Taste

As taste cannot be measured objectively, and because there is considerable variation among consumers as to which tastes are acceptable, a maximum acceptable limit for drinking water has not been specified.

Definition and Measurement

In the assessment of drinking water quality, the sensations of taste and odour are complementary. In general, the sense of taste is most useful in detecting the ionic, inorganic constituents of drinking water, and the sense of smell is most useful in detecting the covalent, organic constituents. Another way in which the senses of taste and smell complement each other is in their detection limits; much lower concentrations of matter can usually be detected by odour than by taste.(1)

It is important to distinguish the taste of a substance from its flavour. The latter is a complex sensation affected primarily by taste, odour and temperature and secondarily by other factors such as texture and pungency. Formal theories and definitions of taste suggest that this sense is responsive only to the sensations of sweetness, sourness, saltiness and bitterness; nuances of taste are thought to be due to the degree to which various taste papillae respond to these sensations.(2) From a rigorous point of view, therefore, the taste of drinking water can be defined as the sensation that is due to the presence of substances in water that have negligible vapour pressures and negligible odours. It follows that taste tests should be performed only on water samples that are free of odour. Failure to make this distinction is responsible for much of the confusion that prevails in the older water quality literature on organoleptic testing.

Two types of taste test have been applied to drinking water. One is an attempt to describe the intensity of the taste quantitatively in terms of a “tasteless” standard (distilled water); the other is an attempt to describe the acceptability of the water’s taste in terms of subjective rating scales that are given numerical values. The Canadian requirement that the taste of drinking water be inoffensive is based on a qualitative variant of the second type of test.

Taste tests in general have received considerable criticism. The use of distilled water as the standard for “tasteless” water in taste threshold tests and as a mouth rinse in subjective tests probably introduces a bias in the test results; only a few investigators have attempted to compensate for this bias.(3) The concept of a sensory threshold has also been questioned.(4) Taste tests that involve large panels of judges are expensive, time-consuming and difficult for small treatment facilities to perform.(5) Taste tests performed in water treatment plants may underestimate the taste of the water delivered to the consumer because, at the plant, objectionable tastes can be masked by residual chlorine, but the masking effect will diminish as the chlorine residual decreases in the distribution system.(5) Alternatively, chemicals employed to dechlorinate water prior to testing in order to avoid this effect may augment the taste of the water.(5) Further criticisms include the large margin of human error possible in taste tests and the possibility of bias owing to local physiological adaptation to and preference for a given taste.(5) Further substantial difficulty arises from differences in how tests are conducted and variations in the statistical manipulation and interpretation of taste test data; much of the difficulty seems to stem from differences of opinion on what point in the wide range of panel test results should be regarded as the taste threshold. Because of the above limitations, it has been the opinion of reviewers for some time that much more research on taste tests and development of new methods for taste testing are required.(6)

The most important consideration with respect to the measurement of taste in drinking water is the difficulty in relating the results of a threshold test panel to the consumer acceptance of a water supply.(7) Taste thresholds can be measured only for individuals, and panel results give a range of threshold values. As communities are much larger than test panels, the upper limit of acceptability for many consumers may lie below the lower limit of detection for the test panel. Purveyors of water must therefore strive for the total elimination of offensive tastes and should continuously monitor the taste of the water during the various stages of its treatment so that preventive action can be taken before consumer complaints begin.

Occurrence

Taste and odour problems in drinking water supplies constitute the largest single class of consumer complaints. They may occur in any type of water and at any time of year; they may be of natural origin or due to industrial activity; and they may be associated primarily with the raw water, the treatment method or the distribution system, or with combinations of the three.

The results of a taste and odour survey of 120 U.S. and Canadian water treatment plants have been published.(8) Of the 11 Canadian plants participating in this survey, only two reported the absence of taste and odour problems. Supplies using groundwater for a raw water source had the fewest problems (40% of respondents). Seventy percent of suppliers using mixed groundwater and surface water and 85% of suppliers using surface water reported taste and odour problems. The majority of the surface water suppliers reported a seasonal variation in taste and odour problems, which suggests that their most frequent problems may be biological in origin.

Relationships with Other Water Quality Parameters

Other drinking water parameters may be associated with taste and odour in any one of three different ways: they may be related to taste only, to odour only or to both taste and odour.

Physical Characteristics

In general, non-specific taste (and odour) problems are associated with high concentrations of colour and turbidity in water, and it has been suggested that this may be due to the presence of colloidal constituents.(9) In support of this hypothesis, it has been reported that occurrences of taste (and odour) are almost non-existent in water from treatment plants in which there is an efficient flocculation process.

Temperature is related to the taste of water in several ways. Taste acuity depends on temperature.(10) An optimum response is obtained with water at or near body temperature.(7) The degree to which taste is influenced by temperature is a function of the specific taste-causing substance, however.(10) Temperature will also affect the taste of water to the degree with which it influences chemical equilibria in favour of taste constituents. The growth rate of micro-organisms, which may produce bad-tasting metabolites, is enhanced by higher temperature, as is the rate of formation of offensive-tasting corrosion products.

The pH of water can notably influence its taste (and odour) in instances in which pH controls the equilibrium concentration of the neutral and ionized forms of a substance in solution. Solution pH also has a strong effect on reactions that produce products with intense flavours, such as chlorophenols.

Microbiological Characteristics

High densities of certain nuisance organisms in water can result in offensive tastes and odours because of the production of low concentrations of metabolic products. Other nuisance organisms, generally referred to by the non-specific term "iron bacteria," cause offensive tastes in water by sporadically releasing relatively high concentrations of iron in distribution systems.

Several studies of the organoleptic properties of residual chlorine have been performed over the years, but further work will be required before the key questions have been answered. Under ideal conditions, the amount of free available chlorine at the consumer's tap should be sufficiently high to attest to its safety and sufficiently low to avoid objectionable taste and odour. The taste and odour thresholds of residual chlorine are thus of considerable interest. The most recent investigation of this subject found that the average taste threshold concentration of free residual chlorine increased from 0.075 mg/L to 0.450 mg/L as the pH increased from 5.0 to 9.0.(11) The average threshold was 0.156 mg/L, with a range of 0.02 to 0.29 mg/L at pH 7.0. These data indicate that taste sensitivity is greater for hypochlorous acid than for hypochlorite ion. As no odour could be detected in any of the test samples, hypochlorous acid would appear to belong to a relatively rare class of substances exhibiting both taste and odour in which the taste threshold concentration is lower than the odour threshold concentration. These findings are at variance with earlier reports that stated that *objectionable* tastes and odours are not produced by residual chlorine concentrations below 2.0 mg/L,(12) that the taste threshold (determined by an unusual statistical evaluation method) of chlorine in distilled water is 5.2 mg/L,(13) that chlorine taste and odour cannot be detected below a concentration of 1.5 mg/L in water(14) and that the characteristic taste and odour of chlorine could be detected in mineralized water at a concentration of 0.8 mg/L.(15) It is evident that a study of the results of panel tests on identical samples in different laboratories would be a valuable addition to the literature in this field. It has been noted that mixtures of free and combined available chlorine can give a large synergistic organoleptic effect.(16)

Although much more work is clearly called for, it is probable that most treatment plant operators have found the appropriate balance between the applied chlorine residual and consumer complaints by trial and error. Studies of taste thresholds for chlorine in mineralized water(15) and in coffee(13) also indicate that other constituents that cause taste in water can influence the magnitude of the threshold concentration. Thus, the nature of the raw water supply will be one major factor in the minimum detectable taste threshold concentration for residual chlorine. It should also be noted that some consumers are assured of the safety of their water supply by the presence of a slight taste of chlorine.

Chemical Characteristics

The parameter that has been most closely related to taste in the past is "total dissolved solids (TDS)." The maximum recommended TDS levels, 500 to 1000 mg/L, have traditionally been set largely on the basis of early estimates of taste thresholds for the major anions and cations of water.(17) In an extensive, well-controlled mineral taste study conducted recently in California, the following relationship was developed between the perceived taste quality of a water supply and its TDS content: excellent, less than 300 mg/L; good, 301–600 mg/L; fair, 601–900 mg/L; poor, 901–1200 mg/L; and unacceptable, greater than 1200 mg/L.(3) Although the authors did not emphasize the point, the above scale is probably valid only for water supplies in which the concentrations of chloride and carbonate are comparatively low. As the constituents of water that are responsible for the properties of alkalinity and hardness are also major constituents of TDS, water supplies with high values for these characteristics will also tend to have offensive tastes.

Many of the inorganic chemical substances that occur in water exert an unpleasant taste at concentrations much lower than those at which acute toxic effects can occur, and limits for these substances are often set at levels at which their tastes (or other undesirable organoleptic properties) are thought to become objectionable to consumers. These substances are discussed briefly below.

Taste thresholds in distilled water for the major cations of drinking water — calcium, magnesium, sodium and potassium — have been reported to be approximately 125 mg/L, 100 mg/L, 30–140 mg/L and 340–680 mg/L, respectively.(18) The uncertainty associated with these determinations is largely due to the taste effect of their associated anions. With the possible exceptions of the threshold for calcium and magnesium, however, these concentrations are substantially higher than levels usually encountered in water. Also, the tastes of the major associated anions are usually more intense than those of the metal ions,(14) and objectionable tastes would therefore tend to occur below the taste threshold concentrations for calcium and magnesium.

Taste threshold tests for iron, as Fe(II), have shown that the most sensitive 5% of the members of a test panel can detect concentrations of 0.04 mg/L in distilled water and 0.12 mg/L in a mineralized spring water with a TDS content of 500 mg/L.(19) Earlier studies reported that small quantities of iron adversely affect the taste of water(20) and placed the taste threshold in distilled water at 0.1 mg/L.(21) The natural range of human taste acuity to iron also seems to be very wide; in the study cited above, the most acute tasters were 6400 times more sensitive than the least acute.(19) Unlike the case of iron, however, there are reports of water supplies containing zinc levels of 20 mg/L that have not been objected to on the basis of taste,(22) and some reviewers have concluded that zinc levels of 30 to 40 mg/L are reasonable for drinking water.(23) Further study of the nature of consumer acceptability ratings would also be of value in this case.

Reliable data on the taste and odour thresholds for sulphide in water are sparse, and the situation is complicated somewhat by the effect of pH on the position of the sulphide – bisulphide – hydrogen sulphide equilibrium. In the normal range of pH for drinking water, the equilibrium favours hydrogen sulphide over bisulphide to the extent of approximately 75 and 50% at pH values of 6.5 and 7.0, respectively, and bisulphide predominates to the extent of 90% at pH 8.0. The sulphide ion is present in appreciable concentrations only above pH 10.(24) Thus, the term "sulphide" in drinking water should be understood to refer to bisulphide or hydrogen sulphide. The median taste threshold for hydrogen sulphide in distilled water has been found to be 0.05 mg/L.(13) The odour threshold concentration for hydrogen sulphide in distilled water, however, is reported to be in the range of 10 to 100 mg/L.(25) On the basis of these data, the odour threshold concentration for hydrogen sulphide in distilled water is approximately one one-thousandth of its taste threshold concentration, and its odour can be masked to a very large extent by other odour-producing substances.

An interesting feature of a 1952 study,(26) performed to test the claim that fluoride at a concentration of 1 mg/L imparts an undesirable taste to water, was the finding that the most successful judges on a taste panel could distinguish between low fluoride concentrations and distilled water at concentrations *below* those at which fluoride was recognized by taste; this phenomenon has been named the subthreshold ionic effect. The most successful panelists also preferred the taste of very dilute fluoride solutions to that of distilled water and reported similar taste sensations for sodium chloride, potassium chloride, sodium fluoride and potassium fluoride at concentrations of 18 mg/L. More errors occurred for the potassium salts, however, which suggests that the subthreshold ionic effect might have been due to the sodium ion.

Health Considerations

The presence of offensive tastes in a public water supply may cause consumers to seek alternative sources of potable water that may or may not be subject to the same degree of protection afforded by the rejected supply. This has been exemplified by a survey, conducted by the California State Department of Public

Health, that found that consumers who objected to the taste of their public water supply were large-scale purchasers of bottled water.[27] Unfortunately, the taste of water provides no assurance that the water is free of pathogens or inorganic chemicals that are chronic toxicants. A degree of protection may be provided by the fact that median taste thresholds are generally much lower than the concentrations of inorganic substances that cause adverse health effects. As very large volumes of water are processed in treatment plants, even massive chemical spills would quickly be diluted to concentrations below the taste thresholds.

The health effects related to the taste of drinking water are thus indirect. Adverse tastes may cause the consumer to prefer an unsafe source; careful treatment to minimize non-specific tastes, however, can be expected to pay dividends by controlling other parameters, such as turbidity, which have a more direct influence on public health.

Conclusion

1. Taste (and odour) problems in drinking water supplies constitute the largest single class of consumer complaints, and experience has shown that the provision of drinking water that has an offensive taste will result in the rejection of the water supply by many consumers, some of whom may select an unsafe source of water as a replacement.

2. A numerical limit for taste in drinking water has not been established because there is no objective method for numerical measurement of taste and because there is considerable variation among consumers as to which tastes are acceptable. In many cases, sensations ascribed to the sense of taste may actually be odours.

3. Short-term changes in the normal taste of a public water supply may signal changes in the quality of the raw water source or deficiencies in the treatment process. The routine provision of water with an inoffensive taste will also assist in the detection of chemical corrosion and biological growths in the distribution system should objectionable tastes arise. The objective is therefore to provide water with inoffensive taste.

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