

Problem Organisms in Water: Identification and Treatment

AWWA MANUAL M7

Third Edition



**American Water Works
Association**

Science and Technology

AWWA unites the drinking water community by developing and distributing authoritative scientific and technological knowledge. Through its members, AWWA develops industry standards for products and processes that advance public health and safety. AWWA also provides quality improvement programs for water and wastewater utilities.

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Chapter 1

Actinomycetes

Actinomycetes are a collection of nine different groups of bacteria. The most familiar of the group are the Streptomyces. These organisms are widely distributed in nature and account for a large part of the normal microbial population of soils and water sediments.

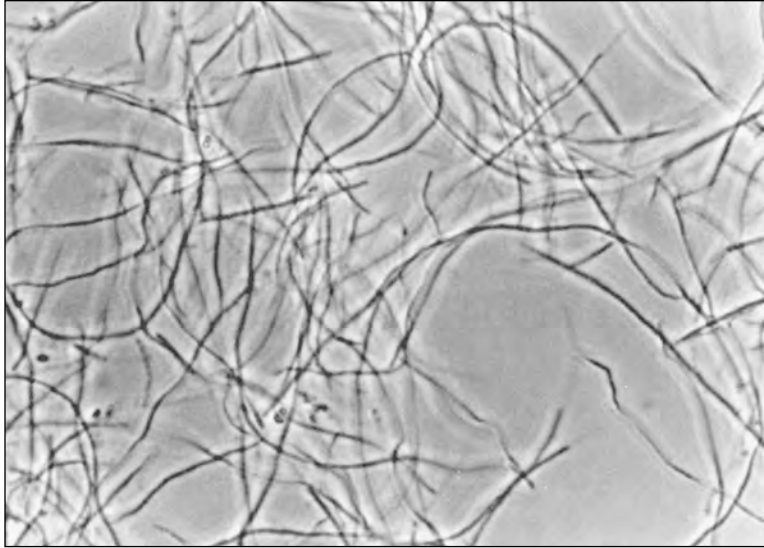
Actinomycetes' significance to the potable water industry relates to their ability to produce, as part of their normal metabolic activities, earthy–musty–moldy taste-and-odor compounds. Five taste-and-odor compounds have been attributed to the actinomycete group. These compounds are

- geosmin or *trans*-dimethyl-*trans*-9-decalol, which imparts an earthy–musty taste and odor
- 2-methylisoborneol (MIB), which imparts an earthy–musty, camphor-like taste and odor
- 2-isopropyl-3-methoxy/pyrazine, which is similar to MIB
- 2-isobutyl-3-methoxy/pyrazine, which has an earthy–musty taste and odor sometimes described as similar to bell peppers
- 2,3,6-trichloroanisole, which is described as musty

BIOLOGY AND ECOLOGY

Actinomycete strains include three types—anaerobic, aerobic, and microaerophilic (requiring a small amount of oxygen to live). This diversity is an advantage in regard to their survival and reproduction in soils and water sediments. They have two different cell forms, filamentous and spore. The most frequently found form is determined by the growth conditions in their immediate environment. The filamentous or vegetative stage is the attached life stage, shown in Figure 1-1, during which they reproduce, producing taste-and-odor compounds.

The alternative stage is the spore form. Although they do not produce taste-and-odor compounds during this stage of the life cycle, it is in this resistant stage that they are easily dispersed in air, land, and water.



Source: Scott Tighe, Analytical Services Inc.

Figure 1-1 Actinomycetes, phase contrast 1,000×

When nutrition and environmental conditions are favorable, spores can germinate into the vegetative stage and produce taste-and-odor compounds. Studies indicate that the vegetative stage grows best in the temperature range of 15 to 38°C. This observation undoubtedly explains why taste-and-odor problems generally occur in the spring, summer, and fall months in temperate areas.

Actinomycetes have been isolated from various aquatic habitats. In general, these organisms prefer the following conditions:

- eutrophic ponds and lakes rich in nutrients, with low concentrations of dissolved oxygen
- shallow ponds
- both clear and turbid lakes
- sediments, although actinomycetes can be found throughout the water

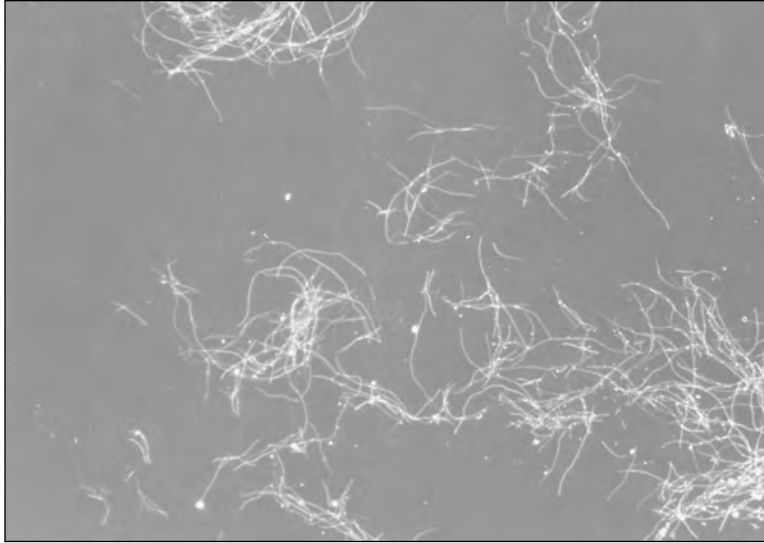
Identification

The transparent body of the vegetative actinomycetes that appears in Figure 1-2 makes these organisms difficult to observe with a compound microscope.

Actinomycetes' general size and shape can be easily confused with other organisms that are not involved in taste-and-odor production. The spore stage, which is even more difficult to observe because of its very small size, is visible at higher magnifications with the light microscope.

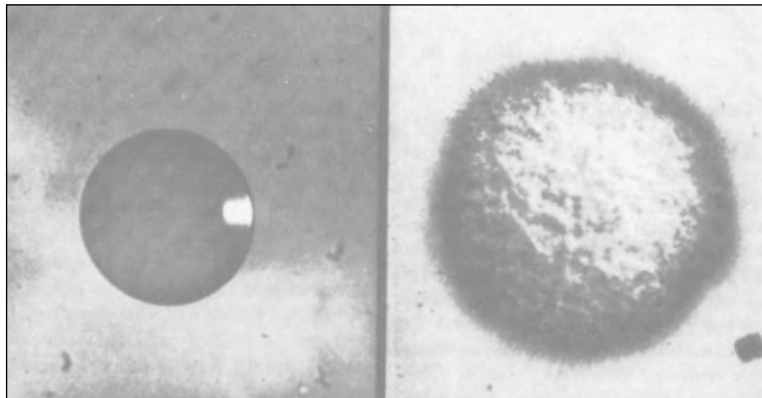
Shown on the left in Figure 1-3 is a typical bacterial colony characterized by a smooth mucous-like appearance and a smooth border. On the right is an actinomycete colony characterized by branching filaments that give it a fuzzy appearance at its border and a dull powdery appearance.

Direct examination of soils, water, and sludges. Actinomycetes are most easily identified by culturing and microscopic examination. Because this process requires from four to seven days to complete, it is not practical for immediate operational control. The customer will be aware of the taste and odor long before the cultures



Source: Scott Tighe, Analytical Services Inc.

Figure 1-2 Actinomycetes, dark-field illumination, 400×



Source: Standard Methods for the Examination of Water and Wastewater.

Figure 1-3 Bacterial colonies—typical colony versus actinomycete colony, 50×

are ready for examination. However, regular sampling and examination for actinomycetes will enable plant staff to develop baseline data for a source water. With these data, staff may predict when problems will occur and make operational changes before the organism becomes a problem.

Cellular morphology. The vegetative stage is characterized by branching and filamentous cells. The filaments can be extremely short, making them hard to distinguish from nonfilamentous, nonactinomycete organisms. Individual filaments vary in diameter from 0.5 to 2.0 μm . Spores are most easily observed when they are attached to filamentous branches. If the spore chains do not break, they may appear as a straight or looped chain. A simple stain, such as crystal violet or safranin, will increase contrast to view specimens more easily under the microscope.

Culture characteristics. The most productive method of observing actinomycetes is to grow them in isolated colonies on a specific agar. This method is more efficient than isolating a single vegetative cell from a reservoir. Samples take from

four to seven days to incubate before microscopic examination. Five media that can be used to isolate actinomycetes are listed in appendix D.

Indirect methods of examination. Odor and flavor testing are useful to determine the concentration of earthy or musty odors that accompany the presence of actinomycetes. There are currently four methods used to determine the concentrations of odors produced by actinomycetes, including threshold odor, flavor profile analysis, gas chromatography, and gas chromatography–mass spectroscopy. The first two tests, threshold odor and flavor profile analysis, are sensory. They are qualitative tests but have the advantage of being quick, inexpensive, and require little training to perform. The threshold odor test is often sufficient for MIB detection, because that compound has a strong smell.

The flavor profile analysis test can be used only on samples safe for consumption. These methods are described in detail in *Standard Methods for the Examination of Water and Wastewater*, Sections 2160 and 2170. The flavor profile method is more quantitative than the threshold odor test. It requires an intermediate level of training and expertise and a panel of at least four trained members to describe the intensities and characteristics of tastes and odors. Reference samples of earthy–musty compounds are required, as well as periodic calibration of the panelists. The panel determines the concentration based on the flavor intensities of the samples.

Two other tests—gas chromatography or gas chromatography–mass spectroscopy—can also be used to measure actinomycete-caused taste-and-odor compounds. The ability of humans to detect these tastes and odors at low levels, however, requires a concentration step before analysis. These methods require expensive equipment and highly trained analysts to yield quantitative information down to 5.0 parts per trillion. These methods are described in detail in *Standard Methods for the Examination of Water and Wastewater*, Section 9250.

SIGNIFICANCE FOR WATER SUPPLIES

Actinomycetes have been isolated from soils, source water, and drinking water treatment plants. The presence of these organisms in soil may become a problem for water utilities when organisms are carried in runoff into source water supplies, establish themselves, and begin producing odors.

It is difficult to positively correlate actinomycete numbers with a taste-and-odor problem since some actinomycetes' spore colonies do not produce tastes and odors.

Actinomycete spores or vegetative cells in the source water may be drawn into a water plant's intake. They can associate with floc and settle in the sludge blanket or in algal mats along the walls of treatment basins. If growth conditions are favorable, actinomycetes may release taste-and-odor compounds. These compounds may also be introduced into the potable water supply when the following conditions occur:

- organisms or spores are retained on treatment plant filters
- soil enters the distribution system during installation of water pipes and repair of main breaks
- a cross connection occurs with an actinomycetes-contaminated source, such as an irrigation pond system connected to standard plumbing without check valves

These taste-and-odor compounds can be detected by humans at extremely low concentrations, for example, 2.0 parts per trillion for MIB. Although consumption of these bacteria or their compounds is not considered a health hazard, the water may still be aesthetically unacceptable to the consumer.

CONTROL STRATEGIES

Water treatment techniques for controlling taste-and-odor compounds produced by actinomycetes depend on the source of the difficulty. Distribution system problems are generally easier to correct than problems in the source water or treatment plant.

Flushing is an effective course of action when the problem is in an isolated area of the distribution system. Actinomycete filaments and spores are susceptible to chlorination. If the problem is persistent, the operator should consider isolating the line and superchlorinating. Both pigging and superchlorination may be necessary if actinomycetes are associated with biofilms.

Taste-and-odor problems due to actinomycete growth at the treatment plant can be controlled by minimizing sludge depth in the sedimentation basin and by maintaining an active basin-cleaning program. Taste-and-odor problems in the source water are the most difficult to control. An alternate source that is taste-and-odor free should be considered first. Sometimes varying the intake depth can be useful.

The oxidants chlorine, chloramines, chlorine dioxide, and potassium permanganate are generally not effective in reducing taste-and-odor compounds caused by actinomycetes. Although some utilities have reported success using these oxidants, others have found their use increases the intensities of tastes and odors.

Ozone, and recently, hydrogen peroxide and ozone, called PEROXONE, have been effective in reducing the concentration of these odorants. Capital costs for this treatment technique are expensive and must be justified on a case-by-case basis.

Activated carbon adsorption has proven effective in many cases. Powdered activated carbon can be added during taste-and-odor episodes to the raw water at an application point that maximizes contact time. Granular activated carbon has been used successfully either as a filter medium or as a postfilter contactor. When considering carbon, it is important to minimize other organics that may interfere with the adsorption of the target odorants and maximize activated carbon and odorant contact time.

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