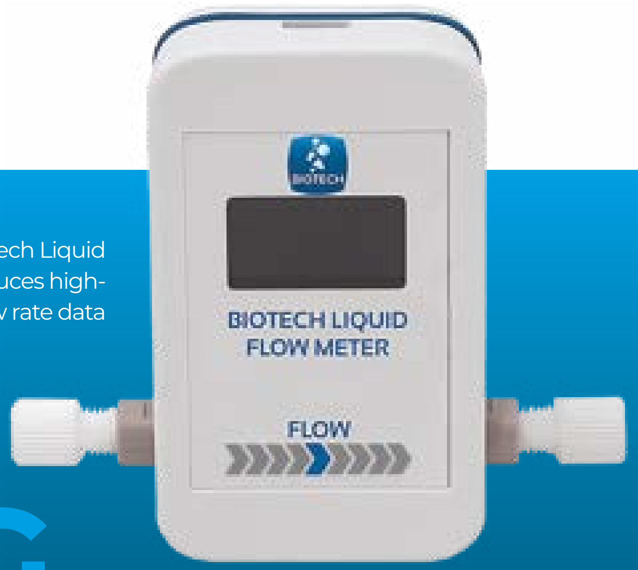

Figure 1. The Biotech Liquid Flow Meter that produces high-resolution flow rate data

PULSING PERFORMANCE

Neelam Akram, Anders Grahn and Tobias Jonsson explore how a high-resolution liquid flow meter can optimise the performance of peristaltic pumps

Peristaltic pumps are attractive for continuous or intermittent dosing of liquid reagents thanks to a simple construction that avoids wetting of any other parts than the pump tubing. However, these pumps inherently generate flow pulsations which potentially can influence the accuracy and precision of the processes they are connected to. Pulsations are influenced by parameters such as the size and number of rollers squeezing the tubing, plus the diameter of the rotor. Such factors are set by the pump construction and thus differ between brands and models. To accomplish a certain volumetric flow rate, the user will vary the tubing inner diameter and material, plus the rotational speed, all of which also may affect the pulsation behaviour.

CHARACTERISATION OF LIQUID FLOW PULSATION

The recent development in small and convenient devices for continuous monitoring of liquid flow rates [1] enables laboratories to characterise and optimise the performance of pumps for various applications. In this report, we used high-resolution

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data from a hand-held bidirectional liquid flow meter (see Figure 1) to test the effect of different pump tubing, all set to accomplish the same average volumetric flow of water (1 mL/min). The experimental setup was very simple (see Figure 2) and included varying tubing dimensions and the rotational speed (rpm) of a small four-roller peristaltic pump. The test comprised four thermoplastic elastomer pump tubing with identical wall thickness (1/16") and varying internal diameters of 1/16", 3/32", 1/8", and 3/16", which correspond to the standardised tubing sizes #14, #19, #16, and #25, respectively.

The gathered flow rate data summarized in Figure 3 highlights significant pulsations of the liquid, at intervals corresponding to the number of rollers passing per time unit. Especially notable was the repeated brief reversed flow with the larger tubing diameters, an effect that appeared most pronounced with the #16 tubing having 1/8" (3.2 mm) inner diameter. All displayed data were recorded with brand new pump tubing since we noted that slightly worn tubing tended to result in more distinct negative flow. This ageing effect was most pronounced with the size #16 pump tubing, with which we

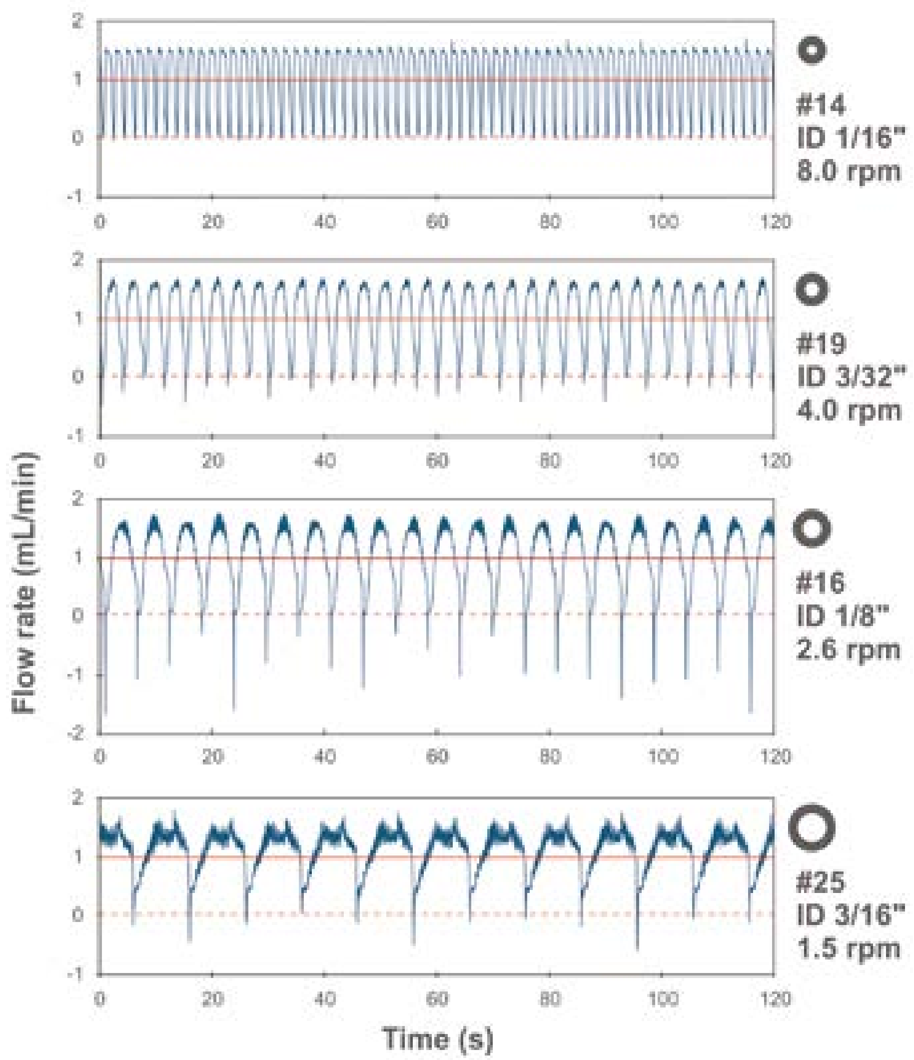


Figure 3. High-resolution flow rate data recorded during two minutes at 78 ms resolution using an AB-40010 Biotech Liquid Flow Meter calibrated with water. The pump was a four-roller peristaltic pump (Shenchen LabS3 Minipump01) operated at various rotational speeds and equipped with four different sizes of PharMed BPT pump tubing as specified in the figure. All pump tubing had been in use less than one hour before the test. The solid red line indicates the set average volumetric flow rate of 1.0 mL/min in each case, and the dashed red line highlights the zero-flow rate value, below which liquid flow was reversed

recorded negative flow rate pulses exceeding -3 mL/min, see Figure 4.

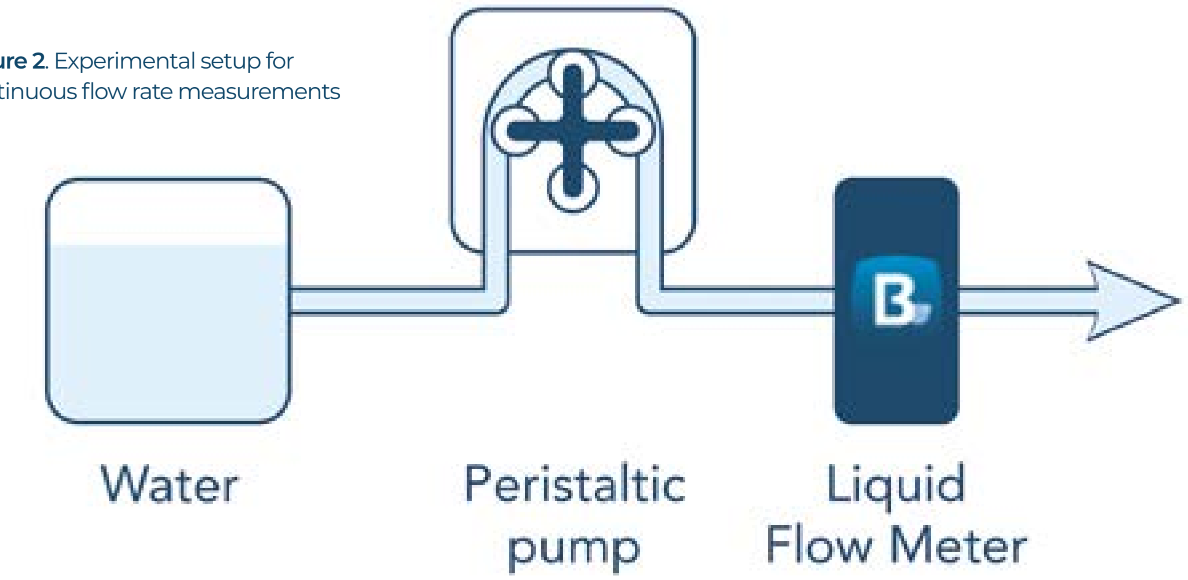
These measurements confirm that the momentary negative flow from peristaltic pumps is a significant contributor to the pulsations, which agrees well with published theoretical calculations [2]. We therefore consider that the more extensive pulsation with the #16 pump tubing, likely was the result from a particularly unfortunate combination of rotor size, rotational speed, roller diameter, and tubing inner diameter.

IMPACT OF FLOW PULSATIONS ON CHROMATOGRAPHIC ANALYSIS PERFORMANCE

Subsequently, the peristaltic pump was applied in a simple and affordable setup for suppressed conductivity detection within a chromatography system for analysis of inorganic anions (fluoride, chloride, nitrite, bromide, nitrate, phosphate, sulphate) using a typical bicarbonate-carbonate eluent (1.7+1.8 mM) delivered at 1 mL/min. In this setup, the peristaltic pump was used to continuously deliver aqueous solutions of dilute sulfuric acid as regenerant for a membrane suppressor [3] positioned between the separation column and conductivity detector.

During the ion chromatography analyses we recorded the noise level (as peak-to-peak noise within two minutes excluding drift) using the ▸

Figure 2. Experimental setup for continuous flow rate measurements



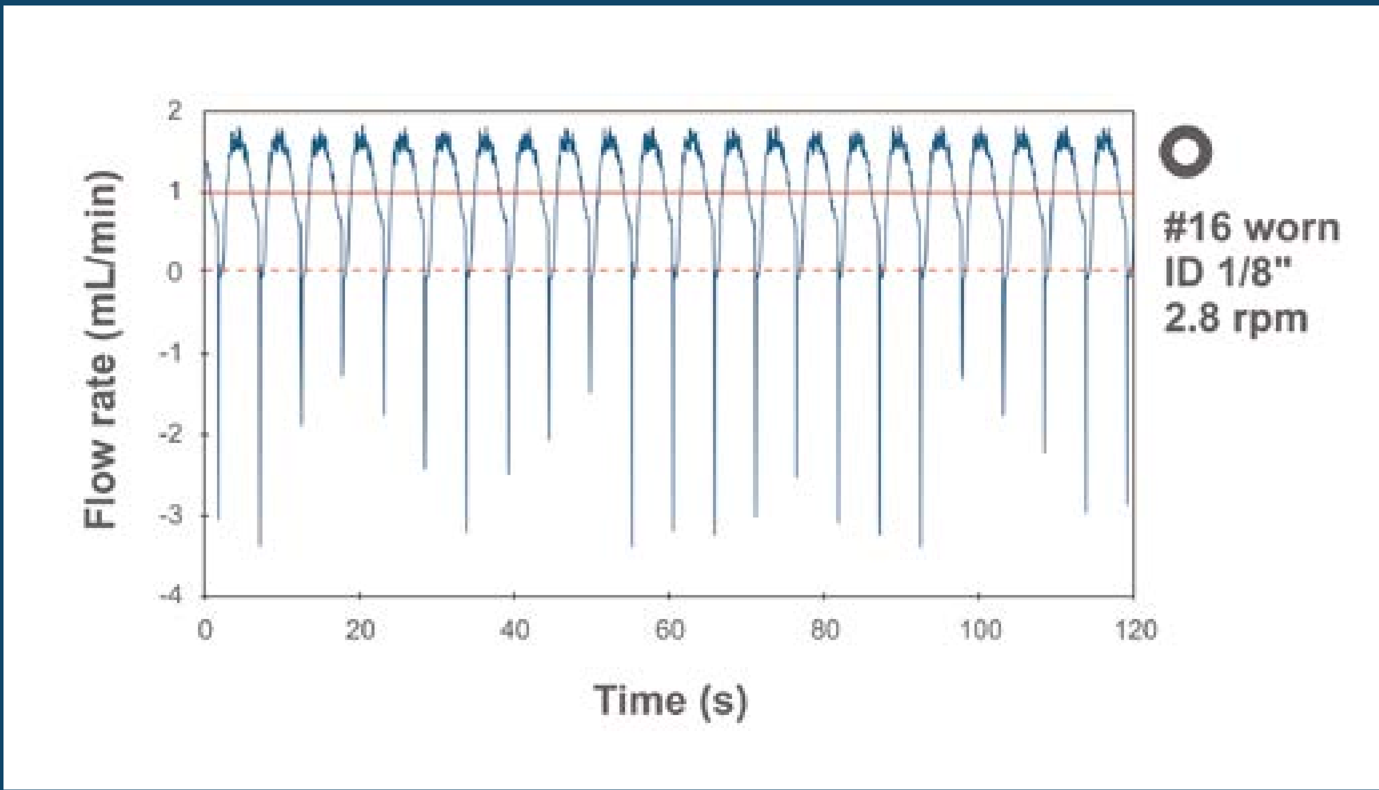


Figure 4. High-resolution flow rate data recorded with a worn pump tubing. Rotational speed was adjusted slightly to maintain average volumetric flow rate at 1.0 mL/min. All other conditions identical to Figure 3

same peristaltic pump tubing and rotational speeds as tested before. It was found that the noise during these analyses could be reduced to 1-2 nS/cm when the peristaltic pump parameters were selected to minimise flow pulsations, whereas it generally was twice that or more at other conditions. The distinct pulsation patterns from the peristaltic pump could, however, not be detected in the chromatogram recordings, presumably due to dampening effects of the connecting tubing and the suppressor.

CONCLUSIONS

The recording of high-resolution flow rate data enabled us to avoid conditions for the peristaltic pump that provided excessive flow pulsations thus allowing selection of more appropriate operational parameters. The less pulsating flows tended to give lower levels of noise during ion chromatography analysis with a chemically regenerated suppressor. This resulted in higher signal-to-noise ratios which consequently would allow for reliable detection and quantifications of lower concentration levels.

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