbon dioxide in the atmosphere with the mineral rocks also determines the composition of the water. Eighty per cent of water analyses indicate dissolved silica concentrations

ranging from $10^{-3.8}$ to $10^{-3.2}$ M, while the range of $[H^+]$ is generally from $10^{-6.5}$ to $10^{-8.5}$ M.

In order to understand how natural waters obtain their compositions, it is necessary to study the processes involved in the weathering of rocks and in the formation of soils. Moreover, the biosphere is also important in weathering phenomena because living matter increases the carbon dioxide content as a result of respiration. The organic matter thus produced in the biosphere serves as a reducing agent to form organic solutes which can complex with cations and contribute to their mobility.

Water Quality Characteristics (Reynolds, Richards ,1995)

Biological Characteristics Microorganisms

Bacteria

- Viruses
- Protozoa
- Coliformbacteria (indicate human waste)
- Helminths
- Fungi, algae

Physical Characteristics taste, odor, color

Total solids (dissolved and suspended)

- Turbidity
- Color (apparent and true)
- Taste & odor (organic compounds in surface water; dissolved gases in ground water)
- Temperature

Chemical Characteristics Natural or Manmade

pH

- Anions & cations(dissolved solids)
- Alkalinity (HCO_3^- , CO_3^{2+} , OH-system)
- Hardness (Ca^{2+} , Mg^{2+})
- Dissolved gases (O_2 , CO_2 , H_2S , NH_3 , N_2 , CH_4 ...)
- Priority pollutants (organic and inorganic)

Microbial Contamination Is Of Major Concern For Water(Faust ,Aly, 1998)

•Protozoans

-Amoeba, cryptosporidium, giardia,

•Bacteria

- Salmonella, typhus, cholera, shigella, ...

•Viruses

-Polio, hepatitis A, meningitis, encephalitis,...

•**Helminths**

–Guinea worm, hookworm, roundworm,...

Disinfection of water

•**Chlorination**

–Highly effective for bacteria, and effective for viruses
–Not effective for protozoa
–Inexpensive, very common

•**Ozonation**

–Highly effective

•**Ultraviolet radiation**

–Effective for low turbidity

•**Boiling**

–Complete sterilization possible

•**Principal transmission is by human waste**

•**Principal purification technique is chlorination, especially for bacteria.**

Disinfection of water (Twort, Rathnayaka, .Brandt ,5th edition,2000)

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Physical characteristics

•Coloris due to dissolved (true color) or colloidal (apparent color) material...iron, manganese, clay,...

•Taste/odor...typically treated by aeration (to release dissolved gas from ground water) or activated carbon (to remove organics from surface water)

- Suspended solids include silt, clay, algae, colloids, bacteria...remove by settling, filtration, or flocculation
- Turbidityinterferes with passage of light, usually as the result of colloidal material

EPA Primary Standards for ~130 chemicals (WHO, 2006.)

- Toxicmetals–Arsenic, lead, mercury, cadmium, chromium,...
- Organiccompounds–insecticides, herbicides, PCBs, petrochemicals, PAH, benzene, halogenated hydrocarbons,...very long list
- Radionuclides–mainly natural alpha emitter
- Secondarystandardsfortaste, odor, appearance: Cl-, SO₄²⁻, pH, color, odor, iron, manganese, copper, zinc, foaming agents
- Nitrateornitrite–fertilizer by product
- Fluorine–damages teeth and bones at high concentrations

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Bibliography and Suggestions for further study

- A.C.Twort, D.D.Rathnayaka, and M.J.Brandt, *Water Supply*, 5thed., IWAPublishing,2000.
- American Chemical Society (1963), *Saline Water Conversion II Advances in Chemistry Series 38*, Washington, DC: American Chemical Society.
- Bailer J C, Emeleus H J and Nyholm R (1973) *Comprehensive Inorganic Chemistry*. New York: Pergamon Press.
- Balmer R (1990) *Thermodynamics*. New York: West Publishing Company.
- Bowen R (1980) *Ground Water*. London: Applied Science Publishers Ltd.
- Bromley L A (1973) Thermodynamic properties of strong electrolytes in aqueous solutions. *AIChE (American Institute of Chemical Engineers) Journal* 19, 313.
- Bromley L A, Singh D, Ray P A, Sridhar S and Read S M (1974) Thermodynamic properties of sea salt solution. *AIChE J.* 20, 326-335.
- Chen S F, Chan R C, Read S M and Bromley L A (1973) Viscosity of seawater solutions. *Desalination* 13, 37.
- Chester R (1990) *Marine Geochemistry*. London: Unwin Hyman.
- Daubert T E and Dammer R P (1989) *Physical and Thermodynamic Properties of Pure Chemicals*. New York: Hemisphere Publishing Corporation.
- Desalination for Safe Water Supply: Guidance for the Health and Environmental Aspects Applicable to Desalination*. World Health Organization, 2007
- Dixey F and Practical A (1950) *Handbook of Water Supply*. London: Thomas Murby and Company.

- Dorsey N E (1940) *Properties of Ordinary Water Substance*. New York: Reinhold Publishing Company.
- Eisenberg D and Kauzmann W (1969) *The Structure and Properties of Water*. New York: Oxford University Press.
- Ellis C B (1954) *Fresh Water from Oceans for Cities and Industries*. New York: The Ronald Press Company.
- F.J. Millero, C.T. Chen, A. Bradshaw and K. Schleicher(1980), A new high pressure equation of state for seawater, *Deep-Sea Research*, 27A, 255–264.
- F.J. Millero, R. Feistel, D. Wright and T. McDougall (2008.), The composition of standard seawater and the definition of the reference- composition salinity scale, *Deep-Sea Research I* 55, 50–72
- Fair G M, Geyer J C and Morris J C (1956). *Water Supply and Waste-water Disposal*. New York: John Wiley and Sons Inc.
- Fletcher P (1993) *Chemical Thermodynamics for Earth Scientist*. Longman Scientific Technical, Essex, England.
- Franks F (1972) *Water: A Comprehensive Treatise*. New York: Plenum Press.
- Guidelines for Drinking-Water Quality: Vol. 1, Recommendations." 3rd ed. World Health Organization, 2008
- H. El-Dessouky and H. Ettouney 2002, *Fundamentals of salt water desalination*, Elsevier, New York
- Hodgman C D, Weast R C and Selby S M (1958) *Handbook of Chemistry and Physics*. Cleveland: Chemical Rubber Publishing Company.
- J.P. Jacobsen and M. Knudsen (1940), Primary standard-water, *Association of Physical Oceanography, Union of Geodesy and Geophysics*, Vol. 7. 38,
- Kemer F N (ed) (1979) *The Nalco Water Handbook*. New York: McGraw Hill Book Company.
- Kent J A (ed) (1992) *Reigal's Handbook of Industrial Chemistry*, 9th edn. New York: Von Nostrand Reinhold.
- Kirk R E. and Othmer D F (eds) (1984) *Encyclopedia of Chemical Technology*, 3rd edn. New York: John Wiley and Sons Inc.
- Koltz I M (1950) *Chemical Thermodynamics*. Prentice Hall.
- Lewis G N and Randall M (1961) *Thermodynamics* 2nd edn. New York: McGraw Hill.
- Luc W A P (1974) *Structure of Water and Aqueous Solutions*. Verlag Chemie Weinheim, Germany.
- M. Al-Ghamdi,(2006) *Saline Water Conversion Corporation: Challenge, Achievement, and Future Prospective*. Lecture notes,
- Matthess G (ed) (1982) *The Properties of Ground Water*. New York: Wiley Interscience Publishing Company.
- Meadows P S and Campbell J I (1988) *Marine Science: An Introduction*. New York: John Wiley and Sons.
- Mellor J W (1946) *A Comprehensive Treatise on Inorganic and Theoretical Chemistry*, Vol. 1. London: Longman's Green and Company.
- National Primary Drinking Water Regulations." U.S. Environmental Protection Agency, 2009.
- Pitchiah P S (1955) *Ground Water*. Jodhpur, India: Scientific Publishers.
- Ray P (1973) *Thermodynamic Properties of Sea Salt Solutions by Boiling Point Elevation Method*. Ph.D. Thesis, University of California, Berkeley.
- Reynolds, T. D., and P. A. Richards. "Water Quality." In *Unit Operations and Processes in Environmental Engineering*. Boston, MA: PWS Publishing, 1995, pp. 78-91
- S.D. Faust and O.M.Aly (1998), *Chemistry of Water Treatment*, 2nded. Boca Raton: Lewis

Publishers/CRC

Salvo Jr J A (1972) *Environmental Engineering and Sanitation*. New York: Wiley Interscience.

Spiegler K S (1962) *Salt Water Purification*. New York: Wiley.

Spiegler K S and Laird A D K (1980) *Principles of Desalination: Part B*. New York: Academic Press.

Stoughton R W and Lietzke M H (1965) Calculation of some thermodynamic properties of sea salt solutions at elevated temperatures from data on NaCl solutions. *J. Chem. Eng. Data* **10**, 254.

Stoughton R W and Lietzke M H (1967) Thermodynamic properties of sea salt solutions. *Chemical Engineering Data* **12**, 101.

Sverdrup H U, Johnson M W and Fleming R H (1942) *The Oceans: Their Physics, Chemistry and General Biology*. New York: Prentice Hall Inc.

T.D.Reynolds and P.A. Richards(1995), *Unit Operations and Processes in Environmental Engineering*, 2nded. Boston: PWSPublishing Co.

Tebbutt T H Y (1992) *Principles of Water Quality Control*, 4th edn. Oxford: Pergamon Press.

Todd D K (1959) *Ground Water Hydrology*. New York: John Wiley and Sons.

Twort A C, Law F M, Crowley F M and Ratnayaka D D (1994) *Water Supply*, 4th edn. London: Edward Arnold, London.

Viessman Jr W (1985) *Water Supply and Pollution Control*, 4th edn. New York: Harper and Row Publishers.

W. Wagner and A. Pruss (2002) , The IAPWS formulation 1995 for the thermodynamic properties of ordinary water substance for general and scientific use, *Journal of Physical and Chemical Reference Data*, **31** ,387–535.

Weber Jr W J (1972) *Physicochemical Processes for Water Quality Control*. London: Wiley Interscience.

WHO Guidelines for drinking-water quality, 3rd edition. Geneva: World Health Organization, 2006.

Wright J and Colling A (1995) *Seawater: Its Composition, Properties and Behaviour*. Oxford: Pergamon Elsevier Science Ltd.

Yaws C L (1977) *Physical Properties: A Guide to the Physical, Thermodynamic and Transport*. New York: McGraw Hill Publishing Company.