IEC 60721-2-7

Edition 2.0 2018-03

INTERNATIONAL STANDARD

Classification of environmental conditions –
Part 2-7: Environmental conditions appearing in nature – Fauna and flora

IEC 60721-2-7:2018-03(en)

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INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

ICS 19.040

ISBN 978-2-8322-5483-7

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

CLASSIFICATION OF ENVIRONMENTAL CONDITIONS –

Part 2-7: Environmental conditions appearing in nature – Fauna and flora

FOREWORD

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International Standard IEC 60721-2-7 has been prepared by IEC technical committee 104: Environmental conditions, classification and methods of test.

This second edition cancels and replaces the first edition published in 1987. This edition constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

a) This edition has been entirely rewritten.

The text of this International Standard is based on the following documents:

CDV	Report on voting
104/741/CDV	104/792/RVC

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts in the IEC 60721 series, published under the general title *Classification of environmental conditions,* can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

CLASSIFICATION OF ENVIRONMENTAL CONDITIONS –

Part 2-7: Environmental conditions appearing in nature – Fauna and flora

1 Scope

This document addresses the occurrence of fauna and flora, including its main effects on electrotechnical products. Exposure and damage from the effects of fauna and flora can occur at almost any time in a product's life cycle. Moreover, there are many agents of attack with various actions.

This document addresses the occurrence and damage arising from fauna and flora in all locations a product can be stored, transported or used. Generally, fauna can be present and cause damage to products in both the natural environments experienced in open-air locations as well as in artificially created environments, such as in a warehouse or building. However, flora will predominantly be present and cause damage to products only in open-air locations. Fungus and bacteria can be present in both open-air locations as well as in warehouses or buildings.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

4 General

The main attacking agents considered in this document are micro-organisms including fungi, bacteria, as well as insects, rodents, algae and marine organisms. Hazards due to other agents are considered to be of lesser importance and have been omitted. These include the corrosive action of juices secreted by some plants, the mechanical action due to the growth of the larger trees, which may be sufficiently great to destroy the foundations of a building or to break cables, and the damage caused by animals such as monkeys and elephants. Birds in flight can be a hazard to aircraft, and in the region of bird colonies, widespread droppings can create corrosion problems. In addition, some agents which are mentioned have other modes of action which have not been included; for example both rodents and insects are occasionally responsible for chemical corrosion or soiling.

The frequency of occurrence of fauna and flora with a possibility of damaging products very much depends on conditions of temperature and humidity. In geographical areas with warm damp climates, fauna and flora, especially insects and micro-organisms such as mould and bacteria, will find favourable conditions of life. Moreover, humid or wet rooms in buildings, or rooms for processes producing humidity, are suitable living spaces for rodents, insects and micro-organisms.

Fauna and flora can affect products in various ways, the most important of which are given in the following examples.

a) Deterioration by physical attack: The functioning of products may be affected by physical attacks of fauna and flora. The materials of a product may be attacked by fauna, particularly by rodents and insects, by the actions of feeding from material, gnawing at material, eating into material, chewing material or cutting holes into material. The severe damage arising from the physical attack by termites is especially emphasized in this respect. Among materials susceptible to attack are natural materials such as wood, paper, leather, textiles, but also plastic materials, including elastomers and even some metals such as tin and lead.
b) Deterioration by deposits: The functioning of products may be affected by deposits originating from fauna and flora. These surface deposits affect the products by chemical and mechanical reactions. Deposits from fauna, especially from insects, rodents, birds, etc., may consist of elements such as the presence of the animal itself, the building of nests or settlements, feed stock as well as the metabolic products such as excrements, enzymes. Deposits from all kinds of flora may consist of material such as detached parts of plants (leaves, blossom, seeds, fruits, etc.), growth layers of cultures of moulds or bacteria and effects of their metabolic products.

5 Occurrence of fauna and flora

5.1 Fungi

5.1.1 Background

The name fungus is used to denote members of a large heterogeneous group of organisms, of which there are about a hundred thousand known species. Most fungi are so small that they can be observed only with the aid of a microscope. The terms 'mould' and 'mildew', although not exactly defined in the biological sense, are used by both biologists and laymen to refer to small non-parasitic fungi, such as those which do not live on other living organisms.

A fungus can, in general, be divided into two parts: the vegetative and the reproductive. The vegetative part, known as the hypha, is essentially a threadlike filament normally having a diameter between 2 µm and 20 µm and may be several centimetres long. In the simplest fungi the hyphae are merely continuous tubes of living matter; in others they are divided by cell walls, called septa, into separate cells. Collectively the hyphae are referred to as the mycelium. The mycelium, together with the reproductive spores, is commonly observed on mouldy bread, shoes, oranges, etc.

In the vast majority of cases the unit of reproduction is the spore. Normally it is unicellular and microscopic, though occasionally, giants 500 µm in length occur. They may be produced directly via the hyphae or from a structure created for this specific purpose, as in the mushroom. From a functional viewpoint spores may be divided into two classes each of which may be produced by the same organism: those which can be produced rapidly and in large numbers but have little resistance to adverse environmental factors, and those which are comparatively few in number but much more resistant to adverse conditions. The former enable the fungus to spread rapidly during good growing conditions and the latter enable it to survive hard times such as winter or drought and have been known to survive for many years in a dry condition.

5.1.2 Growth and survival factors

In order to adapt themselves to changes in their environment or food supply, most species of fungi can slightly change their characteristics and needs over several generations. This may be a very short time; in many cases the whole cycle from spore to spore can be completed in a few days. In addition, it should be noted that the conditions required for the production and dispersal of spores are generally more exacting than those for growth and survival.

The precise minimum, maximum and optimum temperatures for growth appear to be a matter of debate between the various authorities. This may be because these values vary from one species to another. However, in general, the minimum is 2 °C to 5 °C, the maximum 40 °C to 50 °C and the optimum 22 °C to 27 °C. In addition, there are a few fungi that can grow at and below 0 °C, and one species has been reported growing at a maximum of 62 °C. They are, of course, capable of surviving even greater extremes in a quiescent state.

The optimum humidity for the growth of nearly all moulds is a relative humidity of 95 % to 100 %. If submerged in water, however, most fungi will not grow. Any reduction from this optimum will mean a reduced growth rate and few species will grow in a relative humidity of less than 70 %. Optimum growth conditions also occur in still air.

A suitable source of carbon that can be absorbed as food is essential to fungi for their growth. Almost all naturally occurring carbon containing compounds, together with many synthetic organic compounds of a similar structure can be used by fungi as a source of food. All fungi can utilize an organic supply of nitrogen and a few can also use an inorganic source such as ammonia. Nitrogen, other than as a gas, is essential for the growth of fungi.

Most fungi are strictly aerobic, that is they cannot grow in complete absence of free oxygen. In the small number of cases where fungi grow in water, they always do so in a few centimetres near the surface.

Other elements required for the growth of fungi include sulfur (as sulfate), potassium, phosphorus (as phosphate) and magnesium. In some cases minute traces of iron, zinc, manganese, molybdenum, or calcium are required, though in such small quantities that only in a few fungi is there a clear picture of these requirements. Some fungi also require a supply of certain vitamins for growth.

Ultra-violet is known to inhibit the growth of most fungi, although daylight normally has no effect. In a very few instances daylight can influence growth and indeed can cause it to increase. However, the production and dispersal of spores is dependent upon the presence of light for many species.

Most fungi grow best in a slightly acid medium within the range pH 5 to pH 6,5. This varies from one species to another, but few will grow at all below pH 3 or above pH 9.

5.1.3 Habitat and geographical distribution

Since fungi can survive adverse growth conditions in a quiescent state and can gradually evolve to survive more extreme conditions, and since new species are still being identified, it is not possible to define exactly the geographical areas in which fungi will grow. There are, however, certain tendencies which are relevant.

Fungi of one sort or another are found in the soil, water and air over a large part of the earth's surface, whilst others live on or upon both living and dead animals and plants. Those found in the air do not grow there, but are in the form of spores. Most live in the soil and only about 2 % live in water; in both cases they grow in the few centimetres just below the surface.

The best conditions for most types of mould growth are in humid tropical areas, although deterioration due to mould is not confined to the tropics. Equally serious damage can occur in temperate regions, though not so rapidly, and at least one species of mould is often found in the form of spores in the air over arctic regions.

Conditions favourable for mould growth may easily be created artificially inside a building or equipment. Those which are parasitic upon particular animals or plants are among the few which are restricted to geographical regions.

The map in Figure 1 shows areas in which climatic conditions are most favourable for fungal corrosion. It is based on an analysis of relative humidity and temperature data from approximately two thousand meteorological stations throughout the world, as follows:

a) Region A – includes areas with at least one month a year in which the mean monthly relative humidity is from 70 % to 75 % in the hours from 12:00 h (noon) to 14:00 h, and with a mean monthly minimum temperature at the same time of not less than 15 °C.

b) Region B – includes areas where the equivalent relative humidity is from 75 % to 80 %, again with the same temperature as Region A.

c) Region C – includes areas where the equivalent relative humidity is greater than 80 %, again with the same temperature as Region A.

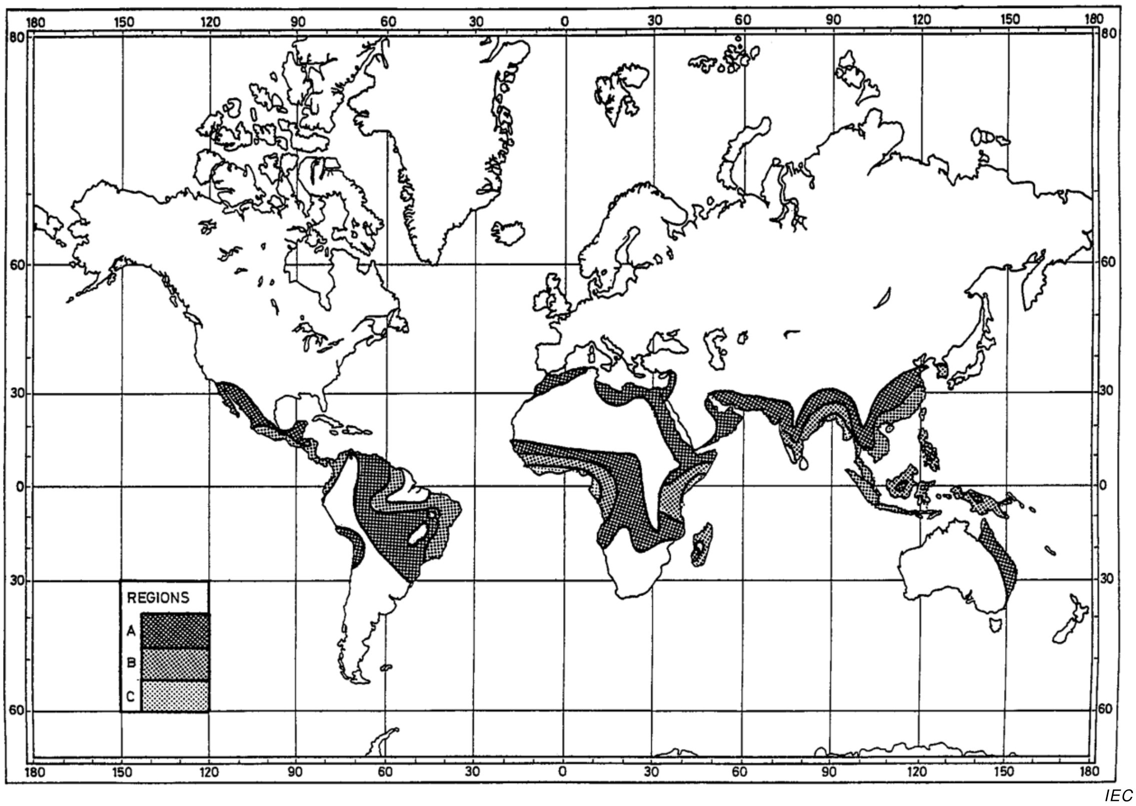

Figure 1 – Map of regions with different degrees of fungal corrosion

It should be noted that the above climatic conditions do not take account of other naturally occurring factors mentioned earlier, such as air flow. It also does not cover cases where favourable conditions may be artificially induced, inside buildings or containers for example. Nevertheless, within these limits, it does provide a useful indication of the natural liability to attack by micro-organisms.

5.1.4 Effects of fungi on materials

Unlike most plants, fungi contain no chlorophyll, the green colouring matter with which plants utilize the sun's energy to manufacture their food from absorbed raw materials. Thus they have to rely on the food in the substratum on which they grow. However, the structure of the cell walls only allows them to absorb this food if it is in solution. To achieve this, the fungi secrete enzymes via their hyphae. This substance converts the food into a soluble form which can then be readily absorbed.

There are three ways in which fungi may cause damage. Each can occur independently, or in association with one or both of the others:

1) A material may be a food for the fungi, in which case the material is gradually eaten away.
2) The waste products of fungi are excreted as juices, many of which are corrosive and cause damage to the substrate on which the fungi are growing. Thus it is possible for fungi to damage a material even though it is not a source of food. For example the minute impurities in finger prints on glass have been known to support growths whose corrosive waste products have etched the surface of the glass. In addition, the mould coating has the effect of retaining moisture and retarding the drying-out process.
3) Fungus may hinder the efficient operation of equipment, even though it has not caused damage to any material part. Examples of this are soiling in optical equipment, or the formation of undesirable conducting paths in electrical equipment.

The preferred method for controlling fungus growth is by the selection of fungus inert materials. Also acceptable is the treatment of potential fungus nutrient materials or by hermetic sealing. Table 1 lists materials which have a known resistance to fungus growth, whilst Table 2 lists those materials which are potential fungus nutrients.

Table 1 – List of fungus resistant materials

Acrylics	Polycarbonate
Acrylonitile-styrene	Polyester
Acrylonitile-vinyl-chloride copolymer	Polyester-glass fibre laminate
Asbestos	Polyethylene, high density (> 0,94)
Ceramics	Polyethylene terephthalate
Chlorinated polyether	Polyamide
Fluorinated ethylenepropylene copolymer	Polymonochlorotrifluorethylene
Fluorocarbon	Polypropylene
Glass	Polystryrene
Metals	Polysulfone
Mica	Polytetrafluoroethylene
Plastic laminate: silicone glass fibre	Polyvinylidene chloride
Plastic laminate: phenolic-nylon fibre	Silicone resin
Diallyl phthalate	Siloxane-polyolefin
Polyacrylonirile	Siloxane-polystyrene
Polyamide	

Table 2 – List of potential fungus nutrient materials

ABS (acrylonitrile-butadiene-styrene)	Polyethylene, low density (< 0,94)
Acetyl resins	Polymethyl methacrylate
Cellulose acetate	Polyurethane (ester types are particularly susceptible)
Cellulose acetate butyrate	
Epoxy-glass fibre laminates	Polyricinoleates
Epoxy-resin	Polyvinyl chloride
Lubricants	Polyvinyl chloride-acetate
Melamine-formaldehyde	Polyvinyl fluoride
Organic polysulphides	Rubbers, natural and synthetic
Phenol-formaldehyde	Urea-formaldehyde
Polydichlorostyrene	

A number of materials have a known susceptibility to damage by fungal growth. A number of these are set out below.

a) Wood: Wood in contact with the ground is particularly prone to decay by fungi. If, however, it is kept off the ground in a dry, well ventilated place it is much more resistant, and if the wood contains less than 20 % water it is not attacked at all. Resistance to attack varies from one species to another, and heartwood is always less liable to attack than sapwood. In use, wood is normally coated or impregnated in some manner. This may modify its resistance to fungal attack. Many fungi cause very little mechanical damage to the wood on which they live but are found to discolour it.

b) Paper and cardboard: Paper, cardboard, and similar products are all susceptible to attack. The basic constituent, cellulose, is affected as well as other substances used during manufacture such as starch, gelatine. The effects are generally revealed as patches of surface discolouration, followed by complete disintegration of the paper. However, mould growth occurs after moisture pick up, and its damaging effects are often considered to be second to those of moisture.

c) Paints and varnishes: Paints and varnishes are made of a complex mixture of oils, cellulose derivatives, solvents, plasticizers, thinners, etc., some of which may be susceptible to attack. Almost all paints will support mould growth under favourable conditions. A few are resistant, but others have been known to support mould even in cold storage rooms. The liability of a paint or varnish to attack is dependent on the type of substance and surface on which it has been placed, and upon climatic conditions, such as sunlight, moisture.

d) Natural cellulose fibres: Natural cellulosic fibres such as cotton, sisal, hemp, flax and jute are all highly susceptible to attack, although protein fibres such as wool and silk are not quite so liable.

e) Synthetic fibres: Synthetic fibres show some variation in their resistance, but are generally superior to natural cellulosic fibres. Fibre forms of cellulose acetate, regenerated protein, polyamides, polyesters, polyacrylonitrile, polyvinylidene chloride, vinyl chlorideacrylonitrile copolymers, vinyl chloride-vinyl acetate copolymers, and glass all have excellent resistance or are inert to fungi. Fibres may have pigment added or be coated, and synthetic fibres may have other additives which can support growth (see also item g) below). In use, when these fibres are in the form of a cloth or cord, they can easily hold moisture and impurities which will nourish moulds.

f) Leather: Tanned leather generally has hygroscopic substances on its surface, such as dextrin, starch, glycerine or sugar, which is often used for dressing, and may support mould growth. Similarly, greases, oils and emulsions used for lubricating leather may also support mould growth. In general, chrome-tanned leather is more resistant than vegetable tanned leather. Mould rarely directly attacks the leather to any significant extent, even when a profuse growth is found on its surface. However, if leather is exposed to mould for protracted periods, enzymes secreted by mould will tend to digest fats, sugars and carbohydrates in the leather, releasing various organic acids. Over time, these acids may react with vegetable tannins producing signs of physical deterioration including loss of strength and surface cracking.

g) Plastic and rubber: Plastic and rubber materials are not subject to deterioration in quite the same manner as other materials such as wood. They nearly always contain one or more additives for example, a plasticizer to reduce the natural brittleness of the plastic, resin to increase the rigidity, pigments for colouring, fillers, stabilizers, etc. Each one is added for a specific effect on the final product and each has a different effect on the final resistance against attack. Hence, to predict the resistance of a given plastic or rubber requires knowledge not only of the material, but also of all its additives, which may constitute as much as 50 % of the total. In certain circumstances moisture rather than mould will contribute to the deterioration of a plastic material, and since it is not possible to have mould growth without the presence of moisture, there is some controversy about which factor contributes most. From investigations it is clear that a given plastic may not support the growth which is found on it, but is merely holding impurities on its surface which nourish the mould, without damaging the plastic itself.

h) Glass: Glass is not a source of food, but its surface is readily covered with moisture to which organic particles will adhere. This favours mould growth which in turn soils and may even etch the surface, thus affecting the efficient use of optical instruments. In addition, Canada balsam which is often used to cement lenses together is also susceptible.

i) Other materials: Other organic materials likely to be attacked include most foodstuffs, adhesives, glues, inks, etc. There are also reports of deterioration of some hydrocarbons, especially jet fuels; in this case the fungi are found in association with bacteria, and the precise manner of deterioration is not clear. The metabolic products of cladosporium resinae, the 'kerosene fungus' that grows at the jet fuel/water interface, are corrosive to aluminium alloy fuel tanks.

5.2 Bacteria

5.2.1 Background

Bacteria are found in a variety of shapes and forms. They are generally unicellular organisms, between 0,5 µm and 10 µm in length and 0,3 µm to 2 µm in diameter. Some species of bacteria can move and possess flexible hair-like projections which enable them to do so, whilst others are carried along in the medium in which they grow. Protection is afforded in some cases by a gelatinous sheath or capsule, but in others this is absent.

A mature cell may reproduce by simply dividing in two. Later these two may divide again and so on at intervals as small as 15 min. Many bacteria can also produce spores. However, unlike the fungi, these spores are produced inside the bacterial cell, with normally one spore per cell. These spores are more resistant to heat and drying than ordinary cells, and they have been known to survive for many years in a dry state.

5.2.2 Growth and survival factors

As a consequence of their minute size, similarity of action to fungi and their association with the same environments, some of the properties and actions of bacteria have not been isolated or fully identified. In addition, bacteria can evolve and adapt themselves to new conditions.

Bacteria are less sensitive than fungi to temperature. The extreme growing temperatures are a matter of debate but generally the range is from -3 °C to +75 °C. Like fungi, they can also survive even greater extremes in the quiescent state. Optimum growth temperatures are generally higher than for fungi. They normally require the presence of water for growth and can flourish even when submerged in water. Consequently bacteria are found growing in conditions that are wetter than for most fungi.

Many bacteria can make use of carbon only when supplied in an organic form. However, others can grow in a medium devoid of organic material and make use of carbon dioxide as their source of carbon. Various bacteria can utilize organic and/or inorganic sources of nitrogen. Some bacteria are aerobic, others are anaerobic and will grow only in the absence of oxygen, whilst others can live either with or without oxygen.

Some vitamins and associated compounds have proved necessary to all bacteria, whilst others are found to be required by only one or two species. Those bacteria which can grow in media devoid of any organic materials obtain their energy requirements from the oxidation of inorganic compounds such as ammonia, various compounds of sulfur and some compounds of iron.

Most bacteria are active in the range of pH 6 to pH 8, but they can survive both higher and lower pH values.

5.2.3 Habitat

Bacteria occur in soil, in natural bodies of water, in the air and internally as causal agents of diseases in animals and plants. Most live in the soil, generally in wetter and slightly more alkaline conditions than fungi, and are capable of surviving greater extremes of environment.

It is not possible to define exactly in which geographic areas bacteria will grow, and only those which are parasitic upon particular plants or animals are at all restricted geographically.

5.2.4 Effects of bacteria on materials

Like fungi, bacteria possess no chlorophyll and secrete enzymes to digest food into a soluble state before absorbing it through their cell walls. Also like fungi, they can evolve and adapt themselves to new conditions.

Bacteria are generally too small to impair the operation of equipment. They can, however, utilize a material directly for food and thus damage it. In addition, they can cause corrosion when obtaining their energy from chemical reaction or by their waste products. They mostly live in the soil near the surface, and it is here that they can cause most damage. Even so, it is generally considered that in most cases more damage is caused by fungi than by bacteria.

Wood, leather, paper products and most associated materials, for example finishes, glues, are all liable to bacterial attack in varying degrees. Natural fibres, of both animal and plant origin are attacked by bacteria. The effect on synthetic fibres is not clear, although it appears to be similar to that due to fungal attack, that is, viscose rayon, cellulose nitrate and a few others are prone, but generally they are rethiobasistant. Most paints and varnishes are attacked by bacteria and so are some rubbers and plastics. However, deterioration of these latter generally occurs only in some specialized circumstances, as when permanently submerged in water. As with fungi, it is often one of the many additives which are attacked, rather than the basic material itself. Petroleum fuels and insulating oils are among the hydrocarbons which are deteriorated by bacteria.

Bacterial attack is generally first noticed as a discolouration of the material concerned. In some instances, however, such as insulating oils and the rubber-covering of cables, low insulation resistance is often the first indication.

Bacterial corrosion is the term used to describe corrosion due to bacteria obtaining their energy requirements from chemical action and to bacterial waste products. In these cases the materials are not used as food. Ferrous metals are most liable to this method of corrosion, but there are examples of attack on stone, rubber and non-ferrous metals. The organisms induce a chemical reaction, for example oxidation, and use the chemical energy thus liberated. Although this means of corrosion is almost exclusively bacterial, it is occasionally applicable to mould.

Bacterial corrosion may be one of the following types:

a) Corrosion due to acid formation:
   i) One of the main forms of corrosion is attributable to the oxidation of inorganic sulfur compounds to sulfuric acid by the members of the thiobacillus species. These are fairly common in soil and water. In the process, they generate and can survive in solutions of up to 12 % sulfuric acid. Iron and concrete pipes, buildings and vulcanised rubber are among objects thus corroded.
   ii) Another form of corrosion is caused by oxidation of iron pyrites to sulfuric acid by the ferrobacillus species. These are often found in association with thiobacillus. Ferrobacillus is responsible for the problems arising from acid water in gold and bituminous coal mines corroding pumping machinery.
   iii) Moulds of cellulose bacteria, which ferment cellulosic material to organic acids, cause corrosion known as 'phenol corrosion'. This can lead to the etching and pitting of stored or buried lead and other cables and also of the paper or other cellulosic materials within.
b) Corrosion at neutral pH values:
   i) Corrosion is often brought about by cathodic depolarization, attributable to bacteria containing an active hydrogenase. This type of corrosion is complex and its exact mechanism is still a matter of debate, but there is no doubt that the sulfate reducing bacteria are the cause. They are anaerobic, are commonly found in waterlogged soil or water and some of them survive and flourish at temperatures around 40 °C. They have been responsible for the corrosion of iron and steel in waterlogged soils, electrical transformers, hot water systems, etc.
   ii) Corrosion often occurs following differential aeration caused by the different seasonal water levels found in flood water pipes, and is attributable to deposits formed by iron bacteria and other micro-organisms. These form insoluble or partly-soluble products that can adhere as films or tubercles to metal surfaces such as the inside of metal water supply pipes.
   iii) Another form of corrosion is due to bacterial metabolism. Certain bacteria produce chemicals simply as the waste product of their digestive systems. These may be corrosive and yet are not acids of the type discussed previously. Corrosion, of this form, can occur remotely from the site of bacterial growth; for example the copper heaters and valves in a high-pressure steam unit showed sulfide corrosion, although the ambient temperature was between 120 °C and 175 °C. The corrosive material was hydrogen sulfide, formed by bacteria growing in the cooler water of the reservoir at the expense of sulfite used to de-oxygenate the boiler water.

Corrosion may also occur because of the loss of a protective coating which has provided food for the bacteria. Examples are the removal of asphalt, waxy, or polyester coatings by bacteria in the soil. In addition, corrosion may be increased by the joint action of several of the different types of bacteria in the same area.

5.3 Insects

5.3.1 Background

There are more than half a million different kinds of insects, with a wide range of eating habits and behaviour patterns. Hence many articles made from materials of animal or vegetable origin, and synthetic materials of a similar structure, are damaged or destroyed by insects. Unlike micro-organisms, the predominant method of attack is mechanical.

Two categories of damage can be distinguished. The first concerns damage by insects to indigestible materials which are used in building nests, etc., or form a barrier between the insect and its goal, or which are damaged in their search for food. The second concerns damage to materials used as food: wood, paper, rayon and other cellulose derivatives, for example.

The life span of the insects considered here is from two months to twenty years. They may be destructive in the larval stage or the mature stage, or sometimes in both.

5.3.2 Habitat

Most of the destructive insects are restricted geographically by the availability of their natural food. However, as most forms of life grow more profusely in the tropics, it is here that insect damage is greatest.

Species of termite confined mainly to the tropics are generally considered to be the most destructive of all insects. Other insects mainly confined to tropical areas include mud wasps, woolly bears, carpenter bees and certain species of beetles, moths, ants and spiders, although strictly spiders are of the Arachnida class.

Insects considered to be more universal in their distribution include cockroaches, crickets, grasshoppers, clothes moths, powder-post beetles, carpet beetles, hide and skin beetles, silverfish, ants, wasps, and insects attacking stored grain and cereals and other foods. In most cases the home of the insect is inside the material which it attacks.

5.3.3 Effects of insects on materials

Liability to attack by insects is greatest on the ground, in the ground, or in buildings in which there is poor drainage or poor ventilation, or unhygienic conditions. Materials, of animal or vegetable origin, which may be attacked by insects, include the following:

a) Wooden products are particularly subject to attack by termites, which use the cellulose for food, and by powder-post beetles whose larvae feed on wood. Damage caused by both of these insects can be severe in tropical regions.
b) Paper is attacked by many insects, particularly termites, cockroaches, silverfish and bookworms.
c) Textiles and cordage may be damaged by many insects including clothes moths, woolly bears, silverfish, etc.
d) Leather products are attacked by termites, hide and skin beetles and carpet beetles, etc.

Generally, materials which are not of animal or vegetable origin are rarely attacked by insects, unless they bar the way to food. For example, red ants and termites can penetrate most plastics and rubbers if they form a barrier between the insect and a source of food. However, such materials rarely form a source of food in themselves. Indeed, the only plastic not attacked during a series of tests, was cellulose acetate. Similarly, paints and varnishes may be attacked by termites, if they bar the termites from a source of food.

5.4 Rodents

5.4.1 Background

Of the many forms of mammals in the world which cause damage, rodents are the most common. They vary in size from the small 15 g mice to the large field rodents of 5 kg or more. All possess chisel-like incisor teeth especially adapted for gnawing, and the damage thus caused is usually the result of their search for food or nesting material. They are found in all parts of the world, even in arctic regions.

5.4.2 Effects of rodents on materials

A wide variety of materials are subject to damage by rats, mice and other rodents. They can ruin textiles by their droppings and urine, or by shredding the cloth for nesting. They may gnaw holes in wooden, cardboard or plastic packing cases, exposing the contents to attack by moisture, insects, moulds and bacteria. In their search for shelter, rodents may undermine foundations, or ruin the insulation of buildings, refrigeration units and electrical cables.

Whilst there is agreement that, under duress, rodents will attack most of the softer materials and even some metals in their search for food, there is no agreement on whether the plastics, paper, wood, etc, are attacked as a source of food.

5.5 Algae and marine organisms

5.5.1 Algae

Algae are rudimentary members of the plant family, and unlike fungi contain chlorophyll and are capable of photosynthesis. The form of the algae can vary considerably from unicellular to complex multicellular. Their methods of reproduction can also vary, being both asexual and sexual. They occur in fresh and salt water, in and on the soil, and in moist places varying from snow and ice to hot springs. Variations in size cover a range from a few micrometres to greater than thirty metres.

5.5.2 Borers

There are two types of borers, the molluscan borers and the crustacean borers. In the former, the animal head or entire body is enclosed in a bi-valve shell which has become a cutting tool. In the latter, boring is accomplished by means of a strong pair of mandibles.

Borers spread by swimming, which can only be done during their larval stage; this varies in duration from a day to a week. Their destructive life begins after this stage. In some waters the attack is most destructive between the tide levels, whereas in others it is most destructive at a depth of 9 m to 12 m or more, or at the mud line. They do not grow in strong currents. In the tropics their destructive action may be several times that found in temperate waters, but they flourish even within the Arctic Circle.

Borers are found mainly in salt water, though some species thrive in fresh water. They live primarily on wood, where they can cause severe damage. They can penetrate the insulation of electrical cables and some protective armouring. The caulking on the bottom of wooden boats is attacked and occasionally they bore through clay, sandstone, shale, marble and inferior concrete.

5.5.3 Fouling organisms

Fouling organisms include barnacles, seaweeds, corals, sea anemones, sea squirts, clams, oysters and mussels.

Some of these provide an environment in which bacteria flourish and cause corrosion, such as dead organisms trapped by barnacles on ships' hulls. Various forms of fouling are found in all parts of the world.

Fouling organisms can produce very serious problems wherever they are encountered. They attach themselves to both wooden and metal hulls of ships, and can raise the cost of driving the ship by between 25 % and 30 %. Another form of damage is in their growth inside inlet pipes, from the sea or fresh water, to cooling systems. In addition, they can penetrate coatings of pitch, etc., and in so doing trap dead matter giving rise to bacterial corrosion.

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