Development and Evaluation of a Novel Sandwich-Type Device for the Determination of Fluoride in Aqueous Samples

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Introduction

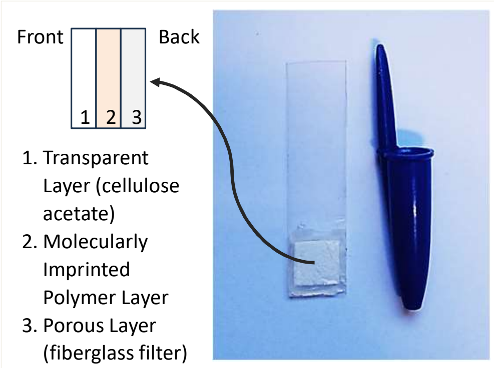
Fluoride's importance spans various domains, being essential for human health while posing toxicity risks at excessive levels. Additionally, elevated environmental fluoride concentrations can harm ecosystems, impacting water and soil quality and ecological equilibrium.

In this context, its important to have sensor-based techniques which enable rapid and in-situ measurements. Our team has developed a simple sensor device for fluoride based on a molecularly imprinted polymer (pending publication) that uses a fluoride specific (1-allyl-3-(pyren-1-yl)urea) binding core.

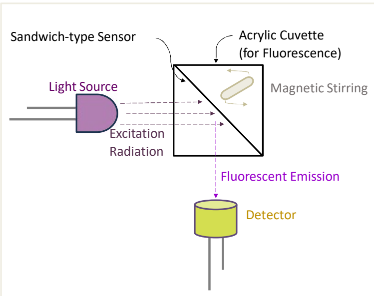
Sandwich-type Sensor

The device consist of a molecularly imprinted polymer layer between two material layers: one UV-transparent and the other analyte-permeable.

To assemble the sensor, the suspended MIP was filtered to retain suitable particles. The retained MIP was then meticulously cut and epoxy-bonded to the transparent layer.



Methodology

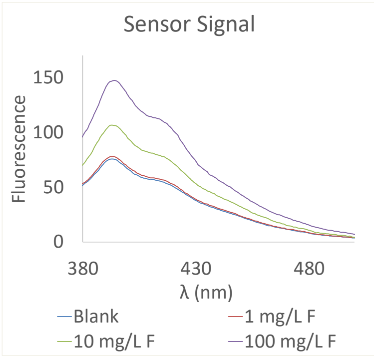


For measurements, the sandwich sensor was positioned diagonally within a fluorescence cell and then filled either with ISO Grade 1 water (blanks) or solutions containing different concentrations of Sodium Fluoride.

Fluorescence signals were acquired utilizing a Shimadzu RF5301 fluorescence spectrometer with an integrated Luma 40 magnetic stirred Peltier-based temperature-controlled cuvette holder.

pH = 7.0 ; T = 20ºC ; λ(excitation) = 355 nm

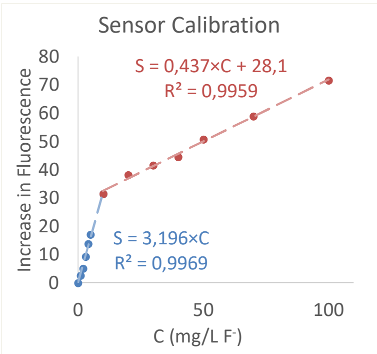
Quantification



Fluorescence increase (at 398nm) relative to the blank was used as the analytical signal

$$S = F_{sample} - F_{blank}$$

Calibration



Two linear ranges with different sensitivities are present:

a) From 1 to 10 mg/L F^-

b) From 10 to 100 mg/L F^-

Validation

Figure of merit	Value	Unit
Limit of detection (LOD)	0.38	mg/L F^-
Limit of quantification (LOQ)	1.29	mg/L F^-
Linear range	1-10[a] 10-100[b]	mg/L F^-
Sensitivity	3.196[a] 0.437[b]	L/mg F^-
Repeatability	2.21	%
Trueness (range)	92.7 - 106.4	%

[a]: First linear range. [b]: Second linear range

LOD and LOQ: 3s and 10s criteria, first linear range slope, (n = 10)

Repeatability: RSD(%) of 30 mg/L fluoride-spiked potable water samples (n = 6)

Trueness: Recovery from 30 mg/L fluoride-spiked samples (n = 6) compared with selective fluoride electrode results.

Conclusions

The sandwich-type sensor developed by our team shows promising performance characteristics for future fluoride determinations in diverse sample matrices (e.g. industrial, environmental or food samples). It showcases appropriate levels of repeatability, accuracy, detectability and linearity characteristics.

The sandwich-type design proved to be versatile as a containment method for the polymer with sensory capabilities, contributing robustness and reusability to the design.

Prospects for Further Research

The team is currently working on a measurement system designed to be easily deployable for field measurements. For that purpose, we are evaluating the performance of UV LEDs as radiation sources, portable fiber optic spectrometers and multispectral sensors as detectors, alongside various custom 3D-printed components.

Acknowledgments

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