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TDS and Temperature Affect Consumer Taste Preferences

Although treatment and regulations drive the drinking water industry, most consumers judge drinking water based on taste, odor, and visual qualities rather than treatment or reported water quality parameters. It's important, therefore, to understand the qualities of drinking water that produce sensory reactions. BY CONOR D. GALLAGHER AND ANDREA M. DIETRICH

CONSUMERS HAVE high expectations of drinking water, including safety and sanitation, as well as aesthetics and taste. Because consumers desire consistency in their food and beverage products, changes in water quality resulting from mineral content or disinfectant levels are so noticeable that they can result in consumer complaints. Accordingly, a utility's ability to produce an acceptable, consistent product is a big part of gaining and keeping the public's trust. Consumers notice when water doesn't taste right. A recent study at Virginia Tech investigated the influence of total dissolved solids (TDS) and temperature on consumers' ability to discriminate water based on taste and to determine their preferences.

VOCABULARY

SENSORY TEST METHODS

Forced Choice. In a sensory difference test, it's good practice to require assessors to choose even when they're uncertain. If they're allowed to respond that they don't know which sample to choose or that there are no differences among the samples, the ability to give an opinion becomes confused with being able to detect the sensory attribute being studied. Also, there is ambiguity about how "don't know" responses should be used in the analysis. In a forced-choice procedure, assessors are instructed not to opt out of choosing and to guess at random if necessary.

Triangle Test. The triangle test is a commonly used sensory-difference test. In this test, three samples are presented to each assessor—two of which are identical and one that's different in some way. Assessors are instructed to indicate which of the three is odd. If the difference is undetectable to the assessor, the probability of making the correct choice is one in three (0.333). If correct choices are made more than one time in three, the best estimate of the probability of making a correct choice is greater than 0.333 and constitutes some evidence that the difference between the two types of sample is detectable. Other things being equal, this evidence is more convincing if there's a greater proportion of correct choices or if the number of trials is greater. If the proportion is correct and the number of trials is sufficiently great, the result may be statistically significant.

Source: StatBasics (www.statbasics.com/difftest/glossary.htm)

TDS LEVELS

Minerals, the major contributor to water taste, usually enter natural waters through weathering or erosion of rock and soil but may also come from man-made sources, such as road salt or industrial discharges. The mineral content of drinking water usually isn't altered much from source to tap, but desalination and blending are changing that paradigm. The mineral content of drinking water is frequently measured as TDS, which includes common cations such as calcium, magnesium, potassium, and sodium, as well as anions such as carbonate, bicarbonate, chloride, nitrate, sulfate, and silicates.

The US Environmental Protection Agency and Health Canada limit TDS to a 500-mg/L maximum, and the World Health Organization established a TDS maximum of 1,000 mg/L. Increasing consumer complaints prompted the Taiwan Environmental Protection Agency to reduce the maximum TDS level from 600 mg/L to 250 mg/L.

Acceptable TDS concentrations vary globally and are influenced by population preferences, from a high of 251–500 mg/L

A water taste competition is a fun and exciting way to draw attention to the intricacies of delivering safe, great-tasting tap water. Each year at the AWWA Annual Conference, winners of AWWA Section taste tests compete for the title of "Best of the Best."

PHOTOGRAPH: DAVE PLANK, AWWA

to a low of less than 100 mg/L. Maintaining TDS at less than 250 mg/L is advisable to avoid a distinct mineral taste. For drinking water in the 100 largest US cities, the range is 22–1,589 mg/L TDS with a median of 186 mg/L. In Canada, TDS levels in drinking water are generally less than 500 mg/L but may be higher in arid western regions.

MINERAL CONTENT AND TEMPERATURE

Temperature also affects what consumers think about their water. Tap water's serving temperature generally ranges from 4°C to about 30°C. North Americans generally have a preference for cold water, but this preference varies globally. Water temperature is known to affect dissolved oxygen content, but the dissolved oxygen content of drinking water has been shown to be unrelated to taste.

Consumers generally detect less of a mineral taste when waters containing 750–1,000 mg/L TDS were chilled to 0°C than at room temperature. A similar temperature-related trend was observed for 11 tap waters ranging from 38 mg/L to 2,460 mg/L TDS, with four of those samples containing less than 500 mg/L TDS and seven samples containing more than 500 mg/L TDS.

Using a forced-choice triangle test (see Sensory Test Methods, page 20) conducted with room-temperature water samples, utility-based consumer panels and sensory experts consistently discerned a difference between treated surface water with ~500 mg/L or higher TDS and desalinated water that was remineralized or blended to much lower TDS values. Reverse osmosis (RO) water from desalination was generally rated as taste free and odor free, with a drying feeling, even when the water was adjusted to up to 100-mg/L alkalinity (as calcium carbonate).

Although major taste factors result from mineral content (TDS) and temperature, the relationship between these factors hasn't been explored much, especially at TDS values greater than 500 mg/L—the upper limit of many secondary standards. In addition, few studies evaluate discriminative *and* preference testing by consumers. This study's objectives were to investigate

- the influence of TDS and temperature on consumers' ability to discriminate among samples.
- consumer preference for waters of different TDS values.
- whether an ability to discriminate relates to preference.

TASTE TESTS

The study's tasting protocol was approved by the Institutional Review Board at Virginia Tech, and participants granted free and informed consent. Approximately equal numbers of males and females (age range 18–60 years) participated. Subjects tasted two ounces of water in three-ounce coded cups presented in a balanced random fashion. Three waters—A, B, and C—were tested at 4°C and 22–24°C. TDS levels of the waters were 25 mg/L, 36 mg/L, and 500 mg/L for A, B, and C, respectively.

Discrimination Testing. Using the triangle test (see Sensory Test Methods, page 20), subjects were simultaneously presented with three samples of water, consisting of two samples of one water and one sample of another. The samples were

Table 1. Water Quality Data

The researchers used commercially available bottled water.

Water Quality Parameter	Water A	Water B	Water C
pH	4.81	4.99	7.28
TOC, mg/L	0.055	0.16	0.05
TDS, mg/L	2.8	31	524
HCO_3, mg/L	0.71	0.22	463

If a treatment change is planned that will significantly alter the historical TDS concentration, a utility should inform customers of the change and consider performing taste tests.

Table 2. Triangle Test Results

Discrimination was based on TDS and temperature. (N = 53; N critical = min 25 correct responses)

Test Waters	4°C		22–24°C	
	Correct Responses	Able to Discriminate	Correct Responses	Able to Discriminate
A vs. B	24	No	19	No
A vs. C	24	No	26	Yes
B vs. C	23	No	35	Yes

coded with random three-letter labels of all possible serving orders (e.g., AAB, ABA, BAA, BAB, BBA, ABB). The subjects were instructed to taste the samples in the order presented and select the one sample that was different.

For the discrimination test, 318 subjects participated, most of whom were North American. Six groups of 53 subjects evaluated one combination of samples at one temperature—Waters A and B, A and C, and B and C. The sample size and significance was based on alpha = 0.05, beta = 0.1, and pd = 0.3; N critical = 25 correct responses out of 53.

Preference Testing. Using the paired-sample test, subjects were presented with two samples of two different waters at 4°C or 22–24°C. The panelists were instructed to taste the samples and choose the one they preferred. The samples were coded with random three-letter labels, and the presentation order was balanced among panelists by using both possible serving orders (AB and BA).

For the preference test, 390 subjects participated. Six groups of 65 subjects evaluated one pair of waters at one temperature: Waters A and B, A and C, and B and C. The sample size and significance was based on alpha = 0.05, beta = 0.1, and pd = 0.3; N critical = 42 correct responses out of 65.

Characteristics of Test Waters. The research used commercially available bottled water that had been refrigerated or stored at room temperature. Bottled water was used for convenience, as it was available in sealed bottles, didn't require dechlorination or refrigeration, and had reproducible water quality. Bottles were stored for up to two weeks before use and weren't opened until it was time to pour the contents into cups for subjects to taste. TDS, organic carbon, inorganic carbon, and pH were measured in a laboratory (Table 1).

TASTE TEST RESULTS

Table 2 presents data for discrimination testing using the triangle test. Table 3 presents data for preference testing using the paired sample test.

The results demonstrated that—at the 95 percent confidence level—subjects couldn't distinguish the three 4°C waters, nor did they prefer one sample over the other in the paired comparison test. When the three samples were 22–24°C, the subjects couldn't distinguish between the two low-TDS waters (A and B) and didn't have a preference for either low-TDS water.

In contrast, at 22–24°C, subjects could distinguish between the high-TDS-level water and either low-TDS water (A vs. C or B vs. C), but there was no preference for 22–24°C water. The results for all combinations—including chilled (4°C) and unchilled water (22–24°C)—indicated the subjects didn't prefer any water even when they could distinguish a taste based on varying TDS levels, from low (25–36 mg/L) to moderate (560 mg/L).

Interestingly, certain individuals were confident in distinguishing the waters and their preference for one water over another, illustrating that some consumers had sensitive palates and strong TDS preferences. The water that elicited the most negative responses was high-TDS Water C. However, pH is unlikely to be the reason for the ability to discriminate Water C from Waters A and B, because the main carbonate species in all three waters was bicarbonate, which is much less flavorful than carbonate.

Table 3. Paired Comparison—Preference Test

Subjects didn't prefer any water even when they could distinguish a taste based on varying TDS levels. (N = 65 for each water pair; N critical = 42 correct responses)

Test Waters	4°C		22–24°C	
	Preference	Ratio*	Preference	Ratio
A vs. B	No	28/37	No	29/36
A vs. C	No	32/34	No	40/25
B vs. C	No	35/31	No	36/29

*Ratio = number of subjects who indicated water was their preference; for example, for A vs. B at 4°C, 28 subjects chose Water A and 37 subjects chose Water B.

WHAT DOES IT MEAN?

The research indicates that utilities should consider how TDS concentrations affect consumers' perceptions. If a treatment change is planned that will significantly alter the historical TDS concentration (such as implementation of RO, blending practices, or alternative source water), a utility should inform customers of the change and consider performing taste tests.

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