

ELECTRONIC SUPPLEMENTARY INFORMATION

Surface modified thread-based microfluidic analytical device for selective potassium analysis

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Thread flow behavior

To evaluate the wicking behavior of unwaxed and as-received cotton threads, the fluid penetration distance was studied while the thread was maintained in a horizontal position. Figure 1S plots the penetration distance of fluid L as a function of time t showing that the scouring treatment improves the hydrophilic character of the cotton as well as the homogenous wicking across the length of the thread as shown by the error bars in Figure S1.¹

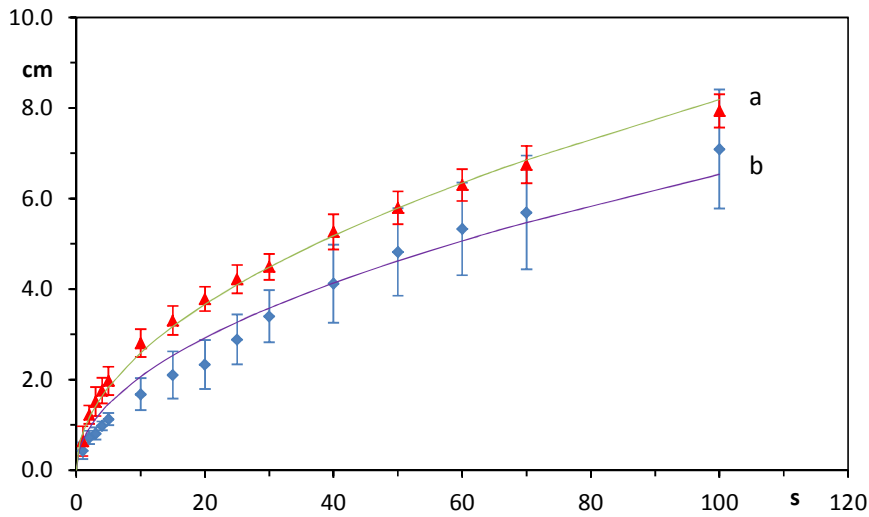


Figure S1. Evolution of fluid penetration in unwaxed (a) and as-received (b) cotton from data obtained from a video. 10-cm long threads wicked with 50 μ L dye solution. Solid lines fit the experimental data to a Washburn equation.

To model the fluid penetration within a thread, the Washburn equation was used (equation S1) where γ is the interfacial tension, θ is the contact angle between the liquid and the thread surface, D is the effective capillary diameter and μ is the viscosity of the liquid.

$$L = \sqrt{\frac{(\gamma \cos \theta) D t}{4\mu}} \quad \text{Equation S1}$$

The fit to the Washburn equation was obtained by fitting the experimental data with a square root function ($L=a\sqrt{t}$) resulting in $a = 0.8185$ with $R^2 =$

0.9963 for the treated thread and $a = 0.6533$ with $R^2 = 0.9714$ for the as-received thread. The experimental data shows some deviation from Washburn-type behavior because some factors are not considered such as the reduction in capillary force by fluid evaporation and the availability of inter-yarn gaps, which are larger than intra-yarn gaps, due to the bilobal cross-sectional geometry (Figure S2) of the cotton thread used.²

The length that different volumes of fluid advance through the thread is another important characteristic for μ TAD design.³ Figure S2 shows the exponential dependence ($L=1.361V^{0.7}$; $R^2=0.9946$)⁴ between the volumes added (V , μ L) and the distance moved through the thread (L , cm).

Figure S2

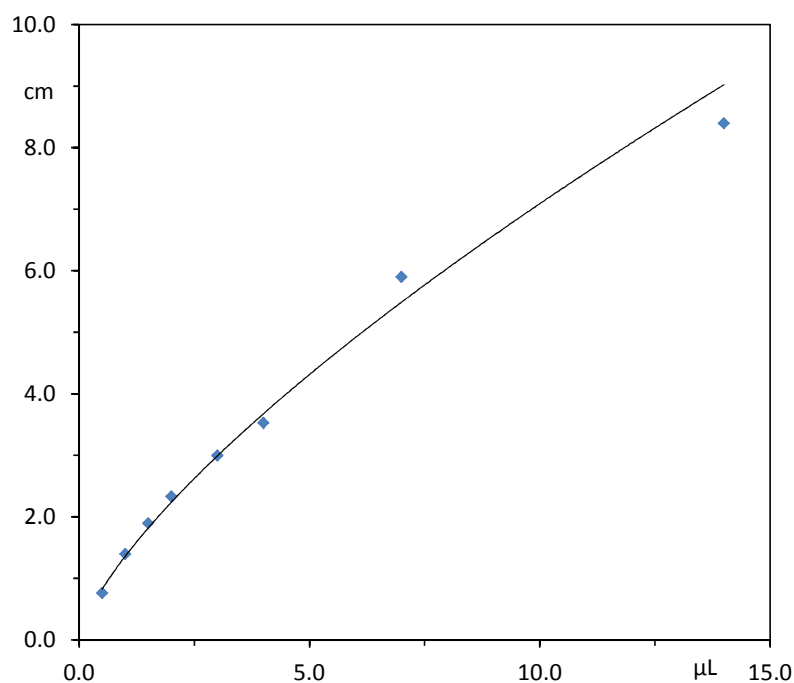


Figure S2. Distance advanced by different volumes (from 0.5 to 15 μ L) of dye solution when added to the end of a 10 cm-long scoured thread.

Selectivity calculation

To calculate the selectivity coefficients for the μ TAD described we used a separate solution method.⁵ The response curves for K(I), Na(I), Ca(II) and

Mg(II) at pH 9.0 were obtained using standard solutions with concentrations ranging from 3.98×10^{-4} M to 0.96 M, with three replicates per concentration. The corresponding exchange constant for each equilibrium was calculated using Equation S2 based on the theoretical model:

$$a_{I^{v+}} = \frac{1}{K_{exch}} \left(\frac{a_{H^+} \alpha}{1 - \alpha} \right)^v \frac{C_R - (1 - \alpha)C_C}{v \left(C_L - \frac{p}{v} (C_R - (1 - \alpha)C_C) \right)^p} \quad \text{Equation S2}$$

Where a_{H^+} is the protonic activity in the sample, C_R , C_C and C_I are the molal concentration of the lipophilic salt, lipophilic indicator and ionophore respectively, p the stoichiometry of the complex ionophore-analyte (1:1 in this case), v the charge of the ion under consideration and $1 - \alpha$ the ratio of the protonated indicator to its analytical concentration calculated from the H value in this case.⁶ The different K_{exch} values were calculated using Mathematica 5 software.

The selectivity of the potassium device against other alkaline and alkaline-earth ions was calculated by the selectivity factor K_{IJ}^{opt} defined by Equation S3:

$$K_{IJ}^{opt} = \frac{v}{z} \frac{K_e^{JL_q}}{K_e^{IL_p}} \left(\frac{a_{H^+} \alpha}{1 - \alpha} \right)^{z-v} \frac{C_L - \frac{1}{v} C_R - (1 - \alpha)C_C}{C_L - \frac{1}{z} C_R - (1 - \alpha)C_C} \quad \text{Equation S3}$$

From plots of the experimental parameter $(1 - \alpha)$ vs. the logarithm ion activity at $\alpha = 0.5$, it is possible to obtain the selectivity factor as the horizontal distance between the calibration curve for K(I) and the interfering ions (Figure S7).

Figures

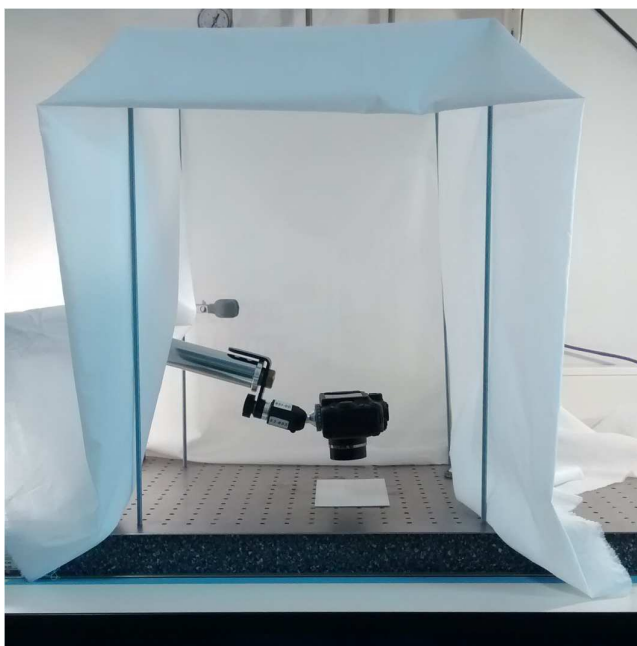


Figure S3. Cube light box setup used for image acquisition from the μ -TAD with the digital camera placed in a fixed position over an optical table illuminated with two LED light bulbs (3000 K) with a luminance of 165 lux at the stage

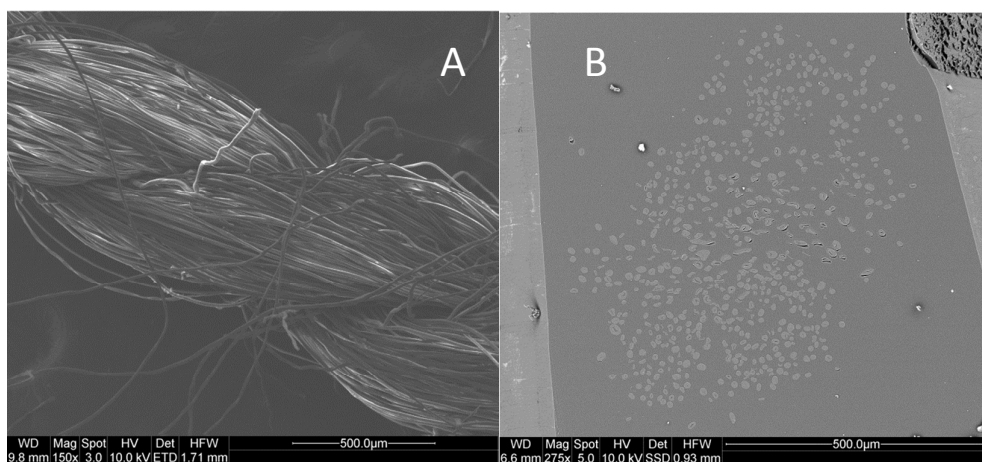


Figure S4. SEM image of cotton thread after scouring treatment. A) SEM micrograph showing the individual fibers arranged in bilobal geometry; B) SEM micrograph of cross-sectional view of thread showing individual fibers and their lumen

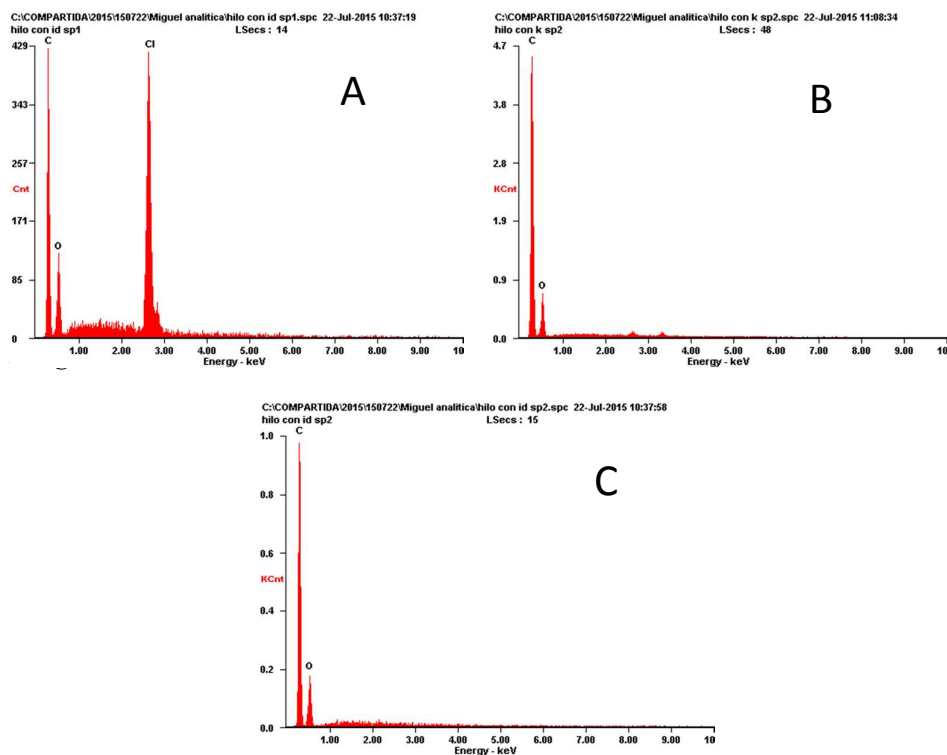


Figure S5. EDX spectra of cotton thread. A) Cotton thread with deposited sensing membrane obtained in areas with sensing membrane; B) Cotton thread with deposited sensing membrane obtained in areas without sensing membrane; C) Cotton thread without sensing membrane

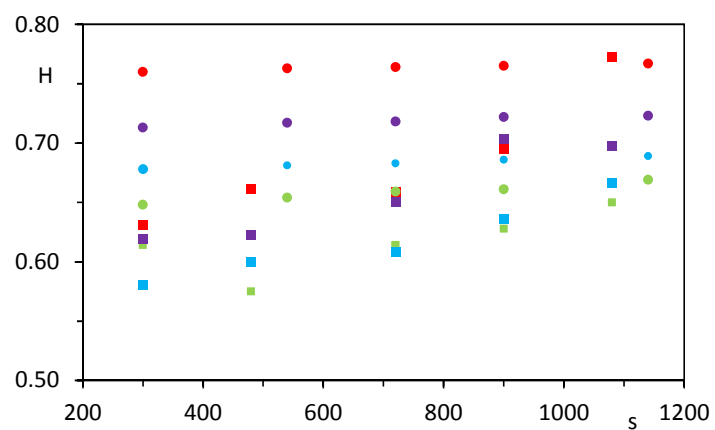


Figure S6. Evolution of H parameter with time after addition of potassium standard to the μ TAD. \circ Potassium standard buffered at pH= 9.0; \square Potassium standard buffered at pH=7.4. Color key: Green dots: 3.98×10^{-6} M; Blue dots: 1.26×10^{-4} M; Violet dots: 3.98×10^{-3} M; Red dots: 3.98×10^{-2} M.

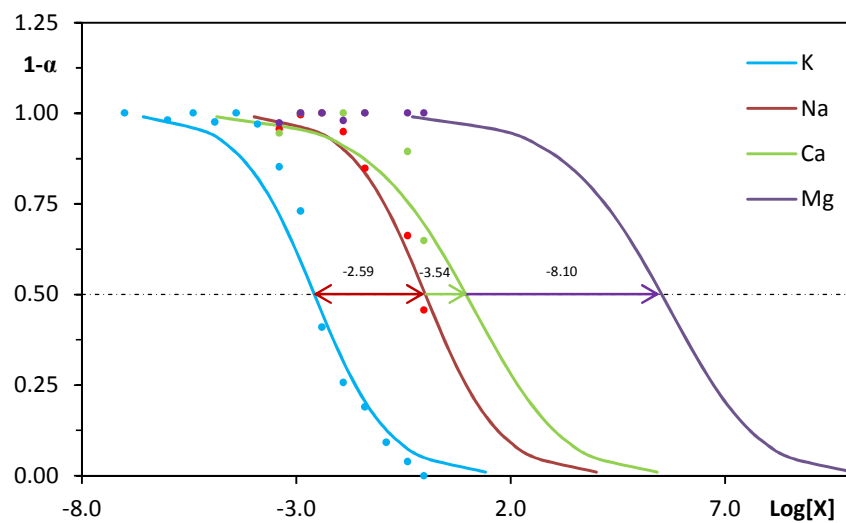


Figure S7. Response of K(I) μ -TAD to various ions. The horizontal distance at $\alpha = 0.5$ gives the selectivity coefficient.

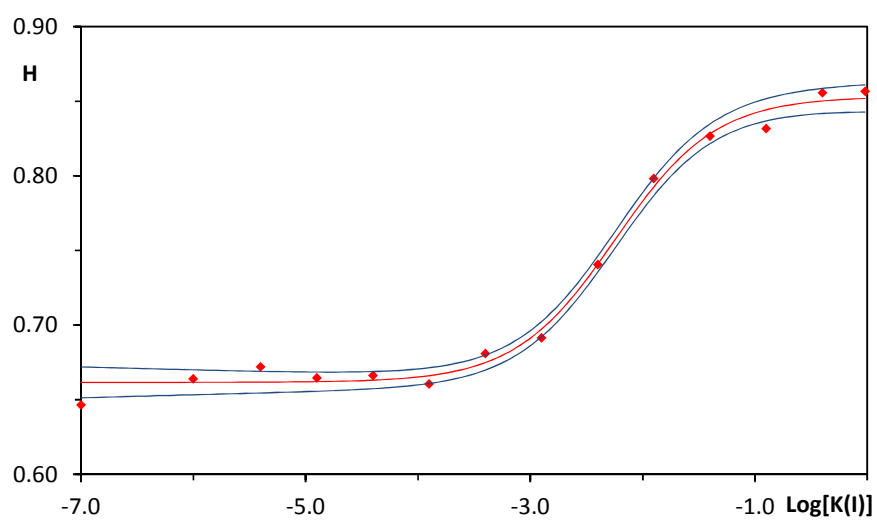


Figure S8. Calibration curve for K(I) measuring at 15 s.

Video

Video S1. Evolution of μ TAD color after addition of 10 μ L standard [K(I)] $12.6 \cdot 10^{-3}$ M.

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