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FURTHER EXPERIMENTS WITH CHEMICALS SUGGESTED AS POSSIBLE WOOD PRESERVATIVES

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FURTHER EXPERIMENTS WITH CHEMICALS SUGGESTED AS POSSIBLE WOOD PRESERVATIVES[1]

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Although a few preservatives have become standard in the wood-preserving industry because of their service records, a need still exists for the extension of our knowledge of the relative effectiveness of other chemicals that may be used on wood. During the past year the writer has had an opportunity to make laboratory toxicity tests with some 60 or more chemical substances, and to check some of these tests with field tests made by the New Orleans Branch of the Division of Forest Pathology. Both wood-destroying and blue-staining fungi were used in these investigations.

The chemicals studied were too widely different in composition to add much to our knowledge of the theory of toxicity, yet the results were interesting and were useful in determining toxicity ranges. Although the primary purpose of the laboratory tests was to eliminate chemicals or groups of chemicals that did not display sufficient toxicity to show promise for the control of sap stains, molds, and wood-destroying fungi on lumber, additional observations of behavior that may indicate the suitability of the chemical for other preservative service were also recorded.

Experimental Procedure

The Laboratory procedure for the tests varied according to the type of chemical used. Liquids, salts soluble in water, and salts insoluble in water were tested. For liquids immiscible with water, a definite volume

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[2] The writer expresses his appreciation of valuable suggestions and criticisms made by F. W. Tilley and J. M. Schaffer of the Bureau of Animal Industry, he acknowledges with pleasure the cooperation of O. A. Nelson of the Bureau of Chemistry in offering suggestions and in supplying materials, and he thanks other interested individuals and firms that have submitted chemicals for test or have helped with the work in similar ways.

of the chemical was added to a given volume of malt agar medium. For water-soluble salts and liquids miscible with water, 3 ml. of the desired concentration of the toxic material in water was added to 17 ml. of the malt agar, the mixture was well shaken, and was then poured into sterile Petri dishes. For salts insoluble in water a weighed amount of the chemical was added to 400 ml. of sterile malt agar, and after thorough shaking, the toxic agar was plated out in Petri dishes. The chemicals, although mixed with the agar when the agar was still warm, were in no case boiled or sterilized with the agar. Sterilization of the chemical was not deemed necessary, for if the chemical being tested was not toxic enough to kill any fungus that it might contain, it would likewise not be sufficiently toxic to the wood-destroying or blue-staining organisms to warrant field tests for controlling sap-staining fungi.

The procedure followed as nearly as possible the methods reported by Schmitz et al.[3] Although there was also some variation in the organisms tested, both blue-staining and wood-destroying fungi were included in virtually all of the tests. Following are the names and the strain numbers of the various strains of fungi used; the first three are wood-destroyers and the last six are blue-stainers:

517--Fomes annosus (Fr.) Cooke
617--Lenzites trabea (Pers.) Fr.
563--Poria incrassata (B. & C.) Burt
134--Ceratostomella pini Münch
181--Ceratostomella pini Münch
3--Ceratostomella pilifera (Fr.) Wint.
76--Ceratostomella pilifera (Fr.) Wint.
198 pl.--Ceratostomella pluriannulata Hedg.
198 gr.--Graphium rigidum (Pers.) Sacc.

A paper presented before this Association last year[4] included data on the toxicity of 25 chemicals. When that paper was prepared the data collected were based on a three-weeks' incubation period on toxic agar media, and then an equal period of incubation of the inoculum block on sterile agar slants. In the later tests, in keeping with the suggestions of Schmitz et al., the test time was shortened to two weeks each on chemically treated agar and on sterile agar slants. This procedure made possible the determination of the percentage concentrations that killed the fungi, the lower concentrations (known as inhibition concentrations)

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[3]Schmitz, Henry, et al. A suggested toximetric method for wood preservatives. Ind. Eng. Chem., Analyt. ed. 2(4):361-63, 1930.
This article has been reprinted in the Proc. Amer. Wood-Preservers' Assn., 1931, pp. 81-86.

[4]Hatfield, Ira. Recent experiments with chemicals suggested for wood preservation. Proc. Amer. Wood-Preservers' Assn., 1931, pp. 304-14.

that neither killed the fungi nor allowed them to grow while in contact with the chemically treated agar, and the still lower concentrations that did permit the fungi to grow when in contact with the chemically treated agar.

For the present report it was also desirable to substitute two lumber-yard blue-stainers, namely, Ceratostomella plurianmulata No. 198 pl. and Graphium rigidum No. 198 gr., for C. pini No. 134 and C. pini No. 181, which are not especially important on lumber because they are more or less confined to insect-infested trees.

Materials

In order to make this paper more nearly complete the toxicity ranges from the earlier chemical tests are tabulated with the information collected subsequently. For convenience, the chemicals that were received from various sources are arranged in the following five groups. Group I contains 21 benzene derivatives, Group II has 16 ethyl mercury and phenyl mercury compounds, Group III is comprised of 5 aniline and fluorine compounds, Group IV includes 9 German proprietary compounds, and Group V is made up of 36 miscellaneous compounds.

Experimental Results

Group I

The results of the tests of the chemicals in Group I are shown in Table 1. Since the primary purpose of the investigation was to evaluate the relative toxicity of the various chemicals tested, it was impractical to do more than determine the range of concentration within which the killing point was located. Hence only the highest concentration tested at which the organism remained alive and the lowest concentration tested that killed the fungus are reported in the tables. No attempt is made to show the range of inhibition, for in some instances it extended over a wide range of percentages and in other instances the inhibition point was not represented in the concentrations tested.

Most of the 21 benzene derivatives showed a fair degree of toxicity toward the blue-stainers and the wood-destroyers, and several were relatively highly toxic. In this last group one would place tetrachlorophenol, sodium tetrachlorophenolate, sodium dinitrophenolate, butyl phenol, 2-chloroorthophenylphenol, and paraxylyl mercuric chloride. Tetrachlorophenol itself was very insoluble, but the sodium salt was soluble and its toxicity range was as good as and perhaps slightly better than the tetrachlorophenol. Sodium dinitrophenolate would probably be objectionable where the yellow discoloration of the wood would be undesirable. Unless the cost of butyl phenol can be reduced, it probably can not compete with the other chemicals mentioned, since cost is highly important to the lumber industries interested in the use of chemicals for dipping lumber. The 2-chloroorthophenylphenol is a viscous, oily material, and hence would be difficult to use in water alone, but perhaps could be used if emulsified. Its sodium salt, however, which will be included in later tests, may perhaps overcome the immiscibility difficulty. Since paraxylyl mercuric chloride is an organic mercurial, the same precautions should be applied to it as to the organic mercurials discussed in connection with Table 2. A word should also be said about the 4-nitro-3, 5-biacetoxymercuri-2-cresol (Metaphen). When the manufacturer submitted it he did not make clear the fact that it was a 1:500 solution. Concentrations were therefore computed as if it were a pure chemical, and hence its toxicity did not show as favorably as it really should. Further tests might be made, but cost, color, and other factors make it interesting at the present time only from the standpoint of its relative toxicity.

Group II

The toxicity information on the ethyl mercury and the phenyl mercury compounds in Group II is tabulated in Table 2. Comparison of the toxicity ranges for some of the compounds shows only slight differences in the effectiveness of some of the chemicals as fungicides. If these same relations hold when the chemicals are applied to wood, some factor other than toxicity to fungi, such as possible effect of mercurials upon workmen, unit cost of the chemicals, noncorrosiveness, or permanence over the period during which protection is needed, will no doubt determine the selection of the chemical for lumber dipping or other fungicidal uses. In evaluating the fungicidal action of any of the chemicals discussed in this paper, one must also consider the use to which the treated wood is to be put. Obviously chemicals that would impart an odor to food materials or would otherwise alter the usability of the food products could not be applied to lumber going into food containers even though the chemicals were highly fungicidal.

The difference in the effective toxicity of the first 14 chemicals as compared with the last 2 chemicals listed in Table 2 should be mentioned here. The 14 were mixtures of active material with certain inerts, whereas the 2 were laboratory samples of active material only. The exact nature of the inerts used need not be given, but it may be well to state that the inerts were added to the toxic ingredients to act as carriers for the toxic material and to reduce the hazard to field men working with the highly potent, chemically pure material. No attempt has been made to present the toxicity range of the mixtures in terms of active ingredients, for the addition of so-called inerts often changes the toxicity of a compound. Since we have not tested the chemically pure materials first and then tested the mixtures, we have no real basis for attempting to evaluate the toxicity of the active material, and so for mixtures we must express the results in terms of the total sample. It should also be pointed out that the test with the phenyl mercury chloride probably does not represent the true toxicity values since the material was not completely soluble at the higher concentrations.

Group III

The third group of chemicals, submitted by the Bureau of Chemistry and Soils, U. S. Department of Agriculture, consisted of five aniline and fluorine compounds, as given in Table 3. The toxicity of these materials toward the organisms reported upon in this paper was determined because a relatively high fungicidal value against certain species of fungi has been attributed by many persons to the component parts of these preparations. Judging from the results obtained, it is probable that none of these chemicals would prove useful as wood preservatives or sap-stain preventives. Besides lacking pronounced toxicity toward these organisms, the copper and fluorine mixtures would be objectionable on wood because of their blue color, and the other three compounds have reduced value because of the color produced by the dye. The color reactions brought about by the growing fungi were interesting to observe, but a report on this phase is not warranted in this paper.

Group IV

Table 4 contains information on nine German proprietary chemicals. The chief reason for testing some of them was to get information on their effects upon Fomes annosus. When such tests were the primary consideration, the blue-staining organisms were not used. Even for some of the chemicals that were tried on both wood-destroyers and blue-stainers the results may have reduced value, for some of the materials containing chromates and dinitro compounds were colored too much to be used as fungicides on lumber where color would be objectionable. To have tested higher concentrations of some of the chemicals, such as Basilit and Benetol, would have been desirable, but at concentrations above those shown in the table these materials were not soluble.

The phenyl mercury acetate and coal tar product mixture is practically no more toxic than phenyl mercury acetate or coal tar creosote individually, and on the other hand it is corrosive to the skin. Of the German chemicals tested, the phenyl arsenic oxide and coal tar product mixture showed the greatest toxicity. Thanalith-U, which is on the market as an improved Wolman salt, shows but a slight difference in its toxic range as compared with the former Thanalith.

Group V

The toxicity limits of the miscellaneous chemicals of Group V are shown in Table 5. Since almost every one of the materials was tried with a particular use or reason in mind, an explanation should perhaps be given for some of them. In a number of the toxicity ranges recorded in the table it is evident that the upper toxicity limit was not reached. From the scientific point of view it would be well to test higher concentrations of the material, but in most of these instances the commercial possibilities did not warrant further tests; since many other chemicals that may prove valuable remain to be tested.

In connection with some of the chemicals tested, the question of chemical composition may be important to the reader. Although this office has made a practice of testing no chemicals unless the composition of the material is known to us, in some instances it has been the wish of the person or firm furnishing the material that we withhold such information because of patent procedure, or for other sufficient reason. Hence only the trade name or the firm name appears for some of the materials.

The ammonium hydroxide and ethyl alcohol mixture was tested because we wanted to know how much of the toxicity of the German mercury compound could be attributed to that mixture, which was used to dissolve the mercury compound. In dissolving the material 5 cc. of ammonium hydroxide, 20 cc. of 95 percent ethyl alcohol, and 75 cc. of water were added to 0.5 gram of the mercury compound. The effective toxicity of the mercury compound was first computed on the basis of the compound alone. Then the question arose as to the possible effect of the solvents, and so the same proportions of solvents were tried with the mercury compound omitted.

Because leaves sprayed with casein-water solutions were afforded some protection against a parasitic fungus, it seemed desirable to test its effectiveness toward the fungi in agar culture. Since a high concentration of casein was required to kill the fungi examined, it is probable that when sprayed on the leaves the beneficial effect could be linked with a mechanical protection or a related phenomenon rather than with actual toxicity.

Glutrin and Goulac are trade names of specially processed sulfite liquors from wood-pulping industries. Glutrin is a liquid material whereas Goulac is a powder.

Pyridine was included because if it were toxic to fungi it might find use as a log spray where a combined fungicide and insect repellant would be valuable. Later experiments, however, have not yet shown the material to serve this dual purpose. Some of the other chemicals had objectionable color, but were tested in order to obtain comparative information.

Sterilac is an alkaline mixture of chloroamines, and minerec is a mixture of xanthic anhydride and ethyloxycarbonyl sulfide. The composition of most of the other materials mentioned in the table of miscellaneous chemicals is indicated by the name. In those where the chemical composition is not given in the table or discussion, the information is being withheld for the reasons already mentioned.

Reference to Table 5 will give evidence that few of the chemicals listed in the miscellaneous group possess a high degree of toxicity to the organisms tried and under the conditions tested. Minerec and the mercury compounds showed the highest toxicity.

Conclusions

Virtually all of the benzene derivatives of Group I showed a fair degree of toxicity. Among the nonmercurials, 2-chloroorthophenylphenol, sodium tetrachlorophenolate, and butyl phenol were perhaps the best. Although sodium dinitrophenolate was quite toxic, its color might be objectionable.

All of the chemicals in Group II showed a high degree of fungicidal efficiency toward the wood-destroying and blue-staining organisms. When a number of similar compounds show only a slight difference in toxicity on agar and the same relationship holds on wood, the choice of the one to use under field conditions should be based on some other factor, such as cost, freedom from corrosiveness, nonpoisonousness to human beings and animals, or some such quality that distinguishes it as most suitable for commercial use.

Probably none of the chemicals of Group III would be useful as lumber dips, for their color or other properties do not satisfactorily meet the needs. Essentially the same can be said of Group IV chemicals, for they are all yellow and if used in a concentration high enough to be fungicidal they would impart a yellow color to the lumber or would otherwise be undesirable.

Something has already been said about the reason for including many of the chemicals listed in Group V. Although some of them may have value as fungicides where the requirements are not the same as those for lumber dipping, they do not have the qualities required here. The data will later be interpreted in terms of log-spray needs, and some of the chemicals may find use there.

Summary

In order to summarize briefly the relative toxicity of the various chemicals tested, Table 6 is presented. The toxicity limits for a representative wood-destroying fungus and a representative blue-staining fungus are given. _Fomes annosus_ No. 517 is selected as the wood-destroyer, since it has been adopted as a standard fungus for toximetric tests. _Ceratostomella pilifera_ No. 3 is selected as the blue-stainer. For convenience of location, the chemicals are arranged alphabetically. To obtain the results of the tests with other fungi, reference should be made to the body of the paper; the last column of Table 6 will assist in locating these results.

TABLE 1. TOXICITY LIMITS[1] OF CHEMICALS IN GROUP I, IN PER CENT OF THE TOTAL MATERIAL IN THE CULTURE CHAMBER

Name of chemical	Percentage limits of toxic material for—								
	Fomes annosus No. 517	*Lenzites trabea* No. 617	*Poria incrassata* No. 563	*Ceratostomella pilifera* No. 3	*Ceratostomella pilifera* No. 76	*Ceratostomella pini* No. 134	*Ceratostomella pini* No. 181	*Ceratostomella pluriannulata* No. 198 pl.	*Graphium rigidum* No. 198 gr.
Butyl cresol	0.006 —0.02	0.006 —0.02	Below 0.006	0.02 —0.05	Above 1.00	Above 1.00	0.05 —0.10		
Butyl phenol	Below 0.006	Below 0.006	Below 0.006	0.02 —0.05	0.02 —0.05	0.02— 0.05	0.02 —0.05		
o-dichlorobenzene	0.10 —0.15	0.05 —0.07	0.02 —0.025	0.10 —0.15	0.15 —0.20	0.10 —0.15	0.07 —0.10		
p-phenylphenol	Above 0.08	Above 0.08	0.012 —0.024	Above 0.08	Above 0.08			Above 0.08	Above 0.08
Sodium *p*-phenylphenolate	0.05 —0.10	0.05 —0.10	Below 0.003	0.05 —0.10	0.10 —0.30			0.10 —0.30	0.10— 0.30
o-phenylphenol	0.006 —0.02	0.006 —0.02	0.003 —0.006	0.02 —0.05	0.02 —0.05	0.02 —0.05	0.02— 0.05		
Sodium *o*-phenylphenolate	0.019 —0.0375	0.009 —0.019	0.009 —0.019	0.009 —0.019	0.0375—0.075	0.0375—0.075	0.0375—0.075		
2-chloroorthophenylphenol	Below 0.007	Below 0.007	Below 0.007	Below 0.007	Below 0.007			Below 0.007	Below 0.007
Dinitroorthophenylphenol	Above 0.50	Above 0.50	Above 0.50	Above 0.50	Above 0.50			Above 0.50	Above 0.50
4-chloro-6-phenylphenol	Above 0.50	0.06 —0.25	Below 0.015	Above 0.50	Above 0.50			0.25 —0.50	Above 0.50
Sodium 4-chloro-6-phenylphenolate	0.168 —0.336	0.042 —0.084	Below 0.01	0.168 —0.336	0.336 —0.672			0.336 —0.672	0.084 —0.168
Pentachlorophenol	Above 0.015	Below 0.007	Below 0.007	Above 0.015	Above 0.015			Below 0.007	Above 0.015
Tetrachlorophenol	0.004 —0.006	0.004 —0.006	0.004 —0.006	0.004 —0.006	0.004— 0.006	0.004 —0.006	0.004 —0.006		
Sodium tetrachlorophenolate	0.00375—0.0075	Below 0.00375	Below 0.00375	0.00375—0.0075	0.00375—0.0075			0.0075—0.015	0.00375—0.0075
Sodium dinitrophenolate	0.005 —0.009	0.001 —0.002	Below 0.001	0.0375—0.075	0.0375—0.075	0.009 —0.019	0.009 —0.019		
Dinitroorthocyclohexylphenol	Above 0.50	Above 0.50	0.25 —0.50	Above 0.50	Above 0.50			Above 0.50	Above 0.50
p-xylyl mercuric chloride	0.004 —0.008	Above 0.008	Below 0.004	Above 0.008	0.004 —0.008			Above 0.008	Above 0.008
3-hydroxy-1-methyl-4-isopropylbenzene (Thymol)	0.015 —0.03	0.015 —0.03	Below 0.0075	0.03 —0.06	0.03 —0.06			0.015 —0.03	0.015 —0.03
1, 3, 5-xylenol	Above 0.03	Above 0.03	Above 0.03	Above 0.03	Above 0.03			Above 0.03	Above 0.03
4-nitro-3, 5-biacetoxymercuri-2-cresol(1·500)(Metaphen)	Above 0.30	Above 0.30	Above 0.10	Above 0.10	Above 0.10			Above 0.30	Above 0.30
Sodium oxymercuri-orthonitrophenolate (Mercurophen)	0.0125—0.025	0.006 —0.0125	0.003 —0.006	Above 0.10	0.05 —0.10			Above 0.10	Above 0.10

[1] The killing point lies between the two concentrations recorded as the toxicity limits.

Z M 27025 F

TABLE 2. TOXICITY LIMITS[1] OF CHEMICALS IN GROUP II, IN PER CENT OF THE TOTAL MATERIAL IN THE CULTURE CHAMBER

Name of chemical and manufacturer's sample number	Percentage limits of toxic material for—								
	Fomes annosus No. 517	*Lenzites trabea* No. 617	*Poria incrassata* No. 563	*Ceratostomella pilifera* No. 3	*Ceratostomella pilifera* No. 76	*Ceratostomella pini* No. 134	*Ceratostomella pini* No. 181	*Ceratostomella pluriannulata* No. 198 pl.	*Graphium rigidum* No. 198 gr.
No. 696, 2 per cent ethyl mercury chloride mixture with 98 per cent inert material	0.022 —0.045	Below 0.022	Below 0.022	0.022 —0.045	0.022 —0.045			0.022 —0.045	0.022 —0.045
No. 652, 3 per cent ethyl mercury chloride mixture with 97 per cent inert material	0.025 —0.05	0.0125—0.025	0.0125—0.025	0.05 —0.10	0.05 —0.10	0.05 —0.10	0.0125—0.025	0.05 —0.10	0.025 —0.05
No. 668, 3 per cent ethyl mercury chloride mixture with 97 per cent inert material	0.0075—0.015	0.0019—0.0037	0.0037—0.0075	0.015 —0.03	0.015 —0.03	0.015— 0.03	0.00375—0.0075		
No. 603, 3 per cent ethyl mercury chloride and 97 per cent soda	0.015 —0.03	0.007 —0.015	0.015 —0.03	0.007 —0.015	0.015 —0.03	Above 0.03	0.007 —0.015		
No. 745, 4.3 per cent ethyl mercury chloride mixture with 95.7 per cent inert material	0.006 —0.0125	Below 0.003	0.003 —0.006	0.006 —0.0125	0.025 —0.05			0.006 —0.0125	0.0125—0.025
No. 697, 2.0 per cent ethyl mercury cyanide mixture with 98 per cent inert material	0.02 —0.042	0.02 —0.042	0.02 —0.042	0.042 —0.084	0.084 —0.168			0.084 —0.168	0.084 —0.168
No. 674, 3.0 per cent ethyl mercury oxalate mixture with 97 per cent inert material	0.005 —0.01	0.0012—0.005	0.01 —0.02	0.01— 0.02	0.02 —0.04			0.01 —0.02	0.01 —0.02
No. 672, 2.5 per cent ethyl mercury phosphate mixture with 97.5 per cent inert material	0.009 —0.0187	0.0012—0.005	0.005 —0.009	0.009 —0.0187	0.009 —0.0187	0.009 —0.0187	0.005 —0.009		
No. 673, 3 per cent ethyl mercury phosphate mixture with 97 per cent inert material	0.007 —0.01	0.002 —0.0025	0.015 —0.020	0.015 —0.02	0.03 —0.04			0.01 — 0.015	0.015 —0.02
No. 671, 4.0 per cent ethyl mercury sulfate mixture with 96.0 per cent inert material	0.0023—0.005	0.0012—0.0023	0.0023—0.005	0.005 —0.009	0.009 —0.0187	0.009 —0.0187	0.0023—0.005		
No. 647, 4.3 per cent ethyl mercury sulfate mixture with 95.7 per cent inert material	0.01 —0.02	0.0025—0.005	0.01 —0.02	0.01— 0.02	0.01 —0.02			Above 0.02	Above 0.02
No. 730, 3 per cent ethyl mercury tetraborate mixture with 97 per cent inert material	0.04 —0.08	0.01 —0.02	Above 0.08	Above 0.08	Above 0.08			Above 0.08	Above 0.08
No. 604, 3 per cent phenyl mercury acetate mixture with 97 per cent inert material	0.03 —0.04	0.007 —0.015	0.004 —0.007	0.17 —0.34	0.17 —0.34	0.17 —0.34	0.17 —0.34		
No. 604-S, 3 per cent phenyl mercury acetate and 97 per cent soda	0.06 —0.08	0.015 —0.03	0.002 —0.007	0.08 —0.12	0.08 —0.12	0.08 —0.12	0.06 —0.08		
Phenyl mercury chloride	Below 0.00097	Below 0.00097	Below 0.00097	0.0156—0.031	0.002 —0.004			0.002 —0.004	0.004 —0.008
X, a sample of phenyl mercury nitrate	0.0006—0.0012	0.0003—0.0006	0.0003—0.0006	0.0032—0.0036			0.0025—0.0028		

[1] The killing point lies between the two concentrations recorded as the toxicity limits.

Z M 27026 F

TABLE 3. TOXICITY LIMITS[1] OF CHEMICALS IN GROUP III, IN PER CENT OF THE TOTAL MATERIAL IN THE CULTURE CHAMBER

Name of chemical	Percentage limits of toxic material for—						
	Fomes annosus No. 517	*Lenzites trabea* No. 617	*Poria incrassata* No. 563	*Ceratostomella pilifera* No. 3	*Ceratostomella pilifera* No. 76	*Ceratostomella pluriannulata* No. 198 pl.	*Graphium rigidum* No. 198 gr.
Preparation No. 3 Copper 60.1 per cent, fluorine 17.2 per cent	0.10 —0.20	0.10 —0.20	0.1000—0.200	Above 0.30	0.20 —0.30	Above 0.30	Above 0.30
Preparation No. 8 Copper 58.35 per cent, fluorine 35.56 per ct.	0.02 —0.05	Above 0.20	0.0120—0.020	0.050 —0.10	0.10 —0.20	0.10 —0.20	0.10— 0.20
Preparation No. 6 Aniline copper fluoride	0.062 —0.125	Above 0.25	0.0625—0.125	Above 0.25	Above 0.25	Above 0.25	Above 0.25
Preparation No. 5 Aniline copper fluoride, copper acid fluoride	Above 0.10	Above 0.10	0.0125—0.025	0.025 —0.05	Above 0.10	Above 0.10	Above 0.10
Preparation No. 12 Aniline copper sulfate	0.200 —0.500	0.200 —0.500	0.500 —1.000	0.200 —0.500	0.50 —1.00	0.200 —0.500	0.200 —0.500

[1] The killing point lies between the two concentrations recorded as the toxicity limits.

TABLE 4. TOXICITY LIMITS[1] OF CHEMICALS IN GROUP IV, IN PER CENT OF THE TOTAL MATERIAL IN THE CULTURE CHAMBER

Name of fungicide	Percentage limits of toxic material for—								
	Fomes annosus No. 517	*Lenzites trabea* No. 617	*Poria incrassata* No. 563	*Ceratostomella pilifera* No. 3	*Ceratostomella pilifera* No. 76	*Ceratostomella pini* No. 134	*Ceratostomella pini* No. 181	*Ceratostomella pluriannulata* No. 198 pl.	*Graphium rigidum* No. 198 gr.
Basilit	Above 0.10								
Benetol	Above 0.20	Above 0.20	Above 0.20	Above 0.20	Above 0.20			Above 0.20	Above 0.20
Fluorosit	0.0312—0.0625	Below 0.0156	Below 0.0156	0.0625—0.125	0.0625—0.125	0.0312—0.0625	0.0625—0.125		
Malenit	0.06 —0.08								
Phenyl arsenic oxide and coal tar product mixture No. H. 146 new	Below 0.007	Below 0.007	Below 0.007	0.03 —0.06	0.015 —0.03			0.03 —0.06	0.015 —0.03
Phenyl mercury acetate and coal tar product mixture No. H. 31/24	0.125 —0.25	0.03 —0.06	0.007 —0.015	0.125 —0.25	0.06 — 0.125			0.25 —0.50	0.06 —0.125
Thanalith	0.0675—0.125	0.0156—0.0312	Below 0.0156	0.0625—0.125	0.125 —0.25	0.0312—0.0625	0.0156—0.0312		
Thanalith-U	0.06 —0.125	0.06 —0.125	0.007 —0.015	0.125 —0.25	0.125 —0.25			0.125 —0.25	0.125 —0.25
Triolit	0.125 —0.25	0.0312—0.0625	Below 0.0156	0.125 —0.25	0.125 —0.25	0.0625— 0.125	0.0625—0.125		

[1] The killing point lies between the two concentrations recorded as the toxicity limits.

TABLE 5. TOXICITY LIMITS[1] OF CHEMICALS IN GROUP V, IN PER CENT OF THE TOTAL MATERIAL IN THE CULTURE CHAMBER

Name of chemical	Percentage limits of toxic material for—								
	Fomes annosus No. 517	*Lenzites trabea* No. 617	*Poria incrassata* No. 563	*Ceratostomella pilifera* No. 3	*Ceratostomella pilifera* No. 76	*Ceratostomella pini* No. 134	*Ceratostomella pini* No. 181	*Ceratostomella pluriannulata* No. 198 pl.	*Graphium rigidum* No. 198 gr.
Alphanaphthyl mercuric chloride	Above 0.0157	Above 0.0157	Above 0.0157	Above 0.0157	Above 0.0157			Above 0.0157	Above 0.0157
Ammonium arsenous trioxide	0.012 —0.023	0.047 —0.094	0.012 —0.023	0.012— 0.023	0.047 —0.094	0.012 —0.023	Below 0.006		
Ammonium hydroxide and ethyl alcohol	1.80 —3.60	0.90 —1.80	0.045 —0.90	0.45 —0.90	0.45 —0.90			Above 3.60	1.80 —3.60
Amyl salicylate	Above 0.05	0.02 —0.05	0.006 —0.02	Above 0.05	Above 0.05	Above 0.05	Above 0.05		
Arsenous acid	Above 0.03	Above 0.06	Above 0.06	Above 0.06	Above 0.06			Above 0.06	Above 0.06
Casein	1.66 —3.32	1.66 —3.32	0.83 —1.66	Above 3.32	1.66 —3.32			Above 3.32	Above 3.32
Copper oxychloride	Above 0.10	Above 0.10	Above 0.10	Above 0.10	Above 0.10	Above 0.10	Above 0.10		
Copper sulfate ($5H_2O$)	0.05 —0.10	0.05 —0.10	0.40 —0.80	0.20 —0.40	0.80 —1.60			0.80 —1.60	0.20 —0.40
Creosote, Belgian coal tar	Above 0.05	Above 0.05	0.006 —0.0125	Above 0.05	Above 0.05	Above 0.05	Above 0.05		
Creosote, colloidal No. 3455	0.125 —0.25	0.062 —0.125	0.031 —0.062	0.125 —0.25	0.125 —0.25			0.125 —0.25	0.062 —0.125
Creosote, wood tar	0.025 —0.05	0.05 —0.10	0.025 —0.05						
Dermatological research preparation No. 1157	0.01 —0.025	0.01 —0.025	Below 0.003	Above 0.10	Above 0.10	Above 0.10	0.05 —0.10		
Ethylene chloride	Above 0.50	Above 0.50	Above 0.50	Above 0.50	Above 0.50			Above 0.50	
Formaldehyde	0.0187—0.037	0.0187—0.0375	0.0046—0.009	0.0187—0.0375	0.0375—0.075	0.075 —0.15	0.0375—0.075		
Furfural—C. P.	Above 0.10	Above 0.10	0.05 —0.10	Above 0.10	Above 0.10	Above 0.10	0.025 —0.05	Above 0.10	0.05 —0.10
German mercury compound	0.0019—0.0037	0.00095—0.0019	Below 0.00095	0.00375—0.0075	0.00375—0.0075			0.00375—0.0075	0.0019—0.00375
Glutrin	Above 3.00	Above 3.00	1.50 —3.00	Above 3.00	Above 3.00			Above 3.00	
Goulac	Above 3.00	Above 3.00	Above 3.00	Above 3.00	Above 3.00			Above 3.00	
Ialine (a colloidal sulfur)	Above 1.20	Above 1.20	Above 1.20	Above 1.20	Above 1.20			Above 1.20	Above 1.20
Mercuric resinate	0.125 —0.25	0.125 —0.25	0.125 —0.25	Above 0.25	Above 0.25			Above 0.25	Above 0.25
Minerec	Below 0.006	Below 0.006	Below 0.006	0.02 —0.05	Below 0.006	0.006 —0.02	Below 0.006		
Non-mercurial No. 733	0.25 —0.50	0.25 —0.50	0.10 —0.25	Above 0.50	Above 0.50			Above 0.50	Above 0.50
Protection (K2DX clear)	0.125 —0.25	0.06 —0.125	Below 0.06	0.125 —0.25	0.25 —0.50			Below 0.06	0.125 —0.25
Protexwood	Above 1.00	Above 1.00	0.50 —1.00	Above 1.00	Above 1.00			Above 1.00	Above 1.00
Pyridine (commercial)	0.08 —0.17	0.08 —0.17	0.08 —0.17	Above 0.17	Above 0.17			Above 0.17	0.08 —0.17
Shale gas oil (300°-400° C. fraction)	Above 1.00	Above 1.00	Above 1.00	Above 1.00	Above 1.00			Above 1.00	Above 1.00
Sodium metasilicate ("Metso")	0.50 —1.00	1.00 —2.00	0.125 —0.25	1.00 —2.00	Above 2.00			Above 2.00	Above 2.00
Sodium salicylanalide	Below 0.007	0.007 —0.015	Below 0.007	0.03 —0.06	0.125 —0.25			0.125 —0.25	0.25 —0.50
Sterilac	Above 0.20	Above 0.20	Above 0.10	Above 0.20				Above 0.20	Above 0.20
Syllit	0.375 —0.75	0.375 —0.75	0.023 —0.047	0.1875—0.375	0.375 —0.75	0.375 —0.75	0.094 —0.1875		
Terminix	0.25 —0.50	Above 0.50	0.125 —0.25	0.25 —0.50	0.25 —0.50			0.125 —0.25	0.25 —0.50
Thallium sulfate	0.06 —0.125	0.06 —0.125	0.015 —0.03	0.125 —0.25	0.06 —0.125			0.125 —0.25	0.06 —1.25
Triethanolamine	Above 0.50	Above 0.50	0.25 —0.50	Above 0.50	Above 0.50			Above 0.50	Above 0.50
Tritreat 5A	Above 0.10	Above 0.10	Above 0.10	Above 0.10	Above 0.10			Above 0.10	
Tritreat 5B	0.50 —1.00	0.50 —1.00	0.10 —0.30	Above 1.00	Above 1.00			Above 1.00	0.50 —1.00
Zinc selenite	Above 0.50	0.05 —0.20	Above 0.50	Above 0.50	Above 0.50			Above 0.50	Above 0.50

[1] The killing point lies between the two concentrations recorded as the toxicity limits.

TABLE 6. SUMMARY OF THE TOXICITY LIMITS[1] OF VARIOUS CHEMICALS TO FOMES ANNOSUS (517) AND CERATOSTOMELLA PILIFERA (3)

Name of chemical	Toxicity limits for— *Fomes annosus* No. 517	Toxicity limits for— *Ceratostomella pilifera* No. 3	For additional information refer to Table—
Alphanaphthyl mercuric chloride	Above 0.0157	Above 0.0157	5
Ammonium arsenous trioxide	0.012 —0.023	0.012 —0.023	5
Ammonium hydroxide and ethyl alcohol	1.80 —3.60	0.45 —0.90	5
Amyl salicylate	Above 0.05	Above 0.05	5
Aniline copper fluoride	0.062 —0.125	Above 0.25	3
Aniline copper fluoride, copper acid fluoride	Above 0.10	0.025 —0.05	3
Aniline copper sulfate	0.20 —0.50	0.20 —0.50	3
Arsenous acid	Above 0.03	Above 0.06	5
Basilit	Above 0.10		4
Benetol	Above 0.20	Above 0.20	4
Butyl cresol	0.006 —0.02	0.02 —0.05	1
Butyl phenol	Below 0.006	0.02 —0.05	1
Casein	1.66 —3.32	Above 3.32	5
2-chloroorthophenylphenol	Below 0.007	Below 0.007	1
4-chloro-6-phenylphenol	Above 0.50	Above 0.50	1
Copper fluoride (Cu 60.1 per cent, F 17.2 per cent)	0.10 —0.20	Above 0.30	3
Copper fluoride (Cu 58.35 per cent, F 35.56 per cent)	0.02 —0.05	0.05 —0.10	3
Copper oxychloride	Above 0.10	Above 0.10	5
Copper sulfate ($5H_2O$)	0.05 —0.10	0.20 —0.40	5
Creosote, Belgian coal tar	Above 0.05	Above 0.05	5
Creosote, colloidal No. 3455	0.125 —0.25	0.125 —0.25	5
Creosote, wood tar	0.025 —0.05		5
Dermatological research preparation No. 1157	0.01 —0.025	Above 0.10	5
Dinitroorthocyclohexylphenol	Above 0.50	Above 0.50	1
Dinitroorthophenylphenol	Above 0.50	Above 0.50	1
Ethyl mercury chloride 2 per cent, 98 per cent inerts (No. 696)	0.022 —0.045	0.022 —0.045	2
Ethyl mercury chloride 3 per cent, 97 per cent inerts (No. 652)	0.025 —0.05	0.05 —0.10	2
Ethyl mercury chloride, 3 per cent, 97 per cent inerts (No. 668)	0.0075—0.015	0.015 —0.03	2
Ethyl mercury chloride 3 per cent, 97 per cent soda (No. 603)	0.015 —0.03	0.007 —0.015	2
Ethyl mercury chloride 4.3 per cent 95.7 per cent inerts (No. 745)	0.006 —0.0125	0.006 —0.0125	2
Ethyl mercury cyanide 2 per cent, 98 per cent inerts (No. 697)	0.02 —0.042	0.042 —0.084	2
Ethyl mercury oxylate 3 per cent, 97 per cent inerts (No. 674)	0.005 —0.01	0.01 —0.02	2
Ethyl mercury phosphate 2.5 per cent, 97.5 per cent inerts (No. 672)	0.009 —0.0187	0.009 —0.0187	2
Ethyl mercury phosphate 3 per cent, 97 per cent inerts (No. 673)	0.007 —0.01	0.015 —0.02	2
Ethyl mercury sulfate 4 per cent, 96 per cent inerts (No. 671)	0.0023—0.005	0.005 —0.009	2
Ethyl mercury sulfate 4.3 per cent, 95.7 per cent inerts (No. 647)	0.01 —0.02	0.01 —0.02	2
Ethyl mercury tetraborate 3 per cent, 97 per cent inerts (No. 730)	0.04 —0.08	Above 0.08	2
Ethylene chloride	Above 0.50	Above 0.50	5
Fluorosit	0.0312—0.0625	0.0625—0.125	4
Formaldehyde	0.0187—0.0375	0.0187—0.0375	5
Furfural, C. P.	Above 0.10	Above 0.10	5

[1] The killing point lies between the two concentrations recorded as the toxicity limits.

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TABLE 6. SUMMARY OF THE TOXICITY LIMITS[1] OF VARIOUS CHEMICALS TO FOMES ANNOSUS (517) AND CERATOSTOMELLA PILIFERA (3)—Continued

Name of chemical	Toxicity limits for— *Fomes annosus* No. 517	Toxicity limits for— *Ceratostomella pilifera* No. 3	For additional information refer to Table—
German mercury compound	0.0019—0.0037	0.0037—0.0075	5
Glutrin	Above 3.00	Above 3.00	5
Goulac	Above 3.00	Above 3.00	5
3-hydroxy-1-methyl-4-isopropylbenzene (Thymol)	0.015 —0.03	0.03 —0.06	1
Ialine (reversible colloidal sulfur)	Above 1.20	Above 1.20	5
Malenit	0.06 —0.08	0.02 —0.05	4
Mercuric resinate	0.125 —0.25	Above 0.25	5
Minerec	Below 0.006	0.02 —0.05	5
4-nitro-3, 5-biacetoxymercuri-2-cresol (1:500) (Metaphen)	Above 0.30	Above 0.10	1
Nonmercurial preparation No. 733	0.25 —0.50	Above 0.50	5
Orthodichlorobenzene	0.10 —0.15	0.10 —0.15	1
Orthophenylphenol	0.006 —0.02	0.02 —0.05	1
Paraphenylphenol	Above 0.08	Above 0.08	1
Paraxylal mercuric chloride	0.004 —0.008	Above 0.008	1
Pentachlorophenol	Above 0.015	Above 0.015	1
Phenyl arsenic oxide and coal tar product mixture No. H. 146 new	Below 0.007	0.03 —0.06	4
Phenyl mercury acetate 3 per cent, 97 per cent inerts (No. 604)	0.03 —0.04	0.17 —0.34	2
Phenyl mercury acetate 3 per cent, 97 per cent soda (No. 604-S)	0.06 —0.08	0.08 —0.12	2
Phenyl mercury acetate and coal tar product mixture No. H. 31/24	0.125 —0.25	0.125 —0.25	4
Phenyl mercury chloride	Below 0.00097	0.0156—0.031	2
Phenyl mercury nitrate	0.0006—0.0012	0.0032—0.0036	2
Protection (K2DX clear)	0.125 —0.25	0.125 —0.25	5
Protexwood	Above 1.00	Above 1.00	5
Pyridine, commercial	0.08 —0.17	Above 0.17	5
Shale gas oil (300°-400° C. fraction)	Above 1.00	Above 1.00	5
Sodium 4-chloro-6-phenylphenolate	0.168 —0.336	0.168 —0.336	1
Sodium dinitrophenolate	0.005 —0.009	0.0375—0.075	1
Sodium metasilicate ("Metso")	0.50 —1.00	1.00 —2.00	5
Sodium oxymercuri-orthonitrophenolate (Mercurophen)	Above 0.30	Above 0.10	1
Sodium orthophenylphenolate	0.019 —0.0375	0.009 —0.019	1
Sodium paraphenylphenolate	0.05 —0.10	0.05 —0.10	1
Sodium salicylanilide	Below 0.007	0.03 —0.06	5
Sodium tetrachlorophenolate	0.0037—0.0075	0.0037—0.0075	1
Sterilac	Above 0.20	Above 0.20	5
Syllit	0.375 —0.75	0.1875—0.375	5
Terminix	0.25 —0.50	0.25 —0.50	5
Tetrachlorophenol	0.004 —0.006	0.004 —0.006	1
Thallium sulfate	0.06 —0.125	0.125 —0.25	5
Thanalith	0.0675—0.125	0.0625—0.125	4
Thanalith-U	0.06 —0.125	0.125 —0.25	4
Triethanolamine	Above 0.50	Above 0.50	5
Triolit	0.125 —0.25	0.125 —0.25	4
Tritreat 5A	Above 0.10	Above 0.10	5
Tritreat 5B	0.50 —1.00	Above 1.00	5
1, 3, 5-xylenol	Above 0.03	Above 0.03	1
Zinc selenite	Above 0.50	Above 0.50	5

[1] The killing point lies between the two concentrations recorded as the toxicity limits.