Odour

As odour cannot be measured objectively, a maximum acceptable limit for drinking water has not been specified.

Definition and Measurement

Odour in drinking water may be defined as that sensation that is due to the presence of substances that have an appreciable vapour pressure and that stimulate the human sensory organs in the nasal and sinus cavities. The response to odour is complex and can lead to confusion between the senses of taste and smell in cases in which a weak odour imparts a flavour to a substance. Problems of this type can usually be resolved by estimating the concentration of substance required to produce the sensation, because the sense of smell generally will respond to a much lower concentration (parts per billion or less) of a substance than will the sense of taste (parts per million or more). The greater sensitivity to odour is all the more remarkable in view of the fact that the concentration of the odour-causing substance in air, in which it is carried to the sensory system, is much lower than its concentration in the water from which it originates.

Odour in water is usually measured in terms of its threshold odour number (TON), the number of times a sample must be diluted with an equal volume of odour-free water to become just detectable by 50% of a panel of judges under very carefully controlled test conditions.[1] One is the lowest TON that is possible by this definition and indicates that the water sample has a detectable odour. Undiluted samples of water that have no detectable odour should be reported as "odourless." As in the case of taste threshold measurements, "values representing mean threshold or quality ratings for a laboratory panel are only estimates of these values for the entire consuming population."[1] Unlike the case of taste measurements, however, no standard test methods are now recommended for judging the acceptability of odours in drinking water, although it has been reported that water with a TON of 2 may stimulate more consumer complaints than water with a TON of 4.[2]

As exceptionally small concentrations of some substances in water can cause very intense odours that result in very large TON values, an alternative measurement, which is known as the odour intensity index (OII), has been employed on occasion.[3] The OII represents the number of times the volume of a sample must be doubled with odour-free water before it is just detectable by 50% of a panel of judges.

Both TON and OII measurements are usually non-specific. Odour intensity measurements for specific substances in water are normally reported in terms of their threshold odour concentrations.[4] This is the measured concentration of a substance in water at which it can just be detected by its odour. The wide variation in individual senses of smell has been markedly illustrated by the use of threshold odour concentrations. It has been found, for example, that in a large population, the most sensitive 5% is able to detect odour reliably at one one-hundredth of the average threshold odour concentration.[5] In other words, the precision of such measurements by large panels is so poor that the range is frequently found to occupy several orders of magnitude.

Occurrence

In general, offensive odours in drinking water may be of biological or industrial origin. Some of the odours of natural origin may be indirectly due to human activities; for example, the dumping of raw sewage into the aquatic environment enhances biological growth and consequently odours. Although the actual cause of an unpleasant odour can be identified occasionally, in most cases the specific agent is unknown. In addition, the nature of the pollution manifested by an odour problem will differ from water source to water source and from treatment plant to treatment plant. Changes in conditions such as wind, runoff, temperature, storm conditions and flow rate also influence the processes that lead to odour production. Thus, useful generalizations are rare, and odour problems must be dealt with on a case-by-case basis. Furthermore, the most intense odours are frequently due to substances at extremely low concentrations, a situation that makes their identification difficult and costly.

Odours of natural origin tend to be described as earthy, musty or sour, on one hand, or fishy, grassy or cucumber-like, on the other. Industrially derived odours tend to smell like iodine, petroleum, medicine, varnish or creosote, for example. Odours of either class are not restricted to any single type of water, although groundwaters tend to have fewer odour problems, or to any particular season of the year, although certain areas may have more frequent complaints at one time of year than at others. Odours also tend to be produced under stagnant water conditions, such as in raw and finished water reservoirs and in low-flow sections of distribution systems. They may also be produced by the water purification process, because of the conversion of substances with weak odours (such as phenols and amines) into others with very intense odours (such as chloramines and chlorophenols), and in distribution systems, because of the proliferation of nuisance organisms such as iron and sulphur bacteria or because of slow chemical reactions and hydraulic phenomena.

Relationships with Other Water Quality Parameters

Just as the chemical sense of taste tends to be associated predominantly with the inorganic characteristics of potable water, the chemical sense of smell is predominantly due to the presence of organic substances in water. Several hundred odour-causing compounds have been reported in water.(6–8) The specific odour-causing substances that are noted in detail have been selected in order to illustrate the effort that is involved in their solution, characterization and identification, and in determining their sources, controlling their formation and minimizing their objectionable characteristics by appropriate treatment. These examples allow certain generalizations to be drawn and illustrate the complex interactions between various aquatic characteristics that can lead to the occurrence of objectionable odours in drinking water.

Physical Characteristics

As has been noted in the review of taste, non-specific odour problems are related to the amounts of suspended and colloidal matter in a water supply, and very careful treatment to minimize the amounts of colour and turbidity in treated water substantially reduces the incidence of taste and odour problems.(9,10) Some of the specific substances of natural origin that are responsible for odour in water — for example, humic substances — do not react with the commonly employed odour-treatment chemicals (chlorine, chlorine dioxide and potassium permanganate) and are consequently best removed from water by the physical process of adsorption by activated carbon.

The odour of drinking water is related to temperature in several ways. As the vapour pressure of any odour-causing substance, and hence its odour intensity, will be directly related to the water temperature, it is important to specify the temperature at which TON and related measurements are made. *Standard Methods for the Examination of Water and Wastewater* recommends a temperature of 60°C for TON measurements, except in cases where very volatile substances are rapidly lost from solution at this temperature, in which case 40°C is recommended.(1) In general, the non-specific fishy, grassy and musty odours that can be associated with algal growth tend to occur most frequently in warm surface water in the warmer months of the year. Some of these nuisance micro-organisms, such as *Synura*, can thrive under ice cover in winter, however.(11) Summer water temperatures also tend to increase both the rate of growth of nuisance micro-organisms and the rate of evaporation of their odour-causing metabolic and decay products; the former effect is the more important one in terms of odour levels.(12) Other odour-causing substances that are the products of specific chemical processes, such as the chlorophenols, will also be produced at faster rates at higher water temperatures.

As has been noted in the context of the taste of water, pH can be related to odour formation under circumstances in which it controls the equilibrium distribution between the neutral and ionic forms of a substance that gives rise to an odour in its neutral form. For example, the chlorinous odour of hypochlorous acid would be expected to be more pronounced at low pH levels, where it is favoured over the odourless hypochlorite ion. Also, the solution pH can influence the rates of some chemical reactions that lead to the production of odours. This can be an important consideration, as insufficient attention to the influence of pH may lead to the production and buildup of odour in the water mains.

Microbiological Characteristics

No direct relationship appears to exist between odour in drinking water and the presence of coliform organisms and related pathogens. Odour in drinking water is attributable to the presence of a wide range of so-called nuisance organisms in water, some 50 of which were identified in the recent survey of taste and odour problems in the United States and Canada.(11) One of the most important groups is *Actinomyces*, or “ray fungus.” The very intense odours of substances produced by actinomycetes (and by at least some algae) can be a major source of odour contamination in public water supplies. For this reason, it has been recommended that in certain instances raw water supplies be monitored for actinomycetes.(1,13) Unfortunately, although such monitoring has positively correlated the presence of actinomycetes with odour problems in some localities,(11,13) other treatment plants have found the converse to be true.(11)

Chemical Characteristics

Some of the chemical parameters that are of concern because of their toxic properties may also cause odour problems. The threshold odour concentration for hydrogen cyanide in water has been reported to be 0.001 mg/L.[14] Thus, a limit for cyanide in drinking water based on odour considerations would be one-half the current objective limit, 0.002 mg/L, and one two-hundredth the recommended maximum acceptable concentration, 0.2 mg/L. This is an example in which the sense of smell is more sensitive than the best available analytical instrumentation. The threshold odour concentrations of common pesticides have been reported by Sigworth; these generally fall in the range of thousandths to a few tenths of a milligram per litre.[15] Except possibly for chlordane, the odours of the pesticides are too weak to allow their detection at or below their maximum acceptable concentrations.

The presence of very low concentrations of phenol has long been known to be responsible for the production of intense taste and odour in water. The threshold odour concentrations of the most odorous chlorination products of phenol are approximately one five-hundredth of that of phenol.[16] Therefore, in order to guarantee freedom from chlorophenolic odours and flavours, it is necessary to maintain phenol at or below one five-hundredth of its threshold odour concentration of approximately 1 mg/L.[16] It will be noted that this rationale is applicable to routine situations; if special treatment is employed (break-point chlorination, super-chlorination/dechlorination, chlorine dioxide or ozone oxidation, activated carbon adsorption), levels of phenol much higher than 0.002 mg/L can be tolerated.

Health Considerations

As is the case with the drinking water standards for taste, the limits for odour are set mainly on the basis of aesthetic considerations, in the knowledge that these considerations may motivate consumers to turn to unreliable alternative sources of drinking water. There is, however, a subtle distinction between standards for taste and odour. Taste in potable water may be of harmless geochemical origin; an odour in potable water is almost invariably indicative of some form of pollution of the water source or of malfunction during treatment or water distribution. Although all of these will be equally troublesome to the consumer, odours of biological origin are indicative of increased biological activity, which may include an increased loading of pathogens on the system, and odours of industrial origin are indicative of pollution of the source of water supply with commercial waste products, some of which may be toxic and relatively odour-free. For these reasons, sanitary surveys should include investigations for possible or existing sources of odour, and attempts should always be made to identify the source of an odour problem. In general, however, pathogens and toxic substances that pose chronic health threats are odourless.

Conclusion

1. Odour in potable water is almost invariably indicative of some form of pollution of the water source or of malfunction during treatment or distribution. Sanitary surveys should therefore include investigations of possible or existing sources of odour, and attempts should always be made to identify the source of an odour problem.

2. It is not possible to specify a maximum acceptable limit for odour, because no method for its objective measurement exists.

3. Odour is rarely indicative of the presence of harmful chemical substances, but the provision of a public supply of water that has an associated odour may cause consumers to seek private sources that could contain pathogens or harmful concentrations of toxic substances. The objective is therefore to provide potable water that has no offensive odour. As with taste, the routine provision of water with an inoffensive odour will assist in the detection of problems should objectionable odours arise.

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