

FROM: Houghton, D.R., R.N. Smith  
and H.O.W. Eiggins (Eds.), Biode-  
terioration 7. NY: Elsevier  
Applied Science, 1988, pp.  
517-522.

## Evaluation of Thermal Pasteurization for Control of Metalworking Fluid Biodeterioration

H.W. Rossmoore, L.A. Rossmoore & A.L. Kaiser

Department of Biological Sciences, Wayne State University, Detroit, MI 48202, USA and  
Biosan Laboratories, Ferndale, MI 48220, USA

### ABSTRACT

*A study was undertaken on metalworking fluids containing high levels of bacteria which were thermally pasteurized every other week for 10 weeks. Samples were prepared in duplicate so that following heat treatment, one was returned to its original biofouled container. Those fluids in the other set were returned to a thoroughly cleaned vessel. Heat treatment eventually proved less effective on the fluid from the 'dirty' container.*

*A shorter experiment (72 h) looked at the effect of biocide treatment of heated fluids. In both 'clean' and 'dirty' systems in the first experiment, bacterial counts were generally reduced > 99.9% but survivors returned to the original levels in 24 h. In the series using biocide, however population grow-back was prevented.*

### INTRODUCTION

Physical methods of controlling microbial populations have one thing in common; subsequent to treatment, there is no residual control of either the surviving population or post-treatment contamination. These methods have been limited to applications preventing contamination or survivor growth. Their use for highly contaminated industrial systems subject to recontamination is not commonplace because of lack of residual activity. Pulse treatment with LD<sub>50</sub>s at intervals equal to

generation times of the dominant population would be satisfactory but may not be technically or economically feasible (Rossmoore & Brazin, 1968).

Metalworking fluids (MWF) are of particular interest because of their propensity for contamination and their ability to support large populations of diverse microorganisms, which can potentially add to the burden of occupational hazards. Thus, any method for controlling microbial deterioration which reduces the burden in the workplace is to be welcomed.

A subsequent report (Heinrichs & Rossmoore, 1971) demonstrated that a regimen of 30 min at 50°C produced a significant decrease in the MWF population. More recently (Hill & Genner 1980, 1981; Hill & Elsmore, 1983), slipstream pasteurization in marine lubricating oil as well as in a MWF oil/water emulsion has been evaluated. Shipboard purifier/heat exchangers remove entrained water from the lubricating oil while increasing temperatures from 70 to 80°C for 10–15 s. Microbial levels in MWF appear to be similarly controlled in the laboratory.

The factors mitigating against success in the field are potentially larger systems, higher contamination levels, shorter generation times, and the need to control the temperature of the MWF below 30°C to maintain its cooling property.

Mechanical devices are employed in MWF systems to separate particulate and insoluble contaminants from the bulk fluid. Filtration of various kinds are found throughout the metalworking industry for removal of non-settlable metal fines or insoluble reaction products of the process.

Filters have been developed that remove bacteria (Symes & Cowap, 1976) but were limited to 10-gallon sumps, and attempts to improve flow rate and increase size have not been successful. Particulate and contaminant oil removed by centrifugation is common practice for small sumps and recycling systems (Rossmoore, 1986). A variation involves increasing temperature (to 71°C) with centrifugation (William & Geraghty, 1986) to increase separation efficiency and reduce microbial levels.

What effect the gross contamination has on the efficiency of pasteurization has never really been shown. It would be helpful if pasteurization could be used in combination with biocides at reduced doses or less frequent dosing to extend the utility of the latter while at the same time diminishing their toxicological impact.

The work presented in this paper evaluates the impact that cleanliness and biocide treatment have on the effectiveness of thermal pasteurization.

## METHODS

### Phase I

The first series of experiments evaluated the effect of sequential thermal pasteurization and centrifugation and the impact of the hygiene of the return vessel on microbial regrowth.

Four 4 litre systems contained the following:

- (a) 35 g mild steel machining chips;
- (b) 50 ml of tramp oil (25 ml hydraulic oil + 25 ml way oil);
- (c) 350 ml of contaminated adapted soluble oil (inoculum); and
- (d) 3150 ml of freshly made soluble oil (2.5% v/v soluble oil emulsion).

The systems were aerated continually for 5 days and left quiescent for 2 days. At this time, additions of water and fluid were made to compensate for 'evaporation'. A sample was removed for bacterial count. The aeration was continued for another 5 days. During the 10 working days, 50 ml of tramp oil was added daily. After the second weekend shutdown, each system was treated.

There were a total of four systems. System 1 was heated at 72°C for 15 s, centrifuged, and returned to its original container. System 2 was heated and centrifuged, but its container was thoroughly cleaned and new steel chips were added. System 3 was centrifuged only and then returned to its original 'dirty' container. System 4 was centrifuged, and returned to a 'clean' container with new steel chips.

Immediately after treatment a sample was removed for bacterial plate count. The study was carried out for 10 weeks. The separations were done in a bench model Alpha Laval high-speed disc bowl centrifuge with a throughput flow rate of 20 litres/h (Model No. 10CC Gyrotester). Fluids were heated and pulsed (Manostat Ministaltic Pump 72-100-000, American Scientific Products) through 5 m of aluminum tubing for 15 s in a water bath (Model BK-33, American Scientific Products) maintained at 80°C. An exit temperature of 72°C was reached from ambient (25°C) in 1-2 s and flowed directly from the water bath into the centrifuge without prior cooling.

### Phase II

The same 5% soluble oil emulsion as described above but without tramp oil or metal chips was used for the study. Fluid was pulsed through the

heated water bath for 15 s at (a) 72°C and (b) 60°C. Samples were collected in 100 ml aliquots in 180 ml bottles contained in an ice bath. After collection, biocide was added to them and to a control series at 25°C. Four biocides were tested. All samples were shaken at room temperature in a reciprocating shaker. At 18, 48 and 72 h aliquots were removed for bacterial counts.

## RESULTS AND DISCUSSION

The cleanliness of the receiving container did not affect bacterial levels in the non-heated systems. However, there was a trend towards decreasing effectiveness of pasteurization, beginning at week 7, of the fluid from the so-called 'dirty' system (Table 1). In the 'dirty' system the same metal chips were retained and there was a build-up of biofilm. The accumulation of non-centrifugable tramp oil and dirt, together with biofilm and retained metal, may have contributed to the differential reduction noted.

The effect of biocide treatment of the heated fluid was examined (Table 2). Although the fluid was cooled in an ice bath immediately following heating, the population reduction was similar to that in previous experiments. In every case, the biocides prevented grow-back.

The demonstration of potentiation of thermal injury and/or chemical injury by combining the two was to be expected. Stressed organisms need recovery media to maintain viability. An excellent summary especially related to food (Jay, 1986) lists a very extensive number of injuries, including sublethal heat and the stress induced by several selective media. Additionally (Jay, 1983), a number of antibiotics used as food

TABLE 1  
Effect of 72 C/15 s Pasteurization on Aerobic Bacteria in Metalworking Fluid

<i>Pasteurized and centrifuged fluid returned to</i>	<i>Week after inoculation<sup>a</sup></i>								
	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>	<i>6</i>	<i>7</i>	<i>8</i>	<i>9</i>
'Clean' system	-3.7	+3.0	-3.3	+4.5	-4.6	+6.0	-3.2	+2.3	-2.7
'Dirty' system	-2.8	+2.1	-2.9	+4.6	-1.3	+2.7	-0.5	+0.8	-1.0

<sup>a</sup>Inoculum:  $3.7 \times 10^8$  bacteria cfu/ml.

- = log<sub>10</sub> reduction. + = log<sub>10</sub> grow-back.

Pasteurization and centrifugation were on odd weeks; bacterial counts were done on odd and even weeks.

TABLE 2  
Effect of Biocides on Pasteurized Metalworking Fluid Bacterial Survivors

Biocide/ppm <sup>a</sup>	Temp (°C):	Log <sub>10</sub> cfu/ml aerobic bacteria											
		Time zero			24 h after pasteurization			48 h after pasteurization			72 h after pasteurization		
		25	60	70	25	60	70	25	60	70	25	60	70
Control		7	<3	<3	6.7	6.1	6.8	6	6	6.1	7.7	6.1	7.1
Bioban P-1487 <sup>b</sup> /250					7.1	<3	<3	7.1	<0	<0	6.3	<0	<0
/500					4.8	<3	<3	4.8	<0	<0	6.8	<0	<0
/750					4.3	<3	<3	4.3	<0	<0	7.1	<0	<0
Kathon 886MW <sup>c</sup> /10					4.7	<3	<3	5	<0	<0	6.4	<0	<0
/25					<3	<3	<3	<0	<0	<0	1.3	<0	<0
/50					<3	<3	<3	<0	<0	<0	<0	<0	<0
Uconex 345 <sup>d</sup> /250					7.4	<3	<3	6.7	4.1	>3	6	5.6	5
/500					7.2	<3	<3	5.4	3.0	1.4	6.1	5.4	6
/750					7.0	<3	<3	7.9	<0	<0	7.4	1.4	<0
Triadine 10 <sup>e</sup> /250					7.2	<3	<3	5.8	2.4	1.6	4.7	5.5	1.6
/500					6.8	<3	<3	5.8	2.7	<0	4.0	<0	<0
/750					6.1	<3	<3	5.8	3.0	<0	5.9	5.6	<0

<sup>a</sup>Ppm of commercial product.

<sup>b</sup>4,4'(2-ethyl-2-nitrotimethylene) dimorpholine (20%) + 4-(2-nitrobutyl) morpholine (70%).

<sup>c</sup>5-chloro-2-methyl-3(2H)-isothiazolone (11%) + 2-methyl-3(2H)-isothiazolone (3.5%).

<sup>d</sup>Glutaraldehyde (45%).

<sup>e</sup>1,3,5-tris(2-hydroxyethyl) hexahydro-s-triazine (63.6%) + sodium 2-pyridinethiol-1-oxide (6.4%).

preservatives all reduce the level of heat required for food protection and pathogen destruction.

A prime target of thermal effects is probably the cell membrane. Although the specific site for action responsible for lethality is not known for any of the four biocides used here, a damaged cell membrane would probably facilitate the activity of all of them.

It can be concluded from these experiments that thermal pasteurization of MWF has a very limited short-term value since even with maximum population reduction, there is a grow-back to original population within 24 h. Since the practice in industry is to centrifuge/pasteurize biweekly, it would have little positive effect on the microorganisms. However, a combination of routine heat treatment and low level biocide dosing appears to have promise for field use.

## REFERENCES

- Heinrichs, T.F. & Rossmoore, H.W. (1971). *Developments in Industrial Microbiology*, **12**, 341-5.
- Hill, E.C. & Elsmore, R. (1983). In *Proceedings of the 5th International Biodeterioration Symposium*. John Wiley, London, pp. 462-71.
- Hill, E.C. & Genner, G. (1980). In *Proceedings of the 4th International Biodeterioration Symposium*. Pitman, London, pp. 37-43.
- Hill, E.C. & Genner, G. (1981). *Tribology International*, April 1981, 62-74.
- Jay, J.M. (1983). In *Food Microbiology*, ed. A.H. Rose. Academic Press, New York, pp. 117-43.
- Jay, J.M. (1986). *Modern Food Microbiology*, 3rd edn, Chapter 5. Van Nostrand, New York, pp. 110-15.
- Rossmoore, H.W. (1986). In *Comprehensive Biotechnology*, ed. Murray Moo-Young, Charles L. Cooney & Arthur E. Humphrey. Pergamon Press, New York, pp. 249-69.
- Rossmoore, H.W. & Brazin, J.G. (1968). In *Biodeterioration of Materials: Microbiological and Allied Aspects*. Proceedings of the 1st International Biodeterioration Symposium, ed. A. Harry Walter & John J. Elphick. Elsevier, UK, pp. 386-402.
- Symes, W.R. & Cowap, D. (1976). In *Proceedings of the Third International Biodegradation Symposium*, ed. J.M. Sharpley & A.M. Kaplan. Elsevier Applied Science, London, pp. 223-42.
- William, G.F. & Geraghty, J.A. (1986). *Filtration News*, July-August, 10-13.