Consumer ability to detect the taste of total dissolved solids

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Minerals, as measured by total dissolved solids (TDS), are a major source of taste in drinking water. Consumers report taste differences in their water supplies when mineral content changes as a result of anthropogenic activities or treatment techniques such as desalination or blending. Using sensory analysis, panels of consumers compared binary combinations of room-temperature water samples containing different TDS concentrations and reported when they could detect differences. Results demonstrate that the amount of change in TDS (Δ TDS) is an important parameter in a consumer's ability to discern differences in taste. With the same Δ TDS, panelists more readily discerned differences between low and moderate TDS concentrations than between moderate and high TDS concentrations. When water with low TDS concentrations (< 100 mg/L) becomes saltier, consumers will more readily detect a difference. Conversely, treatment to reduce high TDS concentrations will require substantial TDS removal to improve taste.

Keywords: *aesthetics, consumers, desalination, drinking water, minerals, sensory perception, taste, total dissolved solids*

Drinking water, whether tap water or bottled, is a product that consumers expect to be safe and sanitary, as well as palatable and devoid of any unpleasant tastes or odors (McGuire, 1995; Dietrich, 2006). Because the minerals in drinking water are responsible for taste, water containing very low concentrations of minerals or no minerals at all is considered to have a flat taste (Burlingame et al, 2007). Mineral content and temperature are major factors in the palatability of water when no competing off-flavors are present. Though an individual may have a preference for cold or room-temperature water for drinking, the minerals have more taste when the water is at room temperature than at 0–4°C (Pangborn & Bertolero, 1972; Gallagher & Dietrich, 2010).

The main sources of minerals in drinking water are not only weathering, erosion, and disturbances of rock and soil (van der Aa, 2003) but also anthropogenic sources such as road salt and industrial discharges, as well as distribution system characteristics—especially those caused by the release of hardness and hydroxide from new cement in pipes or liners (Deb et al, 2010). The total dissolved solids (TDS) concentration is an aggregate measure used to assess aqueous mineral content. Water with a TDS concentration of < 1,500 mg/L is considered freshwater (Masters & Ela, 2007). Drinking water can be rated according to different TDS scales. For example, typical ratings for low-TDS tap water are < 100 mg/L TDS; for moderate-TDS tap water, 101–250 mg/L TDS; and for high-TDS tap water, 251–500 mg/L TDS (Burlingame et al, 2007). Aesthetic guidelines in both the United States (USEPA, 1979) and Canada (Health Canada, 1991) limit TDS concentrations to a maximum of 500 mg/L, and the World Health Organization (1996) has established 1,000 mg/L TDS as its guideline. As a result of increasing consumer complaints and a survey indicating that 60% of Taiwan's residents did not drink their water because it did not taste good, the Taiwan Environmental Protection Administration proposed reducing that nation's maximum TDS concentration to 250 mg/L TDS from 600 mg/L (Lou et al, 2007). The value was reduced to 500 mg/L in the 2009 revisions to the administration's water quality standards (Taiwan EPA, 2009).

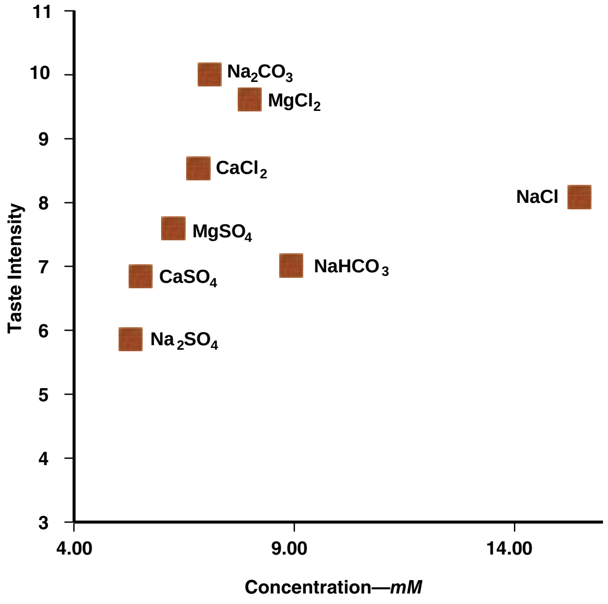
The components of TDS include common cations such as calcium, magnesium, potassium, and sodium, as well as anions including carbonate, bicarbonate, chloride, nitrate, sulfate, and silicate. Different minerals impart different tastes at different concentrations. For example, sodium is responsible for a salty taste (Smith & Margolskee, 2001), which many individuals can taste at 175 mg/L sodium ion in room-temperature water (Zoeteman et al, 1978); magnesium has a more bitter taste than calcium (Smith & Margolskee, 2001); many individuals can taste 10 mg/L magnesium ion in water (Zoeteman et al, 1978); and bicarbonate has a more pleasant and less bitter taste than carbonate (Burlingame et al, 2007). Taste is also affected by pH because it controls the distribution of carbonate species, and basic pH values are associated with a slippery mouthfeel. For the same TDS of 750 mg/L per salt—which equates to different molar concentrations—different salts have different taste intensities, with sodium chloride being more intense than sodium sulfate and less intense than sodium carbonate when tasted in water at room temperature (Figure 1). Free chlorine or chloramines had no effect on the perception of taste in water containing 630 mg/L sodium chloride (Weisenthal et al, 2007), and thus disinfectants are not expected to alter the mineral taste of water.

Because consumers desire consistency in their food and beverage products, changes in the taste and odor of tap water are readily noticed (Doria et al, 2009; McGuire et al, 2007; Lawless & Heymann, 1998). Although conventional water treatment does little to change the TDS content of drinking water, membrane processes alter TDS, tastes, and odors (Duranceau et al, 2012; Devasa et al, 2010; Bruchet & Lâiné, 2005). Permanent, temporary, and seasonal reductions in drinking water minerals are caused by blending or point-of-use devices. Increased mineralization of drinking water can occur as a result of climate change (Norwine & John, 2008; Ramaker et al, 2005) or anthropological activities including the alteration of hydrogeology or stream flows (Hao et al, 2009), saltwater intrusion (Murgulet & Tick, 2008), or industrial activities such as natural gas drilling and mine drainage.

In 2009 the Monongahela River, the primary drinking water source for Pittsburgh and southwest Pennsylvania, periodically experienced unexplained increased TDS concentrations, which resulted in a saltier taste and a surge in customer concerns and complaints. In response, the water utility, the Pennsylvania Department of Environmental Protection, and the news media were obligated to provide public service announcements to quell consumer fears and explain the TDS-induced issue with taste (Hopey, 2009; Pennsylvania American Water, 2009). When consumers of treated Monongahela River water noticed the saltier taste and became concerned about the water's safety, the utility responded because producing a consistently acceptable product is a significant determinant of public trust and confidence in a drinking water utility (Dietrich, 2006; Azoulay et al, 2001; McGuire, 1995).

The question that arises is at what level of change in TDS can consumers detect a change in the taste of their water? To answer this, a brief review of the senses of taste is appropriate. There are only five tastes—sweet, sour, salty, bitter, umami—and humans have taste receptors that respond to all five. Studies have shown that the thresholds for human perception of the five basic tastes are genetic and do not vary with ethnicity, but preferences for some tastes over others vary among cultures and individuals (Laing et al, 1993). For example, some people like salty foods and others do not. The French prefer mineral water containing 300–350 mg/L TDS (Teillet et al, 2010), whereas many North Americans perceive water with < 80 mg/L TDS as excellent for drinking (Table 1; Bruvold & Daniels, 1990). Taste is a response of the taste buds and differs from flavor, which is the combination of taste and odor. The five tastes can combine with thousands of odors, and thus many flavors exist.

FIGURE 1 Taste intensity of mineral salts, each at the same TDS concentration of 750 mg/L, tasted in water samples at 22°C



Different salts have different molar concentrations and taste intensities even when the TDS value is the same. The taste intensity scale ranges from 1 = tasteless to 13 = extremely intense (Pangborn & Bertolero, 1972).

Duranceau et al (2012) reported that aesthetic issues are among the top 10 concerns of drinking water providers who are delivering or considering delivering desalted water to consumers, but few previous studies have assessed human responses to TDS changes in drinking water. When panels of consumers and sensory experts evaluated alternative blends of drinking water for San Diego, Calif., both groups were able to discriminate between room-temperature treated surface water containing 480 mg/L TDS and desalted seawater containing 350 mg/L TDS (McGuire et al, 2007). The two water samples possessed different mineral compositions because the desalted seawater contained a greater concentration of chloride and less hardness and bicarbonate compared with the treated surface water. The same panels of consumers and experts could also discriminate between the treated surface water and blends of 25, 50, or 75% desalted water. Among the consumers, 62% preferred the treated surface water and reported that the flavor of the desalted water was objectionable.

In another study of room-temperature water, a trained sensory panel from Barcelona, Spain, found that the flavor of drinking water improved when TDS concentrations were reduced (Devesa et al, 2010). In this study, conventionally treated river water of 1,000–1,100 mg/L TDS, which was typical of the water distributed to consumers, was blended with 30, 50, or 70% of the same high-TDS river water treated by reverse osmosis or electrodialysis reversal. The samples of blended water contained TDS concentrations ranging from 350 to 760 mg/L. In taste tests, these lower-TDS water samples could be distinguished from, and were preferred to, the conventionally treated high-TDS river water. Whereas few studies compare the taste and flavor of drinking water supplies with different TDS values, there are no studies that report on scaling—whether an increase in the TDS of a water supply containing low concentrations of minerals is perceived differently from an increase in the same amount of TDS or an increase in the amount of change in TDS (Δ TDS) in a supply containing moderate or high concentrations of minerals.

Although medical professionals and public health officials promote water consumption for healthy living and weight loss

TABLE 1 Rating the potability of room-temperature water on the basis of mineral taste*,†

Potability Grade	TDS *mg/L*
Excellent	< 80
Good	81–450
Fair	451–760
Poor	761–1,020
Unacceptable	> 1,021

TDS—total dissolved solids

*Participants included consumers and trained personnel from California.
†Bruvold & Daniels, 1990

(Dennis et al, 2010) and sensory scientists are leaders in flavor analysis, worldwide it is environmental scientists and engineers who understand the subtleties of water quality and treatment. Thus for water to be consistently satisfying for consumers, a greater understanding of taste properties and consumer taste capabilities is needed, especially as treatment techniques such as reverse osmosis and blending become more common and threats of increased mineralization from climate change or salt contributions escalate.

The research objectives of this study were to

- conduct pair-wise taste comparisons between a low-TDS reference water sample (26 mg/L TDS) and samples containing higher TDS concentrations to determine the Δ TDS values at which consumers could detect a difference in taste;
- conduct pair-wise taste comparisons between a high-TDS reference water sample (524 mg/L TDS) and samples containing lower TDS concentrations to determine the Δ TDS values at which consumers could detect a difference in taste;
- determine whether the TDS concentration of the reference water sample and the direction of the TDS comparison (i.e., low to high or high to low) affected detectability of the Δ TDS; and
- provide guidance to water utility professionals about the point at which consumers can detect a difference in taste on the basis of the water's mineral content.

MATERIALS AND METHODS

Human subjects. The sensory protocol for working with human subjects was approved by the Virginia Polytechnic Institute and State University (Virginia Tech) Institutional Review Board under protocol numbers IRB 08-263 and IRB 09-506. Free and informed consent of the participants was obtained. The human subjects were local consumers who received no training before participating in a taste test. Their ages ranged from 18 to 77, and the mean age was 26. There was gender balance among the participants; 52% were female. Different subjects participated in different tests. Table 2 lists the characteristics of each panel of human subjects. The test population favored young adults because taste capabilities decrease significantly after age 50 (Landis et al, 2009; Mirlohi et al, 2011).

Taste test protocol. Subjects were simultaneously presented with water samples coded with random three-digit numbers, and they tasted 2 oz of water in 3-oz coded cups. Water was evaluated at room temperature (22–24 °C), and all samples in a given triangle test were at the same temperature.

The discrimination test and the statistical analyses were based on the triangle test (Meilgaard et al, 2006). Two samples of the same water supply and one of a different supply were presented in a balanced way that represented all possible serving orders (AAB, ABA, ABB, BAA, BAB, and BBA). Subjects were instructed to taste the samples in the order presented and to select the sample that was different out of the group of three. Fifty-four subjects participated in pair-wise taste comparisons of two water samples containing different TDS concentrations. The sample size and significance were based on α, the level of statistical significance for a type 1 error ($\alpha = 0.05$); β, the level of statistical significance for a type 2 error ($\beta = 0.1$); and P_D, the proportion of discriminators ($P_D = 0.3$), which required a minimum of 53 human subjects. The critical number of correct responses considered statistically significant (Meilgaard et al, 2006) was 25 out of 54. The critical number of correct responses compensates for the one-in-three probability that a subject will choose the different sample simply by chance. For this thorough investigation of the taste of TDS, 486 taste tests were performed.

Test water. One brand of bottled water containing high concentrations of minerals (524 mg/L TDS) was purchased from a local store. The water was approved for human consumption, and its quality was assessed in the authors' laboratory by means of the following methods: total organic carbon and inorganic carbon were measured by method 5310C; anions, except bicarbonate, by method 4110; metals by method 3125 using inductively coupled plasma mass spectrometry; bicarbonate by method 2320 (all from *Standard Methods*, 2006); and titration using sulfuric acid at pH 4.5 (initial pH values were < 7.3). TDS concentration was calculated by summing the individual concentrations of cations and anions (*Standard Methods*, 2006).

TABLE 2 Descriptions of the 54-member human sensory panels

Panel	Women %	Mean Age *years*	Age Range *years*	Test Water Comparison of Samples, TDS Concentrations %
1	45	22	18–55	5 versus 25
2	64	23	18–56	5 versus 35
3	49	23	18–55	5 versus 50
4	49	20	18–23	5 versus 67
5	57	20	18–22	5 versus 75
6	54	30	18–58	100 versus 50
7	66	33	18–65	100 versus 35
8	32	30	19–55	100 versus 20
9	37	32	18–77	100 versus 6

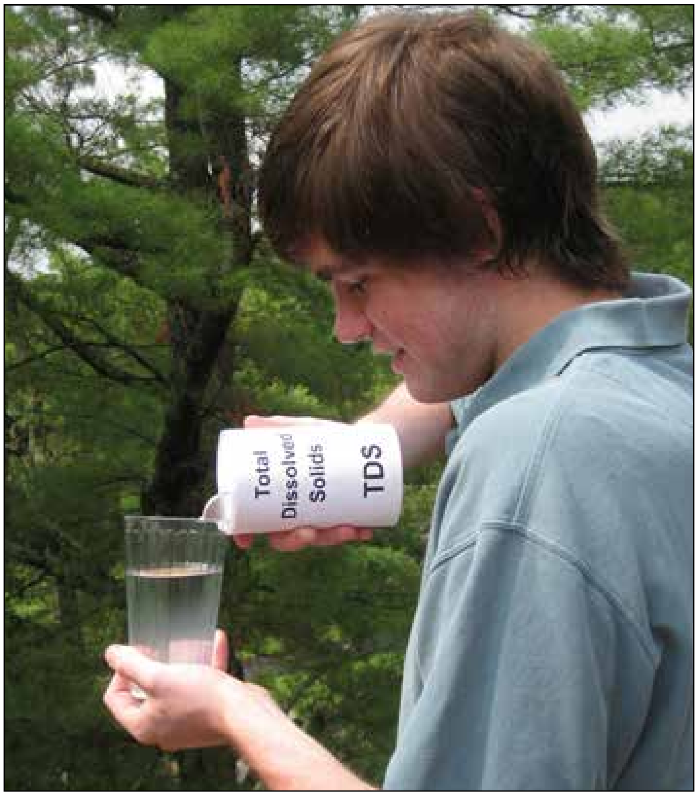
TDS—total dissolved solids

This high-mineral water was diluted with a deionized, carbon-filtered reagent with nondetectable TDS to obtain 5, 20, 25, 35, 50, 67, and 75% concentrations of the original bottled water (Table 2). The water with 100% TDS (524 mg/L) and the water with 5% TDS (26 mg/L) were used as the two reference samples with which other dilutions were compared. A separate water supply prepared for this study had the equivalent of 6% TDS compared with the bottled water. The prepared supply contained 0.16 mg/L total organic carbon, 15 mg/L sulfate ion, 6 mg/L chloride, 3 mg/L potassium, 3 mg/L magnesium, 2 mg/L sodium, and < 1 mg/L bicarbonate and calcium.

The taste and odor quality of the 20, 35, and 50% dilutions and of the undiluted test water supply were evaluated for overall off-flavors (tastes and odors) by an experienced panel of human subjects trained in flavor profile analysis (method 2170; *Standard Methods*, 2006).

RESULTS AND DISCUSSION

The composition of the test water is shown in Table 3. With a TDS concentration of 524 mg/L, this water can be viewed as a high-TDS tap water that is also hard and has substantial bicarbonate alkalinity. The TDS content of the diluted water samples is shown in Table 4. Because the objective of this research was to assess the taste of TDS, it was important that no known off-flavors—such as earthy–musty, floral, metallic, or plastic—be present. No off-flavors were observed in the test water or in the 20, 35, or 50% dilutions when assessed by a trained human panel using flavor profile analysis. The lack of a metallic flavor was confirmed by chemical analysis; the concentrations of copper and iron were below both detection limits and their flavor threshold concentrations of 0.03 mg/L ferrous ion and 0.6 mg/L cuprous or cupric ion (Dietrich, 2009; Ömür-Özbek & Dietrich, 2011; Mirlohi et al, 2011).



Total dissolved solids (TDS) impart taste to drinking water. Knowing how much a water supply's TDS concentration can change before consumers are able to taste a difference will help water providers produce water that is palatable as well as safe and will increase customer satisfaction.

TABLE 3 Water quality data for the test water (pH = 7.28)

Parameter	Concentration *mg/L*
Composite parameters	
Total organic carbon	0.05
Total dissolved solids	524
Silicates as silicon dioxide	19.2
Hardness as calcium carbonate	310
Anions	
Chloride	9.6
Bicarbonate	363.1
Nitrate	0.62
Sulfate	16.0
Bromide, fluoride, nitrite, phosphate	BRL*
Metals	
Aluminum	0.001
Calcium	81.2
Chromium	0.003
Potassium	1.06
Magnesium	26.3
Manganese	0.0003
Sodium	6.3
Nickel	0.0015
Copper, Iron, Zinc	BRL†

BRL—below reporting limit

*Method reporting limits for ion chromatography were 0.125 mg/L bromide, 0.125 mg/L fluoride, 0.05 mg/L nitrate as nitrogen, and 0.125 mg/L phosphate as phosphorus. The method of Winslow et al (2006) was applied to determine limits.

†Method reporting limits for inductively coupled plasma–mass spectrometry were 0.0005 mg/L copper, 0.05 mg/L iron, and 0.001 mg/L zinc. The method of Winslow et al (2006) was applied to determine limits.

The triangle test taste protocol determined the ability of the nine panels—each of which consisted of 54 human subjects—to discern the taste of TDS in water. These data permit inferences about a larger consumer population because of the good statistical power ($\beta = 0.10$ at $\alpha = 0.05$) and the large number of untrained subjects asked to compare water samples on the basis of TDS content (because consumers do not typically perform this task, they were presumed to have few prior biases).

As is typical with sensory analysis, results extrapolated for a larger consumer population are based on a statistical analysis that accounts for panelists guessing the correct answer; the statistical interpretation requires that $\geq 50\%$ of the test subjects must detect a difference (Mielgaard et al, 2006; Lawless & Heymann, 1998). The results demonstrate that at the 95% confidence level, panelists could more readily discern differences between the low-TDS water (26 mg/L TDS) and samples containing moderate to high

TDS concentrations than differences in samples compared with the high-TDS water (524 mg/L TDS; Table 5; Figure 2). For example, when the 26-mg/L, low-TDS water sample was compared with the sample containing 361 mg/L TDS, the combination represented a Δ TDS of 335 mg/L, and panelists detected a difference. Conversely, panelists could not discern a difference between the sample containing 183 mg/L TDS and the 524-mg/L TDS water, even though this comparison represented a similar Δ TDS of 341 mg/L. This indicates that the reference point—whether a low or high TDS concentration—affects panelists' ability to discriminate among samples.

Estimating the Δ TDS necessary to detect a difference. The Δ TDS necessary for a difference in taste to be detected is related to the terms "just noticeable difference" and "difference threshold," which are used to describe the minimum amount by which the intensity of a sensory stimulus must change in order to produce a noticeable variation (Lawless & Heymann, 1998). Although the experimental approach used in this research was not designed to directly address "just noticeable difference," the results showed that a greater difference in TDS concentration is necessary for a change in taste to be noticeable when the reference water has a high TDS concentration than when the reference water has a low TDS concentration. As is common for sensory data, there is some noise in the data, especially near the threshold (Stocking et al, 2001; Lawless & Heymann, 1998). This can be seen with the comparisons of low-TDS water samples—a 26-mg/L TDS sample versus 131-, 184-, and 262-mg/L TDS samples (Figure 2). The comparison of two low-TDS samples (26 mg/L TDS versus 156 mg/L TDS) did not produce a significant difference in taste, even though the tests of samples containing the next lower and next higher TDS concentrations did. These results suggest that a difference of 100–200 mg/L TDS can be discerned by consumers and that some consumer groups will be more sensitive than others.

TABLE 4 TDS concentrations and ratings for the test water and its dilutions

Test Water Dilution* %	TDS *mg/L*	Tap Water Classification Based on Concentration TDS†
5	26	Low
6	31	Low
20	105	Moderate
25	131	Moderate
35	183	Moderate
50	262	High
67	361	High
75	393	High
100	524	High‡

TDS–total dissolved solids

*The 524-mg/L TDS test water was diluted with taste- and odor-free reagent water.
†Burlingame et al, 2007; low = < 100 mg/L TDS; moderate = 101–250 mg/L TDS; high = 251–500 mg/L TDS
‡Although 524 mg/L is slightly greater than 500 mg/L, this sample was classified as high-TDS water for this research.

One way to estimate the Δ TDS necessary for consumers to detect a difference in taste is to calculate a geometric mean based on the highest concentration at which panelists could not detect a difference and the lowest concentration that could be detected when there is consistency in the data (ASTM, 1997). The geometric mean approach provides a best estimate because the Δ TDS at which a difference could be detected would be between the actual values tested. This approach yields a best estimate of Δ 192 mg/L when the low-TDS water (26 mg/L) is compared with moderate- and high-TDS water samples (a Δ 192 mg/L represents the geo-

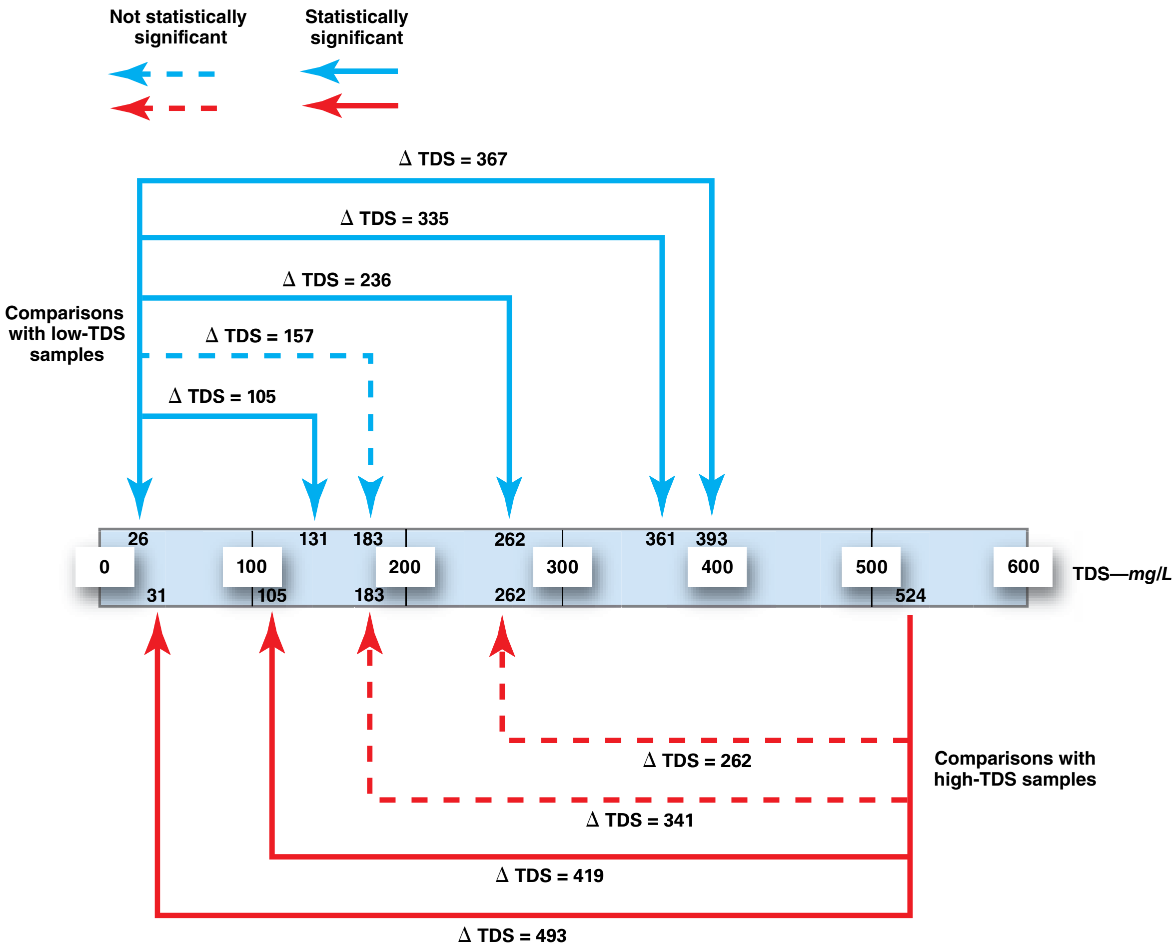
TABLE 5 Taste assessment for comparisons of the test water and its dilutions*

	TDS Concentration of Test Water Samples *mg/L*					
	Reference Sample	Comparison Sample	Δ TDS *mg/L*	Correct Responses *Number*	Correct Responses %	Significantly Different *α = 0.05*
Comparison with low-TDS water sample 26-mg/L	26	131	105	26	48.2	Yes
	26	183	157	23	42.6	No
	26	262	236	28	51.8	Yes
	26	361	335	31	57.4	Yes
	26	393	367	32	59.2	Yes
Comparison with high-TDS water sample 524-mg/L	524	262	262	24	44.4	No
	524	183	341	21	38.9	No
	524	105	419	25	46.3	Yes
	524	31	493	35	64.8	Yes

TDS—total dissolved solids, Δ TDS—amount of change in TDS concentration

*All taste tests were performed with the water samples at room temperature. The triangle test required a minimum of 25 correct responses out of 54 responses to be statistically significant at α = 0.05.

FIGURE 2 Study results demonstrating which binary combinations of drinking water samples with different TDS concentrations could be distinguished by consumers*



TDS—total dissolved solids, Δ TDS—amount of change in TDS concentration

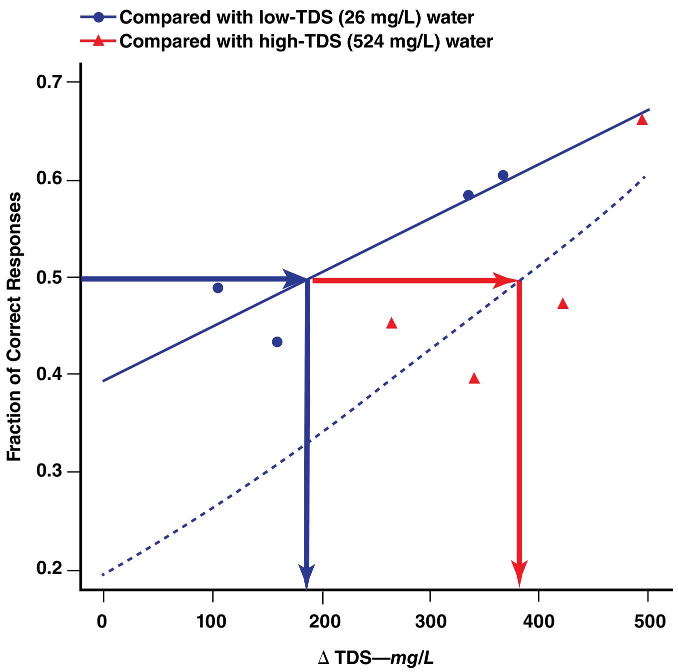
*The TDS concentration of the pairs of test samples are connected by a line ending in arrows that show the two TDS values. The Δ TDS concentration is provided for the pair, along with solid or dashed lines indicating whether consumers could distinguish between the two samples. Solid lines represent a statistically significant ability to distinguish between the two TDS concentrations; dashed lines represent not statistically significant ability. Blue lines represent comparisons with a low-TDS reference water (TDS = 26 mg/L). Red lines represent comparisons with a high-TDS reference water (TDS = 524 mg/L).

metric mean of 157 and 236 mg/L TDS). The same approach yields a best estimate of Δ 378 mg/L when moderate-TDS water samples are compared with the high-TDS water of 524 mg/L (a Δ 378 mg/L represents the geometric mean of 341 and 419 mg/L TDS).

Another way to estimate consumers' ability to detect Δ TDS is to apply logistic regression (ASTM, 1991), which uses binary data to predict a threshold at which 50% of people will detect a difference. An advantage of logistic regression is that all the data for each panelist are graphed, and the threshold is determined on the basis of the complete dataset. As shown in Figure 3, logistic regression plots the fractions of correct responses as a function of the Δ TDS for that taste test. The graph shows the value at which 50% of the population (equal to a fraction of 0.5) can detect a difference. The curve representing the comparison from high- to low-TDS water samples (dashed line) is shifted to the right, toward a greater Δ TDS. The data indicate that a Δ TDS of 185 mg/L is required for consumers to be able to discriminate between a low TDS and a moderate TDS concentration. A Δ TDS of 380 mg/L is required for consumers to be able to discriminate between a high TDS and a moderate TDS concentration.

The consistency of these statistical methods for estimating the Δ TDS required for differences to be detected gives confidence for providing drinking water suppliers with guidance that consumers will likely notice a Δ TDS ≈ 185 mg/L between water supplies containing low TDS concentrations and supplies containing moderate or high TDS concentrations, whereas a greater Δ TDS ≈ 380 mg/L

FIGURE 3 Logistic regression plot showing the change in TDS concentrations required for detection by consumers*



TDS—total dissolved solids, Δ TDS—amount of change in TDS concentration

*A Δ TDS ≈ 185 mg/L was required when the reference water sample had a low TDS concentration, and Δ TDS ≈ 380 mg/L was required when the reference sample had a high TDS value.

will be required for consumers to discriminate between high-TDS supplies and low- or moderate-TDS supplies.

Comparison with other studies. Few published studies provide data about consumer ability to discriminate among water supplies known to contain TDS. A related study used triangle tests to compare the taste of drinking water supplies at room temperature (Gallagher & Dietrich, 2010). Consumers were not able to discriminate between two low-TDS water supplies with different mineral compositions and a low Δ TDS of 28 mg/L, but they were able to discriminate between a low-TDS water and a high-TDS water with different mineral compositions and a large Δ TDS of 521 mg/L. When the mineral compositions of the test water supplies varied, the inability of test subjects to discern a low Δ TDS and their ability to discern a large Δ TDS were consistent with the data reported in this current research.

Two utility-supported investigations applied sensory analysis to determine whether a difference in flavor existed between conventionally treated surface water supplies and membrane-treated supplies (McGuire et al, 2007; Devesa et al, 2010). Although both of these studies were conducted with the triangle test protocol and with the water samples at room temperature, the pair-wise comparisons varied in TDS concentration and in the concentration of cations and anions that contributed to mineral content. Although these studies are not directly comparable to the one reported in this article, they demonstrated that consumers and trained panelists could discriminate among treated drinking water supplies that differed in TDS content.

CONCLUSIONS

Understanding the interrelationship between TDS and consumer taste discrimination will enable drinking water providers to distribute blended or remineralized water supplies that consumers find palatable for drinking. This research considered Δ TDS as a determinant in predicting when consumers can detect a difference in the taste of their drinking water. Major outcomes were:

Panels of consumers noticed a difference in the taste of water when the amount of TDS was changed; panelists' ability to discriminate between water samples depended on the magnitude of Δ TDS and the baseline TDS concentration in the reference water.

When the relative concentrations of anions and cations in the test samples were consistent, a change in the TDS concentration from low to moderate was more readily noticed than a change from high to moderate TDS content.

Consumer panelists could discern a Δ TDS that fell between 100 and 200 mg/L when they compared a low-TDS (26 mg/L) water with samples containing moderate and high TDS concentrations. When data from the individual panels were combined and statistically analyzed to provide an estimated overall value, then a Δ TDS ≈ 185 mg/L was deemed necessary in order for consumers to detect changes from low to moderate and high TDS concentrations.

A greater Δ TDS was required for a difference in taste to be detected when the reference water contained a high TDS concentration (524 mg/L). Statistical analysis of the data estimated that a Δ TDS ≈ 380 mg/L is necessary for consumers to detect a change from high TDS concentrations to low or moderate concentrations.

Individual consumers have variable taste sensitivities to Δ TDS. Some consumers will be capable of more sensitive taste responses than the general population and thus be able to detect smaller Δ TDS values. Likewise, some consumers will be less sensitive than the general population and require greater Δ TDS values to detect a difference in the tastes of two water supplies.

If a utility is planning a change in its source water or its treatment scheme that will significantly alter the historical TDS concentration of its water supply (e.g., instituting reverse osmosis or blending), it should inform its customers of the change and perform site-specific discriminating taste tests if appropriate.

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PEER REVIEW

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