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Occurrence of *Aspergillus fumigatus* During Composting of Sewage Sludge

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Aspergillus fumigatus, a medically important fungal opportunist and respiratory allergen, was isolated from woodchips and sewage sludge used in the production of compost at the U.S. Department of Agriculture's composting research facility in Beltsville, Md. It was also regularly isolated as a dominant fungus during forced aeration composting and after 30 days in an unaerated stationary curing pile; in both cases, the fungus was found in pile zones with temperatures less than 60°C. Compost stored outdoors in stationary unaerated piles from 1 to 4 months after screening out of woodchips contained easily detectable amounts of *A. fumigatus* in the exterior pile zones (0- to 25-cm depths). Semiquantitative studies of the airspora at the composting site revealed that *A. fumigatus* constituted 75% of the total viable mycoflora captured. At locations 320 m to 8 km from the compost site, the fungus constituted only 2% of the total viable mycoflora in the air. Of 21 samples of commercially available potting soil, one had levels of *A. fumigatus* nearly equivalent to those of 1-month-old storage compost; 15 others had lower but detectable levels.

Sewage sludge disposal is an immediate and growing problem for many U.S. municipalities. Composting, one of the alternative disposal/utilization options available, has been investigated from engineering, economic, bacteriological, and viral aspects (6, 11, 20, 48). The agronomic characteristics of the compost have also been evaluated (19). One aspect which has not been investigated thoroughly and evaluated with a view toward health safety is the fungal flora which develops during composting.

Aspergillus fumigatus Fres. is one of the relatively few fungi which are known to infect humans. Records of its ecological distribution and pathogenicity, which follow below, suggested that the fungus might proliferate during composting and thereby pose a health problem for certain individuals.

Ecological distribution. *A. fumigatus* has been found frequently in composting vegetative material (7, 17, 21, 39), self-heating woodchip piles (5, 18, 44), municipal refuse compost (30, 32, 43), refuse-sludge compost (32), moldy hay (24), and sewage (12, 14, 15). Unlike truly thermophilic fungi, which cannot grow below 20°C (16), *A. fumigatus* grows over a range of below 20 to about 50°C (16).

In contrast to the frequent occurrence of *A. fumigatus* in the above-mentioned environments, aspergilli in general have been reported only infrequently and in small numbers in outdoor air (23, 28). Austwick (3, 4) reported low concentrations (10 to $10^4/m^3$) of *A. fumigatus* spores in outdoor air and stated, "*Aspergillus*-type spores in the outside air probably rarely exceed $500/m^3$, but within a farm building following the shaking of mouldy hay Lacey and Lacey (35) found up to 21 million/m^3." Airborne spores in pastures consisted largely of *Cladosporium* sp. and a few other forms but included extremely few spores of aspergilli (33).

A. fumigatus does not appear to be predominant in the fungal flora of most soils (25, 41), even though often isolated. Recent data on sun-heated soils revealed that *A. fumigatus* was the second most frequently isolated thermophilic/thermotolerant fungus from that environment (45); no data are provided on population levels of the fungus in terms of colony-forming units (CFU) per gram of soil.

Pathogenicity and hypersensitivity. *A. fumigatus* is a secondary opportunistic invader of the lungs, sometimes spreading to other organs or to the central nervous system in individuals severely debilitated by primary diseases (18, 27). Ajello (1) supports the observation of Emmons et al. (18) that "pulmonary aspergillosis is often superimposed upon tuberculosis, silicosis, an anatomical abnormality or deficient immunologic response related to corticosteroid or antibiotic

therapy." Emmons et al. (18) noted further that even in the absence of other diseases, infections very occasionally result soon after exposure to large doses of conidia.

Spores of *A. fumigatus* can also cause bronchopulmonary hypersensitivity, marked by asthmatic spasm, fever, malaise, and prostration (18). Although many fungi are capable of inducing such responses (8), among atopic individuals, *A. fumigatus* is a strong allergen which incites a hypersensitivity response in a high percentage of exposed individuals (26, 31). It has been widely used in skin prick tests of asthmatic patients and is recommended (38) as one of five standard allergens for this purpose. In studies of respiratory allergies associated with exposure to moldy hay, the levels of *A. fumigatus* have been cited repeatedly (34–36). Although low concentrations of *A. fumigatus* spores in outdoor air (10 to $10^4/m^3$) do not appear to cause infection in healthy individuals, Austwick (3) suggested that such levels probably do incite allergic responses in sensitized individuals. Vithayasai et al. (46) reported that three asthmatic members of a single family almost simultaneously developed allergic aspergillosis. Their use of potting soil containing *A. fumigatus* (quantities not reported) was suggested as the source of infection.

Our investigation was directed toward determining the occurrence of *A. fumigatus* (i) quantitatively, in all stages of the Beltsville composting process, including the starting materials, undigested sewage sludge (containing large amounts of ferric chloride and lime), and woodchips; (ii) quantitatively, in commercially available potting soils, mulches, and manures; and (iii) qualitatively, in the air at the composting site and at several distances from the site. The information would provide some assessment of the magnitude of the potential inoculum.

MATERIALS AND METHODS

Composting. Details of the Beltsville Aerated Pile Composting Method have been provided by Epstein et al. (20). It consists of five operations: mixing, 3-week composting, curing, screening, and storing. This results in finished compost.

The starting materials consist of: (i) woodchips from commercial tree trimming and removal services, and (ii) vacuum-filtered undigested sludge of approximately 75% moisture content obtained from Blue Plains Wastewater Treatment Plant, Washington, D.C. These are mixed (2:1, vol/vol) and formed into piles 25 by 6 by 2.5 m high, oriented in a north-south direction. Piles are covered with a 30- to 45-cm blanket layer of cured compost for insulation and odor control and subjected to forced aeration for 3 weeks, after which time they are disassembled, repiled, and left unaerated for approximately 4 weeks of curing. Cured compost is screened to remove large woodchips and then stored without aeration for varying periods.

Compost sampling. Seven sludge samples from different deliveries were collected randomly prior to mixing with chips. Woodchips were obtained randomly from old stockpiles and from deliveries of fresh chips. Three-week compost was obtained from high (60 to 82°C), intermediate (40 to 60°C), and low (<40°C) temperature zones, estimated from isotherms, in sectioned, aerated piles. At each sample locus, approximately 100 g of compost was obtained from the inner end of a hole made with a sterile trowel; samples were placed into sterile plastic bags and transported immediately to the laboratory refrigerator (5°C, for 3 h or less) until dilutions were prepared. Cured and freshly screened compost samples were collected randomly and handled aseptically.

Storage compost samples were obtained from a pile (9.1 m in diameter by 2.7 m high) initially and at 1 week, 1 month, 4 months, and 6 months after construction. They were removed aseptically from three randomly selected, equivalently sized sectors of the pile. Samples from depths of 10, 25, and 50 cm, respectively, were composted. Subsamples of the initial storage compost were sealed in airtight plastic bags and stored at approximately 21°C; three bags were analyzed simultaneously with the pile samples at each sampling period.

All piles were exposed to prevailing weather conditions at Beltsville, Md. Temperature measurements of sample loci were made immediately after samples were obtained; measurements were made with calibrated YSI thermistors and thermocouples. In some cases, the temperatures recorded at the time of collection may have been less than previously attained maxima.

For comparison with Beltsville compost, samples of an experimental licorice root/sludge compost from Camden, N.J., were analyzed. Sample collection and handling were the same as above. Also, for comparison, samples of potting soils, manures, and mulches commercially available were analyzed by the detection and enumeration procedures described below.

Air sampling. Two plastic petri dishes (90-mm diameter) containing oxgall-antibiotic agar were opened at the Beltsville compost site for 15 s simultaneously, plates perpendicular to the ground, downwind from sites of (i) mixing, (ii) loading (front end loaders moving compost or cured piles), and (iii) screening. The Beltsville composting site is completely surrounded by dense stands of tall trees. Plates were also opened at very short (320-m) and at greater (1- to 8-km) horizontal distances from the composting site. To catch fungal propagules at the greater distances, plates were opened for 1 to 5 min. A plate from each sample set was incubated at 44 and 25°C. A total of 120 pairs of plates were opened at the compost site; 80 pairs of plates were opened at 17 noncompost sites. The latter sites included dairy barns, fields during cultivation and harvesting, high-speed highways, lawns, pine groves, plant nurseries, and orchards.

Detection and enumeration of fungi. The dilution plate method was used because it favors isolation of spores and conidia (41). To assess potential exposure

to the fungus associated with composting, the determination of the conidial population of *A. fumigatus* was emphasized because inhaled conidia are the most likely cause of infection or allergic response.

Compost (50 g) of 40 to 50% moisture content (wet weight basis) or potting soil (50 g) was added to 250 ml of sterile distilled water containing 0.01% Triton X-100; mixtures were shaken on an International radial-head bottle shaker for 10 min. From the resulting suspensions, dilutions of up to 10^{-4} or 10^{-5} were prepared. Six 1-ml samples of these dilutions were plated with oxgall-antibiotic agar; three plates each were incubated at 25 and 44°C.

The agar medium was prepared with Difco components as follows (grams per liter): peptone, 10; dextrose, 10; oxgall, 15; agar, 20. Antibiotics, filter sterilized with a 0.2-μm membrane filter (Millipore Corp.), were added to cooled (45 to 48°C) medium to give final concentrations of 50 μg of streptomycin, 10 μg of penicillin, and 2 μg of aureomycin per ml. This medium, prepared with a different antibacterial agent, 0.001% crystal violet, is recommended for isolation of saprophytic soil fungi and fungi pathogenic to man (2, 29, 37). Radial advance of most fungal colonies is retarded on the oxgall agar, and most colonies produce identifying morphological structures well before colonies become confluent.

For analyses of 3-week compost by direct plating, microsamples (5 to 15 mg) obtained from the interior of aseptically opened clumps of compost were dispersed in separate petri dishes with 5 ml of sterile distilled water containing 0.01% Triton X-100. Oxgall-antibiotic agar was added to each plate; replicates were incubated at 25 and 44°C.

Average number of colonies per milliliter of the primary dilution was calculated from the plate counts and dilution factors. Countable plates contained 20 to 80 colonies. The number of CFU present per gram of dry weight (GDW) of sample was calculated by dividing the average number of colonies per milliliter by the grams of dry compost per milliliter in the primary dilution (computed on a wet weight basis). For some plates, colonies were too numerous to count and growth was recorded simply as positive for the species noted. Identification of *A. fumigatus* was based on morphological and cultural characteristics described by Raper and Fennell (42). Calculations of CFU of *A. fumigatus* per GDW were based on the countable 44°C plates. The percentage of *A. fumigatus* on those plates was calculated and used as the multiplier of the total thermophilic count resulting in the fraction of CFU attributable to *A. fumigatus* per GDW.

RESULTS

Sludge. Sludge samples all contained between 10^2 and 10^3 CFU of *A. fumigatus* per GDW. Total mesophilic fungi, including filamentous and yeast forms, in these samples ranged from 2.3×10^4 to 5.4×10^4 CFU/GDW.

Woodchips. Microscopic inspection and culture isolations of scrapings from woodchips obtained randomly from the exterior and a 8-cm depth of old stockpiles revealed an abundance of *A. fumigatus*. The grayish-green coloration of the fungus material on the chips was attributed to the presence of dense masses of dry conidia. Samples of fresh and old woodchips contained 10^3 to 2.3×10^5 CFU and 2.6×10^6 to 6.1×10^7 CFU of *A. fumigatus* per GDW, respectively.

Compost. *A. fumigatus* was detected in compost samples obtained from temperature zones of 63°C or less. Quantities of fungal propagules detected in various temperature zones of a compost pile are shown in Table 1. Fungi were not detected in any of 12 microsamples from pile loci with temperatures at the time of sample collection ranging from 58 to 82°C. Although the temperature history of each sample locus was not recorded directly, a reliable estimate based on isotherms from temperatures recorded throughout the 21-day composting period revealed that loci in the hottest zones (60 to 82°C) had achieved temperatures >60°C since day 5. Before that time, there was a gradual increase in temperature from the ambient levels present at the initiation of pile construction. In general, loci in intermediate (40 to 60°C) and low (<40°C) temperature zones had attained, during the 21-day composting period, temperatures higher than those recorded at the time of sample collection, in a few cases above 60°C, for periods of 1 to 10 days.

Numerous fungi other than *A. fumigatus* were observed in the compost in varying frequency. *Ceratocystis, Doratomyces,* and *Trichoderma,* well known to be associated with wood, were detected and may have entered the compost on the woodchips. The thermophiles *Chaetomium thermophile* La Touche, *Humicola grisea*

TABLE 1. *Occurrence of A. fumigatus in nine compost samples from loci of measured temperature and moisture content*[a]

Conditions at sample locus		Thermophilic fungi	
Temp range (°C)	Moisture (%)	Total CFU/GDW	*A. fumigatus* colonies (%)
62–63	28	2.1×10^3	0
53–55	46	$<10^3$	100
52–57	49	3.0×10^3	100
52–54	45	$<10^3$	100
50–55	38	3.5×10^4	90
46–50	46	3.0×10^3	100
46–50	31	$>5.0 \times 10^5$	100
32–41	49	4.5×10^4	100
26–28	51	3.2×10^3	90

[a] Twelve other samples from areas of generally higher temperature than 60°C yielded no detectable fungal CFU. See text for details.

Traaen var. *thermoidea* Cooney & Emerson, *H. lanuginosa* (Griffon & Maublanc) Bunce, *Talaromyces thermophilus* Stolk, *Thermoascus aurantiacus* Miehe, and *Torula thermophile* Cooney & Emerson were found frequently along with *A. fumigatus*.

Licorice root-sludge compost. Licorice root alone contained approximately 4.7×10^6 CFU of *A. fumigatus* propagules per GDW. When combined with liquid sludge, the mixture contained between 2.0×10^6 and 5.7×10^6 CFU of thermophiles per GDW, of which 47 to 100% or 9.4×10^5 to 5.7×10^6 CFU/GDW were propagules of *A. fumigatus*. After 3 weeks of composting, the blanket (licorice root alone)-compost interface zone contained 1.2×10^4 to 2.9×10^6 CFU of thermophiles per GDW, of which 85 to 99%, or 10^4 to 2.8×10^6 CFU/GDW, were *A. fumigatus*.

Cured compost. Of the 1.3×10^5 CFU/GDW detected in the woodchip-sludge compost at 45°C, 7 to 25%, or 8.4×10^3 to 3.5×10^4 CFU/GDW, were *A. fumigatus*. *H. grisea* var. *thermoidea* was the most abundant fungus in all the samples examined. Freshly screened, cured compost contained 2.4×10^5 to 5.7×10^6 CFU of thermophiles per GDW, of which *A. fumigatus* constituted between 7 to 16%, or 1.7×10^4 to 9.1×10^5 CFU/GDW of the total.

Stored compost. In six random compost samples taken from 2- to 4-month-old storage piles, thermophiles constituted 7.2×10^4 to greater than 1.1×10^5 CFU/GDW, the majority of colonies being *T. thermophile* and *H. grisea* var. *thermoidea*; *A. fumigatus* comprised 30% (2.1×10^4 CFU/GDW) or less of the total thermophilic population.

Initial samples of compost used to build the 6-month storage test pile contained 4.7×10^6 CFU of thermophiles per GDW, of which 1% or 4.7×10^4 CFU/GDW were *A. fumigatus*; *Paecilomyces varioti* Bainier was the preponderant fungus. Samples also contained 2.9×10^5 CFU of mesophiles per GDW with *Scopulariopsis brevicaulis* (Sacc.) Bainier as the preponderant fungus.

At 1 week, *A. fumigatus* constituted 1.5% of thermophilic fungi or 2.7×10^4 CFU/GDW at the 10-cm depth. At 25- and 50-cm depths, the fungus constituted less than 1% of thermophiles, or 1.1×10^4 and 5.8×10^3 CFU/GDW, respectively. At 1 and 4 months, *A. fumigatus* was not detected at 25 and 50 cm. At the 10-cm depth, *A. fumigatus* constituted 11.8% of thermophiles, or 3.0×10^5 CFU/GDW, at 1 month, and 1.8% of thermophiles, or 1.3×10^4 CFU/GDW, at 4 months. Negligible to completely undetectable levels of *A. fumigatus* were found in compost from all three depths of the compost pile at 6 months. Similarly, compost bagged and stored 1 week to 4 months exhibited negligible or undetectable levels of *A. fumigatus*. In summary of the above data, the maximum and minimum levels of *A. fumigatus* detected at each stage of the composting process are shown in Fig. 1.

Air spora. Colonies of *A. fumigatus* were frequently detected on agar exposed to air at the compost site (Table 2). Such colonies were detected from air samples obtained during various mechanical activities and machine traffic,

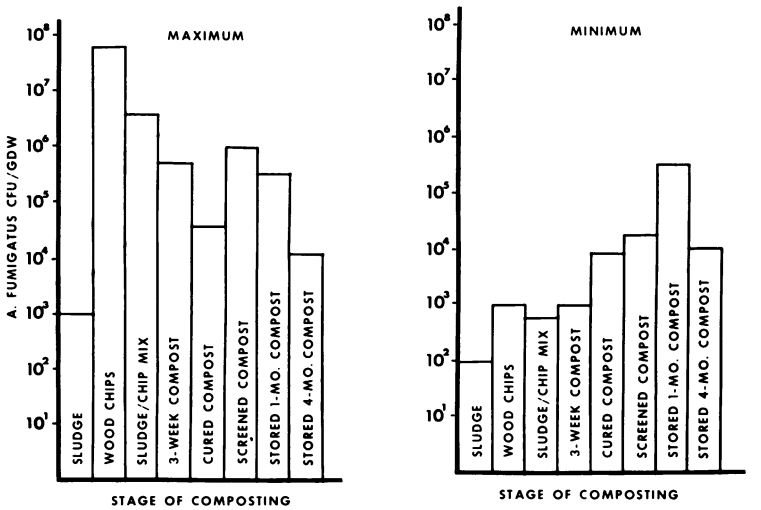

FIG. 1. *Maximum and minimum numbers of CFU of A. fumigatus detected per gram (dry weight) of substrate from each stage of the composting process. Numbers for stored compost represent counts from the 10-cm depth only.*

TABLE 2. *Occurrence of A. fumigatus on oxgall agar plates exposed to air at the Beltsville compost site[a] and at noncompost sites[b]*

Site	Catch frequency[c]		*A. fumigatus* CFU/total CFU at:	
	Plates with *A. fumigatus*/total plates with fungi	Total *A. fumigatus* CFU/total exposure time (min)[d]	25°C	44°C
Compost	167/177	2,991/44.25	1,239/1,969	1,752/2,012
Noncompost	5/50	5/180.75	3/293	2/4

[a] Exposures made during mixing, screening, dumping, loading, and inactivity.
[b] Exposures made at 19 different sites; see Materials and Methods for details.
[c] Total plates exposed: 240 for a total of 60 min at compost site, with 11 plates too numerous to count; 160 for a total of 391 min at noncompost sites.
[d] For plates which contained fungi.

as well as during periods of no machine activity. Of the mesophilic colonies counted, 63% were *A. fumigatus*, and of the thermophilic colonies, 87% were *A. fumigatus*. Plates were exposed for a cumulative total of 60 min to collect a total of 3,981 colonies, of which 2,991 were *A. fumigatus*.

In striking contrast to the above situation, only five colonies of *A. fumigatus* were detected on plates exposed to air at 17 noncompost sites. At these same sites, a cumulative total exposure of 391 min resulted in 50 plates positive for fungal colonies. Of the 297 total fungal colonies detected at 25 and 44°C, only 5, i.e., 2%, were *A. fumigatus*.

Commercial potting soils, manures, and mulches. Levels of *A. fumigatus* in the 21 products analyzed varied greatly; Table 3 shows the levels of mesophiles, thermophiles, and *A. fumigatus* found in each product. Almost all products had at least 10^2 thermophilic CFU/GDW; five products contained no detectable *A. fumigatus*. Of the samples containing the fungus, only one, no. 198, contained levels approximating those found in 1-month-old Beltsville storage compost from a 10-cm depth. Five products, no. 198, 232, 234, 233, and 197, contained *A. fumigatus* levels $>1.3 \times 10^4$ CFU/GDW, the amount found in a 4-month-old Beltsville storage compost from the 10-cm depth. Moisture content and pH of the products varied but were apparently not correlated with the presence or absence of *A. fumigatus*.

DISCUSSION

A. fumigatus occurs at easily detectable levels at each stage of the composting process. Levels varied, reflecting age, temperature, handling, and, to some degree, moisture content of the substrate. Fresh woodchips stored for only a few days contained approximately 10^2 to 10^4 fewer *A. fumigatus* CFU per GDW than chips stored in stockpiles for 1 month or more. The levels of *A. fumigatus* in sludge analyzed in this study were not exceedingly high or variable; however, levels higher or lower than these might occur in sludges from elsewhere. For example, samples of sewage sludge from Ohio (13) collected at different times during a 1-year period were found to contain up to 3.8×10^7 CFU of *A. fumigatus* per GDW.

Occurrence of *A. fumigatus* in a 3-week compost is restricted to zones with temperatures of approximately 60°C or less. One zone with slightly higher recorded temperature, 62 to 63°C, contained 2.1×10^3 CFU of *A. fumigatus* per GDW. Compost from this same zone had a moisture content of 28%, whereas samples from zones with effectively lethal temperatures, ≥60°C, had an average moisture content of 45%. The temperature zones of <60°C were generally confined to the exterior 0.75 m of the piles, including the blanket layer. Thus, these fungal zones constitute approximately 60% of the total volume of a free-standing pile, or 25 to 37% of the total volume of an extended (conjunctive) pile.

High levels of *A. fumigatus* in cured and screened compost (Fig. 1) may be a result of mechanical distribution of conidia and thus reinoculation of previously *A. fumigatus*-free patches. Curing piles still moist and self-heating can easily provide suitable growth conditions for the fungus.

Stationary storage for 1 month or more generally caused a decline in the population of *A. fumigatus* (Fig. 1), especially at depths of 25 and 50 cm. Thus, by the end of the composting process, the total volume of compost contained relatively few propagules of the fungus.

Of the 21 commercial products analyzed, 16 contained *A. fumigatus* and 5 contained levels higher than those found in 4-month-old Beltsville compost from the 10-cm depth. Thus, several commercial products and Beltsville compost are potential sources of the fungus to users of potting soils and mulches; therefore, such products may not be entirely risk free from the standpoint of inciting allergic responses in sensitized individuals, as has occurred with the use

TABLE 3. *Comparison of numbers of mesophilic and thermophilic fungi of A. fumigatus, moisture content, and pH in 21 commercially available potting soils, manures, and mulches*[a]

Product no.	Moisture content (%)	pH	CFU/GDW		
			Mesophiles	Thermophiles	*A. fumigatus*
198	33.2	4.4	1.2×10^6	5.9×10^5	5.7×10^5
232	49.4	7.6	2.3×10^5	1.9×10^5	7.4×10^4
234	27.8	6.8	2.4×10^5	4.6×10^4	2.7×10^4
233[b]	34.3	7.3	4.7×10^5	6.1×10^4	2.1×10^4
197	29.1	5.2	3.0×10^7	1.0×10^6	2.0×10^4
230	55.7	4.8	7.4×10^4	7.7×10^3	7.7×10^3
201	38.7	4.2	3.6×10^5	3.0×10^3	3.0×10^3
196	50.6	3.6	1.2×10^7	7.9×10^3	2.7×10^3
235[b]	14.9	7.5	1.7×10^6	3.3×10^4	2.6×10^3
203	37.3	4.1	3.7×10^5	4.2×10^3	2.1×10^3
213	46.8	6.9	1.6×10^4	1.7×10^3	1.6×10^3
239	67.1	7.0	5.9×10^4	1.9×10^3	1.5×10^3
202	23.5	4.3	4.1×10^5	4.3×10^2	4.3×10^2
195	39.4	6.9	1.0×10^6	8.0×10^2	1.0×10^2
194	31.4	7.2	1.3×10^7	6.4×10^3	<60
229	41.0	7.8	5.8×10^5	3.6×10^2	<3.6
212	61.0	5.2	5.7×10^7	1.0×10^6	0
231	56.1	8.9	3.1×10^6	5.4×10^3	0
237	38.5	7.5	3.9×10^5	7.6×10^2	0
238	35.0	7.1	5.4×10^4	2.1×10^3	0
228[c]	5.2	4.6	$<1.5 \times 10^2$	$<1.5 \times 10^2$	0

[a] Potting soil numbers: 194, 198, 201–203, 213, 233–235, 238; manure numbers: 195, 228, 229, 231, 237; mulch numbers: 196, 197, 212, 230, 232, 239. Products ranked in order of declining occurrence of *A. fumigatus*.

[b] Contain Beltsville compost: 33 and 14%, respectively.

[c] Heat treated.

of potting soil (46). Likewise, gardeners with predisposing medical conditions, as mentioned previously, who use any of these products as mulches could be exposed to large numbers of conidia. Emmons et al. (18) stated that in such situations "the inhaled spores may germinate and the fungus may invade lung parenchyma to produce typical aspergillosis."

In the past, frequency data have been used to indicate relative abundance of fungi, on the basis that members of dense populations have a greater probability of being collected in any one random sample. However, frequency does not adequately describe the preponderance of a species in a sample in terms of propagules per GDW. Soil mycoflora investigations indicate that *A. fumigatus* is found with the following frequencies in different soils (i.e., the percentage of samples analyzed from which the fungus was detectable): forest soils, 7.5 and 14% (10, 22); woodland soils, 1.4 to 4.4%, and cultivated soils, 28.7 to 45.5% (40); open bogs, 1%, and swamps, 0.1% (9); and sun-heated soils, 31% (45). For comparison purposes, *A. fumigatus* had the following frequencies of occurrence: 57% in compost, based on 109 sample analyses; 94% in air at the compost site, based on 177 plate exposures; 10% in air at noncompost sites, based on 50 plate exposures.

If composting of sludge becomes a practiced method of sludge disposal in various municipalities, attempts might be made to compost sludge with numerous bulking agents other than woodchips. Possibilities include: bagasse, carob husks, corncobs and husks, grass seed straw, cereal straws and husks, paper refuse, peanut hulls, urban refuse, and licorice root. All of these are of high cellulose content. Based on evidence that *A. fumigatus* is capable of growing and utilizing cellulose as a carbon source (47), the fungus will very likely be found in such situations.

In conclusion, the on-site problems associated with *A. fumigatus* are worthy of precautionary consideration. Individuals who have a history of asthma, chronic respiratory allergy, or serious lung pathology, or who are being treated on a continuing program of therapy with antibiotics, corticosteroids, or cytotoxins are susceptible to allergic response or infections by the fungus (1, 18, 26, 27). Aerosolized particles of compost which include conidia of *A. fumigatus* may pose a health problem for sensitized or otherwise predisposed individuals. However, such individuals who are, become, or remain employed at composting sites with knowledge of these related facts might achieve some alleviation of exposure if certain practices are initiated, such as (i) wear-

ing of respirators, (ii) water or oil spraying of dry, dusty compost sites periodically as required to reduce dust levels, or (iii) isolating the workers from spore-dispersing parts of the process.

In consideration of off-site health matters related to air dispersal of spores, a buffer distance between a composting operation and health-care facilities or residential areas may be needed. The determination of spore concentrations in air at distances from the composting site is currently under investigation in this laboratory.

Any health hazard associated with the use of finished compost or similar commercial products, insofar as *A. fumigatus* is concerned, is probably closely related to the manner in which the product is handled. Operations which generate dust clouds containing high levels of airborne spores represent a potential exposure problem for hypersensitive or predisposed individuals.

Adequacy of the above cautionary measures and suggestions will require careful evaluation by appropriately informed physicians and epidemiologists.

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