

Fungus aerosols arising from cold-mist vaporizers

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Flares of asthma were noted by two subjects during the operation of cold-mist vaporizers which, when studied, were found to release yeast-contaminated aerosols. Of 22 additional frequently used devices, 15 were found to raise appreciably indoor fungus levels during the operation; concentrations exceeding 5,000 viable isolates per square meter were not unusual during mist generation. Both filamentous fungi and unicellular forms were found to colonize cold-mist vaporizers and to be released with different temporal patterns that may reflect substrate specificity within these devices. Scrupulous and regular cleansing of accessible inner surfaces was found to markedly decrease but not eliminate mycotic contamination of the aerosols. Decisions to use these devices require an awareness of the potential exposure hazards involved and of the need for more than a casual approach to sanitary maintenance.

Adequate ambient humidity is known to promote normal ciliary function and mucus clearance. That excessively moist air can provide additional benefit in respiratory ailments—including asthma—is less clear but this belief is widely held and, in recent years, so-called “cold-mist vaporizers” (actually, aerosol generators) have enjoyed increasing sales and domestic use. The relative popularity of these products is not undeserved, since they do obviate the serious thermal and electrical hazards of older electrolytic steam generators.

Cold-mist vaporizers employ a spinning impeller to drive sheets of fluid against a corrugated surface, where they are sheared into fine droplets. Expulsion of the mist promotes a brisk throughput of room air from which suspended materials may be scavenged by the rapidly moving aerosol and delivered to a well-aerated liquid medium. It is not surprising that slimy deposits commonly form in these devices that, by their mode of operation, seem to invite microbial contamination.

Several years ago, 2 patients reported bouts of asthma on several occasions during operation of cold-mist vaporizers. Both had perennial allergic rhinitis and asthma with prominent house dust and pollen sensitivities worsened by recurrent bacterial superinfection; skin tests to multiple pollen, fungus, and dust extracts were strongly positive. Each had purchased his unit at a physician's suggestion and each patient ascribed his difficulty, with some hesitancy, to the “dampness” produced. The finding of high levels of fungus particles in the emissions of both

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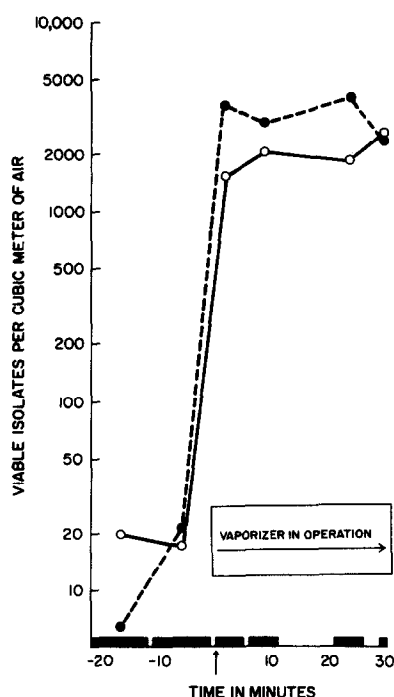


FIG. 1. Levels of fungus particles in bedroom air before and during operation of two vaporizers incriminated in exacerbations of asthma. Black bars along the abscissa indicate the sampling periods employed.

devices prompted an inquiry into the prevalence and mechanism of such contamination.

MATERIALS AND METHODS

Carefully timed, one- to ten-minute collections were made with an Andersen¹ sampler before and during operation of cold-mist vaporizers in 24 homes, including those of the two index patients. A modified technique was employed: a single culture plate beneath the sixth stage of this sieve impinger provided an integrated collection without size-dependent separation. As previously reported,² this arrangement provides valid volumetric data if the sampling period is limited to prevent overloading of the single plate. All collections were made on Difco potato dextrose-agar medium, containing 15 mg. per liter of rose bengal as a bacteriostatic agent. Following exposure, plates were incubated in high humidity at temperatures of 20° to 22° C. An initial gross and microscopic examination of these samples was made 4 to 6 days later, and the plates were inspected periodically thereafter until the final tally of colonies at 3 to 4 weeks' total incubation. Unicellular forms were characterized by gross colonial morphology and pigmentation (or its absence) without attempting generic determination routinely; filamentous types were identified to form genus, where possible.

All samplings was carried out during winter months, and outdoor fungus levels (determined with the Andersen sampler outside each home) never exceeded 170 viable isolates per cubic meter of air. For the purposes of this study, both sampler and vaporizers were operated at floor level in the bedrooms of the homes selected; neither human nor animal activity was permitted in these rooms during collection periods. However, to secure sequential samples, culture plates were changed manually—an operation requiring approximately 20 seconds. In each case, collections were made with the sampler upright, four feet from the vaporizer's discharge port and lateral to its direction of output.

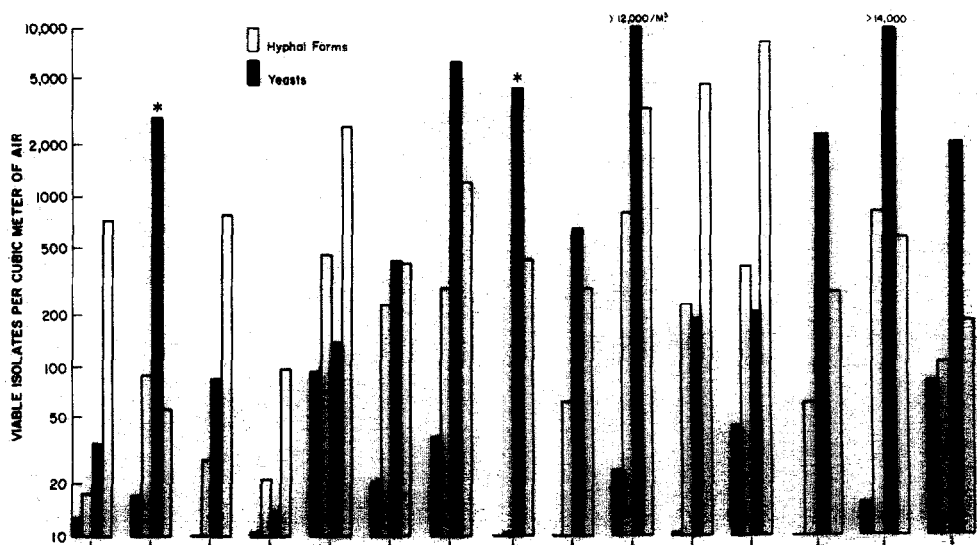


FIG. 2. Levels of viable fungus isolates before and during operation of cold-steam vaporizers in 15 homes where concentration increments were greater than threefold. Arrows signify the beginning of vaporizer operation and separate "baseline" levels from those during aerosol emission. Asterisks indicate two additional instances in which a worsening of asthma was ascribed to the use of these devices.

RESULTS

In the homes of the two subjects reporting asthma associated with vaporizer operation, baseline levels of viable fungus particles (triplicate 10 minute samples) were relatively low by standards of local prevalence in winter.³ However, as depicted in Fig. 1, the levels of viable isolates recovered rose sharply (96 and 240 fold, respectively) during the initial periods of aerosol generation. In both instances, pigmented yeasts later determined to be *Rhodotorula* species were the major sources of the increments observed, although filamentous forms also increased. Sampling sequences were repeated 12 and 17 days, respectively, after the initial collections at a time when these data were appreciated. Both vaporizers had been emptied and stored in the interim; despite this precaution, increases in fungus prevalence of tenfold or greater were recorded during an initial operating period for both units. Having confirmed this effect, an attempt was made to duplicate it by operating a small DC-powered fan at floor level during a comparable sampling sequence. In contrast to the sharp rises previously noted, recoveries of fungus particles were increased no more than twofold by this maneuver, which provided comparable horizontal air velocities. This finding suggested that emissions from the vaporizers, rather than their capacity to disturb indoor air, had produced the recorded increments in microbial contamination.

Subsequently, a comparable sequence of air samples was obtained in 22 additional homes before and during vaporizer operation. The individual devices varied in design, age, frequency of use, and, presumably, the care that each had received; however, each had been operated by its owner within one week of the

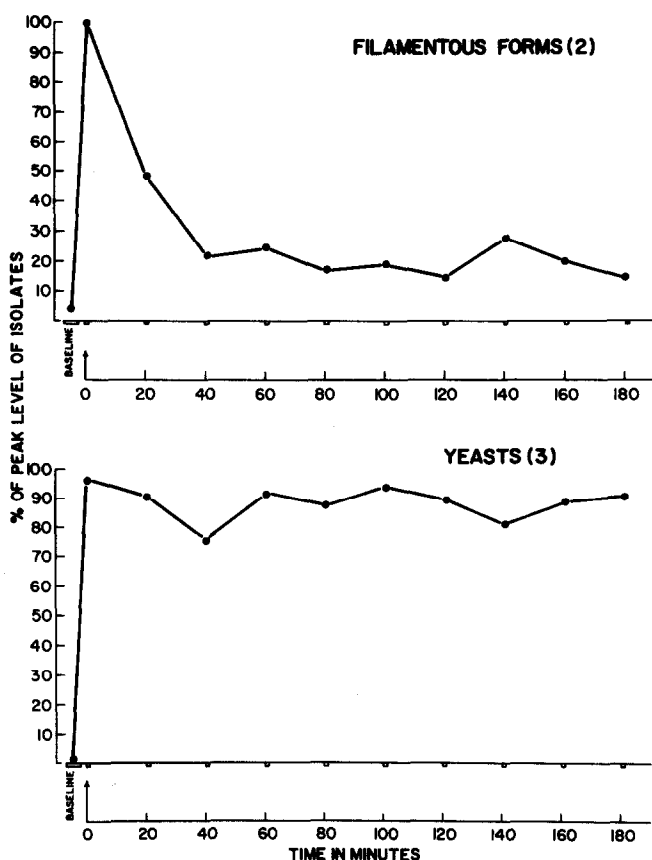


FIG. 3. Trends in indoor particle prevalence before and during operation of vaporizers emitting predominantly filamentous or unicellular forms. Normalized levels are expressed as per cent of peak concentration encountered during the 3 hour sampling sequence.

day of the study. Persons cooperating in this survey, including 2 additional subjects reporting mist-induced asthma, were told merely that we wished to "study the output of their vaporizers" without mention of the microbiologic aspect. In 15 instances, levels of viable fungus particles recorded during mist generation exceeded those in undisturbed room air by a factor of three or more; 11 of these occurred in the 17 homes of atopic subjects studied, while in 7 other homes 4 had significant contamination of the vaporizer effluent. Fig. 2 shows data from these 15 homes plotted on a logarithmic scale with levels of unicellular forms (the dark bars) and filamentous forms (the open bars) displayed separately for the periods before and during use of the vaporizer. Yeasts recovered were, again, primarily red-pigmented forms, suggesting *Rhodotorula* species. In 2 homes, however, ballistospore-producing types typical of *Sporobolomyces roseus* were recovered abundantly. Where the aerosol was heavily contaminated with filamentous forms, the predominant taxa were members of form genera (e.g., *Penicillium*, *Aspergillus*, *Oospora*, *Verticillium*, *Sporothrix*, *Geotrichum*, etc.) that comprise the characteristic fungus flora of homes in our locality in winter.³ As Fig. 2 indi-

ates, baseline levels of fungus particles were often substantial, exceeding 250 viable isolates per meter³ in 9 of the total of 24 homes studied.

In 2 instances in which an *Oospora* form species was the type recovered most abundantly, collections were made at 20 minute intervals for 3 hours after turning on the vaporizer. The pattern of sequential concentrations was similar in both homes and is shown in the upper panel of Fig. 3 as mean per cent of *peak* level with respect to time. This initial "burst" of concentration contrasts with that in 3 cases in which yeast forms predominated (lower panel of Fig. 3), where a relatively stable output with time was indicated.

Systematic clinical testing of exposed atopic subjects was *not* a part of this study. Both index patients were, however, shown subsequently to develop strong (pseudopodial) whealing reactions on epidermal testing with 1:10 w./v. extracts of *both* *Rhodotorula* strains isolated from the vaporizers initially studied; control sites tested with glycerinated diluent and with a 1:10 extract of the sterile medium employed to grow these isolates were negative. Both subjects also underwent bronchial provocative testing with their "personal" *Rhodotorula* isolates utilizing sterile nonglycerinated extracts in phosphate-buffered saline (pH 7.4) containing 0.4 per cent phenol. Although 0.5 ml. portions of the diluent inhaled from a DeVilbiss nebulizer over 5 minutes did not provoke changes from baseline (in FEV_{1.0} or MMFR) at 15 minutes after inhalation, 1:5,000 extract of the respective *Rhodotorula* strain produced definite obstructive responses (subject 1:21 per cent drop in FEV_{1.0}, 31 per cent drop in maximum midexpiratory flow rate (MMFR); subject 2:29 per cent drop in FEV_{1.0}, 34 per cent drop in MMFR, at a similar period after the provocative exposure). Lower respiratory challenge with 1:5,000 extracts of the medium produced less than a 7 per cent drop in FEV_{1.0} and MMFR in both subjects. Each of the 2 *Rhodotorula* extracts in 1:5,000 concentration was subsequently used in bronchial provocative tests of separate pairs of atopic subjects who had had negative reactions on epidermal and intracutaneous (1:500 w./v.) testing with extracts of both strains; in none of the 4 was a decrease greater than 10 per cent recorded in FEV_{1.0} or MMFR 15 minutes after challenge.

DISCUSSION

Adverse effects on health associated with microbial contamination of the moist surfaces and fluid reservoirs of humidifying equipment have been recognized increasingly in recent years. Major attention has been directed to the soiling of aerosol and vapor generators used in inhalation therapy and for humidification with pathogenic bacteria^{4, 5} and the association of extrinsic alveolitis with growth, in console-type and centrally installed furnace humidifiers, of thermophilic actinomycetes.^{6, 7} The ubiquity of imperfect fungi in air affords them continuing access to such niches, where abundant moisture permits growth despite marginal nutritive conditions; the presence of these organisms in cold-mist vaporizers is, therefore, not unexpected, and they should be expected to colonize other fluid reservoirs where mesophilic conditions exist. Similarly, although the use of selective media has focused our attention on fungi, spot samples employing malt agar (without rose bengal) have shown that aerosols from some

vaporizers are richly contaminated with bacteria also; other microbial types have not been sought.

There can be little doubt that these aerosol generators acquire their microbial burdens during periods of intermittent operation that are often prolonged. Sampling of the efflux from newly purchased units or those that had been cleansed, dried, and stored for considerable periods prior to study have shown these to be relatively free of viable fungus particles. However, the intimate process(es) by which organisms soil the output from contaminated units cannot be stated precisely. It was noted (Fig. 3) that the time-course of fungus particle output differed depending upon whether yeasts of filamentous forms predominated in the aerosol. Differences were also noted in the effect of vigorously cleaning the plastic reservoirs of these devices; levels of yeasts usually were greatly reduced by this maneuver or by merely draining the unit completely and refilling it with tap water, while those of filamentous forms were relatively unaffected. In attempting to explain this discrepancy, it was noted that vaporizers having the highest outputs of hyphal forms were those having an effluent stream that communicated more or less directly with the motor housing, while those emitting mist from an eccentric orifice in the reservoir were lesser offenders; the two types did not appear to differ with regard to output of yeast forms. On disassembling several units of the former type, mold growth, coating plastic and rubber components, was often apparent grossly. It is postulated that crops of spores are produced on aerial hyphae in these inaccessible (and, therefore, hygienically exempt) sites and dispersed in a "pulse" at the outset of aerosol generation. The major source of yeasts is probably the reservoir fluid itself, from which they are liberated continuously, entrained in aerosol droplets throughout the period of operation.

Although these findings do indicate an exposure hazard associated with cold-mist vaporizers, its actual prevalence cannot be assessed. The units studied had all been used within one week (often daily), a condition tending to favor serious contamination. On questioning owners of these vaporizers, it became clear that the devices were often refilled daily over many weeks, with no attempt to drain, much less cleanse, the reservoirs. The frequency of this casual practice deserves attention, since contamination of vaporizer output could be markedly reduced, though not eliminated, by regular scrubbing of accessible inner surfaces. Of the 24 vaporizers for which data are presented, 14 had been purchased specifically at the direction of a physician or as a means of providing *recommended* humidification. Since these devices are relatively safe, economical, and efficient as aerosol generators, their continuing popularity seems assured—especially in the management of acute and chronic respiratory ailments. As with other treatment modalities, an awareness of the risks involved, judicious patient selection, and attention to practical preventive measures are prerequisites for achieving clinical benefit.

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Select the ONE best answer for the following question from the Allergy Foundation of America Self-Assessment Program:

Question 3. The physical sign most useful in diagnosing chronic obstructive lung disease is

- (A) an increase in the anteroposterior diameter of the chest.
- (B) dyspnea after mild exertion
- (C) accentuation of the pulmonic second sound (P_2)
- (D) restricted diaphragmatic movement
- (E) distant breath sounds

The correct answer and bibliographic reference will be found on page 254 of this Journal.