Effect of Temperature and Sodium Chloride on Drag Reduction by Sodium Carboxymethylcellulose and Guar Gum

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Abstract □ The effect of variations in temperature and sodium chloride concentrations on drag reduction by sodium carboxymethylcellulose and guar gum was studied with water in turbulent flow, using a simple flow tube. Two different drag-reducing mechanisms apparently exist for sodium carboxymethylcellulose and guar gum. Sodium chloride significantly reduced the drag-reducing property of sodium carboxymethylcellulose but did not appear to affect drag reduction by guar gum. The effect of variations in temperature (10–45°) on drag reduction was different for each drag-reducing agent.

Keyphrases □ Sodium carboxymethylcellulose—effects of temperature and sodium chloride on drag reduction □ Guar gum—effects of temperature and sodium chloride on drag reduction □ Drag-reducing agents—effects of temperature and sodium chloride on sodium carboxymethylcellulose and guar gum

Drag reduction may be defined as the effect that occurs when the rate of flow of fluid at a constant pressure gradient is increased upon addition of a colloidal additive (generally in amounts insufficient to cause large changes in the viscosity of the fluid). Drag reduction occurs in turbulent flow and is, therefore, of great potential value to the processing industry where most flows are turbulent. Most such drag-reducing agents are polymers of high molecular weight (1–3).

Recently, Rodriguez (4) observed the drag reduction by polymeric aluminum soap using a simple flow tube. The flow tube is L-shaped Pyrex glass tubing with a 500-ml capacity reservoir connected to the upper end of the vertical portion. This apparatus can be used by measuring "jet action" as the fluid leaves the horizontal tube. Previously, sodium carboxymethylcellulose, guar gum, and many other polymers were reported to be drag-reducing agents (2).

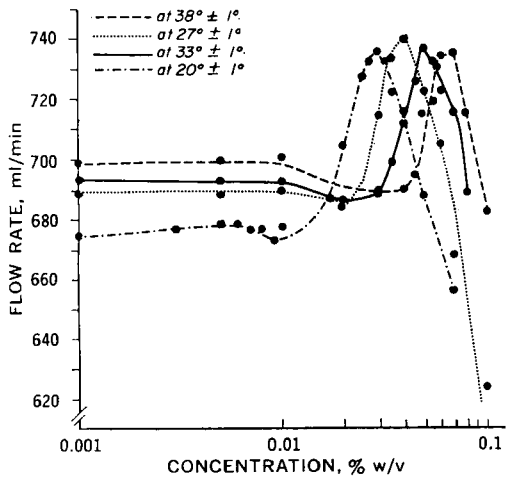

Figure 1—*Effect of concentration of sodium carboxymethylcellulose on flow rate of water at different temperatures.*

Table I—Effect of Sodium Chloride on Some Aqueous Systems at 27 ± 1°

System	Rate[a], ml/min
Water (distilled)	686.5 ± 1.11
Water plus:	
0.05% guar gum	814.78 ± 2.58
0.05% guar gum + 0.9% NaCl	812.57 ± 1.98
0.05% sodium carboxymethylcellulose	723.59 ± 1.96
0.05% sodium carboxymethylcellulose + 0.9% NaCl	670.55 ± 2.51
0.9% NaCl	688.4 ± 1.73

[a] Rate ± standard deviation for five readings.

This paper reports the effect of temperature and sodium chloride concentrations on the drag reduction by sodium carboxymethylcellulose and guar gum, in turbulent flow of water, using a flow tube as previously reported (4).

EXPERIMENTAL

Experiments were carried out in three different categories.

Effect of Temperature on Drag Reduction at Various Concentrations of Sodium Carboxymethylcellulose—The different concentrations of sodium carboxymethylcellulose[1] from 0.001 to 0.1% were run through the flow tube, the time required for 500 ml of solution to flowthrough was noted, and the rate (milliliters per minute) of flow was calculated and plotted against log concentration at 20 ± 1, 27 ± 1, 33 ± 1, and 38 ± 1° (Fig. 1).

Effect of Temperature on Drag Reduction by Guar Gum—The different concentrations of guar gum[2] from 0.001 to 0.15% were run through the tube. The time required for 500 ml of suspension to pass through the tube was noted, and the rate was plotted against log concentrations at 27 ± 1° (Fig. 2). The 0.05% guar gum suspension, which gave a maximum drag reduction at 27°, was tested at 9 ± 1, 15 ± 1, 19 ± 1, 27 ± 1, and 45 ± 1°. The rate was calculated and plotted against the log temperature (Fig. 3).

Effect of Sodium Chloride on Drag Reduction by Sodium Carboxymethylcellulose and Guar Gum—To study the effect of

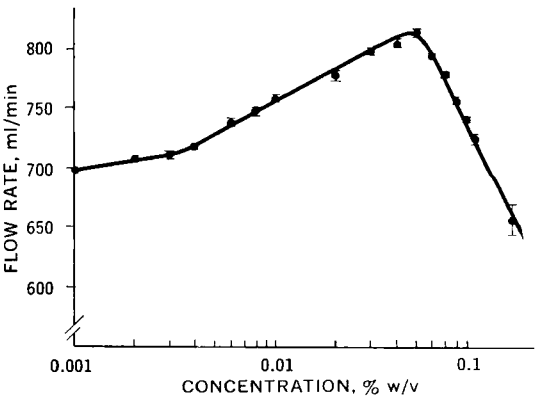

Figure 2—*Effect of concentration of guar gum on flow rate of water at 27°.*

[1] Mallinckrodt Chemical Works, St. Louis, Mo.
[2] S. B. Penick & Co., Chicago, Ill.

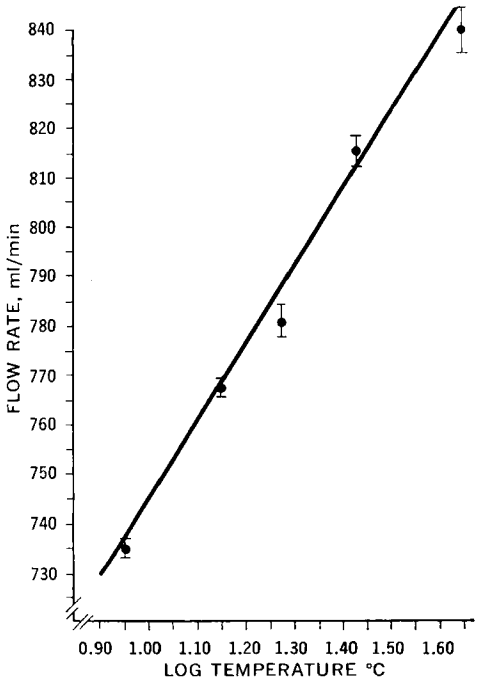

Figure 3—*Effect of temperature on flow rate of 0.05% guar gum suspension.*

sodium chloride[1] on the drag-reducing property of sodium carboxymethylcellulose, 0.05% sodium carboxymethylcellulose was run through the tube with different concentrations of sodium chloride from 0.0001 to 0.05% and the rate of flow was calculated. The rate of flow was plotted against log concentration of sodium chloride (Fig. 4).

No significant change in rate was observed when 0.05% guar gum suspension was run through with 0.9% NaCl (Table I).

RESULTS AND DISCUSSION

In the study of effect of temperature on the flow rate of sodium carboxymethylcellulose, it was observed that an increase in temperature increased the flow rate at initial concentrations. This was probably due to a decrease in viscosity of the solution. An increase in temperature also increased the concentration required to obtain maximum drag reduction. The maximum amount of drag reduction that can be achieved by sodium carboxymethylcellulose remained practically the same at all temperatures. Any increase or decrease of temperature in a system at maximum drag reduction concentration resulted in a decreased flow rate. The effect of temperature on the flow rate of guar gum differed from that of sodium carboxymethylcellulose; there was an increase in the flow rate of a 0.05% guar gum suspension with an increase in temperature.

In the study of the effect of sodium chloride on the drag-reducing property of sodium carboxymethylcellulose, it was observed that up to about 0.0008% NaCl concentration, there was no significant change in flow rate of 0.05% sodium carboxymethylcellulose solution. At around 0.001% NaCl concentration, there was a slight increase in the flow rate followed by a sharp decrease.

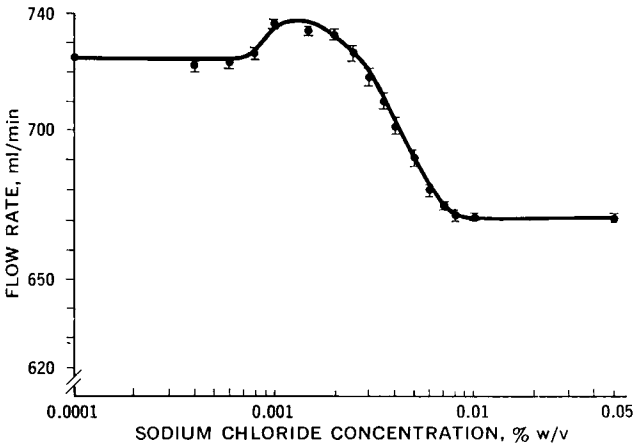

Figure 4—*Effect of sodium chloride concentration on flow rate of 0.05% sodium carboxymethylcellulose at 27°.*

The increase in the rate of flow in 0.05% sodium carboxymethylcellulose with increasing sodium chloride concentrations around 0.001% can be explained as follows. The 0.05% sodium carboxymethylcellulose solution at 27 ± 1° is a drag-reducing concentration, but it is above the concentration required for maximum drag reduction, which is 0.04% sodium carboxymethylcellulose. Apparently, the concentration of the sodium carboxymethylcellulose at the interface is reduced when sodium chloride is added to 0.05% sodium carboxymethylcellulose solution, since there is a significant increase in flow rate at the initial concentrations of sodium chloride, which corresponds to the maximum drag reduction concentration. Further addition of sodium chloride reduces the concentration of sodium carboxymethylcellulose at the interface below the concentration required for maximum drag reduction and, therefore, produces a reduction in the flow rate.

From the data, it would appear that two different mechanisms of drag reduction are operative.

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ACKNOWLEDGMENTS AND ADDRESSES

Received November 26, 1973, from the *College of Pharmacy, University of Illinois Medical Center, Chicago, IL 60612*

Accepted for publication March 20, 1974.

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