Actinomycetes and Tastes and Odours in Water Supplies

A Review

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ACTINOMYCETES AND TASTES AND ODOURS
IN
WATER SUPPLIES

A REVIEW

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Discussion

The development of tastes and odours in a body of surface water can be caused by any one of several situations; it may be due to the discharge of chemical substances such as phenols into the water, or it may be biologically caused. The source of the majority of chemically-caused taste and odour problems is normally relatively simple to determine and eradicate, but problems arising from a biological agent are more difficult to deal with.

Biological tastes and odours have been attributed to the growth of many different species of algae, bacteria and also Actinomycetes, or to the combined growth of these organisms; it is sometimes difficult to allocate the blame to any one particular agent. In mid-Western rivers in the United States, taste and odour problems of short duration occurred during the Spring run-off periods, subsiding as the flood stage subsided. These odours were attributed (1) to vegetative decay products, which were leached off the soil surface. Many species of algae have been incriminated as agents of taste and odour production. Only about 8% of reported problems in waterworks in the United States (U.S.) were said to be due to the Actinomycetes, but this is probably due to a lack of facilities for their isolation and identification (2).

A great volume of published work has been produced during studies of the Actinomycetes, which are looked upon as a specialised group of fungi; however, most of this work has been undertaken in the U.S., particularly in the South-West and Mid-West areas. Very little information is available regarding Actinomycetes in Canadian waters, and work from the United Kingdom (U.K.) is limited to several papers from the early thirties and an isolated report (3), concerning the growth of

Actinomycetes within warmed water pipes carrying river water.

The possible reason for the lack of information on Actinomycete tastes and odours from Northern American states, Canada and the U.K., becomes apparent when the conditions under which the organisms flourish are studied. Silvey (4) investigated the life cycle of these organisms, and found that at temperatures below 7°C, the development of all stages of growth is inhibited. This would certainly account for the lack of Actinomycete odours in Canada in the winter, when in all bodies of water the temperature would be 4°C or less. The spores will not germinate in the absence of oxygen; the turnover period results in the presence of oxygen at all levels in the water and under such conditions the primary stages may be present throughout the water; the primary stages, however, do not produce the tastes and odours. For the development of these primary stages, moderate temperature, organic carbon and nitrogen are required. Although the latter two commodities would probably be available in most lakes, it is doubtful whether the temperature optimum of 25°C to 27°C for the growth of these forms, would ever be reached in the Northern U.S. and Canada, except for relatively short periods. Burman (5) has stated that the U.K. probably remains relatively free of Actinomycete problems because water temperatures rarely reach this level.

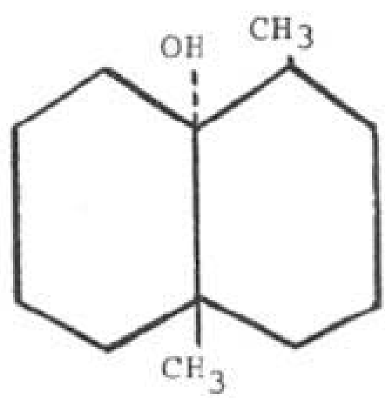
The primary stages of the Actinomycetes are normally transient and where conditions are favourable give rise to the secondary stages, which produce the typical earthy or musty odours as by-products of their metabolism. The submerged secondary stages usually occur immediately following a blue-green algal or diatom bloom, when the most intense odours develop. It has been suggested (6), that the high nitrate content of the blue-green algae contributes to the prolific growth of the Actinomycetes.

Actinomycete tastes and odours persist in the water until the development of Gram-positive bacilli, which appear to utilise the taste and odour compounds as a nutritive source (4).

The exact requirements for the proliferation of the Actinomycetes under natural conditions to produce nuisance levels of taste and odour is unknown. Normally, levels of more than 0.2 ppm of the odorous by-products are associated with the development of noticeable musty odours (7). In one instance (1), incomplete treatment of sewage, subsequently discharged into the river, was thought responsible for the rapid increase in Actinomycetes. However, there was another case (8) where there was apparently no correlation between the biological oxygen demand (BOD) of the river water and the development of Actinomycetes, since the same BOD levels produced a taste and odour problem in one year but not in the following year. Algal blooms in both years were apparently almost identical. This would indicate that the mere presence of sufficient nutrients is not the only factor involved in the development of these organisms to a nuisance level.

The limited in vitro studies which have been carried out, indicate that the aquatic Actinomycetes require some form of organic carbon, a nitrogen source which can be either nitrate or ammonium, and orthophosphate (0.02 - 0.14 ppm) in order to grow (9). It has been noted that growth is better in alkaline waters (7). The presence of organic nitrogen appears to stimulate odour production, and also renders treatment of the water with residual copper considerably less effective (10), because of its chelating effect.

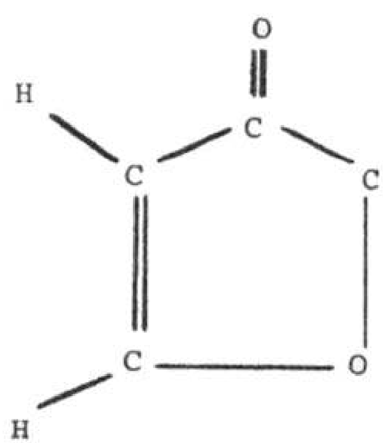
The composition of the compound or compounds which are responsible for the typical musty or earthy tastes and odours is currently under determination. At one time, it was suggested that they were simply a combination of small metabolites - iso-butylamine, β-hydroxybutyric acid etc. (11,7) - mixtures of which compounds were said to yield musty odours. However, other workers (12) have isolated a single substance, geosmin, which when dissolved in water in extremely low concentrations produces an intense earthy or musty taint. Geosmin has been studied by several groups of workers (12,13) with particular reference to its chemical structure, which was finally identified as trans-1, 10-dimethyl-trans-9-decalol (14).



Trans-1, 10-dimethyl-trans-9-decalol (Geosmin)

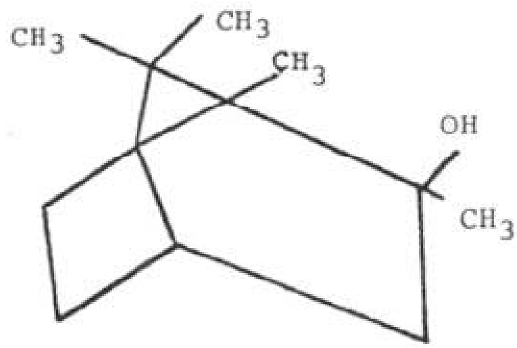
The blue-green alga, *Symploca muscorum*, was found (15) to produce an earthy-smelling substance identical with geosmin; this gave rise to the possibility that earthy tastes and odours are produced by several different kinds of organism, but all are due to the production of the same common compound, geosmin. Considerable weight was lent to this hypothesis when other workers (16) discovered that geosmin was also produced by the blue-green alga *Oscillatoria tenuis*. These findings must be tempered with the statement made by Silvey and Roach (9), that in their studies - *"No pure algal cultures that produced musty, woody or earthy odour in discernible concentrations have been reared. When these odours are present they appear to be caused by the presence of (contaminating) aquatic Actinomycetes*".

Further studies were undertaken with an Actinomycete isolated from an actual taste and odour problem (17); the organism was of the Streptomyces group but was not further identified. Following mass culture, a musty-smelling compound was isolated whose major component was named mucidone. The substance was chemically distinct from geosmin, and possible chemical structures were proposed on the basis of ultraviolet and infrared spectral analysis of pure samples.



Mucidone

Rosen *et al* (18) identified a further musty odorant from a strain of *Streptomyces lavendulae* as 2-exohydroxyl-2-methyl-bornane (2-methylisoborneol), and Medsker (19) and co-workers found the same compound in another strain.



2-exohydroxyl-2-methyl-bornane (2-methylisoborneol)

Geosmin was also found to be component in the crude extracts from these organisms, and the latter workers submit that tastes and odours found in waters may be caused by a mixture of several of these compounds. The proportion of geosmin or other components present, depends on the species of Actinomycete and possibly on the cultural conditions. Additional close analysis of the taste and odour products of other species of Actinomycetes and algae, could reveal a series of such compounds.

Very little progress has been made in the treatment of these tastes and odours. In many cases, remedial action is undertaken on a trial and error basis without any real knowledge of the actual substances causing the problem or the conditions under which they develop in the water. Routine measures normally intensify odours of Actinomycete origin, and the treatment found to be most effective is the application of activated charcoal (20).

Few specific treatments exist. One, developed and patented by Silvey and reported by Hoehn (21), consists of the growth of quantities of a culture of the bacterium B. cereus. This is then applied to the margins of the body of water to be treated, in this case a reservoir; the preparation can also be applied to the settling basins of a treatment plant. The bacillus rapidly destroys the taste and odour compounds resulting in a reduction of the threshold odour in the water.

A further treatment process, thus far only tested on a laboratory scale, is the application of gamma irradiation (22). Odour waters were produced artificially by the addition of the taste and odour component extracted from an Actinomycete culture to tap water. The threshold odour numbers of these odour waters ranged from 200 to 600, and they were treated with various doses of gamma irradiation in a Gammacell 220*. It was found that a dose of 8.4×10^3 rads was as successful in the reduction of odour, as 50 ppm activated charcoal applied for a contact period of thirty minutes. The gamma irradiation was equally effective with waters of low and high threshold odour. At the present time, large-scale treatment of water supplies with gamma irradiation would be more expensive than conventional procedures. However costs may be expected to become competitive, as the costs of isotopes decrease and other uses for irradiation develop.

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* Gammacell 220-RTM-Atomic Energy of Canada Ltd., Commercial Products Division.

Recommendations

Further studies of the part played by Actinomycetes in the development of tastes and odours in waters should proceed along the following lines.

a) Laboratory culture of the organisms incriminated in taste and odour problems, and the isolation and identification of the component responsible. Such work would include the development of improved techniques for the detection of the chemical substances producing the odour, both in culture and in the field.

b) Elucidation of the conditions under which nuisance levels of these organisms are produced, so that in the future, preventive measures may be used to avert the problem.

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