Utility quick test for analyzing materials for drinking water distribution systems for effect on taste-and-odor

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Abstract A workshop of international drinking water experts was convened in Sedona, Arizona, March 26–27, 2001 for the purpose of developing a method for testing drinking water system components for their potential to contribute to taste-and-odor problems in drinking water. The workshop participants derived a method using provisions from European Standards as well as newly developed approaches. It is intended that this method can serve as a temporary procedure for water utilities, as well as a recommended template to derive an official standard. Materials to be tested may include pipes, fittings, ancillaries, joints, lubricants, tanks, and reservoirs. The recommended method includes a migration (leaching) test with chlorinated water, followed by sensory analysis of the samples from the migration test after dechlorination. Sensory analyses use both statistical (e.g., triangle test) and descriptive (e.g. Flavor Profile Analysis) techniques. A decision tree for the results is provided.

Keywords Distribution system; sensory analysis; taste-and-odor

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Introduction

Common sources of taste and odor problems in drinking water include microbial (e.g. cyanobacteria, actinomycetes, or bacteria) and chemical (e.g. source water pollution from industrial discharge, surface runoff, or treatment chemical additives) sources. Much of the research has focused on tastes and odors originating from source water and on treatment processes for these sources. Less is known about tastes and odors resulting from materials leaching and subsequent reactivity in the distribution system, even though most materials (e.g. pipes, coatings, lubricants, gaskets, and application solvents) have the potential of impacting the organoleptic quality of the drinking water. Also, the use of organic materials in distribution systems is growing due to lack of corrosion and scale build-up in pipes made of organic materials such as polyvinyl chloride (PVC) and chlorinated polyvinyl chloride (CPVC-C). Other organic materials used in distribution or storage systems include high density polyethylene (HDPE), cross-linked polyethylene [PEX], and polybutylene.

There are several examples of materials that have been reported to cause taste-and-odor problems. In France, taste and odor problems related to the use of organic materials occurred after new applications of organic coatings in water towers that had leached toluene, acetone and methyl isobutyl ketone (Rigal, 2001). The refurbishment of water tanks lead to taste-and-odor problems associated with polyester resins and a vinyl polychloride additive. Chemicals associated with these materials included styrene and chlorophenols (Rigal and Danjou, 1999).

Phenolic compounds leaching from coating materials have contributed to a number of taste-and-odor episodes described as medicinal (Bruchet, 2001). Khiari *et al*. (1999) reported taste and odor episodes where phenol, leached from the new lining (acrylic coating reinforced with fiberglass) of a reservoir, reacted with the chlorine residual in the

distribution system producing bromophenols and bromochloroiodomethane. The odor threshold concentrations (OTC) for bromophenols range from 0.5 ng/L for 2,6-dibromophenol to 600 ng/L for 2,4,6-tribromophenol (Whitfield, 1988).

Phenols can also be biotransformed to anisoles by fungi in the distribution system. For example, chlorophenol is biotransformed (methylated) to trichloroanisole (Montiel, 1987). In Paris, 1998, a persistent taste and odor problem was solved when earthy-musty odors were attributed to 2,4,6-tribromoanisole (TBA). The TBA was thought to have been a fungal biotransformation product of 2,4,6-tribromophenol – a fungicide in the formulation of an organic additive used in a tank coating (Bruchet, 2001). TBA and other haloanisoles have odor thresholds of about 30 pg/L (Bruchet, 2001), about 100 times less than their precursor halophenols (Montiel *et al.*, 1987).

Burlingame *et al.* (1994) and Fadel *et al.* (1993) reported that oleate-based pipe joint lubricants used in the construction of new mains or repair of distribution systems cause taste-and-odor problems. These lubricants caused odors described as wet paper, chalky, or wood putty at concentrations above 10 mg/L, but when oxidized by air or disinfectants such as chlorine, they produce aldehydes that have lower odor thresholds such as hexanal (descriptor: lettuce heart or pumpkin), heptanal (rancid walnut oil flavor), and nonanal (hay-like) (Fadel *et al.*, 1993).

In most cases the taste and odor problems caused by leaching of organic chemicals from materials used in distribution systems occurred in spite of pre-testing and certification. Significant problems may also arise from improper installation of approved materials, such as inadequate ventilation or improperly mixing ratios of material components. It is therefore imperative that materials be tested under realistic conditions, and the materials used only as directed by the manufacturer.

European Member States are collaborating to produce a harmonized approval system for materials in contact with drinking water (RG-PDW). The United States has no standard for testing materials for their potential impact on organoleptic properties of drinking water, but the National Sanitation Foundation (NSF) tests and certifies drinking water system components for health effects (ANSI/NSF Standard 61). Thus, the American Water Works Association Research Foundation identified a need to develop a standard method for the analysis of new materials used in drinking water distribution systems or water treatment processes for their taste-and-odor impact on drinking water quality. Since metals can easily be tested by analytical techniques, only organic materials are addressed in this utility quick test.

Methods

A workshop of drinking water experts evaluated existing European Standards and other alternative approaches to develop this utility quick test. This utility quick test is also intended to be developed into a working standard method for the evaluation of organic materials used in distribution system components on their potential impact on the taste-and-odor of drinking water. The Standards that were evaluated included British Standard 6920-2.2.1:2000, French AFNOR Standard XP P41 250, European harmonized: NF-EN 1622, PrEN 1420-1, PrEN Ed.C. draft (2001) N299, prEN 12873-1, and ANSI/NSF 61.

The components of the test that were evaluated included a procedure for migration or leaching of the material and a method for evaluating the leachate waters of the migration test. For the migration test, the characteristics of the reference water used in the test were discussed as well as other conditions of the test including sample preparation, the surface area to volume of test material, and the number and duration of test samples. Because the leachate waters from the migration test would need to be subjected to some type of analysis in order to determine potential impact on taste-and-odor, the workshop participants evalu-

ated analytical and sensory-based techniques in order to recommend a testing approach, which included evaluation criteria constructed as a decision tree.

Results and discussion

The utility quick test, developed by the team of drinking water experts during the previously described workshop, is hereby presented as a standard operating procedure for the analysis of organic drinking water system components to identify potential contributions to tastes and odors. The toxicity of chemicals that leach from materials used in drinking water distribution systems shall be tested by laboratories accredited to test products using NSF/ANSI Standard 61. The effect of materials on inhibition or promotion of microbial growth in the distribution system is also not addressed with this method; consult method BS 6920-2.4:2000. Finally, this method does not measure the effects on the long-term chlorine demand of the materials.

Materials to be tested may include pipes, fittings, ancillaries, joints, lubricants, and tanks and reservoir linings. This method is designed for testing drinking water system components made from or containing organic materials. Only those materials that come into direct contact with drinking water need be tested.

Principle of the utility quick test

Following a defined procedure of flushing, stagnation in the presence of chlorine disinfectant, and then prewashing with chlorine-free water, the surface of test material is brought into contact with extraction waters under conditions that simulate its function in drinking water systems. Leachate and extraction waters are then analyzed by sensory evaluation in comparison to a blank. Trained panelists are required for the descriptive component of the procedure, offering descriptors that may provide insight into the chemical(s) present, which would aid the manufacturer in their processes.

Utility quick test – step 1: cleaning component samples

- Thoroughly clean surfaces of the component sample, removing any tape/labels, etc.
- Wash or soak in reference water* for 60 minutes.
- Disinfect sample by soaking for 3 hours in 50 mg/L chlorine.
- Rinse sample until wash water contains ≤ 2 mg/L chlorine (or chloramines, if used in distribution system).

* Local drinking water (dechlorinated) or bottled water

Test pieces may be either factory made products or site-applied products. The material may be tested once, or in duplicate or triplicate.

Solids – plastic, elastomeric (rubber). The test article shall be prepared such that only the surface intended to come into contact with drinking water is exposed to the test waters. For multi-layer products, it may be necessary to seal the cut edges of the test pieces. When the product has the same material composition for the outside and inside surfaces, then the test pieces may be immersed in test water.

A sample of the test material shall be kept intact as much as possible (i.e. not chopped into fine pieces). Use whole components if small. Cut edges should be kept to an absolute minimum; in the case of thermosetting materials, the cut edges would not have received the same curing/post-curing conditions as the normal water contact surfaces, therefore keeping cut edges to a minimum will ensure the most consistent test results are achieved. When testing a pipe material, if there are different sizes of pipes available, the one with the smallest internal diameter shall be used in order to serve as a worst-case. For large components such as tanks and reservoirs, obtain a sample of the material, the size of which will be determined by convenience (determined by size of component and test vessel available) so long as the

surface area-of-material-to-volume-of-test water criterion is met as described in Table 1, below. A reasonable size of test material for large components is on the order of 6 inches in length. For small components, combine to achieve total surface area of 150 cm^2; in the case of "O" rings the total number of items required to give one composite sample can be calculated as follows: Number required to give an area of 150 $cm^2 = 150/\pi^2(R^2–r^2)$, where, R = outer radius in cm and r = inner radius in cm.

Site-applied products. Site-applied products to be tested are agents that come in contact with drinking water such as coatings, linings, paints, composite products, sealants, and solvent cements. For lubricants, see below.

General requirements: The manufacturer shall provide a copy of the detailed application instructions, which accompany the product and covering aspects such as:

- Surface preparation
- Mix ratios and method of mixing
- Method of application
- Minimum cure temperature, time and conditions
- Product film thickness
- Associated products, e.g. primers and undercoats

If specialized equipment is required for site application of a material, the test samples shall be prepared by a competent contractor under site conditions. Follow the application instructions.

Lubricants. Lubricants are used in easing pipe assembly, for leak control, and for lubrication. When lubricants may come into contact with the drinking water, either initially or over time, they may impart a taste or odor to the drinking water.

Lubricants shall be tested separately from the material on which it is used unless the lubricant is incorporated into the product such as in certain gland packings. Additionally, the lubricant plus material on which it is intended to be used, may be tested for interaction of lubricant with the solid material. For testing straight lubricant, apply the lubricant as an even film over the surface of a clean glass plate, consistent with end use, at a field surface area-to-volume ratio greater than or equal to a typical installation.

Step 2: leaching (migration) process

- Place component sample for leaching in a glass container with chlorinated water (2 mg/L) for three consecutive 72–hour periods, under static conditions.
- After each leaching period, decant the leachate for separate analysis. Replace water with fresh chlorinated water.
- Dechlorinate the three leachates before conducting sensory analysis on each.
- A blank control should also be conducted, where the same procedure is conducted, but without the test material present (i.e. place reference water in a glass container).

Step 3: sensory analysis

Dechlorinate the leachate and blank water samples with either ascorbic acid or sodium thiosulfate. Evaluate the samples and blanks from each 72-hour migration procedure separately as follows, below. Consult Figure 1, the decision tree, below to determine whether a material is deemed appropriate for drinking water systems and not expected to significantly impact the organoleptic quality of the drinking water.

Sensory analysis part #1: triangle test. The triangle test is a forced-choice method using three samples, two that are identical, and one that is different. Select three samples for the

Table 1 Selecting sample surface area and volume of leaching water
Table 1A: S/V ratio for factory made products

Item	Surface area/volume test ratio (dm^{-1})
Storage vessels	2.5
Ancillaries	1.5
Adhesives, elastomeric seals	0.2

Table 1B: S/V ratio for site-applied products

Item	Surface area/volume test ratio (dm^{-1})
Paints, linings on reservoir floors, walls and baffles	2.5
Repair systems: adhesives, primers, and sealants	1.5
Resin anchors, solvent cements, water tightness products, lubricants	0.2

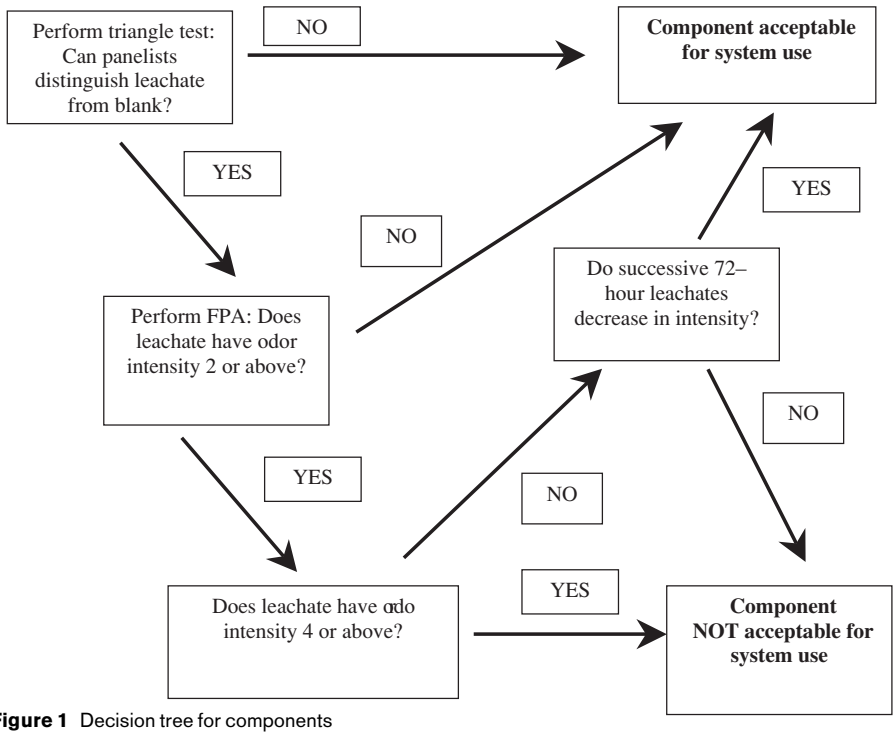

Figure 1 Decision tree for components

triangle test – two blanks and a leachate sample, or two leachate samples and a blank (randomly select whether the blanks will be identical, or the leachate sample will be the identical pair). The blank is dechlorinated reference water; leachate samples are the water extracts from each stage of the leaching process. Panelists are instructed that they must select which one of the three samples differs from the other two. Record the results and continue with sensory analysis, part #2, below.

Sensory analysis part #2: flavor profile analysis (FPA). FPA, Standard Methods 2170 (APHA, AWWA, WEF, 2000), is a sensory method used to describe tastes and odors. Panelists choose a descriptor and an intensity level for each odor in the leachate sample. Instruct trained panelists to describe odors of samples from the leaching process, and assign an intensity for each odor based on a point scale with 7 defined levels: **1** (threshold), **2**, **4**, **6**,

8, **10**, and **12**. Record all descriptors and their intensities. Consult the decision tree, Figure 1, to assess the test material.

Conclusion

The workgroup convened in Sedona, Arizona proposed a procedure to assist water utilities in rapid evaluation of the taste-and-odor-producing potential of system components. This method focuses on extracting organic compounds from system components, followed by sensory analysis of the extracts by trained panelists. An official test standard may be developed later.

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