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Controlling Coolant Contamination

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Controlling Coolant Contamination

A look at the problems caused by microbial growth in fluid-transfer systems, the types of organisms found and the methods for evaluating contamination.

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As industry seeks to improve the economy of plant operation, responsible managers are paying more attention to factors that affect efficient and reliable operation of their facilities. One area of attention that can pay off handsomely is the control of microbiological activity in coolant systems. Many engineers and plant operations personnel are just beginning to appreciate the effects on their machining operations caused by their plant "biosphere," which contains bacteria, fungus, mold and other contaminants.

Understanding how microbial life affects metalworking fluids helps plant managements determine how best to minimize microbial problems with confidence. Such knowledge also enables managements to more effectively evaluate the data provided by plant operators and service-company representatives.

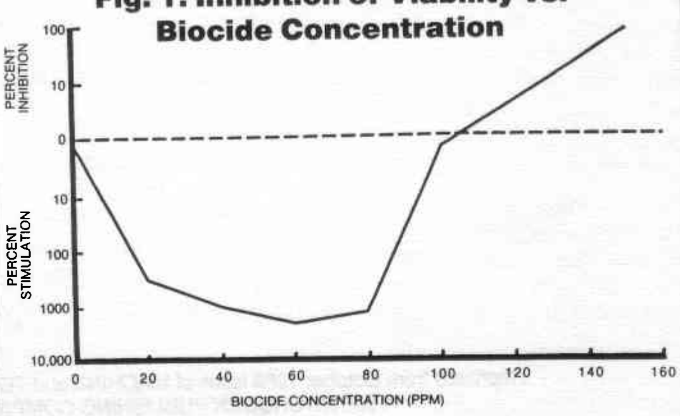
Effects of Microbial Growth

Fluid-transfer systems consist of pipes, valves, sumps, treatment units, towers and storage tanks used for containing and/or transporting working fluids or process fluids in an industrial operation. Excessive microbial growth causes seven principal types of problems: deterioration of working or process fluids; generation of odors; fouling of lines, valves and filters; acceleration of corrosion; poor quality and production performance; environmental deterioration, including immediate workplace; and other areas such as possible contributions to skin and/or respiratory irritation.

The deterioration of fluids is a complex process, the progress of which depends on the chemical composition of the fluid. Metalworking fluids contain a variety of organic compounds that may serve as both food and energy sources for microbes. Hydrocarbons, petroleum sulfonates, fatty acids and fatty esters, to name a few, although attacked slowly by individual types of microbes, can be degraded rapidly by consortia of microorganisms.

"Consortium" is the currently accepted term used to describe a mixed population of microbes acting as a unit to carry out activities that individual members of the population cannot. These consortia can and do attack the chemicals in various additive packages such as anticorrosives and even biocides. Fig. 1 illustrates how biocides used at low doses can actually stimulate microbial growth.

Fig. 1. Inhibition of Viability vs. Biocide Concentration

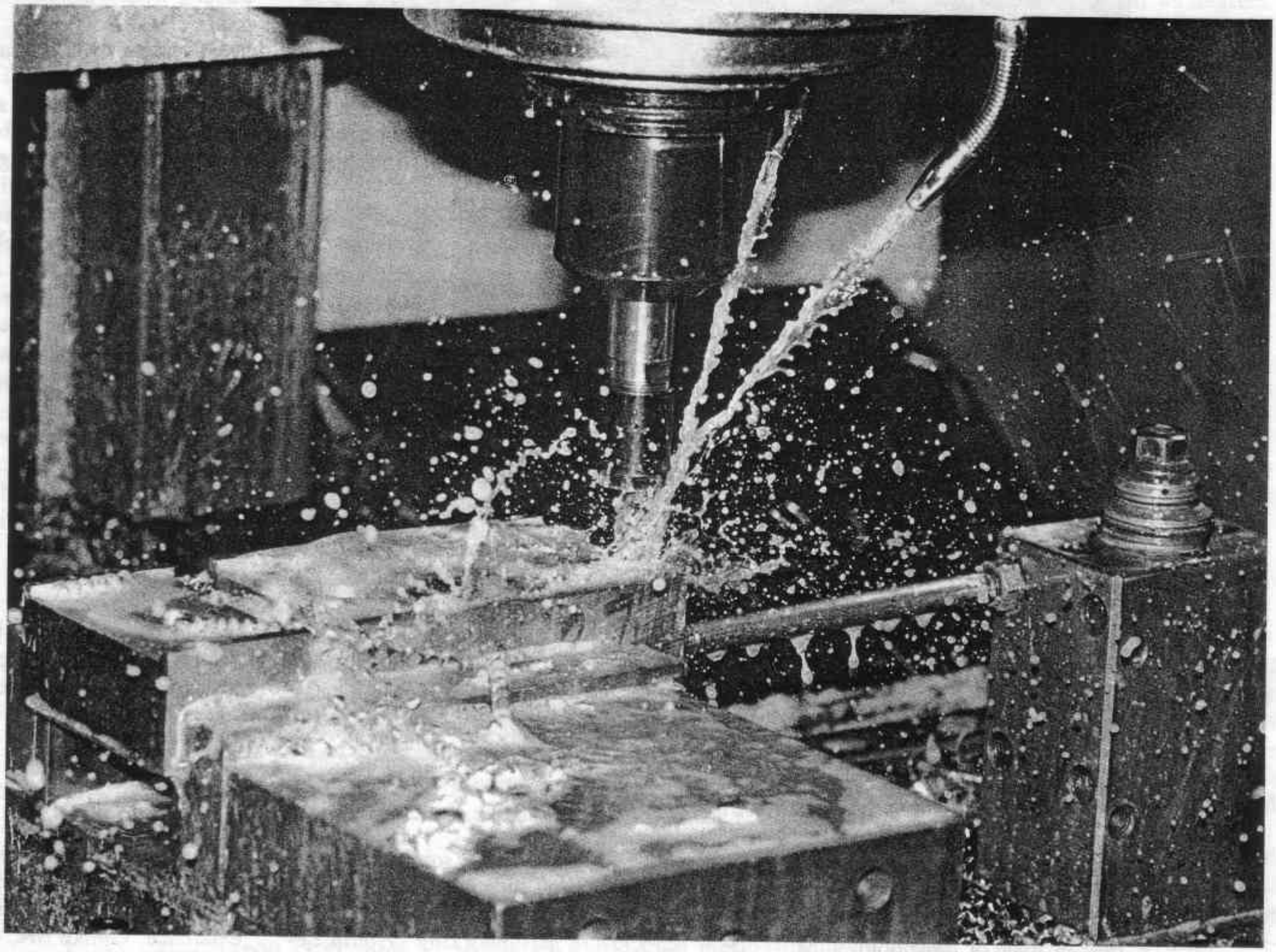


Indirect effects of microbial deterioration of working fluids include loss of pH control, lubricity, cooling properties and emulsion stability. Fluid viscosity may either decrease, as is most often the case, or increase, depending on the specific organisms and chemicals present.

Odor production is closely related to fluid deterioration since it is the result of the liberation of volatile products of microbial metabolism. A variety of odor-causing chemicals is produced, some of which are noxious, and others, such as hydrogen sulfide, are highly toxic. Adding deodorizers to sumps neither addresses the problem nor eliminates its cause.

Microorganisms tend to form films on surfaces. These films can become several millimeters thick, causing flow restrictions, preventing proper valve operation and substantially reducing filter life. Additionally, these films are good insulators and can cause significant reductions in the efficiency of heat exchangers.

Microbes living within films are often protected against biocide treatment. This is why biocides that seem to work well in bench



Metalworking fluids operate in a plant "biosphere" that contains bacteria, fungus, mold and many other contaminants.

tests are sometimes ineffective in actual plant situations. Microbes within the film, which are referred to as the "glycocalyx," are important agents of microbial corrosion.

Physically, the film forms a nonuniform barrier between the fluid and pipe or other component surface. This causes electropotential differences around certain regions of the component surface, creating microscopic galvanic cells. In addition to producing hydrogen sulfide, which is highly corrosive itself, sulfate-reducing bacteria and certain other species use the hydrogen ions that tend to accumulate at the cathode of these cells. This accelerates the galvanic reaction. Other microbes in the film produce corrosive organic acids as byproducts of their metabolism.

From a human health standpoint, the primary microbial concerns relate to skin and perhaps respiratory irritation, discomfort and general unpleasant conditions.

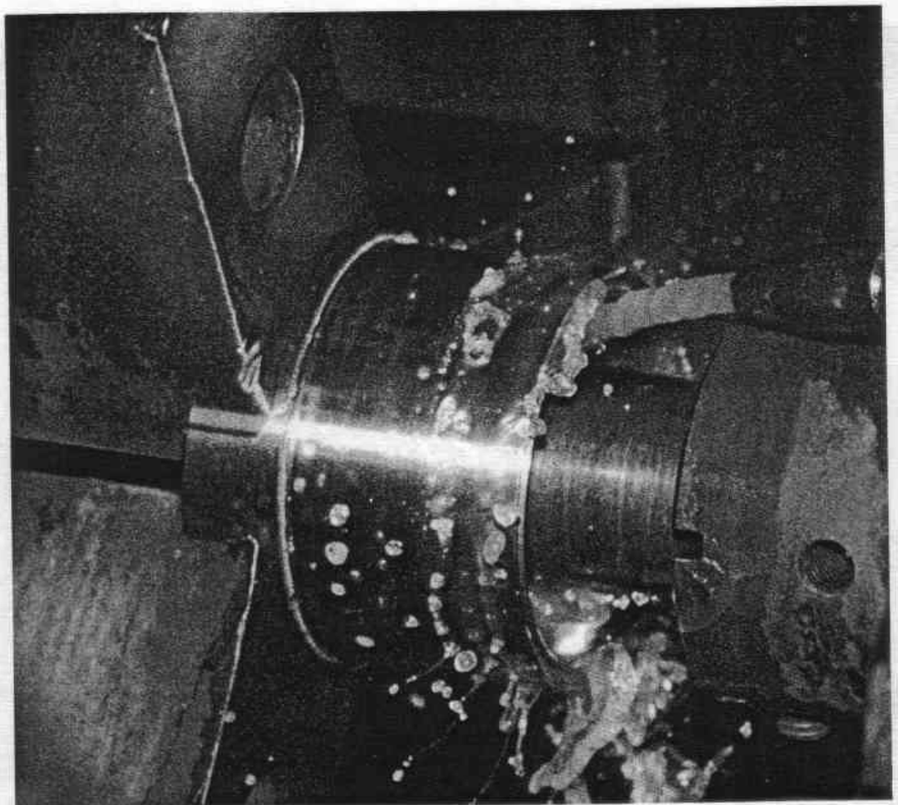
Types of Microorganisms Found in Metalworking Systems

Two principal groups of microorganisms that create problems in metalworking fluids are bacteria and fungi. They can coexist in the system. Either bacteria or fungi can predominate in a system at any given time, depending upon the existing physical and chemical conditions. For example, fungi tend to have a higher temperature and lower pH tolerance than most bacteria. However, bacteria are the only organisms found at extreme temperatures or pHs.

Bacteria are microscopic, single-cell organisms that differ from the rest of the biological kingdom by their lack of an obvious internal organization. Fungi, though also microscopic, occur as either single cells or filaments. They have a cell structure similar to all higher organisms.

Fungi may occur as yeasts or molds. As yeasts, they are single-cell organisms that reproduce by budding. As molds, they form complex mazes of filaments and colorful, spore-bearing structures that give many molds their powdery appearance. A single species of fungus may exist either as a yeast or mold, depending on environmental conditions and the stage of its life cycle. Most fungi, however, exist primarily in either the yeast or mold form.

Cephalosporium is a slime- and odor-forming mold commonly recov-



Each coolant system is unique, and coolant additives should be designed specifically for each system.

ered from metalworking fluids. Fungi, like higher organisms, are generally classified by their physical appearance or morphology. Morphological descriptions are supplemented with nutritional and biochemical information.

Several approaches are applied to classification or identification of bacteria. Bacterium may change form depending on its state of well-being and may gain or lose nutritional capabilities as conditions change. The classification and identification process, therefore, dictates the use of several hundred biochemical, nutritional capabilities as conditions change.

Bacteria can be categorized roughly by their shape and ability to hold a dye known as the "Gram" stain. Gram negative rods are the predominant forms found in metalworking fluids.

Another way of classifying bacteria is based on their need for oxygen. Aerobic bacteria require oxygen in order to grow. Anaerobic bacteria cannot grow in the presence of oxygen, although some (aerotolerant) can survive exposure to oxygen. These latter forms are of concern in metalworking systems because they tend to survive periods of aeration. A third group of bacteria, very important in industrial systems, uses the same metabolic machinery as the aerobes. As oxygen is used up, they shift gears and use the same biochemical pathways as anaerobes. These bacteria, called "facultative anaerobes," play an important role in creating an environment in which anaerobes that are present can grow.

A third way of classifying bacteria considers their metabolic capabilities: their ability to use certain compounds as nutrients, degrade them without using them as nutrients, or produce specific byproducts (such as ethanol). This approach is particularly useful in industrial situations where it is more important to know what the bacteria are doing rather than what to call them. In this scheme, bacteria are identified as sulfate reducers, hydrocarbon degraders, iron bacteria as sulfate reducers, hydrocarbon degraders, iron oxidizers, etc.

Often, it doesn't matter whether the activity is the result of the action of a single species or a consortium. The consortium can be treated as though it were a single organism. This is much like dealing with your body as a whole rather than with blood cells, muscle cells and brain cells as discrete units. An industrial system that is experiencing uncontrolled microbial growth may be treated as though it were diseased, the metabolic activities being the symptoms.

If one were to list the predominant bacteria from rivers, ponds and lakes, it would be strikingly similar to a listing of bacteria most commonly recovered from metalworking fluids. This suggests that makeup water is the principal source of microbial contamination in metalworking operations. Dust particles, general, man-contributed contamination and refuse also add to microbial loadings.

Factors Affecting Microbial Growth

Just as fire depends on air, heat and fuel for its existence, microbes have definite requirements for their existence. Unlike fire, microbes have a complex variety of requirements that are much more difficult to isolate. Nevertheless, by understanding the principal factors that affect microbial growth, metalworking plant operators can make intelligent decisions about their microbe-control programs.

The primary factor controlling microbial growth is the availability of nutrients. All microbes need sources of carbon, nitrogen, phosphorus, sulfur and energy. In metalworking fluids, these elements are readily available in some coolant chemical formulations. Though not all components of a metalworking fluid are degraded at the same rate or to the same extent, the net result is the deterioration of the fluids over various time cycles. Even biocides may serve as nutrients at low concentrations. The concentration of neat oil or synthetic chemical affects its biodegradability. Reports over the past three

pH Effect on Growth			
ORGANISM	MINiMUM	pH OPTIMUM	MAXIMUM
PSEUDOMONAS SP.	5.6	6.6-7.0	8.0
PROTEUS SP.	4.4	6.0-7.0	8.4
AEROBACTER SP.	4.4	6.0-7.0	9.0
CLOSTRIDIUM SP.	5.0-5.8	6.0-7.6	8.5-9.0

decades have indicated that bacterial populations grow optimally in oil-water emulsions in various concentration ranges. Fungal growth appears to predominate in more concentrated fluids.

Inorganic salts also play an important role, both as nutrients and as ionic buffers. Bacteria survive longer in a balanced-salts solution than in deionized water. It has been reported that the concentration of inorganic salts, particularly those of calcium and magnesium, has a profound effect on microbial growth and coolant life. Fungi tend to prefer softer water (hardness less than 700 ppm $CaCO_3$), while bacteria grow better in hard water (1000-1500 ppm $CaCO_3$). Hard water interferes with the antimicrobial action of many biocides. The concentration of the principal inorganic constituents of river water is quite variable. Water hardness, for example, can vary by as much as 37.5 percent through the course of a year. Obviously, this can have a significant effect on a plant's microbe-control program.

Microorganisms grow best at neutral or slightly acidic pH. Generally, fungi grow better at moderately lower pH (4.5-5.0) than do bacteria. However, some of the iron-oxidizing grow well in 2N sulfuric acid (pH-1.0). These are called acidophilic bacteria.

Most bacteria are neutrophiles, preferring life in the 6-8.5 pH range. A few alkalinophilic bacteria grow well at pH 9-10, but these organisms do not tend to cause spoilage problems in metalworking fluids maintained at pH greater than or equal to 9.5. Some of the pH ranges for bacteria commonly isolated from metalworking fluids are listed in Table 1.

Alkaline solutions tend to draw carbon dioxide from the atmosphere, a process that neutralizes the solution. This reaction can lower the pH sufficiently to enable bacteria to grow. That is why alkalinity, a measure of a solution's buffering capacity, is as important a parameter to monitor as pH.

Different bacteria tolerate different temperature ranges. For example, bacteria have been isolated from icebergs and from the mouths of geysers. The bacteria most commonly recovered from metalworking fluids can withstand exposure to temperatures up to about 45 degrees C (113 F). However, thermal treatment is usually not a viable option for controlling growth in metalworking plants.

Of the four principal factors effecting microbial growth in metalworking operations, water quality and pH are most easily controlled on site. Nutrient availability can be controlled through the careful selection of coolants, emulsions and accompanying treatment packages. Temperature control is a less practical option. Other factors such as oxygen availability and moisture content (availability of water) are important in some applications, but are not profitably controlled in metalworking operations.

Microbial Growth in Fluid-Transfer Systems

Fluid-transfer systems can be classified as open, closed or semiclosed. A closed system is one to which less than one percent makeup fluid is added each day. Storage tanks, hydraulic systems and closed-loop cooling systems are examples of closed systems.

In closed systems, microbial growth follows batch-culture dynamics (Fig. 2). Initially, during the lag phase, growth is not evident. Mi-

Fig. 2. Growth in a Closed System