The Path Ahead for Metalworking Fluid Microbiology

By Frederick J. Passman

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Studies of metalworking fluid microbiology coincided with the development of water dilutable metalworking fluids, also called water miscible, emulsifiable or—incorrectly—water soluble fluids. Although the first paper on the topic, "A Study of the Nature, Growth and Control of Bacteria in Cutting Fluids," was published in 1941, serious and continuous research didn't start until a decade later.

A paper by Ratul Shah and Robert Donofrio published in 2012 purported to review the history and current state of knowledge of metalworking fluid microbiology, but did not include reference to E.O. Bennett, the first microbiologist to pursue metalworking fluid microbiology as a lifelong research focus. Between 1954 and 1991, he published 170 papers about the topic and associated health risks.

Without knowledge of Bennett's contribution—which online literature searches do not easily capture—or the considerable body of existing knowledge about metalworking fluid microbiology, young researchers, lab technicians and fluid managers may be more likely to report "discoveries" that simply affirm findings first reported decades go. There is so much further research to be done that it would be a waste of limited resources to spend time relearning previously established science.

The 77-year history of metalworking fluids microbiology can be divided into four periods, each spanning one or two decades. A brief summary of this history leads to unexplored research questions that will inform the future of metalworking fluids.

Origins (1950 to 1970)

In the early 1950s, as sales of water miscible metalworking fluids grew, Texaco's technical staff began to wonder if machinists exposed to diluted metalworking fluids would be at increased risk of disease caused by pathogenic microbes. The company reached out to Ed Bennett—then a postdoctoral fellow at the University of Houston—and funded his initial metalworking fluid microbiology research.

Similarly, nearly a decade later, Clyde Sluhan, co-founder and CEO of Master Chemical, asked Harold Rossmoore (an associate professor at Wayne State University in Detroit) to investigate the risks associated with worker exposure to pathogenic microbes in water miscible metalworking fluids.

At the time, all water miscible metalworking fluids were emulsifiable oils. Although Bennett, Rossmoore and others routinely detected potentially pathogenic bacteria from both in-use metalworking fluids and the water used to dilute them, they found no relationship between microbe detection and disease frequencies. Thus, the short answer to this period's focus on whether machinists who used water miscible metalworking fluids were more likely to contract microbial infections was "no."

Biodeterioration Focus (1970 to 1990)

Until the Clean Water Act of 1972 listed used metalworking fluids as hazardous waste, metalworking fluid biodeterioration was a non-issue. Before operators began to actively monitor for and control microbial contamination, they routinely discarded used metalworking fluids after eight to 12 weeks, most commonly because of odor complaints. Flash corrosion on machine parts was another common reason for changing metalworking fluids.

Research in the early 1970s demonstrated that uncontrolled microbial contamination caused water miscible metalworking fluid performance failures. Although rank odor was the most commonly reported symptom, increased difficulty in maintaining pH, emulsion stability and corrosion inhibition were linked to heavy microbial loads greater than 1 million to 10 million colony forming units (the red spots that form on inoculated culture test paddles) per tenth of a milliliter.

It was also during this period that many biocide manufacturers registered their products for use in metalworking fluids. More than 90 percent of all biocide active ingredients were brought to market between 1970 and 1990, and biocides came to be perceived as value-added products. This perception coincided with the early 1980s advent of fluid management.

By the late 1980s, typical service intervals between system dumps increased from quarterly to greater than a year. The best managed systems were able to run for years without needing to be drained, cleaned and recharged. Although uncontrolled microbial contamination was not the only relevant failure mechanism, it was generally recognized as a common, major contributor to metalworking fluid failure. Metalworking fluid microbiology research then focused on biocide performance and alternative use strategies. This work was complemented with formulation improvements to extend performance life.

Health Effects, Revisited (1990 to 2000)

In 1992, a number of workers at an automotive parts plant were diagnosed with hypersensitivity pneumonitis—a lung disease that results from an allergic response to various microbes. This event triggered substantial renewed interest in metalworking fluid microbiology research.

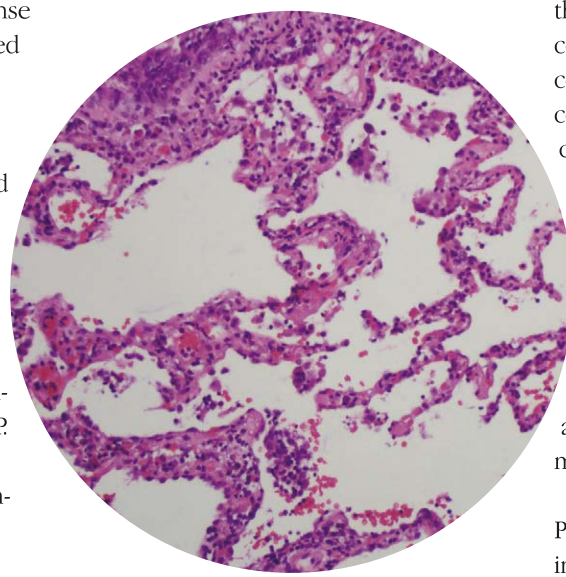
Between 1992 and 2000, there were approximately 250 cases of HP reported throughout the metalworking industry. Invariably, HP occurred in clusters ranging from four to more than 40 cases at a given facility. More than a dozen different types of bacteria and fungi, commonly recovered from metalworking fluids, are known to induce HP.

However, speculative comments by Rossmoore at an industrial hygiene conference led many stakeholders to focus on one organism: the acid-fast Mycobacterium immunogenum. At least one major automotive manufacturer banned a commonly used biocide based on Rossmoore's incorrect theory that so-called rapidly growing bacteria (those that produce visible colonies within 48 hours) inhibited M. immunogenum growth, and that the use of biocides to suppress the rapidly growing microbes made M. immunogenum growth possible.

A decade later, Katalin Rossmoore, Harold Rossmoore's widow, and son Leonard Rossmoore and I collaborated on a study that demonstrated that there was no link between the presence or absence of other microbes and that of M. immunogenum. It became apparent that the microbe was a common metalworking fluid contaminant once testing for M. immunogenum became part of routine microbiological condition monitoring.

It turned out that, historically, M. immunogenum colonies were only seen if culture plates or paddles were incubated and observed for at least a week and only if there were no faster-growing microbes present. Unless the medium growth included antibiotics to suppress rapidly growing bacteria, it would be overgrown with colonies of other microbes before M. immunogenum could form. The focus on M. immunogenum serves as an excellent case study of the perils of disregarding data that does not fit one's forgone conclusions.

In addition to HP-focused research, numerous papers noted the relationship between metalworking fluid mist, also known as endotoxin exposure, and respiratory function. Endotoxin is an integral component of the cell wall of bacteria, classified based on their negative reaction to the Gram stain (hence the name Gram negative bacteria). Although neither sampling nor analytical techniques were standardized, researchers reported endotoxin concentrations in metalworking fluids and metalworking fluid aerosols.



Hypersensitivity pneumonitis, seen in this lung biopsy, became a problem among workers at an auto parts plant in the early 1990s. (Photo: Mutleysmith/Wikimedia Commons)

In several studies, the reported airborne endotoxin concentrations were in the range that researchers at the United States National Institute for Occupational Safety and Health had previously linked with toxic shock syndrome. However, at the facilities where high endotoxin concentrations (greater than 7,000 milligrams per cubic meter) were detected, the incidence of allergies or industrial asthma were no different than at facilities where fewer than 100 mg of endotoxin were detected.

At the turn of the millennium, there was broad consensus that exposure to bioaerosol (airborne microbes) was responsible for allergenic diseases that ranged from mild eye and throat irritation (allergic rhinitis) to potentially lethal industrial asthma and HP. There remained considerable disagreement regarding the specifics of how to best control bioaerosol formation, but there was general agreement that reducing total mist exposure would reduce disease risk. Throughout the 1990s, machine enclosures and mist collection systems became increasingly common. By 2000, mist containment and control became the industry norm. Not coincidently, the frequency of respiratory disease reports plummeted, and interest in bioaerosol research and monitoring all but vaporized.

Modern Times (2000 to present)

Since the start of the century, metalworking fluid biodeterioration has again become the center of focus for microbiology research.

Implementation of the European Parliament's Biocidal Products Directive in 1998 created pressure against the use of metalworking fluid microbicides. Since then, the number of available microbicides in the European Union has shrunk from more than 180 down to 27 active substances, according to the European Chemicals Agency.

Similarly, the list of microbicides approved in the U.S. for use in metalworking fluids has shrunk to fewer than 50, ASTM International noted. The decrease in available microbicides has provided impetus for the development of bioresistant metalworking fluid additives and finished formulations.

In an effort to bypass the regulatory issues, some formulators are using toxic chemicals that are not registered as biocides, but which serve no other function in formulations. One might ponder whether there are unintended health risks associated with the use of these fluids. Generally speaking, synthetic metalworking fluids are less susceptible than semi-synthetic or emulsifiable oil formulations. Determining why remains an

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unmet research need.

A Glimpse into the Future

There are several other important yet unaddressed metalworking fluid microbiology research needs. Industry stakeholders need to develop consensus methods for collecting and analyzing bioaerosol samples. If the endotoxin data obtained in the 1990s are accurate, we need to understand why the relationships seen between endotoxin exposure and disease among agricultural workers is not also seen among machinists. If the historic data are inaccurate, we need to better understand actual exposures.

Microbes produce microbial volatile organic compounds. Many MVOCs are known to be allergenic or toxic. To date, however, no research has been reported on MVOC concentrations in a facility where metalworking fluids are used.

Fluid managers are beginning to recognize the importance of biofilm control to overall microbial contamination control. Biofilms are dynamic microbial communities that grow embedded in a complex, slimy substance called extracellular polymeric substance. However, there are no consensus methods for sampling or testing biofilm communities in metalworking fluid systems.

Recently, genetic tools have been used to characterize microbial communities in metalworking fluids. Genetic testing detects many microbes that are undetectable by traditional culture test methods. This information provides a better understanding of both population size and its diversity; often, different types of microbes working in concert can cause more biodeterioration than that caused by a single type of microbe.

Looking into the future, metabolomic testing promises to reveal which genes are switched on in a contaminated system where microbes are causing problems. This line of research promises to light the way to more cost-effective, environmentally benign strategies for preventing in-use metalworking fluid biodeterioration and accelerated biodegradation during biological waste treatment.

These new lines of research are likely to reveal questions we have not yet thought to ask. ∎

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