

MICROBIOLOGICAL CONTROL & TESTING
IN
COMMERCIAL & INDUSTRIAL WATER SYSTEMS

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MICROBIOLOGICAL CONTAMINANTS

By definition, microbiology is a branch of science that deals with living microscopic forms of plant and animal organisms.

Micro-organisms are widely distributed in nature, being present in streams, rivers, lakes, air, soils, crude oil, foods, decaying organic matter, as well as human and animal bodies. Their most useful activity consists of restoring the natural balance of life cycles wherever these cycles are disturbed. As long as these microscopic life forms remain isolated in single cells, they present no problem. However, when the balance of nature is disturbed, ideal places are provided for microbiological breeding and growth.

The forms of microbes which affect the operation and integrity of commercial & industrial water systems consist of algae, fungi, and bacteria.

Algae are forms of plant life which contain chlorophyll. They produce their own food from air, sunlight, and water. They will not grow in the absence of any one of these essential necessities of their life. Consequently, their presence is restricted to open cooling water systems.

MICROBIOLOGICAL CONTAMINANTS (continued)

The three main groupings of algae consist of the diatoms, the green, and the blue-green algae. The appearance, as well as the pH & temperature which favor the growth of each algae type are presented in Table 1 below.

Table 1: Characteristics of Algae

<u>Type</u>	<u>Appearance</u>	<u>pH</u>	<u>Temperature (F)</u>
Diatoms	brown	5.5-8.9	64-96
Green	green	5.5-8.9	86-95
Blue-green	blue-green	6.0-8.9	95-104

Fungi are forms of vegetable or plant life that do not produce chlorophyll. They can not produce their food by photosynthesis as do most plants. Wood destroying varieties of fungi obtain their food through enzyme action, converting the cellulose in the wood to soluble materials they can absorb. Fungal attack may be concentrated in the inner sections of the wood, in which case it is referred to as "deep rot", or it may be concentrated on the outside surfaces of the wood, in which case it is referred to as "surface rot".

BIOLOGICAL CONTAMINANTS (continued)

two main groupings of fungi consist of the filamentous fungi or molds, and the yeasts. Both of these fungi forms require moisture for their growth, but they do not generally grow under water because they require atmospheric oxygen. Therefore, fungal growths are usually only encountered above water line on the wood components of cooling towers. appearance, as well as the pH & temperature which favor growth of each fungi form are presented in Table 2 below.

Table 2: Characteristics of Fungi

<u>Type</u>	<u>Appearance</u>	<u>pH</u>	<u>Temperature (F)</u>
Filamentous Mold	black, tan, blue-yellow, green, white, tan, pink, brown	2-8	32-100
Yeast-like	leathery or rubbery growths, usually pigmented	2-8	32-100

BIOLOGICAL CONTAMINANTS (continued)

Bacteria are forms of animal life which occur as a single cell, in pairs, or in larger groups. Some types require air for survival, whereas other types grow only in the absence of air. They will grow in any water that contains nutrients in the form of organic matter or certain inorganic salts. Therefore, bacteria are found in most locations of industrial and commercial water systems. The characteristics of some bacteria types are presented in Table 3 below.

Table 3: Characteristics of Bacteria

<u>Type</u>	<u>Problem</u>	<u>pH</u>	<u>Temperature (F)</u>
Aerobic capsulated	forms slime	4-8	50-158
Aerobic spore forming	forms slime	5-8	50-158
Aerobic sulfur	sulfides converted to sulfuric acid	0.6-6	50-158
Anaerobic sulfate reducing	forms H ₂ S	4-8	50-158
Iron	forms slime	7.4-9.5	50-158

CORROSION DUE TO MICROBIOLOGICAL ACTIVITY (continued)

A typical concentration cell is formed when oxygen, iron, and water are present in the same environment. At the anode, metal ions dissolve at certain points on the metal surface to form ferrous ions and electrons. The ferrous ions are then converted by oxidizing agents, first to ferrous hydroxide, $\text{Fe}(\text{OH})_2$, and then to ferric hydroxide, $\text{Fe}(\text{OH})_3$. To preserve electrical neutrality, the electrons left in the metal by the anodic dissolution of iron must be consumed by other reactions. These reactions occur at points on the surface called cathodes. The H^+ ions in the water will react with and remove the electrons, making room for additional electrons formed by the breaking away of additional metal ions. Equilibrium is attained at the cathode surface as a result of the low solubility of H_2 in water. This equilibrium can be upset by the removal of either atomic hydrogen or molecular hydrogen. If equilibrium is maintained, the atomic hydrogen forms a thin coating or layer over the cathodic area. This coat of atomic hydrogen prevents the electrons from leaving the metal and thus stops the corrosion process.

CORROSION DUE TO MICROBIOLOGICAL ACTIVITY (continued)

Unfortunately, the atomic hydrogen is easily removed either by direct combination with other chemicals in the water or indirectly by first forming molecular hydrogen.

The formation of the atomic hydrogen layer is called polarization. Depolarization is the removal of the hydrogen layer. It is by way of cathodic depolarization that sulfate reducing bacteria cause corrosion problems.

Concentration cells are formed by slime deposits on metal surfaces. These cells are of particular interest because micro-organisms can change the concentration of ions in their immediate environment, which may have a pronounced effect on corrosion.

Oxygen concentration cells are a special case of concentration cells in that oxygen depolarizes a metal surface by the removal of hydrogen to form water. Similarly, the anaerobic areas on the metal surfaces (caused by the micro-organism deposit) become anodic to the aerobic sections of the surfaces. If two portions of the same metal receive oxygen at different rates, a corrosion cell is established

BIOLOGICAL MONITORING

In addition to visual inspection, direct monitoring of biological activity is performed by taking counts of the micro-organisms in the system. Techniques such as total plate count can be used in the laboratory or the field. The basic procedure for both of these techniques involves the addition of the water sample onto a sterile culture plate to which nutrients have been added, incubation for a 24-48 hour period, and counting of visible bacterial colonies

The laboratory procedures are generally more versatile because the water sample may be tested for a wider variety of specific biological forms (ie., sulfate reducing bacteria, iron bacteria, nitrifying bacteria, etc.); however, unless the water sample, which has been collected in a sterilized bottle, can reach a laboratory within 24 hours after the sample is collected, the field test kit method is considered to be more accurate for the total plate count determination.

BIOLOGICAL MONITORING (continued)

The most acceptable field test kit for the determination of aerobic bacteria and fungi populations consists of a see-through plastic container with a screw-on cap to which a slide containing a nutrient pad is affixed. The slide is simply dipped into the water sample, the cap is screwed onto the container, and after a 48 hour incubation period, the total plate count is determined by comparing the density of the colonies which have grown on the slide to a standard density chart

In order to monitor the effectiveness of the biocide program and to prevent corrosion due to biological activity, water samples of open cooling water and air washer humidifier systems should be tested for total plate count at least once per month by the field test kit method, whereas chilled water systems should be tested for sulfate reducing bacteria by laboratory analysis when repeated caustic addition is required in order to maintain the pH level within its control limit of 8.5 to 9.5

CONTROL OF MICROBIOLOGICAL ACTIVITY

As stated previously, when organisms multiply to form visible deposits, a fouling and/or corrosion problem exists. Therefore, it is desirable to keep the concentration of micro-organisms below the level at which visible deposits appear. The generally accepted tolerable levels of organisms in commercial and industrial water systems are presented in Table 4 below.

Table 4: Tolerable Levels of Troublesome Organisms

<u>Organism Type</u>	<u>Tolerable Level of Organisms/ml</u>
Bacteria	
non-sporeforming	50,000
sporeforming	100
corrosive	0
iron-depositing	0
Fungi	00
Algae	few
Total Bacterial Count	500,000

CONTROL OF MICROBIOLOGICAL ACTIVITY (continued)

Biological growth-control materials consist of biocides and biostats. Biocides kill the organism, whereas biostats inhibit their growth and reproduction. Biocides are further sub-divided into oxidizing and non-oxidizing types.

Chlorine and sodium hypochlorite are the most commonly used oxidizing biocides. Oxidizing chemicals irreversibly oxidize protein groups, thus resulting in a loss of normal enzyme activity, and subsequently the rapid death of the cell. However, they are most effective in the pH range of 6.5 to 7.0 and are totally ineffective at pH levels greater than 9.5. They also lead to deterioration of the wood surfaces of cooling towers and paper surfaces of air washer humidifier systems.

The proprietary non-oxidizing biocides kill bacteria growths by either interfering with the normal transfer of materials through the cell walls or interfering with the metabolism of the cell. These biocides are also effective, but their application is dependent on the effects to the environment i.e. contamination of blowdown from cooling water systems and contamination of air streams in air washer humidifier systems.

CONTROL OF MICROBIOLOGICAL ACTIVITY (continued)

Generally, algae are easier to kill than bacteria, but if the algae population is eliminated, the nutrients for bacterial growth are also eliminated. Similarly, the potential for bacterial growth is reduced by operating the system at a suspended solids concentration of less than 100 ppm

In any event, the type, frequency, and dosage of biological growth material by shock dosing addition to commercial and industrial water systems are determined by the biological monitoring program.