MICROBIOLOGICAL CORROSION OF METALS — MARINE WOOD BORERS — RODENT ATTACKS ON STORED PRODUCTS — FOULING OF SHIPS BY BARNACLES — DETERIORATION OF STONE BY BACTERIA — ROTTING OF WOOD BY FUNGI — BACTERIAL BREAKDOWN OF ASPHALT — MILDEWING OF LEATHER — INSECT DAMAGE TO BOOKS — BIRD HAZARDS TO AIRCRAFT — FUNGI IN JET FUEL TANKS — TERMITES IN TIMBER — MICROBIOLOGICAL ATTACK ON RUBBERS PLASTICS AND PAINTS — FUNGAL ETCHING OF GLASS.

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The Bulletin acts as a vehicle for the publication of works on all aspects of biodeterioration, i.e. the deterioration of materials of economic importance by micro-organisms, insects, rodents, etc.

Contributions may be in English, French, German or Spanish and should be submitted in triplicate on international A4 size paper (21.0 cm × 29.7 cm or 8.27 in. × 11.69 in.); typewritten on one side of the paper only. A summary of 25-100 words should accompany each contribution.

Illustrations should be clearly drawn in Indian ink or should be photographed. The reduction desired should be clearly indicated and illustrations when reduced are not to exceed 17 cm × 26 cm. Where figures are to be inserted in the text the approximate position for each one should be clearly marked in the typescript.

The bibliographic references are to be indicated in the text as, e.g.:

Reese and Levison (1952).

and in the bibliography:


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25 reprints will be sent free of charge to each author. Additional reprints are obtainable on application to the Publications Editor at a charge of £5 ($12) per 100.
NEWS AND COMMENT

The 1959/60 edition of the Annual Report on Wood Protection, edited by Günther Becker and Gerda Theden, has now been published. The text is in both German and English and the publication is divided into a classified abstracts section and an alphabetical (by author) bibliography section. There is also a subject index.

Details are now available of the investigations into the growth of algae on the 16,000-year-old cave paintings at Lascaux in France. The organism causing the trouble was the green alga Palmelloccocus. The spread of the organism was attributed to the rapid recirculation of air by the air conditioning plant and it was believed that the artificial lighting was a major factor in encouraging growth. It was found, however, that turning off the air conditioning and lighting did nothing to halt the spread of the algae. The strain of Palmelloccocus involved was found to be heterotrophic and a major factor in its spread is now thought to be the large amounts of organic matter introduced to the cave on the shoes of the many visitors. Control of the organism was finally only possible by spraying with dilute formaldehyde solution and by continuing treatment of the cave entrance area with formaldehyde and detergent. It is still not thought advisable to reopen the cave to the general public until the continuing safety of the paintings can be assured. A full report of the investigations at Lascaux has been published in Studies in Speleology. (Abstracted from The Times.)

The Agricultural Research Council is setting up a new unit of invertebrate chemistry and physiology based on the Universities of Cambridge and Sussex. The research carried out by the unit will be particularly directed towards insect pests of agriculture, with Sussex dealing mainly with insect biochemistry and Cambridge with insect physiology and biophysics. It is hoped that the work will considerably further knowledge of the mode of action of insecticides. (Abstracted from The Times.)

M & T Chemicals Inc. have announced two new products. BioMeT 12 Rodent Repellent is a plastic based coating containing an organotin chemical which can be painted, sprayed or extruded on plastic jacketed wire, cable, hose, tube, pipe, equipment etc. The manufacturers' field tests have shown, to date, a reduction in damage of 93% for a period of two years and they claim that the product should give such protection for a period of five years or even longer under the severe environmental conditions.

The second new product is BioMeT 14 which is an odourless antibacterial and antifungal formulation which is used as an additive to flexible PVC systems. The manufacturers claim that this product provides outstanding protection for PVC against mildew and discolouration under soil burial conditions. Possible applications are for products such as wall coverings, shower curtains and rug undercoatings. M & T Chemicals Inc., Rahway, N.J. 07065, U.S.A.

Information on analytical methods for pesticide residues is available from the Pesticide Residue Analysis Information Centre, which has been in operation since 1965 at the Ministry of Technology's Laboratory of the Government Chemist, London. The service is primarily postal and is based mainly on published information although, where appropriate, enquiries are referred to research workers known to be active in the field of the enquiry. Normally information is supplied free, but a charge may be made if experimental work or a lengthy literature search is required. Enquiries should be addressed to: PRAIS, Laboratory of the Government Chemist, Cornwall House, Stanford Street, London, S.E.1., England.

The unique feature of gamma radiation is that it is extremely penetrating and allows the contents of large sealed containers to be processed. For practical purposes it is a "cold" method and the temperature rise associated with even high doses is only a few degrees C. There is no possibility whatever of anything becoming radioactive as a result of being exposed to cobalt-60 gamma rays.

Radiation dosage is measured in terms of rads, a megarrad being one million rads. (One rad = energy deposition of 100 ergs per gramme). Dosage is the only criterion required in the control of the process and simple routine methods of achieving this have been developed.

The resistance of living organisms to radiation varies considerably and to a large extent is related to their level of organisation. The following table indicating the likely lethal dose ranges makes this clear.

The use of gamma radiation from cobalt-60 for the sterilisation of medical equipment is now a well established commercial process. There are five plants in the United Kingdom and six in Europe, all engaged on commercial operation.

The applications for gamma radiation on this scale were and are being developed in the U.K. by the Wantage Research Laboratory of the U.K.A.E.A. Several types of gamma irradiation facility are available at the Wantage Research Laboratory. They include two large cobalt-60 plants handling material on a commercial scale, a spent fuel element assembly and 23 individual cobalt-60 cells of the research type, All these facilities are available to industry, hospitals, universities, research establishments, etc.

The selection of the most appropriate facility for a particular application is the responsibility of the Gamma Irradiation Service, to which enquiries should be directed.

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Two fluids, Bibliotex 1 and 2, have recently been introduced by Richardson & Starling Ltd. for the protection of books and manuscripts from fungi and insects. Both contain tri-n-butyl tin oxide and y-BHC. No. 1 is intended for application to cellulosic materials and No. 2, which contains anhydrous wool fat, to leather and parchment, application of both fluids being by means of a fine spray. The manufacturers claim that neither fluid has any adverse effect on print, illuminations, photographs or dyes, if properly applied and that protection is given against fungi and insects for many years. Richardson & Starling Ltd., 21 Hyde Street, Winchester, Hants., England. Telephone: Winchester 5001.

A market research service for the chemical and plastics industries is provided by the Chemicals and Plastics Unit of Business Intelligence Services Ltd. The unit is staffed by chemists and plastics technologists recruited from industry who also have previous marketing experience. Two types of work are undertaken: multi and single or private client. Examples of reports which have been prepared in the past are: "The United Kingdom Textile Processing Industry as a Market for Chemicals" and "The United Kingdom Paper Making Industry as a Market for Chemicals." Business Intelligence Services Ltd., Chemicals and Plastics Unit, Newland House, 139 Hagley Road, Birmingham 16. Telephone: 021-454 8331.

The Drew Chemical Corporation has introduced a new slime control agent, Biosperse 224. This consists of a dry synergised blend of polychlorophenates, organosulphur compounds and dispersing agents. It is claimed to have rapid dispersion throughout the treated system and is suitable for all types of industrial water systems. Drew Chemical Corporation, 522 Fifth Avenue, New York, N.Y. 10036, U.S.A.

An information and research centre covering diseases of both plants and animals has been set up at the University of California, Irvine. The Center for Pathobiology aims to collect both specimens and literature, to prepare teaching courses and to carry out research. The services of the centre will be available to qualified individuals and institutions throughout the world. Further information may be obtained from: Edward A. Steinhaus, Director, Center for Pathobiology, University of California, Irvine, Ca. 92664, U.S.A. Telephone: (714) 833-6446.

**BIOLOGICAL DEGRADATION OF LIGNIN**

Jerzy Trojanowski

Summary. The catabolism of lignin as a part of the general metabolism of aromatic compounds in microorganisms is considered. The oxidative depolymerisation of lignin is mainly performed by the Hymenomycetales. The role of bacteria in the break-down of lignin is rather limited.

La dégradation biologique de la lignine. Le catabolisme de la lignine en tant que partie du métabolisme général des composés aromatiques dans les microorganismes est étudié. La dépolymerisation oxydante de la lignine est principalement effectuée par les Hymenomycetales. Le rôle des bactéries dans la dégradation de la lignine est plutôt limité.

The decomposition of lignin constitutes an important process in the total biological deterioration of wood. The ability of fungi to decompose wood lignin can be economically important but this is rarely so with bacteria.

Lignin is a substance with a high degree of chemical stability, consisting of aromatic rings with side chains and -OH and -OCH₃ groups.

According to Nord and Schubert (1967) the term lignin does not imply a single and chemically defined compound but refers to a group of highly polymerised amorphous substances possessing a similar composition. The chemical definition given by Brauns (1963) states that "lignin is a wood constituent which when oxidised with nitrobenzene, yields vanillin and syringaldehyde in deciduous woods and hydroxybenzaldehyde, vanillin and syringaldehyde in the case of monocotyledons".

Nord and Schubert (1967) draw the attention to the technical difficulties as far as the purification of wood lignin and its separation from the cellulose is concerned. The lignin preparations are never identical with the natural lignin obtained from the wood. On the basis of the investigations of monomers and oligomers various structural formula of lignin macromolecule have been proposed (Fig. 1).

![Fig. 1. Constitutional model of spruce lignin according to Freudenberg (1965).](image-url)
Biological Degradation of Lignin, J. Trojanowski.

Among the bonds connecting the monomers the most important are alkyl-aryl ether and C-C bonds which are strong covalent bonds.

Fungal degradation of lignin

The Basidiomycetes (Hymenomycetales) are among the best known destroyers of wood lignin. Führnaeus and others (1949) reported a loss of lignin amounting to 80% in beech sawdust caused by Polyporus abietinus, Stereum rosum and Marasmius scorodonius.

The mycelium of Pholiota mutabilis grown on liquid media containing glucose brought about the degradation of pure Björkman's lignin as shown by the decrease of the lignin mass by 42% after six weeks and in the content of methoxyl groups by 16, 8% (Trojanowski and Leonowicz, 1963).

Numerous investigations carried out by other authors have confirmed these results showing a high degree of lignin depolymerisation caused by Basidiomycetes.

The fungi capable of wood degradation are usually divided into two groups: white rot fungi and brown rot fungi. This discrimination was based on the colour of the residual material at an advanced stage in the decay of solid wood; the ability to decompose preferentially the lignin or cellulose; the greatly increased alkali solubility of the residual wood and the simultaneous decrease in the degree of polymerisation of the residual cellulose during brown rot; and differences in the exoenzymes produced, especially oxidative enzymes.

Earlier Bavendamm (1928) considered that white rot fungi produced polyphenol oxidase and thus possessed the ability to decompose the lignin. In view of recent findings, this opinion can no longer be generally held.

At present some white rot species are known which do not secrete polyphenol oxidase e.g. Poria taxicola (Kirk and Kelman 1965) but which still cause lignin degradation. The discrimination between the ability to decompose lignin and cellulose is a quantitative rather than a qualitative characteristic.

Shimazono (1955) has proposed a new criterion of the discrimination between white rot and brown rot fungi: the first possess oxaloacetic decarboxylase and due to this fact oxaloacetic acid does not accumulate in the medium in contrast to the brown rots.

Kawase (1962) proposed a new classification of the types of wood decay caused by fungi which was based on the ratio of holocellulose to lignin in the material subject to decomposition; three classes being differentiated.

Class 1. The ratio is less than one (e.g. in the wood of Taxus cuspidata decayed by Coniophora the ratio is 0.24).

Class 2. The process is characterised by the very small amount of lignin left (e.g., the wood of Quercus crisipula decayed by Grifola sp. where the ratio was 30).

Class 3. The process is characterised by a holocellulose content two to five times that of lignin (e.g. in Quercus crisipula decayed by Stereum frustulosum the ratio is 2.18).

The first class corresponds to the so called brown rot and the remaining two groups belonging to white rot.

The three classes just described differ to a great extent in the chemical properties of the products left in the media. The lignin left in the first case has a greater solubility and a smaller content of OCH₃ as compared with the other two classes. The holocellulose in the first and second classes reveals substantial differences as far as the content of mannans and xylans is concerned. In the third class the properties of the components are similar to those of healthy wood.

Some workers have differentiated the so called soft rot type (e.g. Seltier, 1966). He investigated the changes taking place in birch wood decayed by the soft rot organism Chaetomium globosum and found its effect to be intermediate between white rot and brown rot as far as the intensity of lignin decomposition was concerned.

Demethylation activity of soft rot fungi is higher as compared to other species. The author considers demethylation to constitute an important step in the lignin degradation pathway and the formation of soluble lignin as a substantial factor in the enzymatic breakdown of polysaccharides.

The determination of the chemical changes produced in the medium, by fungi grown on the wood seems to be a more suitable criterion of the classification of the types of lignin degradation than the individual enzymological differences in Hymenomycetales. This is the direction of new research, e.g. Hata (1966) separated lignin from spruce-wood decayed by Poria subacida for several months and compared its properties with milled wood lignin from sound wood. The decayed lignin had a high content of carboxyl and carboxyl groups and after oxidation with nitrobenzene more vanillic acid and less vanillin was found in the products. The biochemical mechanism of lignin degradation by fungi has been the main topic of many studies in the field of enzymology and biochemical analysis.

The main enzymes are laccase and peroxidase—the so called inductive enzymes. Leonowicz and Trojanowski (1965) reported the identification of the inductive exoenzymes of Pholiota mutabilis.

The following tests were used to identify these enzymes: heat inactivation (at 60°C), spectrum characteristics in wave lengths from 380 to 660 mu, the benzidine test and the action of inhibitors DlECA (inactivates laccase), hydroxylamine (inhibits peroxidase and catalase) and sodium azide (inactivates all three enzymes).

The results of the tests confirmed the presence of laccase, peroxidase and catalase in the culture. The activity of peroxidase and laccase (determined quantitatively in the culture of Pholiota mutabilis) with the addition of Björkman's lignin are several times greater than in the culture without lignin.
Ishikawa, Schubert and Nord (1963) drew attention to peroxidase secreted by the fungi *Fomes fomentarius* and *Collybia velutipes*. This enzyme caused a shortening of side chains in phenolpropane units, considered to be model compounds of lignin.

Ishikawa *et al.* (1963) found that the degradation of guaiacyl-glycerol-β-coniferyl ether as the model for lignin is catalysed by the enzymes of the laccase and peroxidase type, secreted by *Fomes fomentarius* and *Collybia velutipes*.

The aim of the work of Trojanowski, Leonowicz and Hampel (1966) was to investigate the role of these enzymes in the process of demethoxylation of Björkman's lignin and vanillic acid.

After a four week's incubation of *Pholiota mutabilis* they found a 12% decrease in methoxyl groups in the case of lignin and about 80% in the case of vanillic acid.

After 24 hours incubation period of vanillic acid solution with the culture filtrate of the fungus a 36.8% decrease in methoxyl groups was observed. The greatest effect of demethoxylation was attained after the addition of H₂O₂, a total inhibition occurring after the addition of inhibitors DIECA and hydroxylamine which inhibit both laccase and peroxidase.

The results indicate that peroxidase and laccase are specially active in the process of demethoxylation of vanillic acid and lignin and confirm the hypothesis of Leonowicz and Trojanowski (1965) explaining the mechanism of the degradation of lignin by fungi (Fig. 2). The demethoxylation process constitutes an important step in the primary processes of lignin breakdown. The enzyme laccase reacts with the odiphenolic groups, arising after demethylation, and causes their oxidation to o-quinone or semi-quinone. In turn, the vicinity of o-quinone groups may cause a loosening and even cleavage of the aryl-alkyl-ether bonds, joining the phenylpropane subunits in lignin. After the disruption of —O— bonds, the quinone groups might be reduced and o-diphenol may be formed (Trojanowski *et al.*, 1967).

So far only a few cases of catalytic effect of peroxidase on demethylation process are known.

![Fig. 2. The hypothetical mechanism of the degradation of lignin by fungi according to Trojanowski *et al.* (1966)](image-url)
Trojanowski et al. (1967) reported that a purified preparation of peroxidase demethylated veratric acid (two OCH₃ groups) to vanillic and protocatechuic acids.

The cultures of Coriolus versicolor and Xanthochrous pini also caused demethylation of veratric acid. When mycelium free filtrate was incubated with veratric acid a similar effect was observed. From the experiments carried out with the use of specific inhibitors it was evident that fungal peroxidase also caused the demethylation of veratric acid yielding mono- and o-diphenols.

The results of these investigations confirm the hypothesis of Leonowicz and Trojanowski (1965).

The views concerning the role of fungal laccase (polyphenol-oxidase) in lignin breakdown have been enlarged. Lately a link between the cell energetics and laccase production was noticed. Lyr and Ziegler (1959) considered that the laccase induction by pentachlorophenol is connected with uncoupling of oxidative phosphorylation.

Grabbe, Koenig and Haider (1968) support the view that, when oxidative phosphorylation is uncoupled, fungi show an enhanced intensive production of laccase. Among the substances with uncoupling effects are also monooiodoacetic acid and 2,4-DNP at a concentration of 2, 10⁻⁴M and the products of lignin degradation such as ferulic, vanillic, protocatechuic and caffeic acids (10⁻³M). The addition of these agents to the media bring about an increase in laccase production by mycelium in the same way as when lignin is added. The laccase action in this case is such that it prevents the damaging effect of phenolic uncouplers by oxidising them which results in the creation of polymers.

A different and sole opinion on the role of fungal laccase in the process of lignin depolymerisation was advanced by Kirk et al. (1968).

They investigated the effect of this enzyme obtained from Polyporus versicolor and Stereum fruticulatum on syringlyglycol-β-guanyl ether which was considered to be a model lignin compound. It was shown that an oxidative process was possible involving laccase and in which alkyl-phenyl bond cleavage occurred.

The chemical changes accompanying lignin degradation in the wood decayed by fungi are not explained and constitute a separate problem.

The starting point for some of the research is lignin demethylation under the effect of fungi (Trojanowski et al., 1966, 1967). Haider (1966) investigated the fate of ¹⁴COOH and ¹⁴CH₃ in DHP molecule (synthetic lignin) added to a culture of Pleurotus ostreatus. The polymer of DHP after eight days exhibited the transition of 14% of ¹⁴COOH groups into CO₂ and 23% of ¹⁴COOH groups were found to be incorporated by mycelium. Under the same conditions 16% of ⁰¹⁴CH₃ groups were found to evolve as CO₂ and 58% being incorporated into mycelium. So far there is no complete picture of chemical processes underlying lignin degradation by white rot fungi. Sopko (1968) has recently reviewed the latest opinions concerning the problem.

Many investigators have concluded that o-diphenols are always among the products of the decomposition. Such compounds are subject to further complicated oxidation and polymerisation changes in the media.

Mansskaya and Kodina (1968) gave an analysis of the relevant studies demonstrating that the products of partial depolymerisation of lignin or the monomers arising as results of the effect of the microorganisms on dead plant tissues constitute precursor compounds for the secondary condensation processes to the so called humus compounds. A similar treatment can be found in Alexandrowa (1968).

Kononowa (1968) gave an analysis of the research concerning the changes of the lignin of dead plant tissues into humus compounds as a result of the action of microflora. She regards lignin as a substantial source of o-diphenols, these compounds arising in the process of demethylation and being important precursors in the condensations leading to the formation of humus compounds.

The mechanism of the formation of nitrogen heterocyclic polycondensed substances was explained by Trautner and Roberts (1950). According to them the benzoquinones which are the results of o-diphenol oxidation can take part in nucleophilic addition reactions with amino acids resulting in the formation of Schiff's bases. Fukuzumi et al. (1964) found the production of methoxy-p-benzoquinone as a metabolite of vanillic acid fungi with the ability to break down lignin.

Flaig (1964) demonstrated in his model studies that Schiff's bases formed from quinones and amino acids can form humus compounds as a result of polymerisation.

Schanel (1966) reported that the wood decomposed by some of the white rot fungi became red in colour but this later faded. This author also demonstrated red pigmented cultures of Tramaetes sp. on pine wood saw dust with the addition of 3% peptone after 4 months incubation at 25°C. The spectrum of this culture was similar to that of the products obtained in the system composed of catechol + amino acid + polyphenolase and its characteristics were apparently close to those of a Schiff's base. (two peaks at 333 mλ and 480 mλ).

Phenolic products are not always the terminal metabolites in fungal decomposition of lignin. Oxygenative disruption of o-diphenolic compounds derived from the depolymerisation processes should be also taken into account.
Biological Degradation of Lignin, J. Trojanowski.

Haider et al. (1962) demonstrated with the use of radioactive tracer technique the possibility of oxidase breaking the protocatechuic acid ring with cultures of Polystictus versicolor.

In the experiments with radioactive DHP (synthetic lignin) Haider and Grabbe (1967) obtained results suggesting that lignin degradation might be initiated by oxygenative breakdown of aromatic rings with the liberation of phenolic monomers occurring in the second phase. The first period characterised by an accumulation of aliphatic compounds would make possible the utilisation of lignin as a source of carbon. The phenolic compounds formed during the second phase might induce laccase which oxidises phenolic monomers detached from the lignin macromolecules seems to be limited to side chains only or to monomers detached from the lignin by fungi.

So far few studies have been carried out on this subject. Jaschhof (1964) has obtained a series of Xanthomomas sp. and Micrococcus sp. which when incubated for 100 days with alkaline lignin brought about a 4-10% weight decrease and a simultaneous rise in -OCH₃ content of the remaining lignin. The author considers that bacteria detach aliphatic side chains from the lignin molecule but phenol-ether bonds remain unaffected.

Konetzka et al. (1957) demonstrated that some bacteria possess the property of metabolising methoxyphenylpropane monomers of lignin to protocatechuic acid which is a source compound for the oxygenation, e.g. Pseudomonas aeruginosa transforms ferulic acid into protocatechuic acid (demethylation and shortening of the side chain). According to Sundman (1964) the strains of Agro bacterium possessing the ability to decompose dimers of -conidendrin or oliv type (without phenol-ether bonds) can intensively oxidise these compounds. Guaiacetyl-glycerol-l-coniferyl ether or Brauns' lignin preparations are oxidised by Agrobacterium only very slightly. Trojanowski and Wojtas (unpublished) observed the ability of Agrobacterium to decompose veratryl-glycerol-l-coniferyl ether (model lignin compound) with the production of vanillin and methoxybenzoquinone as reaction products.

Sundman and Haro (1966) studied the metabolites freed from lignans by Agrobacteria inhabiting soils rich in wood remnants. After a short period of action of these bacteria on the lignan, -conidendrin, mainly isovanillic acid is produced, whereas after a longer incubation methoxy-p-benzoquinone can be found among the metabolites.

O-diphenols are the substrates for oxygenation processes in many bacteria.

According to Dagley et al. (1960) the catechol metabolism initiated by a specific oxygenase called pyrocatechase proceeds in Pseudomonas as follows: catechol → cis-cis-muconic acid → muconolactone → β-oxoacetic acid → acetyl CoA + succinic acid. Similar changes occur with protocatechuic acid in Pseudomonas where they are initiated by protocatechuic acid 4,5-oxygenase and result in the formation of malate and pyruvate.

Dagley and Stopher (1959) detected another oxygenase (metapyrocatechase) in soil Pseudomonas. This enzyme splits catechol to α-hydroxymuconic semialdehyde whose further pathway is similar to the ones described above.

According to Evans (1963) protocatechuic acid and catechol are the most important substrates in the catabolism of aromatic compounds leading to the formation of aliphatic acids, which entering the Krebs cycle might act as energy source.

References

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Biological Degradation of Lignin. J. Trojanowski.


Summary: The work of the Bundesanstalt für Materialprüfung Berlin-Dahlem on the biodeterioration and preservation of wood, textiles, plastics, paints, bitumen and optical glass is reviewed. Results of research published within the last five years are covered.


1. The institute, its equipment and activity

In the Bundesanstalt für Materialprüfung Berlin-Dahlem, the origins of which go back to 1871, research and testing work on biodeterioration was started in 1935 by B. Schulze (1938). He defined the term “Werkstoff-Biologie” (1938), studied mainly wood preservation problems, but also the deterioration of textiles, insulating and other materials. After World War II, wood preservation required a large number and a wide spectrum of fundamental investigations, but for more than a decade, almost all materials have been covered by biodeterioration research.

The section “Biodeterioration of Materials” (Becker, 1965d) comprises more than 20 air-conditioned culture and storage rooms, three chambers for the simulation of any climate, many incubators and normal apparatus for biological work, two gas liquid chromatographs, a fluorometer, an atom absorption spectograph, an amino acid analyser and other equipment for chemical investigations. There are four cylinders for vacuum and high pressure treatment of wood, two of them for 50, one for 80 atm. pressure, testing machines and research devices for technological investigations and a pilot plant for the manufacture of wood-based materials.

The section carries out fundamental research and testing in the whole field of biodeterioration of materials and of wood preservation. It cooperates with other sections of the Bundesanstalt für Materialprüfung if materials other than wood and different fields of research and testing are concerned. The Bundesanstalt für Materialprüfung (with a total staff of some 860 persons) is a state-operated organisation. Additional funds from research organisations are used for special programmes.

Recent Research Work on Biodeterioration of Materials in Berlin-Dahlem

The following report gives a brief survey of results of research on biodeterioration and protection problems carried out in Berlin-Dahlem during the last 5 years.

2. Deterioration of wood and wood-based materials

2.1 Basidiomycetes

Chemical investigations on the process of the enzymatic degradation of wood have shown that the brown-rot fungus Coniophora puteana produces much cellulase in an early stage of attack and then uses more short-chained carbohydrates. Polystictus versicolor as a representative of the white-rot fungi decomposes cellulose, pentosans and lignin almost at the same rate. It also dissimilates the lignin, the composition of which is altered after the decomposition of the carbohydrates (Seifert, 1966 a,b, 1968).

The nitrogen metabolism of brown-rot fungi was studied with Coniophora, Merulius, Poria, and Lentinus species each on pine sapwood. After removal of the samples from a nitrogen-containing nutrient no further increase in the nitrogen content in the wood was observed despite vigorous fungal development. This indicates that atmospheric nitrogen was not utilized by the Basidiomycetes (Starfinger, 1967).

In a special testing device the oxygen consumption of growing fungus cultures increases to a maximum within 2 weeks (with 27°C) and then decreases to low values. The consumption shows rhythmical fluctuations with a period between 6 and 28 hours. The length of the periods and the time until maximum consumption proved to be species-specific. Additions of nitrogen may influence growth and oxygen consumption remarkably (Damaschke and Becker, 1966).

Permanent registration of the consumption of oxygen can be used for testing the efficacy of wood preservatives. Results can be obtained within 3 weeks. Results with *Coniophora puteana* using sodium fluoride and copper sulphate as test chemicals were in agreement with the thresholds gained by means of the DIN standard method (Damascke, 1968).

The institute participated in an international cooperative comparison of laboratory testing methods with Basidiomycetes (Becker, Hof, et al., 1966). This study is a basis for international standardisation of wood preservatives.

Laboratory testing of the efficacy of wood preservatives with small blocks leads to unrealistic distribution of the preservatives in the wood. In order to be able to use timber specimens of normal size, a so-called “fungus-cellar” test was developed (Gersonde and Becker 1958). Recently results have been published on the efficacy of wood preservatives applied by non-pressure methods after 4 to 5 years’ storage under cover (Gersonde 1967). While some types of oil and hydrogen fluoride still gave protection against *Merulius laevis*, the applied quantities of silico fluorides proved to be unsafe in case of *Coniophora puteana* and *Poria vaillantii*.

The chemical preservation of wood particle boards has become indispensable since these boards, a large quantity of which is produced in Germany, are used in buildings as wall, floor and roof material, especially in pre-fabricated building elements. Preservatives against fungi incorporated during the manufacturing process of the boards were tested comparatively with Basidiomycetes by exposing the material in the fungus cellar and determining the remaining mechanical strength properties. (Deppe, 1967; Gersonde and Deppe, 1968).

2.2 Soft-rot fungi

Microscopic investigations of the occurrence of soft-rot attack at ground level in about 600 pine and spruce poles with different preservatives applied in a first and a remedial treatment showed that 28% of the pine poles after 24 to 47 years’ creosote impregnation, 90% of the pine poles after 11 to 20 years’ salt impregnation, and 82% of the spruce poles after 10 to 29 years’ salt impregnation were infested. The creosoted poles were attacked throughout the cross section if the creosote content was too low, the salt-impregnated poles containing chromium-fluorine-arsenic preservative mainly in the outer zone (Gersonde and Meyer, 1964).

Soft rot fungi were isolated from pine stakes treated with different wood preservatives and exposed in a testing field in Berlin-Dahlem. In 126 cultures investigated, 30 species were determined which were able to decompose cellulose. *Fusarium solani*, *Penicillium janthinellum* and *Phialophora aurantica* were found rather frequently. The attack on pine wood was heavy with *Coniothyrium fuckelii*, *Cladosporium herbarum*, *Doratomyces stemonites*, *Fusarium aquaeductuum*, *Mammaria* sp., *Paecilomyces inflatus*, and *Phialophora* sp. (Gersonde and Kerner-Gang, 1968).

Another study was made with pine sapwood blocks exposed to soft-rot fungi in different natural soils in a laboratory test. Out of 118 cultures, 71 were able to utilize cellulose, these belonging to at least 26 species. The optimum growth temperature varied between 30 and 34°C. Only some of the fungi utilizing cellulose were capable of decomposing wood. Heavy attack of the wood was found in 17 cultures, comprising *Cephalosporium sp.*, *Chaetomium alba-arenulum*, *Chaetomium globosum*, *Fusarium sp.*, *Glenospora graphii*, *Humicola grisea*, *Petriella setiifera*, and *Trichurus spiralis*. *Fusarium sp.*, *Glenospora*, *graphii*, *Humicola grisea*, *Petriella setiifera*, and *Trichurus spiralis*. *Fusarium sp.* and *Petriella setiifera* caused weight losses of more than 10% in beech wood at 30°C within 8 weeks. With the exception of the two *Chaetomium* species, the wood-destroying fungi isolated proved to be markedly hydrophilic (Kerner-Gang, 1966a).

Limits and the most favourable range of water content for the decomposition of beech and pine wood were determined for the soils suggested by Theden (1961) for laboratory testing with soft rot fungi. Plastic containers were recommended instead of the originally proposed ceramic containers. The decisive factor for fungal attack is the wood moisture resulting from the respective water content of the soils, the water-holding capacity of which was very different. The lower limit for wood deterioration is about 30—35% wood moisture, the upper limit for pine sapwood about 60—80%, for beech about 80—120%. Nitrogen content of the soils and aeration influence the degree of decomposition; different soils may lead to the same optimum values for destruction of wood. First studies with defined culture media were carried out by using sand or sandpeat mixtures with additions of nitrogen and minerals for certain fungal species (Becker and Kaune, 1966).

As a biologically practically indifferent substrate also for soft-rot tests “Vermiculit”, i.e. an aluminium-iron-magnesium silicate seemed to be suitable. Weight losses caused by 6 soft-rot fungi, which were used individually, were lower than in soil with beech wood, but almost equal with pine sapwood (Kaune, 1967).

The chemical decomposition of wood by soft-rot fungi, investigated with *Chaetomium globosum*, is characterized by the dissimilation of cellulose and pentosan without accumulation of secondary products (Seifert, 1966c).

Wood particle boards and hemp shive boards were exposed to the attack of mixtures or single species of mould fungi, some of which had cellulytic capacity. The mechanical strength properties decrease due to the influence of high air humidity. The fungi caused a remarkable loss of mass and strength of the hemp shive boards and also influenced the urea-resin particle boards, while special phenol-resin particle boards proved to be very resistant to fungus attack (Kerner-Gang, 1966b, 1967a).
2.3 House Longhorn beetle

Contrary reports on the influence of blue stain on the development of larvae of *Hylotrupes bajulus* L. induced investigations with several individual blue stain fungi. The result is explained by the fact that some species favour and some limit the growth of the larvae. Soft-rot fungi and other Ascomycetes and Fungi imperfecti showed remarkable differences in their influence on *Hylotrupes* larvae. Some were indifferent; some like *Fusarium aquaeductuum* and *Physalospora aurantiaca* stimulated the development, which was 10 to 30 times faster than that of larvae in wood uninfested by fungi; some species or strains of special fungi like *Aspergillus flavus* proved to be highly toxic to the larvae (Becker, 1968b).

2.4 Termites

Experience with culturing termites including tropical species was recorded (Becker, 1965e). Special data were given on some species of *Coptotermes* which is an economically very important genus in the tropics (Becker, 1966g).

The activity of termites in various moisture conditions was determined by measuring the wood consumption of several species of *Kalotermes*, *Heterotermes*, *Reticulitermes*, and *Nasutitermes*. The reaction of *Kalotermes* is quite different from that of the Rhinotermitidae. With these the limits and the optimum range of water content are different in relation to the water-holding capacity of soils. Soils with a high water-holding capacity provide a rather broad range of favourable moisture content and thus are very suitable for culturing and tests with respect to the change of water content by evaporation (Becker, 1965b).

Termite species may have different limits of tolerable temperature and optimum temperature. Species of *Kalotermes*, *Cryptotermes*, *Zootermopsis*, *Heterotermes*, *Reticulitermes*, *Coptotermes*, and *Nasutitermes* were used for a comparative investigation. *Zootermopsis* is an exception with a low temperature optimum. Tropical species of the genera *Heterotermes*, *Coptotermes*, and *Nasutitermes* cannot survive for long at 20 or even 22°C (Becker 1967a).

Among the physical factors influencing the activity of termites (Becker 1966b) are also meteorological radiation changes, the "atmospherics" (Damaschke and Becker, 1964).

Since 1953 investigations have been carried out on the attractiveness of fungus-decayed wood to termites. The reaction of several termite species to various brown rot fungi was studied. Infestation of wood by these fungi may have a nutritional value for the termites especially in the range of 5–10% weight loss of the wood (Becker, 1965e, 1966c).

Special acids and aldehydes formed in wood by enzymatic activity of Basidiomycetes attract termites in very low concentrations. The termite species tested reacted differently. Vanillic acid, p-hydroxy benzoic acid, p-coumaric acid and protocatechuic acid attracted all the species used (Becker, 1964d).

Special mould fungi, mainly some *Aspergillus* and *Trichoderma* species are highly toxic to termites which are killed by them within a short time. Some of the fungi including particular strains of toxic species are indifferent or even beneficial to termites (Becker and Kerner-Gang, 1964).

Pine sapwood has a deterrent effect on termites which disappears after leaching (Becker, 1966d).

The digestion of soft- and hardwood species by termites was investigated chemically. The rate of dissimilation of the wood substance and its constituents differed with termite species, depending also on their feeding behaviour. The utilization of food by termites is far more intensive than by other wood-destroying insects (Seifert & Becker, 1965).

The trail-laying efficiency of ball-pen inks containing special glycol compounds on termites was studied with numerous species (Becker, 1966b; Becker and Mannesmann, 1968; Becker and Petrovitz, 1967).

2.5 Marine borers

In a chemical study on the nutrition of the isopod *Limnoria tripunctata* Menzies the relation of the crustaceans to marine microorganisms was investigated. *Limnoria* utilizes 30% of the wood consumed, mainly cellulose which they break up to 40 to 50%. The microorganisms concerned decompose celluloses only to cellodextrins and prefer hemicelluloses. The attack on lignin is insignificant. Bacteria and fungi probably contribute to the nitrogen balance of the crustaceans, as concluded earlier by Seifert (1964).

Life history, nutrition, dependence on environmental factors, association with *Limnoria*, and economical importance of the amphipod *Chelura terebrans* Philippi was studied in detail and the results were published in a monograph on the species (Kühne and Becker, 1964).

Some relations among *Teredo*, *Limnoria*, and *Chelura* were described (Kühne, 1966).

In laboratory tests of three tropical timbers with three *Limnoria* species, *Bastralocus* (Dicorynia paranensis Benth.) and *Bongossi* (*Lopira procer A. Chev.*) remained undamaged over a period of 4 years. The heartwood of *Greenheart* (*Nectandra rodii* (Schomb.) Hook) was slightly and the sapwood strongly attacked on the surface (Kühne, 1968a).

3. Wood Preservation

3.1 Efficacy of wood preservatives

Comparative tests of the efficacy of wood preservatives against brown and soft-rot fungi and wood-destroying insects were evaluated (Becker, 1964b, 1966c).

The permanence of the efficiency of creosote against wood-destroying organisms was studied thoroughly by means of gas-liquid and thin-layer chromatography of different parts of beech and pine wood railway sleepers after different periods of service time up to 25 to 30 years. While pine wood lost much of the lower and middle range boiling substances during exposure, they remained in the beech wood for a long time (Petrowitz and Becker, 1964). This difference in evaporation depends on the microstructure of the wood species; the cell walls of the tracheae of beech are not permeable, and condensed creosote closes these vessels at their ends (Becker and Petrowitz, 1965). According to laboratory tests with Basidiomycetes, sleepers remain protected against fungi, if the amount of creosote does not fall below 50 kg per m³ of wood (Becker and Hoffman, 1966). Thresholds of aged creosote against Coniophora puteana do not exceed about 20 kg per m³ wood of injected oil, while they are about 100 kg in the case of Lentinus lateritius provided that the creosote contained enough high boiling substances (Becker and Starfinger, 1967). Thresholds of aged creosote against soft rot fungi were rather high; but the retention of the preservative in the sleepers provides sufficient protection (Becker and Kaune, 1967). General conclusions were drawn from the series of investigations on the ageing of creosote (Becker, 1968a).

The permanence of the efficacy of wood preservatives against larvae of Hylobrytus bajulus L. was tested after ten or more years storage under constant and naturally changing climatic conditions. Synthetic contact insecticides in quantities which are applied in practice give a safe protection after more than ten years and can be expected to remain efficient even after longer periods (Becker 1964e, 1965a, 1966a).

Toxic limits of copper compounds and copper-containing salt mixtures against Hylobrytus larvae were determined in a comparative study (Becker, 1967b).

The efficacy of synthetic contact insecticides and water-soluble wood preservatives against several termite species was tested by means of different laboratory methods (Becker, 1965f, 1966e, 1966f).

3.2 Treating methods

A critical survey was given on the present status of wood preservation for transmission poles (Becker, 1964e).

Absorption, depth of penetration and quantitative distribution of a water-born preservative in spruce and pine poles after pressure impregnation under practical conditions were investigated for the first time with a chromium-fluorine-arsenic salt mixture. Conclusions were drawn on the influence of wood species and properties and directions deduced for a quality control (Gersonde and Becker, 1965).

The leachability of chromium-fluorine-arsenic, chromium-copper-arsenic, and chromium-copper-boron salt mixtures from four wood species was studied by means of chemical tests. The leachability increases in the sequence copper, arsenic, fluorine, and boron. The portion of leached salt is higher in hardwood than in soft-wood species (Becker and Buchmann, 1966).

In Germany fluorides are widely used for protection and insect eradication measures in buildings. The loss of fluorides from the wood by HF-evaporation and its dependence on wood properties and climatic factors were investigated. The permanently remaining concentration depends also on the chemical composition of the preservatives (Becker and Berghoff, 1965, 1966, 1968).

The difficulty in treating seasoned spruce by vacuum-pressure due to its refractory behaviour does not exist with the sap-replacement methods. The disadvantage of the old Boucherie process led to the scrutiny and improvement of the sap-replacement techniques. By means of newly developed caps which over the whole cross-section and allow the application of higher pressure the process now can be shortened to less than 24 hours vs. from 10 to 14 days before, and the sapwood is much better impregnated. The quantitative distribution of the compounds of various salt mixtures according to different sap-replacement methods was studied thoroughly and conclusions were drawn from the results for the preservation of spruce poles (Gersonde, 1968).

4. Textiles

4.1 Fungi for laboratory tests

Although natural fibres are increasingly replaced by synthetic fibres preservative-finished cotton textiles had occasionally to be tested for their resistance to mould attack. The applicable draft standards DIN 53 931 and 53 932 had the disadvantage of mentioning too few test fungi. They recommend for textiles in general Aspergillus niger, strain ATCC 6275, and Chaetomium globosum, without specifying a strain. For testing fibre textiles also Trichoderma viride is to be applied. For all textiles pure cultures of other mould fungi may additionally be used; these fungi are not specified. As certain requirements are necessary for test fungi, not any mould can be used. For this reason investigations were carried out in the BAM to select suitable fungi for determining mould resistance of textiles (Kerner-Gang, 1966b, 1967a). Primarily those fungi were chosen which had previously been isolated from attacked textiles and from other cellulosic material.

The test fungi Aspergillus niger and Chaetomium globosum mentioned in the draft cause losses of tensile strength of only 4 to 5% of copper-treated textiles. Fungal cultures which had been isolated from attacked textiles in the BAM, on the other hand, were essentially more destructive to the textiles tested. The following losses of tensile strength were recorded: certain strains of Humicola grisea 17%, Penicillium funiculosum 100%, Sphingomonas xyloclena 81%, Trichoderma sp. 34%, Trichoderma viride 33%, Trichurus spiralis 18%. Penicillium funiculosum and
4.2 Resistance of cloth moth larvae to preservatives

The adaption of natural resistance to insecticides is a general problem in applied entomology. It was investigated from the point of view of the number of generations required for cloth moths to become resistant to contact insecticides or stomach poisons. Larvae of *Tineola bisselliella* were exposed to special doses of Dieldrin and Mitin as representatives of the two preservative groups. The resistance against the contact insecticide increased more than 70 times within 20 generations and then remained nearly steady, whereas the resistance against the chemical change of the wool fibre could be increased only twice (Kühne and Becker, 1965).

Co-resistance and inheritance of resistance against Dieldrin was studied (Kühne, 1967). The Dieldrin-resistant strain was studied with respect to co-resistance to other contact insecticides and with regard to the mode of inheritance of the resistance.

4.3 Deterioration of textiles by insects

Deterioration of textiles by crickets (*Acheta domestica* L.) and cockroaches (*Periplaneta americana* L.) were described (Kühne, 1964).

5. Plastic materials

5.1 Testing of plastics with fungi

Much fundamental research has been carried out in the field of the microbial corrosion of plastics and particularly in the susceptibility of plasticisers and filler materials, so that one is often in a position of judging the probable behaviour of these materials towards mould attack when the plastics composition is known. When this cannot clearly be predicted a reliable mould test can be carried out based on tried test methods. The BAM spraying of the samples with an aqueous solution of spores of certain strains of *Aspergillus amstelodami*, *A. flavus*, *A. niger*, *Chaetomium globosum*, *Paecilomyces variotii*, *Penicillium fumiculosum*, and *Trichoderma viride* proved to be successful. The samples are subsequently suspended for 4 weeks at 30°C and at almost saturated relative humidity (Kerner-Gang, 1965). They are then inspected microscopically.

Special attention has in recent years been focussed on the testing of plastic floor coverings. This material, often with a supporting layer of felt, tissue or cork which is being used increasingly, is susceptible to mould attack when it is laid in rooms which are not dry enough. This attack often manifests itself in heavy discolourations. For this reason it was necessary to develop a test method with staining moulds. Investigations carried out with different types of floor coverings revealed that certain strains of *Aspergillus versicolor*, *Chaetomium alba-areolatum*, *Epichlorella nigrum*, *Penicillium janthinellum*, *P. purpureogenum*, and *P. verruculatum* cause especially heavy discolourations (Kerner-Gang, in preparation).

5.2 Resistance of plastic materials to termites

The termite resistance of plastics is essential for their use in tropical countries. Laboratory tests were carried out with 5 termite species and 50 types of plastics. The highest resistance to termites was found with hard and porefree phenoplasts and aminoplasts, glass fibre-reinforced polyesters, very hard polyvinyl chlorides and their copolymers, and polymethyl methacrylate. Mineral fillers such as mineral dusts, asbestos and glass fibre improve the termite resistance. This decreases in PVC as more plasticiser is added and in synthetic rubber with increasing brittleness. Foam plastics are very easily destroyed. The susceptibility of sheets is influenced by the chemical composition and their thickness. A correlation was stated between hardness tested by means of an indentation instrument and the attack by termites. From the results of the comparative investigations conclusions were drawn for laboratory testing techniques with termites (Becker, 1963, 1964a).

6. Paints

The fungicidal effectiveness of paint systems which are to be applied in moist rooms, cellars, kitchens etc. is also occasionally evaluated in the BAM. It proved to be suitable to use the fungal cultures individually. Nutrient media in Petri dishes are inoculated with one fungal culture each; subsequently filter paper treated with the paint to be tested is laid on the substrate. The zone around the sample which is not overgrown indicates the fungicidal effectiveness of the paint. Reliable statements can only be made when several fungal species are used for such tests. In the BAM certain strains of the following species are used: *Alternaria humicola*, *Aspergillus flavus*, *A. niger*, *A. terreus*, *Aureobasidium pullulans*, *Mnemiopilus echinata*, *Paecilomyces variotii*, *Penicillium funiculosum*, and *Phoma sp.*

7. Bitumen

As bitumen is widely used, the problem of its resistance to biodeterioration is occasionally to be considered. In recent years bituminous sealing compounds, insulating material of bituminised hemp shavings or rice chaffs and bituminised cardboard were repeatedly examined regarding their resistance against mould attack. As the relevant literature does not suggest any suitable test methods, such methods were developed for the three groups of materials with special fungi (Kerner-Gang, 1967b).

The investigations carried out to determine appropriate test fungi have revealed that it is not useful to choose the same fungal species for testing sealing materials, bituminised insulating materials and bituminised cardboard. Only *Trichoderma viride* grew...
equally well on all three groups of materials. In a test series with a relatively resistant material a fungus spread vigorously which had already been on the samples before inoculation; it was identified as Absidia litchiheimi (Lucet et Cost) Lendner and was proposed as a test fungus, too.

For the testing of bitumen as a sealing compound it is suggested to introduce liquefied bitumen into Petri dishes. The area between the edge of the dish and the bitumen is filled with salt-mineral agar. After the material has congealed it is inoculated with a spore suspension composed of the following mould species: Aspergillus flavus strain QM 380, Aspergillus ustus str. BAM T 70, Aspergillus versicolor str. BAM GP 29, Dactylium fuscilloides str. BAM T 59, Penicillium citrinum str. BAM V 23, Trichoderma viride str. BAM T 42.

Bituminised insulating materials as hemp shavings or rice chaffs are introduced into Petri dishes on mineral-salt agar and are inoculated each with a 1 ml mixed spore culture of the following fungi: Absidia litchiheimi strain BAM V 51, Aspergillus niger str. ATCC 6275, Aspergillus ustus str. BAM T 70, Chaetomium globosum str. ATCC 6205, Paecilomyces variotii str. R. 1115, Trichoderma viride str. BAM T 42.

Samples of 5 cm x 5 cm are cut out of bituminised cardboard and are placed—hanging freely—into appropriate glass vessels the bottom of which is filled with water to adjust a high relative humidity. The following fungi were chosen for the mixed spore suspension: Aspergillus flavus str. QM 380, Aspergillus versicolor str. QM 432, Chaetomium globosum str. ATCC 6205, Cladosporium resinae str. CBS, Penicillium citrinum str. BAM V 23, Trichoderma viride str. BAM T 42.

8. Metals

The bacterial corrosion of iron is not only produced by sulphate reducers as supposed so far. Bacteria which are isolated from corroding iron surfaces in sea water and which decompose glucose to CO$_2$ and H$_2$ under anaerobic conditions proved to induce iron corrosion extensively (Frenzel, 1965a, b). The corrosion was directly connected with the presence of the bacteria and could not be induced in the same degree by products of the metabolism of the bacteria (Frenzel, 1966).

The weight loss of the iron caused by acid-producing bacteria corresponds to their end metabolites. Corrosion proceeds only when the nutrient medium is not too strongly buffered and when the H-ions of the organic acids can become fully effective. The limiting influence of increasing H-ion concentration on the metabolism of the bacteria in laboratory cultures is permanently compensated by the iron. Organic acids or filtrates of bacteria induce iron corrosion only for a limited period and probably produce a protective film on the metal surface the formation of which, however, is prevented by the presence of bacteria (Ehler, 1967).

A survey was given on metal destruction caused by insect attack and on damage of the lead sheeting of a cable induced by the beetle Serropalpus barbarus Schall. (Kühne, 1968b).

9. Optical glass

Earlier investigations on the attack of optical lenses by fungi were carried through with the aim of establishing laboratory testing conditions by means of which preservative measures against fungal attack may be evaluated. Factors influencing deterioration were investigated, and it was tried to find out which fungi damage glass surface of optical apparatus.

The then developed testing method proved to be valuable and is applied in the BAM for investigations carried out on behalf of the optical industry. Two test series are recommended. In the first series, a punched sterilised nutrient agar plate which is suitable as nutrient medium is transferred to the centre of the glass sample and is inoculated. It may be called the "agarmethod". In the second series, a "spore germination method", dry spores of the test fungi are applied to the glass sample by means of a sterile piece of cotton wool. The glass samples of both series are kept in moist chambers at 30°C.

The test fungi which are at present considered to be particularly appropriate are i. a. Paecilomyces variotii and Aspergillus versicolor for the agar method and Aspergillus vitricola and Penicillium funiculosum for the spore germination method (Kerner-Gang and Theden, 1964; Theden and Kerner-Gang, 1964, 1965).

Later investigations dealt in particular with the development of fungal etching pattern on optical lenses. Large-scale investigations were carried out on the influences of the acid resistance of glass, of temperature and humidity on the over-growing of glass surfaces as well as on the development of etching patterns. The fungal species, too, influenced the corrosion pattern. Within the framework of these investigations it was found that fungal filtrates do not produce the typical corrosion patterns as they are produced on the glass by the fungi themselves. (Kerner-Gang, 1968).

References


Recent Research Work on Biodeterioration of Materials in Berlin-Dahlem. Becker & Kerner-Gang, W.


BOOK REVIEWS

ADVANCES IN PEST CONTROL RESEARCH

VOLUME 8. 1968.
Edited by R. L. Metcalf

The present volume contains three articles; The Behaviour and Fate of s-Triazines in Soils; Insect Sex Pheromones; and The Bipyridylium Herbicides.

The Behaviour and Fate of s-Triazines in Soils, by a group from the Crop Research Division, U.S.D.A., Beltsville is an exhaustive description of the topic. After a useful historical summary of the s-Triazines, and their basic chemistry, the authors examine the methods currently used for extraction and analysis. The behaviour in various soils is discussed with regard to their physical and chemical properties. A chapter on persistence in soils deals with the relative residual phytotoxities, and describes the possible relationships between structure and residual life. A short chapter on the uptake of s-triazines by plants is followed by the final section on the interaction of s-triazines and soil microorganisms, and especially with the metabolism of s-triazines by soil micro-flora. There are 188 references.

Insect Sex Pheromones, by Shorey, Gaston and Jefferson, of the University of California, Riverside, is a wide ranging survey of the knowledge regarding these increasingly important substances. The literature appears to have been covered up to the beginning of 1967. The existence of sex pheromones in the orders Lepidoptera, Orthoptera, Diptera, Coleoptera, Hymenoptera, Neuroptera, Mecoptera and Homoptera is discussed. In particular, the relationship of the pheromone to total sexual behaviour. The section on bioassay underlines the problems inherent in quantifying this measurement. The emphasis on the use of “dosage-response” curves rather than “behavioural thresholds” is welcome, as is the warning of the need to control environmental conditions for accurate assay. Pheromone production and release are discussed briefly. Orientation to the sex pheromone source is covered more fully. The chapter on the physiology of sex pheromone behaviour is especially important and underlines the need for exact control of all factors when studying sex pheromones. The hormonal control of these materials is of particular interest because of its possible use in pest control. In the section on environmental control of sex pheromone behaviour it is interesting to note that the temperature thresholds of activity of the examples quoted are all within the narrow region 15-21°C. A considerable interest is being shown at present in the species specificity of sex pheromones and a number of cases of cross specificity are reported.

The chapter on chemical aspects deals firstly with extraction and purification followed by a short summary of identification methods. The structures of five known compounds are given, and it is a measure of the rate of increase of knowledge in this field that the number has more than doubled in the two years or so since this article was written. Mention is made of the masking of pheromone activity by other extracted substances. The limited information on the correlation of chemical structure and biological activity indicates an area where considerable more work could be done. The morphology of sex pheromone glands is examined briefly but clearly. The final section on the use of sex pheromones in insect control underlines the many practical problems involved in such methods. The possibilities opened up by the few positive experiments on these methods of control are potentially of great value, especially in the light of the growing concern over environmental contamination by pesticides. As the authors state in their concluding remarks “A great deal of basic chemical and biological study is necessary before one can intelligently devise a behavioural control program...” The article contains 211 references.

The Bipyridylium Herbicides by Calderbank is a detailed and thorough survey of paraquat and diquat. The first part, on the synthesis of these compounds includes details of C14 and tritium labelling. The chemical and physical properties of the herbicides are discussed and related to their biological activity. The structure activity relationships are dealt with more fully in the section on mode of action, together with the plant physiological and biochemical aspects. Their various uses in weed control are outlined. Analytical methods are discussed, including biological methods. The interesting effects of light and dark on the the translocation of these compounds in plants is dealt with at the start of the chapter on the fate of paraquat and diquat in plants; the author then examines the problems of residues in crops. There is very little evidence for metabolism in plants and most degradation would seem to be non-enzymic, the long section on photodecomposition would suggest that this is the principle degradative process. The well documented adsorption of these herbicides is elaborated. After a section on degradation by microorganisms, the fate of the herbicides in water is examined from the point of view of their use on water plants and the possible residue problems. The article ends with a chapter on the toxicology of paraquat and diquat in relation to man, farm animals and wildlife. There are 225 references.

The volume contains a fairly brief subject index and a cumulative title index to volumes 1-8. One criticism of the volume is that there is no direct indication in any of the articles of the date of the review. Although, from the references, one can infer that the first two articles are circa 1966 and the third 1967, it would be helpful for the reader to be told this without having to examine the references in detail.

D. F. Horler
This volume contains the proceedings of a conference held in London on the 19th and 20th of September 1967. The purpose of this conference was to present the current status of hydrocarbon microbiology to those members of the petroleum industry normally not associated with the role of biology in this industry. A group of twelve leaders in hydrocarbon research were assembled to survey the various aspects of hydrocarbon microbiology. It is the viewpoint of this reviewer that the papers presented were of excellent quality and covered briefly but in an erudite fashion the important fundamental and applied aspects of this field of study.

The scope of the symposium is well outlined by Professor Hughes in his paper. He briefly covers the historical development of the petroleum industry and its tie to microbiology. In this paper he describes microbes as "energy and chemical transducers" which is of course their main interest to the petroleum industry. The fundamental physiology and biochemistry of microorganisms is described in a concise and lucid manner.

A summary of the research in hydrocarbon biogenesis is presented by J. G. Jones and A. Williams. They describe the work done in API Project 43A by Professor ZoBell and the development of the concept of the "geological fence" by Dr. Cox. The role of the geochemist in the mid-century is outlined in which they correlated the structure of the hydrocarbons in soils and natural materials with those hydrocarbons present in crude oil. It is pointed out that crude oils contain a C-odd: C-even ratio of unity whereas soils and sediments contain mainly C-odd aliphatic hydrocarbons, the differences in ratios being ascribed to microbial action. Finally, this paper provides a summary of the recent studies on hydrocarbon genesis by various biological systems.

Professor Quayle, has in the short span of eleven pages provided an excellent review of the biochemical mechanisms by which various aliphatic and aromatic hydrocarbons are degraded by microorganisms. He discusses the nature of the microorganisms involved in these degradations and the question of substrate specificity. A particularly pertinent section in relation to present work in hydrocarbon microbiology deals with co-oxidation. This process offers great possibilities for hydrocarbon transformations of industrial importance.

From this point on, the conference centered on the applied aspects of hydrocarbon metabolism, with particular emphasis on biomass. The paper by J. H. Atkinson and F. H. Newth introduces the large-scale manufacturer of products by fermentation. Culture methods, extraction procedures and analytical techniques are covered in a brief but adequate manner. Considerable space is used to describe the air-lift fermentor, its operation, design and the type of results obtained with it. The value of this type of fermentor over the conventional stirred vessel fermentor is well documented.

Dr. Ribbons discusses the chemical and biochemical problems encountered in the production of biomass. He has clearly explained the problem of world protein shortage and the advantages of microorganisms as an aid in overcoming this problem. Ribbons also mentions the use of biomass for the production of enzymes and extracellular products. His work emphasizes the role of methane consuming bacteria for the production of biomass, and the difficulty in working with these organisms. The data presented in this paper includes an analysis of the amino acid content of two typical methane bacteria.

This volume includes the only complete discussion of the production of protein concentrate biomass from hydrocarbon which is readily available to the general public. In his discourse, Llewelyn has outlined the activities of the BP group in protein production on a large scale basis. The basic requirements for biomass production are discussed step by step. Included in the paper are recent analyses of the hydrocarbon grown yeasts, as well as, the results of field-scale feeding trials with Broiler chicks, laying hens and pigs. The long range effects of feeding on rats and the details of toxicological testing are covered. Excellent information is presented on the integration of protein plants with oil refineries and the economics of the manufacture of single cell protein and its utilization.

Dr. E. C. Hill's paper is concerned with the true deterioration problems of the oil industry. He describes the fuel contamination problem with particular emphasis on the survival of Cladosporium in fuel samples. Also mentioned is the problem of corrosion caused by bacteria and the spoilage of oil-water emulsions used in cutting operations. Some brief comments are made on the control of these problems.

The last technical paper by F. C. Webb deals with biochemical engineering. This is a new and exciting subject which is not well known by many microbiologist or engineers. His paper describes the concern of the biochemical engineer with utilization efficiency, mass transfer, and the chemical kinetics of enzyme catalysed reactions. The final portion of this paper outlines the potential for the production of useful biochemicals from hydrocarbon fermentations.

Each paper in this conference was followed by a question and comment period. Many pertinent questions are raised and answers provided which add to the formal content of the program. Dr. H. J. Bunker's closing address provides an overall view of hydrocarbon microbiology, its value to the petroleum industry, and its possibilities for the future.

This short (103 page) volume is indeed a valuable contribution to microbiology, the petroleum industry and persons interest to biodeterioration, as it deals with an important applied aspect of the ability of microorganisms to degrade natural materials. As a book on biodeterioration it demonstrates the positive aspect of biodeterioration, that is, the harnessing
of the microbe’s degradative ability to the production of valuable products from low value hydrocarbon stocks. The various sections are well written, clear and concise. It is recommended for the professional worker in the petroleum industry who should be aware of the microbe’s power and ability as well as the general student of microbiology and biodeterioration.

R. W. Traxler

MATERIALS PERFORMANCE AND THE DEEP SEA

This small book of 146 pages records the proceedings of a symposium presented at the 71st Annual meeting of the American Society for Testing Materials held in June 1968, and one paper presented by Dr. C. J. Wessel at a previous meeting of ASTM in January, 1968. This paper, while interesting in pin pointing sources of information relating to biodeterioration, has already appeared in print. Scientists have enough work to keep abreast with the present volume of literature without needless repetition.

Ten papers are presented but only three are concerned with biodeterioration. The first paper by J. S. Muraoka deals with the “Effect of deep-ocean environment on plastics” and is followed by Dr. J. Kohlmeyer’s paper on the “Deterioration of wood by marine fungi”. The latter includes a short section on bacteria. Both papers present original work and the latter shows how little is known of marine fungi in deep waters. It is a pity the opportunity was not taken to include an account of marine borers, along the lines of Dr. Kohlmeyer’s paper.

Each paper starts off with a short abstract and key words. Misprints are commendably few and the illustrations are generally good. This small book is a useful addition to the literature and clearly shows the need for further work in this field.

E. B. Gareth Jones

CATALOGUE OF MAIN MARINE FOULING ORGANISMS. VOLUME 4. ASCIDIANS OF EUROPEAN WATERS.
R. H. Millar.

This small volume of 34 pages includes 14 colour plates and gives a brief description of 21 species. The quality of the colour plates requires a high grade paper of some weight which sits uneasily in the metal strip binder. It promises a rather short life in normal laboratory use.

Dr. R. H. Millar gives a brief and clear introduction to the anatomy and biology of ascidians which, with his authority, could well have been made longer to explain such items as the compound oral tentacles mentioned in the key, and branchial folds. Oviparous and larviparous forms of reproduction are mentioned in single sentences, but a more detailed reference to the duration of swimming and speed of settlement could have relevance to the density of fouling populations.

Concerned with fouling organisms, the reader will naturally expect to find immigrant species treated, as indeed occurs with Styela clava and Symplegma viride. The title is in fact modified to include those found on ships coming into European waters, but this should not be held to justify the exclusion of species long established in the British and European fauna. The reviewer finds it surprising that Stylopsis (Dendrodoa) grossularia is not included; that Styela plicata and partita are distinguished but no reference is made to S. coriacea, and Molgula complanata is chosen to the exclusion of M. citrina.

For those who are handling problems of the identification of fouling organisms this volume will undoubtedly prove helpful, but the ascidians are a group of very variable appearance. This is due in part to the settlement of other organisms on their surface. In this circumstance the best of coloured plates cannot be more than an aid and is no substitute for accurate anatomical description and diagnosis. The text makes no claim to exhaustive treatment, but less experienced readers might be misled into thinking that ascidian identification is easy. They will be perplexed by finding that quite common species are not provided for in the key. At 31/- we feel entitled to expect more and the failure to provide any kind of reference to original detailed accounts severely limits the usefulness of this book.

A. R. Hockley

THE ACTINOMYCTES: A SUMMARY OF CURRENT KNOWLEDGE
S. A. Waksman

Professor Waksman’s comprehensive treatise on the actinomycetes (The Actinomycetes, Vols I-III, 1959-62) remains among the recognised standard reference books on these organisms. To accommodate some of the more recent information, on their classification and properties, Professor Waksman chose to condense the earlier three volumes and the more recent work into a short, comprehensive book which is the subject of this review. He does mention, in his preface, that an alternative approach would have been to bring together contributions from a number of experts actually working with these organisms to provide a more extensive and up-to-date coverage of the subject. After reading the book, the reviewer feels that this alternative was the one that should have been chosen.

The amount of new information included in this “Summary of Current Knowledge” is very limited and appears to have been added to previously summarised sections of the earlier volumes rather than used to
re-evaluate some of the observations and theories of earlier workers. This is particularly evident in the section on classification where old and new schemes for classifying the various genera and species are included without the arguments supporting the advantages of some of the newer schemes. The bias towards the earlier work on the actinomycetes is also reflected in the selected bibliography where it can be seen that almost 70% of the 500 papers listed were published prior to 1959.

The worker consulting this book for information on the activities of actinomycetes as agents of spoilage and deterioration will find the relevant nine line paragraph on the penultimate page. He will find far more information in the six page review article by S. T. Williams (Int. Biodetn Bull., 2(2): 125-133, 1966) on the role of actinomycetes in biodeterioration which also contains references to 59 original papers and books. Workers who are already interested in the actinomycetes will find little in the way of new information or ideas. Perhaps the student of microbiology will find the book a useful introduction to the actinomycetes but the style is not conducive to easy reading. It is unfortunate that this book does not fill the gap in the literature which exists for an up-to-date, readable and informative book on these interesting organisms.

T. Cross

A DICTIONARY OF MICROBIAL TAXONOMIC USAGE
S. T. Cowan
( Oliver & Boyd, Edinburgh, 1968. 118 pp. Price £2.2.0)

Taxonomy, and in particular microbial taxonomy, has recently taken on a new lease of life with many workers in the diverse fields of morphology, biochemistry, molecular biology and genetics, all making valuable contributions to the subject. A dictionary of microbial taxonomic usage such as this volume by Dr. Cowan is, therefore, a timely event. The entries cover a wide range, and, while biased somewhat towards the author's main interests, are on the whole satisfactory. Many of the entries contain more than just a cold, dry, bald definition, being accompanied by comments in which the engaging personality of the author comes through, and consequently one finds oneself, unlike with most dictionaries, reading page after page. Many readers will be amused, if not edified, by some of the definitions and comments, e.g. of "taxonomy," "taxonomist," "systematics" and "numerical taxonomy." Cowan disarms criticism when he states in the introduction that "a Dictionary of this kind cannot be impersonal and objective, but must reflect the character, bias and opinions of its author and a medical bacteriologist to boot." Undoubtedly, this bias is responsible for many of the Dictionary's deficiencies. Thus, there are some curious omissions. "Halophil," "psychrophil" and "thermophil" are defined, but not "osmophil" or "barophil"; "bacillus", "cocccus", "micrococcus" are entered but not "spirillum" or "vibrio"; "zoo", but not "zoogla", "swarm(ing)", "fluorescence" and "salt tolerant" are not synonyms; "acetobacters" even "in the lower case" are not just bacteria able to produce acetic acid. Similar remarks could be made regarding "psychrophil" and "psychrotroph"; "medium" and "substrate". The Delft Collection of the late Professor Kuyver contained many other important microorganisms, mainly bacteria, besides yeasts and the comment accompanying the definition of the NCIB is somewhat misleading. Indeed the comments on the other National Collections, apart from the NCTC, could have been expanded with profit.

It is unfortunate that repeatedly authors are mentioned without adequate references being given, e.g. Silvestri & Hill on page 13, Quadling & Martin (p.17), Stanier, p.79 and Eddy (1960) p.83.
The impact of genetics on taxonomy appears to have been given less attention than it deserves. Thus “genetics”, “allele”, “episome” and “DNA” are defined but not “cistron”, “gene”, “hybridization”, “operon” or “procaryotic”.

The potted biographies are so limited we doubt their usefulness, and if “Bergey” finds a place why not “Lehmann” & “Neumann” and even “Adanson”.

Despite these criticisms, some of which no doubt will be corrected in the next edition, this Dictionary should be read by most microbiologists, and all taxonomists will wish to have it constantly at their elbows.

M. Shewan
Chitin decomposition of soil. II. The ecology of chitinoclastic micro-organisms in forest soil. [Fungi, Bacteria, Actinomycetes.]

Chitin decomposition of soil. II. The ecology of chitinoclastic micro-organisms in forest soil. [Fungi, Bacteria, Actinomycetes.]

Biodeterioration in the leather industry. [Fungi.]

Biodeterioration in the leather industry. [Fungi.]

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