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Actinomycetes and Fungi in Surface Waters and in Potable Water

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In Finnish lakes and rivers used as water supplies, mesophilic fungi and actinomycetes were common, whereas thermophilic fungi and actinomycetes were present only in low concentrations. Fungi and actinomycetes were more abundant in eutrophic and mesotrophic lakes than in oligotrophic lakes. River water contained more thermophilic actinomycetes and fungi and mesophilic actinomycetes than did lake water. Runoff from soil seemed to be an important factor contributing to the incidence of these microbes in water. Chemical coagulation removed actinomycetes and fungi efficiently, but sand filtration allowed their passage. Disinfection could not prevent actinomycetes and fungi from reaching the distribution system. During infiltration in the production of recharged groundwater, mesophilic actinomycetes could even multiply appreciably.

Although many fungi are found in the aquatic habitat (17), more studies have been carried out on actinomycetes than on fungi because of the serious odor and taste problems caused by actinomycetes. Silvey and Wyatt (24) reported a maximum density of actinomycetes in rivers and reservoirs soon after the algal bloom, when the water temperature was highest. Densities higher in Texas—up to 7×10^5 actinomycetes ml^{-1}—(24) than in Great Britain (5) and Finland (18, 23), where the concentrations have been reported to be between 10 and 200 ml^{-1}, have been observed. Concentrations of actinomycetes have been found to be higher in river water and in lake sediments than in lake water (28).

The relative abundance of *Streptomyces* and *Micromonospora* species in the Thames River is the same as the abundance in soil (5). According to Burman (5), it is probable that under normal conditions, actinomycetes are washed out into the water from the soil. Persson's (18) observations of actinomycete concentrations reflecting washout from soil support Burman's view. Cross and Johnston (7) observed a *Thermoactinomyces vulgaris* concentration of 2 ml^{-1} in river water coming from pastureland.

Burman (5) investigated the behavior of actinomycetes during water treatment and in distribution systems. Only 30 to 40% of the actinomycetes, which consisted of *Micromonospora* and *Streptomyces* species, are removed during slow sand filtration. Burman concluded that actinomycetes belong to the normal flora of sand filters, where they can decompose compounds difficult to biodegrade. Actinomycete spores, especially those of the genus *Micromonospora*, tolerate normal disinfection with chlorine so well that a considerable fraction persists.

Exposure to actinomycetes and fungi can lead to allergic respiratory symptoms in sensitive persons. In particular, thermophilic species such as *T. vulgaris* and *Micropolyspora faeni* are known to cause extrinsic allergic alveolitis when introduced in high quantities into the atmosphere. These diseases include farmer's lung, begassosis, sequoiosis, maltworker's lung, and hypersensitivity pneumonitis (14). Thermophilic species grow in environments in which the temperature varies from 30 to 60°C; such environments include damp hay and humidifiers (3, 6, 9, 14, 19, 22, 25, 26).

Metzger et al. (15) reported *Pullularia* fungus to be the etiological agent of an epidemic of allergic alveolitis. The fungus was growing in the water container from which water was taken for steam production in a sauna.

Symptoms caused by potable water and resembling those typical of extrinsic allergic alveolitis have been reported in Sweden (2) and Finland (16). In Sweden, toxins of cyanobacteria (blue-green algae) have been proposed to be the possible etiological agent (2). Endotoxins of gram-negative bacteria and cyanobacteria may have been the causative agents in the Finnish

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TABLE 1. Waterworks studied

Waterworks	Municipality	Water supply	Treatment	Vol produced (m^3 day^{-1})
Sand filtration				
a	Pohja	Lake Myllyjärvi	Fast sand filtration; disinfection (hypochl)[a]	640
b	Imatra	Lake Immalanjärvi	Multilayered filtration; alkalified (lime) disinfection (Cl_2)	8,500
c	Juva	Lake Salajärvi	Slow sand filtration; disinfection (hypochl); phosphate addition	780
d	Ristiina	Lake Yövesi	Fast sand filtration; alkalified (lime) disinfection (hypochl)	290
e	Leppävirta	Lake Sorsavesi	Fast sand filtration; disinfection (hypochl)	270
f	Laukaa	Lake Leivonvesi	Fast sand filtration; disinfection (Cl_2)	430
g	Lappajärvi	Lake Lappajärvi	Fast sand filtration; disinfection (hypochl)	420
h	Vaala	Ala-Salmi Pond	Pressure filtration; disinfection (hypochl)	
i	Nokia	Lake Järvenjärvi	Fast sand filtration; disinfection (hypochl); phosphate addition (used until April 1979)	600
Artificially recharged groundwater				
j	Porvoo	Porvoonjoki River	Chemical coagulation; artificial groundwater	5,460
k	Pori	Lake Tyvijärvi	Chemical coagulation; artificial groundwater	11,500
l	Lappeenranta	Lake Hanhijärvi	Production of artificial groundwater as sole treatment procedure	950
Chemical coagulation				
m	Espoo	Lake Dämman	Chemical coagulation; disinfection (Cl_2)	21,000
n	Turku	Aurajoki River	Complete chemical coagulation; disinfection (Cl_2)	59,000
o	Nokia, Siuro, and Linnavuori	Lake Jokinenjärvi	Chemical coagulation; disinfection (Cl_2)	153

[a] hypochl, Sodium hypochlorite.

epidemic as well, but actinomycetes and fungi cannot be excluded as the possible pathogens (16).

Hutchinson and Ridgway (11) listed microbiological problems associated with slow sand filtration. During putrefactive decomposition of algae, excessive growth of bacteria, including coliforms, can occur. Furthermore, spore-forming bacteria may become established in the filter bed, and spores may pass through in relatively large numbers. At the onset of the Finnish epidemic of extrinsic allergic alveolitis caused by tap water, a massive *Anabaena* bloom occurred in the water supply. Therefore spore-forming organisms and endotoxins of cyanobacteria or of gram-negative bacteria could all have been the etiological agents of alveolitis (2, 21, 24).

In this investigation, the occurrence of mesophilic and thermophilic actinomycetes and fungi in Finnish lakes and rivers used as water supplies was examined. Their occurrence in treated water and in distribution systems was also studied. The efficiencies of different waterworks in removing these organisms were compared.

MATERIALS AND METHODS

Waterworks. The majority of waterworks studied used sand filtration as the main water treatment method (Table 1). Only three of the waterworks use chemical coagulation, and another three use artificial groundwater. Chlorination is performed to disinfect water at all of the waterworks except the waterwork at the town of Lappeenranta, where water is not disinfected at all. The quality of raw water was, in general, better at waterworks where sand filtration was used and was more eutrophic at waterworks where chemi-

TABLE 2. Methods for determining the presence of actinomycetes and fungi

Organism	Sample vol (ml)	Incubation time (days)	Incubation temp (°C)	Membrane filter	Growth medium[a]
Actinomycetes					
Thermophilic	100–500	2–5	50	Millipore HA black with grid 047A0; pore size, 0.45 μm; autoclaved at 120°C for 15 min	Half-strength nutrient agar + cycloheximide (50 μg ml^{-1}) + novobiocin (25 μg ml^{-1}) (6, 13, 27)
Mesophilic	1–500	7–14	22	Millipore HA, white with grid 047S0; pore size, 0.45 μm	Actinomycete Isolation Agar + cycloheximide (50 μg ml^{-1})
Fungi					
Thermophilic	10–500	2–5	45	Gelman GN-6; pore size, 0.45 μm; (20)	Malt extract, agar + Rose Bengal (35 mg $liter^{-1}$) + aureomycin (35 mg $liter^{-1}$) (4, 13)
Mesophilic	10–500	7–14	22	Same as for thermophilic fungi	Same as for thermophilic fungi

[a] Cycloheximide was obtained as Acti-dione from The Upjohn Co.; novobiocin was obtained as novobiocin sodium salt from Sigma Chemical Co.; Actinomycete Isolation Agar was obtained from Difco Laboratories; Rose Bengal was obtained from Fluka AG; and aureomycin was obtained from Lederle Laboratories.

cal coagulation was performed. However, some filtration water treatment plants did use eutrophic raw surface waters.

Samples. Raw water samples for the analysis of fungi and actinomycetes and for physical and chemical analyses were taken in 1979 at the end of July and August and in the middle of September and October. Samples for plankton analysis were taken at the same times, excluding October.

Samples for the study of fungi and actinomycetes were taken as profile samples from the euphotic zone and from 1 m above the bottom into sterile polypropylene containers with clean Ruttner-type water samplers. Samples for physical and chemical analyses were taken from 1 m above and 5 m below the surface, from the middle of the water column, and from 1 m above the bottom. For plankton analysis, samples were taken only from the euphotic zone.

Samples from treated water and from the distribution system were taken on the same dates as those at which raw water samples were taken. The samples from the distribution system were taken mainly from the cold-water tap, but samples were also taken from the hot-water tap from three distribution systems. The same analyses, except oxygen saturation, chlorophyll a, and plankton studies, that were performed for the raw water samples were performed for treated-water and distribution system samples (see below). In addition, the concentration of residual chlorine was analyzed. Sodium thiosulfate was not used in sample bottles intended for microbial analyses. Fungi and actinomycetes were plated within 1 day after sampling took place.

Methodology for actinomycete and fungus determination. The membrane filtration technique was used for determination of the presence of actinomycetes and fungi (Table 2). The membranes were immersed in hot sterile water for a few minutes before filtration, because higher counts have been reported when this pretreatment is used (1).

Plankton analyses. Water samples for plankton analyses were preserved with Formalin or Keefen solution. The procedure for counting and calculating results was that described by Heinonen (10).

Physical and chemical analyses. Temperature was measured at the time of sampling. Finnish standard methods (SFS, Finnish Standards Association) were used in the determination of conductivity (SFS 3022), pH (SFS 3021), permanganate number (SFS 3036), oxygen saturation (SFS 3040), and copper (SFS 3047), and Swedish standards (Swedish Standards Institution [SIS]) were used in the analyses of total nitrogen (SIS 028131) and total phosphorus (SIS 028127). Sodium, potassium, and magnesium were determined by atomic absorption spectroscopy and atomization with flame. Chlorophyll a was analyzed in accordance with the recommendation of the Baltic Marine Biologists (8). The analyses were performed at the local Water District Office Laboratories and at the Water Research Laboratory of the National Board of Waters, Helsinki.

RESULTS

Raw water. No positive correlations were recorded between the occurrence of actinomycetes and fungi and the biomass of algae and cyanobacteria; however, the incidence of fungi and actinomycetes was high in mesotrophic and eutrophic water supplies, and the organisms were observed less frequently in oligotrophic water supplies (Table 3; see Fig. 1, 3, 5, and 7).

Mesophilic fungi were abundant in all raw water supplies (Table 3; see Fig. 5). Most raw water samples also contained mesophilic actinomycetes, but the concentrations of these organisms were highest in river water (Table 3; see Fig. 1). River water contained elevated amounts of thermophilic fungi, whereas their incidence in lake water was low (Table 3; see Fig. 7). The incidence of thermophilic actinomycetes was

TABLE 3. Occurrence of actinomycetes and fungi in lakes and rivers used as raw water sources by the water industry[a]

Waterwork	Sample	No. of actinomycetes[b]		No. of Fungi[b]		Trophic level
		Thermophilic	Mesophilic	Thermophilic	Mesophilic	
Sand filtration						
a	Comb[c]	1	0	0	4	Oligotrophic
	1 m[d]	1	2	0	4	
b	Comp	1	1	0	4	Oligotrophic
	1 m	0	0	0	4	
c	Comp	0	0	0	4	Oligotrophic
	1 m	0	2	0	4	
d	Comp	0	1	1	4	Oligotrophic
	1 m	1	3	0	4	
e	Comp	0	1	0	4	Oligotrophic
	1 m	0	2	1	4	
f	Comp	1	2	1	4	Oligo- or mesotrophic
	1 m	3	2	1	4	
g	Comp	1	1	2	4	Meso- or eutrophic
	1 m	1	1	1	4	
h	Comp	0	1	1	4	Not studied
	1 m	0	1	0	4	
i	Comp	4	1	0	4	Eutrophic
	1 m	3	3	1	4	
Total	Comp	8/36	8/36	5/36	36/36	
	1 m	9/36	16/36	4/36	36/36	
Artificially recharged ground water						
j	Comp	4	4	3[e]	4	Polluted river
	1 m	4	4	3[e]	4	
k	Comp	2	4	1	4	Oligo- or mesotrophic
l	Comp	4	4	2	4	Eutrophic
	1 m	4	3	0	4	
Total	Comp	10/12	12/12	6/11	12/12	
	1 m	8/8	7/8	3/7	8/8	
Chemical coagulation						
m	Comp	4	2	1	4	Meso- or eutrophic
	1 m	3	3	2	4	
n	Comp	4	4	4	4	Polluted river
	1 m	3[e]	3[e]	3[e]	3[e]	
o	Comp	3	2	2	4	Eutrophic
	1 m	4	4	1	4	
Total	Comp	11/12	8/12	7/12	12/12	
	1 m	10/11	10/11	6/11	11/11	

[a] Trophic levels were estimated by plankton analysis.
[b] No. of positive samples among four samples studied.
[c] Comp, Composite sample from the euphotic layer.
[d] 1 m, Sample taken from 1 m above the bottom.
[e] Only three samples studied.

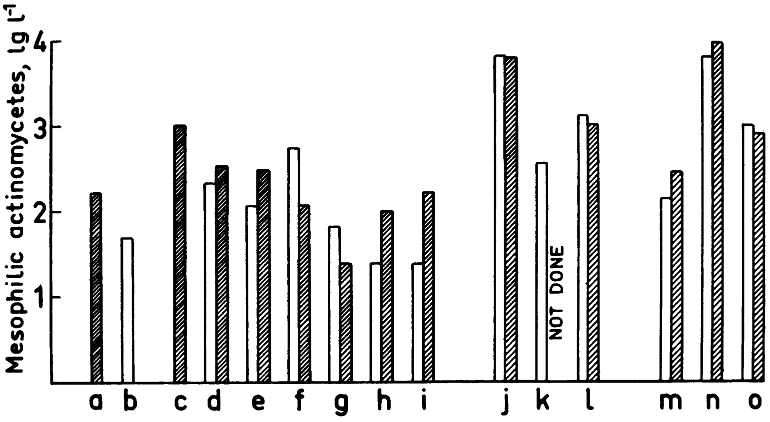

FIG. 1. Mesophilic actinomycetes in lakes and rivers (indicated by lowercase letters; see Table 1) used as raw water supplies. The results are expressed as $\log_{10}$ of the average concentrations of four composite samples (open bars) and four samples from 1 m above the bottom (hatched bars).

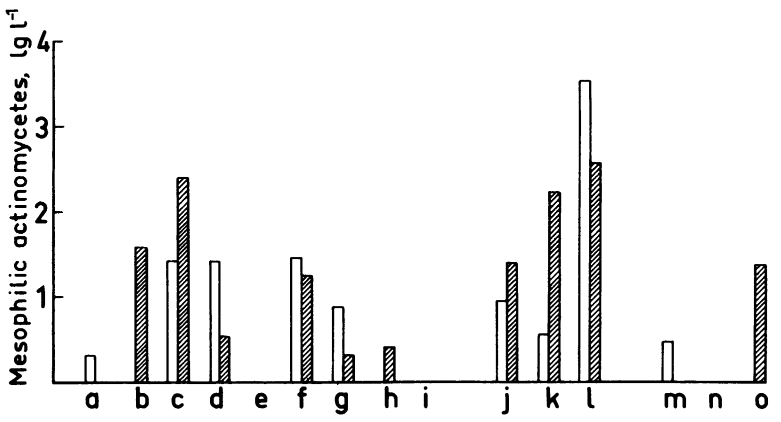

FIG. 2. Mesophilic actinomycetes in treated potable water (open bars) and tap water (hatched bars). The results are expressed as $\log_{10}$ of the average concentrations of four samples. See Table 1 for water sources, which are indicated by lowercase letters.

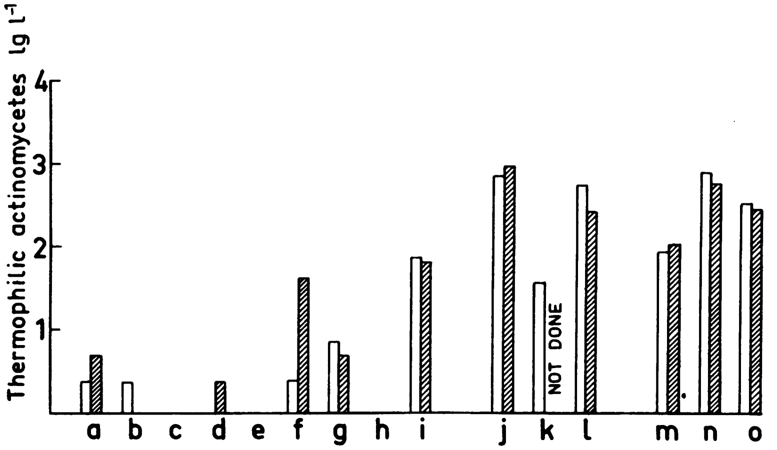

FIG. 3. Thermophilic actinomycetes in lakes and rivers (indicated by lowercase letters; see Table 1) used as raw water supplies. The results are expressed as $\log_{10}$ of the average concentrations of four composite samples (open bars) and four samples from 1 m above the bottom (hatched bars).

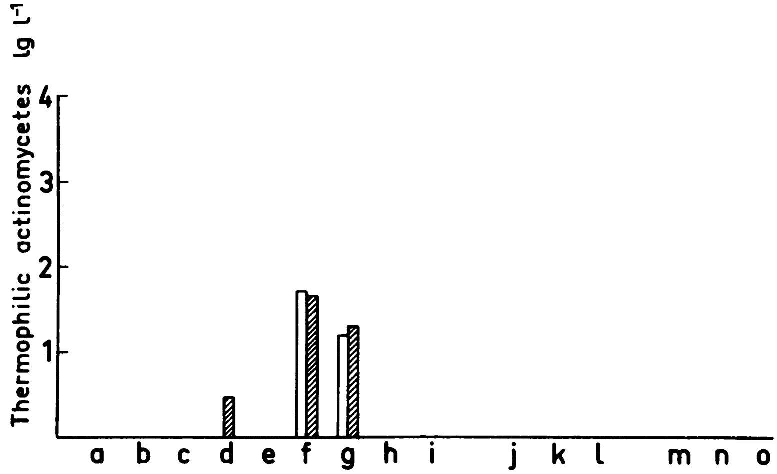

FIG. 4. Thermophilic actinomycetes in treated potable water (open bars) and tap water (hatched bars). Results are expressed as $\log_{10}$ of the average concentrations of four samples. See Table 1 for water sources, which are indicated by lowercase letters.

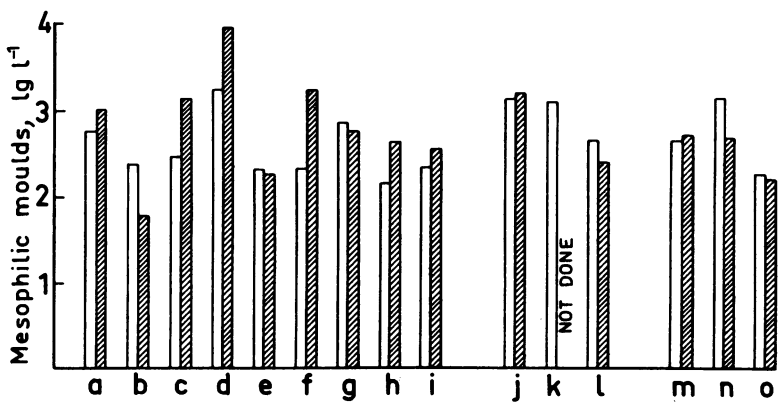

FIG. 5. Mesophilic fungi in lakes and rivers (indicated by lowercase letters; see Table 1) used as raw water supplies. The results are expressed as $\log_{10}$ of the average concentrations of four composite samples (open bars) and four samples from 1 m above the bottom (hatched bars).

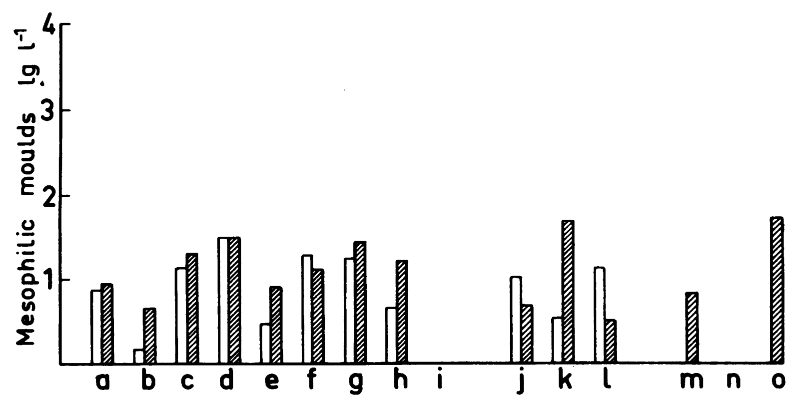

FIG. 6. Mesophilic fungi in treated potable water (open bars) and tap water (hatched bars). Results are expressed as $\log_{10}$ of the average concentrations of four samples. See Table 1 for water sources, which are indicated by lowercase letters.

TABLE 4. Correlations between the occurrence of actinomycetes and fungi and the physical and chemical variables studied

Organism	Correlation (df)					
	Mesophilic actinomycetes	Thermophilic fungi	Mesophilic fungi	Cu^{2+}	Na^{+}	K^{+}
Actinomycetes						
Thermophilic	0.78^{c} (18)	0.57^{d} (12)	0.51^{e} (28)	0.17 (20)	0.69^{c} (26)	0.65^{c} (26)
Mesophilic		0.63^{e} (14)	0.43^{e} (27)	0.26 (19)	0.72^{c} (25)	0.66^{c} (25)
Fungi						
Thermophilic			0.58^{e} (17)	0.59^{d} (13)	0.71^{c} (15)	0.70^{c} (15)
Mesophilic				0.17 (45)	0.38^{e} (54)	0.35^{e} (54)

[a] γ, Conductivity of water.
[b] COD_{Mn}, Chemical oxygen demand: oxidation with permangate.
[c] $P = 0.001$.
[d] $P = 0.05$.
[e] $P = 0.01$.

low in oligotrophic water supplies (Table 3; see Fig. 3). These organisms occurred more frequently in eutrophic water supplies and especially in river water.

The correlations between microbial parameters and physical and chemical parameters (conductivity and the concentrations of sodium, potassium, magnesium, total nitrogen, and total phosphorus) were positive (Table 4). The concentrations of actinomycetes and fungi were also intercorrelated. Because these correlations imply that runoff from soil contributes remarkably to the occurrence of actinomycetes and fungi in waters, the correlations between microbial parameters and the percentage of cultivated land in the drainage basins were calculated. Positive correlations were observed for thermophilic actinomycetes ($r = 0.67$ [$P = 0.001$], where r = coefficient of correlation; df = 59), mesophilic actinomycetes ($r = 0.48$ [$P = 0.001$]; df = 59), and thermophilic fungi ($r = 0.57$ [$P = 0.001$]; df = 58), whereas a weaker correlation ($r = 0.25$ [$P = 0.05$]; df = 59) for mesophilic fungi was found.

Treated water and tap water. The incidence of fungi and actinomycetes was in general lower in water treated by chemical coagulation than in water treated by sand filtration, although the opposite case was true for relative levels in the corresponding raw waters (Tables 1, 3, and 5; Fig. 1 through 8).

Mesophilic fungi were present in the vast majority of samples, and mesophilic actinomycetes were also common (Table 5; Fig. 2 and 6). The incidence of these organisms in treated water at Siuro in the municipality of Nokia was low, but the concentrations were higher in some tap water samples from the Linnavuori area (Table 5). These organisms in the distribution system possibly originated from an earlier period when the raw water source was Lake Järven-

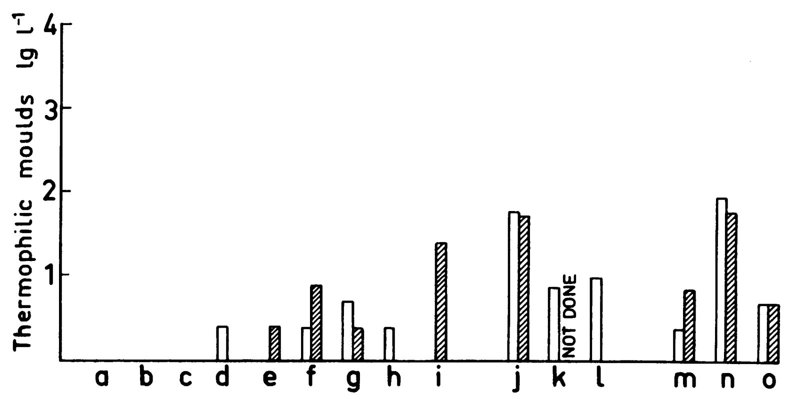

FIG. 7. Thermophilic fungi in lakes and rivers (indicated by lowercase letters; see Table 1) used as raw water supplies. Results are expressed as $\log_{10}$ of the average concentrations of four composite samples (open bars) and four samples from 1 m above the bottom (hatched bars).

TABLE 4.—*Continued*

Correlation								
Mg^{2+}	Temp	% O_2	γ[a]	pH	COD_{Mn}[b]	Total N	Total P	Chlorophyll a
0.64[c] (26)	−0.05 (28)	−0.18 (27)	0.66[c] (27)	0.00 (27)	0.20 (28)	0.63[c] (28)	0.66[c] (28)	0.21 (20)
0.73[c] (25)	−0.02 (27)	−0.16 (26)	0.66[c] (26)	0.02 (26)	0.13 (27)	0.66[c] (26)	0.72[c] (26)	0.07 (16)
0.78[c] (15)	0.22 (17)	−0.27 (16)	0.81[c] (17)	−0.01 (17)	−0.06 (17)	0.75[c] (17)	0.73[c] (17)	0.04 (11)
0.42[c] (54)	0.05 (59)	−0.16 (58)	0.42 (58)	0.03 (58)	0.11 (59)	0.42[c] (58)	0.41[c] (59)	0.05 (45)

järvi and the treatment procedure was sand filtration.

The average concentration of mesophilic actinomycetes was high at Juva, where the concentration was 1,000 $liter^{-1}$ in one tap-water sample, whereas other samples had remarkably lower concentrations (Fig. 2).

At the Lappeenranta treatment plant, which produces artificial groundwater, the concentrations of mesophilic actinomycetes were consistently high in treated water, whereas they were lower in tap water (Table 5; Fig. 2). Small, pale-yellow colonies on Actinomycete Isolation Agar plates (Difco Laboratories) were predominant in water filtered through soil.

Thermophilic fungi were rare in treated water and in tap water (Table 5: Fig. 8). Treatment plants using chemical coagulation could efficiently remove thermophilic fungi from raw waters; thermophilic fungi were present more often in these plants than in the water supplies of waterworks using sand filtration.

Thermophilic actinomycetes were rarely found in water treated by chemical coagulation. Only 1 sample of 24 was positive. They were more often present in water filtered through sand, although their incidence was lower in the raw water of waterworks using sand filtration than in the raw water of plants using chemical coagulation (Table 5; Fig. 4). They were consistently present in treated water and tap water in the Laukaa and Lappajärvi municipalities, where sand filtration was used as the treatment procedure and where the concentration of organic material in the treated water was high (Table 5).

In addition to cold tap water, hot tap water was investigated in three municipalities. Mesophilic actinomycetes and fungi were present in 5, mesophilic fungi in 2, and thermophilic actinomycetes in 1 of the 12 samples studied. No thermophilic fungi were observed in these samples.

The majority of the thermophilic actinomycetes isolated during this investigation belonged to the species *T. vulgaris*, and the majority of the thermophilic fungi belonged to the species *Aspergillus fumigatus*.

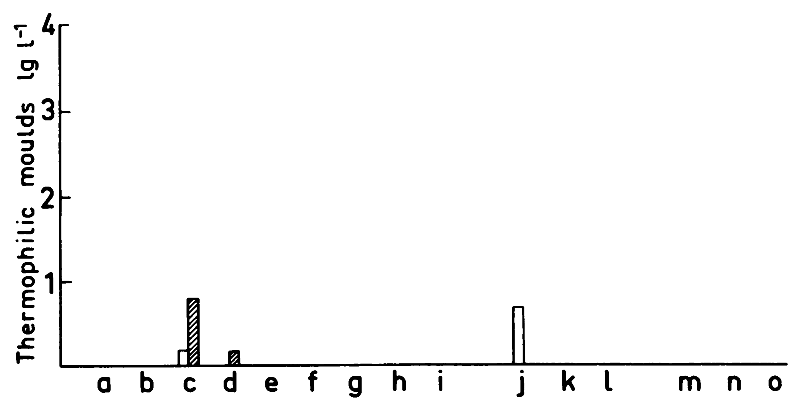

FIG. 8. Thermophilic fungi in treated potable water (open bars) and tap water (hatched bars). The results are expressed as $\log_{10}$ of the average concentrations of four samples. See Table 1 for water sources, which are indicated by lowercase letters.

TABLE 5. Occurrence of actinomycetes and fungi in treated and tap water

Waterwork	Sample	No. of actinomycetes[a]		No. of fungi[a]		Range of $KMnO_4$ no.
		Thermophilic	Mesophilic	Thermophilic	Mesophilic	
Sand filtration						
a	Treated	0	1	0	4	17–18
	Tap	0	0	0	3	17–18
b	Treated	1	2	0	2	8–10
	Tap	1	3	0	4	6–8
c	Treated	0	4	1	4	15–17
	Tap	0	3	1	4	13–16
d	Treated	1	3	2	4	19–21
	Tap	3	2	2	4	18–20
e	Treated	0	0	0	3	18–20
	Tap	0	0	0	3	17–18
f	Treated	4	2	0	4	22–24
	Tap	4	3	1	4	17–23
g	Treated	3	2	1	4	36–40
	Tap	4	1	0	4	35–40
h	Treated	0	0	0	4	2–3
	Tap	0	1	1	4	0–3
Total	Treated	9/32	14/32	4/32	29/32	
	Tap	12/32	13/32	5/32	30/32	
Artificially recharged ground water						
j	Treated	0	3	1	4	8–11
	Tap	0	1	1	4	8–11
k	Treated	1	4	0	3	10–15
	Tap	1	3	0	4	8–12
l	Treated	0	4	0	4	10–12
	Tap	0	2	0	3	8–9
Total	Treated	1/12	11/12	1/12	11/12	
	Tap	1/12	6/12	1/12	11/12	
Chemical coagulation						
m	Treated	0	2	0	1	10–13
	Tap	0	0	0	3	8–11
n	Treated	0	0	0	1	13–19
	Tap	0	0	0	0	14–18
o	Treated	0	1	0	2	12–14
	Tap	1	1	0	4	10–15
Total	Treated	0/12	3/12	0/12	4/12	
	Tap	1/12	1/12	0/12	7/12	

[a] No. of positive samples among four samples studied.

DISCUSSION

Actinomycetes and fungi are distributed around the world, and therefore it is to be expected that their spores are present in rivers and lakes. Their numbers, however, vary remarkably from one geographical area to another. Silvey and Wyatt (24) reported that, in association with taste and odor problems, high concentrations of actinomycetes are found in subtropical reservoirs, whereas in temperate climates, the reported concentrations are lower (5, 18, 23).

River water, which can wash out microbes from surrounding soil, contained more mesophilic and thermophilic actinomycetes and more thermophilic fungi than did lake water. Mesophilic fungi were common in all raw water samples. The correlations between concentrations of actinomycetes and fungi and chemical and physical parameters could be a reflection of the stimulating effect of minerals on microbial growth. However, it is more likely that these correlations, as well as correlations between microbes and the percentage of cultivated land in the drainage basin, reflect the importance of runoff for the occurrence of these microbes in lakes and rivers under normal conditions, when the microbial concentrations are rather low. Actinomycetes occur in soil in concentrations of 10^6 to 10^8 organisms g^{-1} of dry soil (12). The importance of washout for the occurrence of actinomycetes in waters is supported by the findings of Burman (5), Cross and Johnston (7), and Persson (18).

The concentrations of mesophilic actinomycetes were higher in artificial groundwater than in eutrophic raw water and were also higher than the concentration in tap water at Lappeenranta. The number of colonies and the uniform colony morphology of mesophilic actinomycetes cultivated from this artificial groundwater imply that a single species was able to grow substantially in the filtering soil. The recommendation of Hutchinson and Ridgway (11) that, owing to microbiological dangers, only the recharge of fully treated water should be permitted, is not followed at this treatment plant.

The ability of actinomycetes to degrade resistant organic compounds makes them important as a constitutent of the normal flora of sand filters (5). This is supported by the finding that thermophilic actinomycetes were more often present in treated water than in raw water at the two waterworks using sand filtration for raw water with a high concentration of organic material. This finding is surprising because of the high optimum growth temperature of thermophilic actinomycetes.

The investigation showed that actinomycetes and fungi, including low concentrations of thermophilic strains, were present in raw water supplies and that they could pass through both sand filtration and disinfection and therefore can occur in drinking water. Treatment plants using chemical coagulation and disinfection effectively remove actinomycetes and fungi from the water. However, these organisms may be occasionally found in the distribution system.

It is unlikely that concentrations as low as those observed in this study can cause respiratory symptoms. However, piped water can offer a transmission route, and if their aftergrowth in the distribution system or in the consumer occurs, they constitute a potential health hazard.

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