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The Production of Arsenous Gases By Wood-Rotting Fungi[1]

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Approximately 120 years ago in Europe is was learned that certain fungi liberated arsenous gases when they were grown on substrates containing arsenic. This was especially apparent when certain molds grew on paste on wall paper in damp rooms, converting arsenic-containing pigments in the wall paper into a gas with a garlic-like odor. This resulted in numerous cases of arsenic poisoning of people living in these rooms; some of these people died. The identity of the gas was unknown until 1932 when Challenger and his co-workers demonstrated that it was trimethylarsine $(CH_3)_3As$ (3). Several species of *Aspergillus*, *Penicillium*, and *Scopulariopsis* (Fungi imperfecti) and a species of *Mucor* (Phycomycetes) are capable of methylating arsenical compounds (2).

Small concentrations of this gas can be detected by the garlic odor. One of the more sensitive methods of determining the presence of arsenic is to extract the suspected material with water, concentrate the solution, add a few drops of the concentrate to a slice of potato, and inoculate the slice with *Scopulariopsis brevicaulis* Thom. Within a few hours an odor of garlic will be noted if arsenic is present in concentrations of more than about one part per million in the concentrate (2).

In studies involving the resistance to decay of wood fiber products treated with preservatives, it was noted that *Lenzites trabea* Pers. ex Fr., a brown-rotting fungus in the Basidiomycetes, produced a gas with a strong garlic odor when grown on wood which had been treated with arsenical preservatives. This had been noted previously by other workers, but the gas was not identified (1). Since arsenical wood preservatives are commonly used, not only in posts, poles, and mine props, but also in lumber and wood fiber building boards used in home construction, these studies were made to identify the gas and to determine if other wood-rotting fungi also were able to produce this gas.

Materials and methods: A medium of the following composition was prepared:

malt extract	15 g
agar	20 g
As_2O_3	0.1 g
distilled water	1 liter

The medium was autoclaved, poured into petri dishes, and allowed to solidify. Pieces of inoculum approximately 5 mm square from cultures grown 2 weeks on malt agar were transferred to the dishes, the dishes stored 14 days in diffuse light at 28° C, and notes taken. A total of 65 species of wood-rotting fungi were used, with 3 replicate dishes of each. The fungi selected represented a wide variety of fungi capable of decaying wood or similar material.

Alkyl arsines react with mercury to form insoluble complexes which crystallize out of solution (3). To identify the gas, barley was saturated with water, sprinkled with arsenic trioxide, sterilized in gallon jars, and inocu-

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TABLE 1. Fungi not producing a gas with a garlic odor when grown on a medium containing arsenic trioxide.

Species		
Asterostroma cervicolor (Berk. & Curt.) Massee	Fomes pini (Thore ex Fr.) Karst.	Polyporus dryophilus var. vulpinus (Fr.) Overh.
Boletus castaneus Bull.	Fomes pinicola (Swartz ex Fr.) Cke.	Polyporus spraguei Berk. & Curt.
Chaetomium globosum Kunze	Fomes robustus Karst.	Polyporus sulphureus Bull. ex Fr.
Chaetomium piluliferum Daniels	Fomes subroseus (Weir) Overh.	Polyporus versicolor L. ex Fr.
Coniophora puteana (Schum. ex Fr.) Karst.	Lentinus tigrinus Bull. ex Fr.	Polyporus zonatus Fr.
Coprinus comatus Fr.	Lenzites betulina (L. ex Fr.) Fr.	Poria andersonii (Ell. & Everh.) Neuman
Corticium radiosum Fr.	Panus rudis Fr.	Poria cocos (Schw.) Wolf
Corticium lividum Pers.	Panus strigosus Berk. & Curt.	Poria incrassata (Berk. & Curt.) Burt
Cyathus sp.	Peniophora gigantea (Fr.) Massee	Poria monticola Murr.
Daedalea quercina L. ex Fr.	Pholiota adiposa Fr.	Poria punctata (Fr.) Karst.
Daldinia concentrica (Bolt.) Ces. & de Not	Pleurotus corticatus Fr.	Poria subacida (Peck) Sacc.
Favolus alveolaris (D.C. ex Fr.) Quel.	Pleurotus ostreatus Jacq. ex Fr.	Poria vaillantii (Fr.) Cke.
Fomes annosus (Fr.) Cke.	Polyporus anceps Peck.	Poria xantha (Fr.) Cke.
Fomes applanatus (Pers ex Wallr.) Gill.	Polyporus adustus Willd. ex Fr.	Schizophyllum commune Fr.
Fomes conchatus (Pers. ex Fr.) Gill.	Polyporus arcularius Batsch ex Fr.	Sphaerobolus sp.
Fomes everhartii (Ell. & Gall.) von Schrenk	Polyporus compactus Overh.	Stereum complicatum (Fr.) Fr.
Fomes geotropus Cke.	Polyporus gilvus (Schw.) Fr.	Stereum frustulatum (Pers. ex Fr.) Fckl.
Fomes igniarius (L. ex Fr.) Kickx.	Polyporus graveolens (Schw.) Fr.	Stereum gausapatum (Fr.) Fr.
	Polyporus hirsutus Wulf. ex Fr.	Stereum sanguinolentum (Alb. & Schw. ex Fr.) Fr.
	Polyporus lucidus Leys. ex Fr.	

lated with *L. trabea*. Air was passed through concentrated sulfuric acid, then through 15 of the jars in series, and finally into a solution of mercuric chloride in dilute hydrochloric acid.

Results and discussion: The fungi listed in Table 1 failed to produce a gas with a garlic odor.

On the basis of cultural characteristics, wood-rotting fungi have been placed into groups of theoretically closely-related species (4). It was thought that the ability to produce this gas might occur in species within the same group as *L. trabea*. Accordingly, cultures of these fungi from different parts of the world were obtained and compared with several isolates of *L. trabea*. These fungi are listed in Table 2. All isolates of *L. trabea* and *L. saepiaria* produced the gas while none of the isolates of the other fungi within the group did so.

TABLE 2. Production of arsenous gases by isolates of *Lenzites trabea* and related species.

Species	Isolate Nmber	Odor of Garlic Produced
Lenzites abietina (Bull. ex Fr.) Fr.	1	no
Lenzites abietina	2	no
Lenzites saepiaria (Wulf. ex Fr.) Fr.	1	yes
Lenzites saepiaria	2	yes
Lenzites striata (Swartz ex Fr.) Fr.	1	no
Lenzites striata	2	no
Lenzites trabea Pers. ex Fr.	1	yes
Lenzites trabea	2	yes
Lenzites trabea	3	yes
Lenzites trabea	4	yes
Lenzites trabea	5	yes
Trametes americana Overh.	1	no
Trametes americana	2	no

Several attempts to obtain a precipitate from the gas failed. No crystals were evident even after the gas had been passed through the solution for four months. However, the gas was absorbed by the solution, since a garlic odor could be detected in the air passing into the solution, but none in the air coming out.

Both *L. trabea* and *L. saepiaria* are wood-rotting fungi commonly found in wooden buildings, especially in roofs, window sills and door frames, and to some extent in siding. Both species can tolerate high concentrations of arsenical compounds. Building materials used in these situations are sometimes treated with wood preservatives containing arsenic. However, the production of this gas is not likely to be a problem. The treated products are generally used in the roofs or in outside sheathing, and even if these materials were to become decayed by these fungi, the gas would probably not diffuse through the inner walls or ceiling into the rooms. The gas is produced in such small amounts that it would probably never be of such concentrations as to create a health hazard in a well-ventilated building. Decay in these products is not likely to occur commonly, and thus will be a problem only when poor construction leads to excess moisture, which is required before these fungi can develop.

Conclusions: Of 65 species of wood-rotting fungi studied, only *Lenzites trabea* Pers. ex. Fr. and *Lenzites saepiaria* (Wulf. ex Fr.) Fr. produced a gas with a garlic odor when grown on a medium containing arsenic trioxide. This gas was probably trimethylarsine (3), but all attempts to identify the gas were unsuccessful.

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