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Publisher's version / Version de l'éditeur:
https://doi.org/10.4224/40000827
Canadian Building Digest, 1970-04

Canadian Building Digest

Division of Building Research, National Research Council Canada

CBD 124

Biological Attack on Organic Materials

Originally published April 1970

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Please note

Biological attack may be defined as an assault by any living organism on an object either dead or alive. This is a wide-ranging definition that places no restriction on the type of attacker. The meaning of biological attack is generally confined to the activities of some of the lower forms of plants and small animals These. together with how they affect organic building materials, are discussed in this Digest.

Attacking Organisms

The lower forms of plant life that take part in biological attack include fungi, bacteria and algae. Both fungi and bacteria are non-chlorophyllous, which means that they cannot produce their own food from basic materials like carbon dioxide and water, but must obtain nutrients from more complex substances. The term microbe, which includes bacteria and fungal organisms, relates to the fact that magnification with a microscope is required in studying the individual. Mildew and mould are fungi whose colonies are generally visible to the naked eye. Fungi require air for life, but bacteria may be aerobic or anaerobic.

As algae contain chlorophyll, they can produce their own food. They do not attack organic building materials directly, but are unsightly when growing and may be a source of food for other organisms, which then attack the substrate.

In the animal kingdom all organisms must obtain their food in synthesized form. Some animals are adapted to a wide range of materials; others are extremely selective. Social habits, such as preparation of homes in which to rear the young, can frequently be a reason for attack on organic materials. Biological attack on land is generally considered to comprise only the actions of insects, rodents and birds. Insects, are the most varied and prolific living organisms. so that it is natural for their activities to range from beneficial to harmful, from the standpoint of man. Those that attack organic building materials include termites, ants, beetles, moths and weevils. The rodents most commonly encountered are rats, mice, woodchucks (groundhogs), porcupines and squirrels. Marine animals involved in biological attack are chiefly molluscs and crustaceans.

Reasons for Biological Attack

There are four basic reasons why a material may be attacked by one of the above organisms.

1. It may be a source of food. Although this might appear to be the most obvious cause, it is not always of greatest significance with building materials. Materials not normally considered susceptible may be attacked it they become impregnated with nutrients.
2. It may be a barrier to be penetrated in the search for food. This applies especially to building materials. It has been said that to get at food, rats and mice will gnaw through anything softer than the enamel of their teeth if it presents a gnawing edge.
3. It may not be resistant to a by-product of a life process. Most micro-organisms secrete enzymes that digest their food, and some bacteria produce chemicals as the end result of their life cycle. An example of the latter is sulphuric acid from a bacteria that feeds on sulphides. A building material may be degraded by these compounds even though the organism may not benefit from the reaction.
4. It may provide shelter or attachment during the life of an organism. There may not be any direct degradation involved in attachment, which is a prominent feature of the marine environment. Insects or rodents seeking a shelter generally cause damage by removing a material so as to have living space.

With gnawing animals there may be a fifth reason for attack on a material, i.e., the fact that it is there. Rodents must maintain their incisor teeth at a desirable length by wearing them away.

Conditions for Attack

Most living organisms grow and multiply best under a given set of conditions. Some are very specific in their requirements, but others are quite adaptive. Ideal conditions for many organisms are relatively similar: moderately warm temperatures. an oxygen-containing medium, a source of water, and an adequate supply of food. The more the environment departs from the ideal, the slower growth becomes until it eventually ceases altogether. The organism may then become dormant, as with chipmunks which hibernate and bacteria which form endospores (heat and drought resistant bodies within the cell). If the environment becomes hostile enough, death occurs.

In considering whether conditions are conducive to attack it should be noted that the environment in question is not the original undisturbed site but that prevailing after construction has been completed and the structure is in use. For example, excavation and back- filling markedly increase microbial activity in soil as a result of aeration and mixing of different layers.

Temperature

Bacteria, especially in the endospore form, are very resistant to temperature extremes. Their growth is usually arrested only by low temperatures, and moderately high temperatures (175°F) are required to bring about death. Fungi behave like bacteria but are less resistant to high temperatures. Adult insects are killed by both high and low temperatures, but survival in cold weather is ensured through the egg or larval form if the adults do not build a colony that is protected from low temperatures. It is not always appreciated that insects, through the heat given off in respiration. can moderately raise the surrounding temperature provided that conduction or convection losses are not high. The increase in temperature leads to greater activity so that there is an accelerating effect. Indeed, in moist grain the temperature can become high enough (45°C) to kill immature stages, which cannot retreat. Many rodents hibernate in winter; others build insulated nests or obtain entry into warm buildings.

Oxygen

Bacteria are the only organisms that do not necessarily require oxygen. Some need it to survive, some do not need it but can survive in it, and others are killed by oxygen. Almost all fungi require oxygen for growth so that its low solubility in water prevents them from growing more than a short distance below the surface of still water. For this reason wood does not rot when submerged in water. All animals require oxygen whether they obtain it from air or water.

Water

Bacteria generally require liquid water for growth; with fungi, high humidity is sufficient. Both become dormant without necessarily dying when the moisture content drops. Land animals require access to water at intervals but, except for termites, do not need high humidity to grow. Molluscs and crustaceans must live in a water environment, not so much for the water itself but because their oxygen-absorbing organs only function in water. Some are adapted to live in the tidal zone where they are exposed to air for several hours without injury.

Light

Light is indispensable for the continued existence of chlorophyllous plants, but is not immediately essential for the lower forms of plants or for animals. Preferences for the presence or absence of visible light may, therefore, vary greatly with the individual species in any one class involved in biological attack. Most fungi prefer subdued light but can grow in complete darkness; bright light can kill the mycelium, which is the network or mat of growing branches. This is why mildew is more prevalent on the north side of buildings. Many insects are indifferent to light but some prefer the night. Termites generally avoid light except during the mating flight. Many rodents are more active at night, not because light (per se) is injurious to them but because it makes them more visible to predators.

UV light of less than about 320 nm kills bacteria and fungi, and is therefore called biologically active UV. Sufficient amounts of such UV would also kill other living organisms because the energy in the radiation is strong enough to degrade the protein polymers from which animals are made and the cellulose polymers of plants. As discussed in **CBD 121** there is, fortunately, very little such UV received at the earth's surface.

Materials Subject to Biological Attack

The organic building products that are most attacked for food purposes are those that are made from or chemically resemble natural materials. In the ages during which life has existed on earth different organisms have evolved in such a way that they can live on the most readily available nutrients. Nutrition is pre-eminent; if ready availability were the only criterion, compounds of silica such as sand and granite would be the chief dietary items. Because living organisms are made from organic compounds, they must necessarily feed mainly on the compounds of carbon.

The most abundant organic material in nature is cellulose. Wood, which is composed of 40 to 50 per cent cellulose, is readily attacked by organisms adapted to utilize it, providing other conditions are right. Attack upon derivatives of cellulose depends upon how closely the compound resembles cellulose and whether the added chemical groups interfere with the process. For example, rayon and cellophane, both of which are regenerated cellulose, are susceptible to microbiological attack, but acetate rayon (cellulose acetate) has good resistance. Cellulose nitrate has poor resistance because the nitrate group also has nutritional value. Water soluble cellulose derivatives used to increase the consistency of latex paints are easily attacked and require preservatives to stop putrefaction from occurring in the can.

Similarly, materials containing natural fats and oils are sources of food. Thus, oil paints readily support the growth of mildew, natural rubber and leather are subject to microbial attack, and wool is susceptible to certain insects, fungi, and bacteria.

Completely synthetic polymers such as those used in plastics, sealants, and many coatings are not normally sources of food. Their chemical structure inhibits attack, and resistance is enhanced by their hardness, surface smoothness, and limited moisture absorption. This inertness applies chiefly to the pure polymer, which in practice is not usually used alone but contains additives such as plasticizers and stabilizers. It is possible, therefore, for a product to be attacked, even though the basic resin is immune, if compounds of nutritional value are present. Plasticizers containing fatty acid components are particularly susceptible but other types generally contain chemical groupings similar to those in natural oils. Consequently, the probability of attack increases in proportion to plasticizer content unless those which are inert

are used. Resins that are internally plasticized, i.e., the plasticizer is chemically bonded to the polymer chain, are less subject to attack than those that are simply physical mixtures. Natural organic fillers in plastics, such as wood flour or paper, also increase the danger of attack.

In an environment favourable to biological attack it is not sufficient simply to specify use of a polymer that is immune. It is also necessary to ensure that the final compounded product will be resistant to its service conditions. Strictly speaking, there is probably no material completely immune under all conceivable circumstances. It is nearly always possible to find some fungus or bacteria that will grow on a particular organic substrate.

Organic building materials are seldom subject to by-product attack, but almost all are susceptible to attack for the remaining reasons listed under Reasons for Biological Attack. This is particularly true if a material blocks a pathway to food. In the marine environment, inert materials usually become objects of attachment. To prevent assaults from either of these causes more than simple immunity is required: the material must be actively repellent to the organisms.

Methods and Examples of Attack

The actual mechanisms of microbial attack are little understood and even today there is not much basic research in this field. Most work is empirical, designed only to obtain a quick answer to an immediate problem. In general, it can be said that bacteria and fungi act at the molecular level. Their secretions break chemical bonds and degrade the molecules to fractions that can be assimilated by the organisms. Most secretions are solutions of enzymes and even when the secreting organism has died the enzymes may continue to function.

With animals, digestion of food usually occurs within the organism. The primary attack is physical at the structural level of the material, i.e., gnawing or boring. The magnitude of the impression made on the material is related to the size and numbers of the animal; rats will make bigger holes than weevils, but a colony of termites will cause more damage than a single woodpecker.

The most familiar examples of attack on building materials are fungal decay of wood and mildew of oil paints. Common types of mildew appear to be black and are sometimes difficult to distinguish from dirt collection. The simple chlorine bleach test is usually adequate for this purpose. With it organic fungus is decolourized and dirt is not. One fungus that sporadically causes trouble secretes a purple dye soluble in coating solvents and binders. Even after the fungus has been killed the dye remains and frequently bleeds through subsequent coats unless special sealers are used. Coatings based mainly on synthetic resins do not support growth of mildew, but latex paints may because the thickeners and emulsion stabilizers are often cellulose or protein derivatives. Preservatives used to stop bacterial putrefaction in the can are not necessarily effective against fungal attack on the dry film.

Wood decay, or the decomposition of wood by fungi, is of two main types referred to as brown rot and white rot (**CBD 111**). In the former, the cellulose and related compounds are decomposed but the lignin is unchanged. Hence, the wood darkens in colour and shrinks into cubes or oblong pieces. In white rot, all wood components are degraded and the wood becomes paler. Termites are not a danger to wood in Canada, except in Southern Ontario where isolated attacks have occurred.

As described earlier, plastics generally are not attacked for food purposes unless they contain nutritive additives. Only a few resins such as polyvinyl acetate and cellulose nitrate are reported to have inherently poor microbiological resistance. Most other polymers require protection, however, because of the addition of plasticizers, fillers, mold lubricants, anti-oxidants, heat stabilizers, UV absorbers and colorants. Soil burial is a severe service condition for plastics because of the complex mixture of solids, liquids, gases and living organisms of various sizes. Vinyl coverings on electrical cables have been attacked by everything from bacteria to chipmunks; and plastic films used to line irrigation ditches and earth dams have been pierced by muskrats. Algal growth on swimming pool liners is a serious problem. Vinyl

coated fabrics are subject to pink staining, which is not the result of direct attack on the vinyl but is the bleeding into it of a pink dye secreted by microbes feeding on the adhesive or the backing material. Shower curtains may display mildew growth which is really occurring on soap films splattered onto them, and plastics used for heat insulation may be attacked by warm blooded animals. The foamed type of plastic is usually hollowed out to form the shelter, and fibrous material may be taken away to line nests in other locations. Most plastics immersed in the ocean have shown little damage from microbes or borers, although they were subject to attachment. Half of the vinyl and nylon specimens tested by Bell Laboratories, however, were attacked by marine borers.

Sealants are not often the object of biological attack unless they are the only major barrier blocking access to the interior of a building. Even linseed oil putty seldom supports mildew because of its low oil content. Roofing materials made from asphalt or coal tar are also little affected. Moss or lichens may grow on them but without causing damage. Liquid- or film-applied synthetic roofings are manufactured from basically the same resins as are used in plastics or elastomers and behave in essentially the same manner. Except for ponding of water on flat roofs, conditions are not conducive to extensive biological attack.

Conclusion

This Digest has discussed the organisms responsible for biological attack, the reasons for it. the conditions that lead to it, and the organic building materials that are subject to it.

The qualitative prediction of deterioration through biological action is difficult because of the many factors involved and the variability of environmental conditions. The manufacturer is best able to provide the basic information relating to his product. Designers and builders must be aware of the nature and likelihood of biological attack in order that optimum selection and application of materials are achieved.