11 Total Dissolved Solids (TDS)

Total dissolved solids (TDS) is defined as all inorganic and organic substances contained in water that can pass through a 2 micron filter. In general, TDS is the sum of the cations and anions in water. Ions and ionic compounds making up TDS *usually* include carbonate, bicarbonate, chloride, fluoride, sulfate, phosphate, nitrate, calcium, magnesium, sodium, and potassium, but *any* ion that is present will contribute to the total. The organic ions include pollutants, herbicides, and hydrocarbons. In addition, soil organic matter compounds such as humic/fulvic acids are also included in TDS. There are a variety of ways to measure TDS. The simplest is to filter the water sample, and then evaporate it at 180° C in a pre-weighed dish until the weight of the dish no longer changes. The increase in weight of the dish represents the TDS, and it is reported in mg/L. The TDS of a water sample can also be estimated fairly accurately from the electrical conductivity of the sample via a linear correlation equation dependent upon specific conductivity. Finally, TDS can be calculated by measuring individual ions and simply adding them together.

Total dissolved solids is a non-specific, quantitative measure of the amount of dissolved inorganic chemicals but does not tell us anything about **its** nature. TDS is not considered a primary pollutant with any associated health effects in human drinking water standards, but it is rather used as an indication of aesthetic characteristics of drinking water and as a broad indicator of an array of chemical contaminants.

Essentiality

Although many essential elements may contribute to TDS, the measurement technique does not, itself, differentiate essential from toxic elements.

Metabolism

Since TDS represents an undifferentiated collection of just about everything dissolved in a water sample, it is impossible to speak of the "metabolism" of TDS.

Toxicity

Interestingly, early epidemiologic studies suggested that "moderately high" TDS concentrations ("high" in this context being less than 1,000 mg/L) protected people against cancer and heart disease.[641-644] Although the mechanism(s) underlying these early observations are not completely understood, it was first narrowed down to "hardness" as opposed to TDS. It now appears certain constituents of TDS, notably Mg, interfere with the formation of thrombi in arteriosclerosis.[641,645] Another hypothesis for the protective effect is that some components of hardness decrease leaching of toxic elements from plumbing.[644] The inclusion of other cardiac risk factors, such as Na, in the total TDS of earlier studies probably accounts for the conflicting results in the older literature.

Saline waters may adversely impact animal health by several possible mechanisms. One of the most important biological functions of water in mammals is as a solvent for nutrients, waste products, etc. The presence of extraneous solutes decreases the ability of water to serve this function by decreasing its ability to dissolve additional solutes. A similar, related factor is plasma osmolarity. Solutes exert an attraction on water across membranes, and inappropriate water movement is disastrous to cells and tissues. An extreme example of this effect is water intoxication that results in death, as was the case with a young woman in California.[646] Mammals expend a considerable amount of energy maintaining the osmolar concentration of various body compartments within a fairly narrow range. The presence of excessive solutes in drinking water adds to this burden and consumes resources that would otherwise be used for growth, milk production, or fighting off disease. It is well-accepted that extreme drinking water TDS concentrations in the 1.5%-3% range are incompatible with life[546,551,557,586,647,648]; however, the effects of lower TDS concentrations are too multifactorial, involving species, age, sex, diet, pregnancy, lactation, environmental conditions, etc., to lend themselves to simple all-or-nothing results. Also, the fact animals may "tolerate" (in other words, survive) a particular concentration is not the same as proving they remained productive on it.

Elevated TDS adversely affects the palatability of water. In humans, taste panels rated the palatability of water with 300 mg/L as "excellent," 300-600 mg/L "good," 600-900 mg/L "fair," 900-1,200 mg/L "poor," and greater than 1,200 mg/L "unusable." Earlier criteria for human health were based upon this fact.[649] In livestock, decreased palatability is well-recognized as an important determinant of water consumption and, indirectly, feed consumption and performance. Cattle given water containing 6,000-15,000 mg/L TDS exhibited decreased water intake, feed intake, and average daily gain (ADG).[550,618,626,650-652] Five thousand mg/L decreased feed intake and gain of cattle on a high roughage diet.[653] Dairy cows given 2,040 mg/L water consumed less water and produced less milk when the peak ambient temperature was 32.1 C than cows given desalinated water.[654] Similar decreases in milk production attributed to consuming saline water were seen in Arizona.[547,655] Swine subsisting on water containing 10,000-15,000 mg/L drank less, ate less, and performed more poorly than controls.[565] Sheep seem to be more tolerant of saline waters than most domestic species and will drink them if introduced to the saline water over a period of several weeks.[540,541,575-580,656,657] The two references regarding saline waters in horses indicate they are reluctant to drink such water[551], and it has been alluded they can be maintained on water containing up to 9,500 mg/L TDS.[658] Limited studies with farmed deer in Australia indicate TDS concentrations as high as 4,000-6,000 mg/L are tolerated without any reduction in feed or water consumption.[659,660] We were unable to find any reports addressing the effects of salinity on wild deer.

Even when animals drink more in an attempt to compensate for poor water quality, the increased metabolic load imposed by high solute water may result in impaired performance. Water containing 1.5% NaCl (15,000 ppm) and given to cattle for less than a week resulted in a 13.7% reduction in weight, as well as decreasing feed and water-intake, and marked hypernatremia.[550] In a similar, short-term experiment at cool temperatures, cattle given 15,000 mg/L TDS water drank more, ate and grew less, and showed clinical signs of dehydration.[558] Five-thousand mg/L TDS for 51 days decreased gain in heifers.[651]

Summary

Total dissolved solids in drinking water serves as a very poor predictor of animal health. As noted above, TDS is a measure of all inorganic and organic substances dissolved in water. These individual solutes range in toxicity from relatively non-toxic substances, such as Ca^{2+}, to extremely toxic (Hg^{2+}, Se^{+4}), but tests of TDS do not differentiate between them. Several early studies suggest no significant effects in sheep at TDS concentrations up to 13,000 mg/L or cattle and swine up to 5,000 mg/L, and the NRC[661] accepted larger concentrations as tolerable "for older ruminants and horses," yet the authors have seen animals poisoned by waters in which the TDS was measured as slightly less than 500 mg/L,[415,662] and there are reports of decreased productivity in dairy cattle at 2,000-2,500 mg/L. Early epidemiologic studies in people suggested high drinking water TDS decreased the incidence of cancer and heart disease in people. Later, however, studies narrowed the active component of TDS that was negatively correlated with heart disease, first to hardness, then finally to the Mg^{2+} ion concentration. In human health, the World Health Organization dropped health-based recommendations for TDS in 1993, instead retaining 1,000 mg/L as a secondary standard for "organoleptic purposes." *The test is just too non-specific to be reliable.* As noted by Chapman et al.[663], in a study of aquatic toxicity, "Toxicity related to these ions is due to the specific combination and concentration of ions and is not predictable from TDS concentrations."

We do not recommend relying upon TDS to evaluate water quality for livestock and wildlife; **however, if no other information is available, TDS concentrations less than 500 mg/L should ensure safety from almost all inorganic constituents. Above 500 mg/L, the individual constituents contributing to TDS should be identified, quantified, and evaluated.**