Total Dissolved Solids (TDS)

An aesthetic objective of *≤500 mg/L* has been established for total dissolved solids (TDS) in drinking water. At higher levels, excessive hardness, unpalatability, mineral deposition and corrosion may occur. At low levels, however, TDS contributes to the palatability of water.

Definition

Total dissolved solids (TDS) comprise inorganic salts and small amounts of organic matter that are dissolved in water. The principal constituents are usually the cations calcium, magnesium, sodium and potassium and the anions carbonate, bicarbonate, chloride, sulphate and, particularly in groundwater, nitrate (from agricultural use).

Occurrence

Total dissolved solids in water supplies originate from natural sources, sewage, urban and agricultural runoff and industrial wastewater. In Canada, salts used for road deicing can contribute significantly to the TDS loading of water supplies. Concentrations of TDS in water vary owing to different mineral solubilities in different geological regions. The concentration of TDS in water in contact with granite, siliceous sand, well-leached soil or other relatively insoluble materials is usually below 30 mg/L.[1] In areas of Precambrian rock, TDS concentrations in water are generally less than 65 mg/L.[2] Levels are higher in regions of Palaeozoic and Mesozoic sedimentary rock, ranging from 195 to 1100 mg/L[2] because of the presence of carbonates, chlorides, calcium, magnesium and sulphates.[1,3] Concentrations of TDS in some streams and small lakes in the arid western regions of Canada and the United States are often as high as 15 000 mg/L.[3,4]

Concentrations of TDS, expressed as the sum of its constituents, were below 500 mg/L in 36 of 41 rivers monitored in Canada.[5] In a survey of the Great Lakes, TDS levels ranged from 61 to 227 mg/L.[6] The levels of TDS in all of the Great Lakes except Lake Superior increased between 1900 and 1970. A threefold increase in chlorides and a twofold increase in sulphates, sodium and potassium in Lakes Erie and Ontario[7] increased the TDS concentration in those lakes by 50 to 60 mg/L.[6,8–10]

Concentrations of TDS in drinking water in Canada are generally below 500 mg/L but are considerably higher in some locations, particularly the arid western regions. Levels of TDS in Newfoundland and Labrador were below 500 mg/L in 96% of 103 communities sampled from 1969 to 1989 (range 10 to 2263 mg/L; average 146 mg/L).[11] In Quebec, samples of distributed water taken at 19 plants between 1987 and 1989 contained TDS at mean concentrations ranging from 58 to 213 mg/L.[12] Concentrations of TDS in distributed water from 31 plants in Ontario during 1987 and 1988 ranged from 91 to 470 mg/L.[13] In Manitoba, TDS concentrations measured during 1988 in the treated water of 168 communities ranged from 56 to 2510 mg/L; concentrations were less than 500 mg/L in 19% of these communities.[14] Levels of TDS in 1978 samples of community drinking water taken between 1970 and 1989 in Saskatchewan ranged from 6.5 to 5376 mg/L.[15] Concentrations of TDS in 54% of 1042 communities surveyed in Alberta in October 1989 were below 500 mg/L (range <100 to 1000 mg/L).[16] In British Columbia, concentrations of TDS in individual well water supplies ranged from 120 to 4662 mg/L; those in community (generally surface water) supplies were commonly less than 500 mg/L.[17]

Analytical Methods and Treatment Technology

The method most commonly used for the analysis of TDS in water supplies is the measurement of specific conductivity with a conductivity probe that detects the presence of ions in water. Conductivity measurements are converted to TDS values by a factor that varies with the type of water.[18,19] The practical quantitation limit for TDS in water by this method is 10 mg/L.[20] High TDS concentrations can also be measured gravimetrically, although this method excludes volatile organics.[21] The constituents of TDS can also be measured individually.

Total dissolved solids are not appreciably removed using conventional water treatment processes. In fact, the addition of chemicals during conventional water treatment generally increases the TDS concentration.[22] Certain treatment processes, such as lime–soda ash softening and sodium exchange zeolite softening, may

slightly decrease or increase the TDS concentration, respectively.[23] Demineralization processes are required for significant TDS removal. Although the technology is available to reduce TDS levels significantly, the economic cost may be a major constraint.[23] Reverse osmosis and electrodialysis would probably be the most economical processes for removing TDS from public water supplies.[24]

Health Considerations

Recent data on health effects associated with the ingestion of TDS in drinking water have not been identified; however, associations between various health effects and hardness, rather than TDS content, have been investigated in many studies. These data are discussed in the section on hardness. As well, some of the individual components of TDS can have effects on human health. Effects that can be attributed to specific constituents are discussed in separate reviews for those constituents.

In early studies, inverse relationships were reported between TDS concentrations in drinking water and the incidence of cancer,[25] coronary heart disease,[26] arteriosclerotic heart disease[27] and cardiovascular disease.[28,29] Total mortality rates were reported to be inversely correlated with TDS levels in drinking water.[29,30]

Conversely, a summary of an Australian study reported that mortality due to all categories of ischaemic heart disease and acute myocardial infarction was increased in a community with higher levels of soluble solids, calcium, magnesium, sulphate, chloride and fluoride, alkalinity, total hardness and pH, when compared with a community in which levels were lower.[31] No attempts were made to relate mortality due to cardiovascular disease to other potential confounding factors. The results of a limited epidemiological study in the former Soviet Union indicated that the average number of “cases” of inflammation of the gall bladder and gallstones over a five-year period increased with the mean level of dry residue in the groundwater.[32] It should be noted, however, that the number of “cases” varied greatly from year to year in one district, as did the concentration of dry residue in each district, and no attempt was made to take into account possible confounding factors.

Other Considerations

The presence of dissolved solids in water may affect its taste.[33–42] The palatability of drinking water has been rated, by panels of tasters, according to TDS level as follows: excellent, less than 300 mg/L; good, between 300 and 600 mg/L; fair, between 600 and 900 mg/L; poor, between 900 and 1200 mg/L; and unacceptable, greater than 1200 mg/L.[37] Water with extremely low TDS concentrations may also be unacceptable because of its flat, insipid taste.

In addition to palatability, certain components of TDS such as chlorides, sulphates, magnesium, calcium and carbonates also affect corrosion or encrustation in water distribution systems.[21] High TDS levels (above 500 mg/L) result in excessive scaling in water pipes, water heaters, boilers and household appliances such as tea kettles and steam irons.[43] Such scaling can shorten the service life of these appliances.[44]

Rationale

1. The most important aspect of TDS with respect to drinking water quality is its effect on taste. The palatability of drinking water with a TDS level less than 600 mg/L is generally considered to be good. Drinking water supplies with TDS levels greater than 1200 mg/L are unpalatable to most consumers.

2. Concentrations of TDS above 500 mg/L result in excessive scaling in water pipes, water heaters, boilers and household appliances.

3. An aesthetic objective of ≤500 mg/L should ensure palatability and prevent excessive scaling. However, it should be noted that at low levels TDS contributes to the palatability of drinking water.

References

1. Rainwater, F.H. and Thatcher, L.L. Methods for collection and analysis of water samples. Geological Survey Water-Supply Paper, U.S. Department of the Interior. U.S. Government Printing Office, Washington, DC (1960).

2. Garrison Investigative Board. Water quality report (Appendix A). Garrison Diversion Study, report to the International Joint Commission (1977).

3. Durfor, C.J. and Becker, E. Constituents and properties of water. In: Water quality in a stressed environment: readings in environmental hydrology. W.A. Pettyjohn (ed.). Burgess Publishing Company, Minneapolis, MN (1972).

4. Rawson, D.S. and Moore, J.E. The saline lakes of Saskatchewan. Can. J. Res., 22: 141 (1944).

5. Fisheries and Environment Canada. Surface water quality in Canada. An overview. Water Quality Branch, Inland Waters Directorate (1977).

6. Upper Lakes Reference Group. The waters of Lake Huron and Lake Superior. Vols. I to III, Parts A and B. Report to the International Joint Commission (1977).

7. Great Lakes Water Quality Board. Great Lakes water quality 1974. Appendix A. Water Quality Objectives Subcommittee report to the International Joint Commission (1975).

8. Beeton, A.M. Indices of Great Lakes eutrophication. Publ. No. 15, Great Lakes Research Division, University of Michigan, Ann Arbor, MI (1966).

9. Kormondy, E.J. Concepts of ecology. Prentice-Hall, Englewood Cliffs, NJ. p. 182 (1969).

10. Vaughn, J.C. and Reed, P.A. Quality status of southern Lake Michigan. J. Am. Water Works Assoc., 62: 103 (1972).

11. Dominie, K. Personal communication. Newfoundland and Labrador Department of Environment and Lands (1989).

12. Durocher, H. Personal communication. Ministère de l'Environnement, Gouvernement du Québec (1990).

13. Vajdic, A. Personal communication. Ontario Ministry of the Environment (1989).

14. Rocan, D. Personal communication. Manitoba Department of Environment (1989).

15. Nargang, D. Personal communication. Saskatchewan Department of the Environment and Resource Management (1989).

16. Spink, D. Personal communication. Alberta Ministry of Environmental Protection (1989).

17. Willoughby, B.A. Personal communication. B.C. Ministry of Health (1989).

18. Ontario Ministry of the Environment. Outlines of analytical methods. A guide to the occurrence, significance, sampling and analysis of chemical and microbial parameters in water. February (1975).

19. Singh, T. and Kalra, Y.P. Specific conductance method for in situ estimation of total dissolved solids. J. Am. Water Works Assoc., 67(2): 99 (1975).

20. Forbes, M. Personal communication. Canada Centre for Inland Waters, Burlington, Ontario (1988).

21. Sawyer, C.N. and McCarty, P.L. Chemistry for sanitary engineers. 2nd edition. McGraw-Hill Series in Sanitary Science and Water Resources Engineering, McGraw-Hill, Toronto (1967).

22. Department of National Health and Welfare. Water treatment principles and applications: a manual for the production of drinking water. Canadian Water and Wastewater Association (1993).

23. Canadian Council of Resource and Environment Ministers. Total dissolved solids. In: Canadian water quality guidelines. Prepared by the Task Force on Water Quality Guidelines. Environment Canada, Ottawa, March (1987).

24. Clark, J.W., Viessman, W., Jr. and Hammer, M.J. Water supply and pollution control. 3rd edition. Harper & Row Publishers, New York, NY (1977).

25. Burton, A.C. and Cornhill, J.F. Correlation of cancer death rates with altitude and with the quality of water supply of the 100 largest cities in the United States. J. Toxicol. Environ. Health, 3(3): 465 (1977).

26. Schroeder, H.A. Relation between mortality from cardiovascular disease and treated water supplies. Variation in states and 163 largest municipalities. J. Am. Med. Assoc., 172: 1902 (1960).

27. Schroeder, H.A. Municipal drinking water and cardiovascular death rates. J. Am. Med. Assoc., 195: 125 (1966).

28. Sauer, H.I. Relationship between trace element content of drinking water and chronic disease. Univ. Ill. Bull., 71(108): 39 (1974).

29. Craun, G.F. and McCabe, L.J. Problems associated with metals in drinking water. J. Am. Water Works Assoc., 67: 593 (1975).

30. Crawford, M., Gardner, M.J. and Morris, J.N. Mortality and hardness of local water supplies. Lancet, i: 827 (1968).

31. Meyers, D. Mortality and water hardness. Lancet, i: 398 (1975).

32. Popov, V.V. Cholelithiasis and calculi, hardness of drinking water. Gig. Sanit., 33(6): 416 (1970).

33. Bruvold, W.H. and Pangborn, R.M. Rated acceptability of mineral taste in water. J. Appl. Psychol., 50(1): 22 (1966).

34. Bruvold, W.H., Ongerth, H.J. and Dillehay, R.C. Consumer attitudes toward mineral taste in domestic water. J. Am. Water Works Assoc., 59: 547 (1967).

35. Bruvold, W.H. Scales for rating the taste of water. J. Appl. Psychol., 52: 245 (1968).

36. Bruvold, W.H. Mineral taste and the potability of domestic water. Water Res., 4: 331 (1970).

37. Bruvold, W.H. and Ongerth, H.J. Taste quality of mineralized water. J. Am. Water Works Assoc., 61: 170 (1969).

38. Cox, G.J., Nathans, J.W. and Vonau, N. Subthreshold-to-taste thresholds of sodium, potassium, magnesium and calcium ions in water. J. Appl. Physiol., 8: 283 (1955).

39. Bryan, P.E., Kuzmunski, L.N., Sawyer, F.M. and Feng, T.H. Taste thresholds of halogens in water. J. Am. Water Works Assoc., 65: 363 (1973).

40. Pangborn, R.M. and Bertolero, L.L. Influence of temperature on taste intensity and degree of liking of drinking water. J. Am. Water Works Assoc., 64: 511 (1972).

41. Bruvold, W.H. and Pangborn, R.M. Rated acceptability of mineral taste in water. J. Appl. Psychol., 50: 22 (1966).

42. Pangborn, R.M., Trabue, I.M. and Little, A.C. Analysis of coffee, tea, artificially flavoured drinks prepared from mineralized waters. J. Food Sci., 36: 355 (1971).

43. Tihansky, D.P. Economic damages from residential use of mineralized water supply. Water Resour. Res., 10(2): 145 (1974).

44. McQuillan, R.G. and Spenst, P.G. The addition of chemicals to apartment water supplies. J. Am. Water Works Assoc., 68: 415 (1976).