

# Microbial Problems in Metalworking Fluids<sup>©</sup>

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All metalworking-fluid formulations share the common problem of susceptibility to microbial attack. This is not all bad news, since we need the used dilute fluid to be biodegradable for disposal purposes. However, the challenge for both formulators and metalworking facility operators, using water-based fluids, is to minimize the adverse economic impact of uncontrolled microbial contamination in metalworking operations. The following discussion will focus on water-extended fluids. A short glossary is provided in Table 1 to assist the reader who is unfamiliar with the microbiological terms used in this article.

Metalworking fluid spoilage can be defined as any change in the fluid which adversely affects its utility. Table 2 lists the most common indications of spoilage in metalworking fluids.

When any of these listed problems begins to occur with a coolant that has previously performed well, uncontrolled microbial contamination should be suspected, and corrective action taken.

In order to determine what action is appropriate, a manager must have a feel for the fundamental nature of the problem. We will discuss some of the more salient principles of metalworking-fluid microbiology.

Metalworking fluids become "rancid" because they contain rich blends of nutrients that encourage microbial growth. Mineral oil base stocks, glycols, fatty acid soaps, amines and other nearly universal constituents of metalworking fluid concentrates provide all of the essential nutrients required for growth. Not all fluids contain the same nutrients nor are they used under identical conditions. Consequently, the types of microbial contaminants which predominate may vary.

Two types of microorganisms contaminate metalworking fluids: bacteria and fungi. Bacteria are single-celled microorganisms which lack a true cell wall. Unlike higher organisms, their shape and nutritional requirements often reflect the environment from which they are recovered, rather than their genetic makeup. Consequently, a broad spectrum of genetic, physiological and morphological tests are generally needed for identifying a given bacterium. Gross classification can often be accomplished with as few as eight tests, but complete identification may require over 300 tests.

In contrast to bacteria, fungi have true cell walls, like the cells of all of the higher plants and animals. In coolant systems, fungi may appear as single-celled yeasts or as

TABLE 2  
PRIMARY SYMPTOMS OF MICROBIAL SPOILAGE  
IN METALWORKING FLUIDS

- |  |  |
|--|--|
| • Odor development                                       | • Clogged filters, screens and lines         |
| • Decrease in pH   | • Increased work piece rejection rates       |
| • Changes in emulsion stability                          | • Decreased tool life                        |
| • Increase in corrosion rates                            | • Unpredictable changes in coolant chemistry |
| • Increased incidence of dermatitis and skin irritations |  |
| • Surface-finish blemishes                               |  |

TABLE 3  
BACTERIA AND FUNGI FREQUENTLY RECOVERED  
FROM METALWORKING FLUIDS

BACTERIA	FUNGI
<i>Pseudomonas aeruginosa</i>	<i>Fusarium</i> sp. <sup>1</sup>
<i>Proteus mirabilis</i>	<i>Candida</i> sp. <sup>1</sup>
<i>Enterobacter cloacae</i>	<i>Cephalosporium</i> sp. <sup>1</sup>
<i>Escherichia coli</i>	
<i>Klebsiella pneumoniae</i>	
<i>Desulfovibrio</i> spp. <sup>1</sup>	

Note: 1) "sp." and "spp." are abbreviations for "specie" and "species," respectively.

filamentous molds. Many fungi spend part of their life cycle as yeasts and part as molds. The factors which determine whether a fungus will propagate in one form or the other are beyond the scope of this discussion. Some of the bacteria and fungi most commonly found in metalworking fluid are listed in Table 3.

In reality, the specific identity of a bacterial or fungal contaminant is of limited practical value in managing contamination problems. It is much more valuable to know:

- What are the contaminants doing to the system?
- What can be done to prevent that from happening?

By understanding a few basic concepts about microbial life, the plant manager can take effective measures to monitor microbial contamination and control it intelligently.

TABLE 1  
GLOSSARY OF USEFUL MICROBIOLOGICAL TERMS FOR THE METALWORKING INDUSTRY

<b>Aerobe</b>	A microorganism that can only grow when adequate oxygen is present. Oxygen serves as the terminal electron acceptor.	reactions of all biochemical pathways. Active enzymes can cause fluids to become rancid even though the cells may be judged "dead" by some other criterion, such as plate counts.
<b>Anaerobe</b>	A microorganism that can only grow in the absence of oxygen. Nitrate, sulfate or organic compounds serve as terminal electron acceptors in different species.	
<b>Bacterium</b>	A single-cell organism. Bacteria are the smallest living units capable of carrying out, independently, all of the basic functions that characterize living beings (respiration, growth, assimilation, metabolism, excretion and reproduction). Bacteria may be as small as 0.1 $\mu\text{m}$ ( $4 \times 10^{-6}$ in.) in diameter and may appear as spheres, rods, commas, or spirals under a microscope. As a kingdom, the bacteria represent a vast diversity of nutritional and survival capabilities.	<b>Essential elements</b> Carbon, hydrogen, oxygen, phosphorous and sulfur are the elements without which life, as we know it cannot exist. All of these elements are present in abundance in metalworking fluids.
<b>Biocide</b>	A chemical that kills living organisms.	<b>Facultative anaerobe</b> A bacterium that lives like an aerobe when oxygen is present, and like an anaerobe when oxygen is absent. Facultative anaerobes play a key role in creating and maintaining environments in which anaerobes can grow.
<b>Biofilm</b>	Complex layer comprised of microorganisms and their secretions as well as detritus trapped within the biofilm matrix. Biofilm thickness may range from a few microns to several centimeters. Physical and chemical conditions within biofilms are controlled by the microorganisms growing there, and may be very different from conditions in the bulk fluid. Many species of microorganisms form the biofilm community.	<b>Fungicide</b> A chemical that preferentially or selectively kills fungi.
<b>Biomass</b>	The total amount of living organisms in a given volume of material. Difficult to measure directly, biomass is generally extrapolated from the measurement of a chemical component of the living cells within the mass. Optimally, the average concentration (per cell) of the chemical being measured is either known, or a standard conversion factor has been established.	<b>Fungus</b> The simplest microorganisms having a true cell wall. They appear as single-cell yeasts (approximately 10,000 times the volume of most bacteria) or as filamentous "molds." These filaments are long strands (hyphae) of cells which form the fibrous network of growth one sees when looking at moldy food. The colored bodies found in a filamentous mat contain spores. One of these bodies may contain several hundred spores, each of which can give rise to a fungal colony.
<b>Biostat</b>	A chemical substance that prevents the growth or proliferation of living organisms, but does not necessarily prevent metabolism.	<b>Growth</b> Growth is the measurable increase of an individual's or population's biomass. See definition of "biomass."
<b>Colony</b>	The mass formed on the surface or within the matrix of microbial growth media as a result of the reproduction of ostensibly one cell. A bacterium with a generation time of 1 hour (population doubles each hour), will form a colony containing over 2 billion cells in about 30 hours. The colony, visible to the naked eye, is easier to count than individual microbes. Problems arise because not all microorganisms grow on the same nutrients or under the same conditions. Bacteria and fungi growing in a coolant often fail to form colonies on solid growth media.	<b>Growth rate</b> The amount by which the biomass increases per unit period of time (usually hours). Often growth rate is reported as the amount of time it takes for the population to double, assuming that biomass per organism is constant.
<b>Corrosion-enhancing microbial activities</b>	Some bacteria, like the sulfate-reducing bacteria, contain the enzyme "hydrogenase," which scavenges hydrogen ions and creates a galvanic cell. Corrosion is accelerated at the cathode of that cell. Many microbes manufacture organic acids which attack metal surfaces directly. The very presence of nonuniform biofilms causes electropotential gradients to develop. All of these activities tend to accelerate corrosion rates.	<b>Inhibition</b> The prevention of any particular activity. Corrosion inhibition, microbial growth inhibition and foam inhibition are examples of inhibiting functions required of metalworking fluids. Inhibition is rarely absolute, so cost-benefit ratios should be computed to determine the merits of various inhibitor products.
<b>Detritus</b>	Unwanted particles floating on the surface, suspended in the bulk mass or precipitated out to the bottom of metalworking fluid. Swarf, flocs of biomass, detached rust deposit fragments all make up typical detritus in coolant systems.	<b>Metabolism</b> The enzymatic reactions by which cells break down food sources (anabolism) and create new cell material (catabolism), giving off heat and waste "metabolites" in the process.
<b>Dip stick/dip slide</b>	One of a number of paddle-like devices either coated or saturated with a growth medium. They are dipped into the coolant to be tested, incubated for 1-2 days and observed for the development of colonies. They provide a simple means of getting very approximate plate count data.	<b>Microbially-mediated process</b> Processes such as corrosion and pH drop which are the direct or indirect result of microbial activity. For example, bacteria secrete organic acids which react with pH buffers, leading to a loss of pH control. The consequent drop in pH is microbially-mediated.
<b>Disinfect</b>	To destroy or inactivate harmful bacteria. <i>Not</i> equivalent to sterilization.	<b>Microbicide</b> (Often written "microbiocide") is an agent which is designed to kill microorganisms, i.e., both bacteria and fungi.
<b>Electron-acceptor molecule</b>	A molecule like oxygen that captures electrons and becomes reduced to water. All cells derive their energy from a sequence of reactions involving the transfer of electrons along a "cascade" of molecules. The last molecule in this sequence is the <i>terminal electron acceptor</i> . For aerobic organisms, oxygen is the terminal electron acceptor. Sulfate serves this function for sulfate-reducing bacteria.	<b>Mold</b> See "Fungus."
<b>Enzyme</b>	A molecule or cluster of molecules composed of long chains of amino acids. The enzymes are the cell's metabolic factories. They act as catalysts for the metabolic	<b>Nutrient</b> Any substance that an organism needs in order to grow and proliferate. In order for a chemical to function as a nutrient, the organism must be able to assimilate it (bring it into contact with the appropriate enzymatic machinery). Nutrients are "essential" if an organism cannot survive without them. "Non-essential" nutrients are important for healthy growth, but not for survival.
		<b>Pasteurize</b> To heat-treat a fluid (usually with steam) in order to kill-off potentially pathogenic microorganisms. Pasteurization requires exposure to 61-63°C (142-145°F) for 30 min. Note: many non-pathogenic microorganisms generally survive pasteurization.
		<b>Plate counts</b> A standard method for enumerating bacteria and fungi. A small sample portion is spread onto the surface of a suitable nutrient-containing gel. After incubation, colonies develop. (see "Dip-sticks") This traditional technique is called the "plate count" because the nutrient gel is generally contained in a standard 100 mm "petri dish" or "plate." Like dipstick methods, microbes must grow on the nutrients provided to form visible colonies. Consequently, these methods are often referred to as "viable counts."
		<b>Proliferation</b> The increase in the number of individuals in a population. It may or may not be proportional to growth: for example, if cells are dividing, but there is no net biomass increase, the population is proliferating but not growing. Often, in metalworking systems, biomass increases are not accompanied by increased cell numbers. If viable counts are the only measurements of microbial contamination being used, the data may be dangerously misleading.
		<b>Sterilize</b> The complete destruction of biological activity.
		<b>Yeast</b> See "Fungus."