Smartphone-based Optode Sensor for Calcium and Magnesium Continuous Detection in Water Sample

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Hard water is water that has a high mineral content, mainly Calcium and Magnesium.

The more calcium and magnesium dissolved in the water, the harder the water becomes.

Over 120mg/L of CaCO$_3$ is hard water
Hard water

- Protective effect on cardiovascular mortality
- Kidney stone are composed of calcium salt
- Form limesacle in industrial facility

Our approach-Smartphone colorimetric detection
Device structure

3D printing mold

Main structure
Working principle

Working condition: Calcium ion detection in Acetate buffer (pH=5.3), Total water hardness detection in Tris-Hcl buffer (pH=7.2)

The color change is based on the protonation of chromoionophore

\[
1 - \alpha_{eff} = \log(I_{X\downarrow NaOH}) - \log(I_{X\downarrow buffer}) - \log(I_{X\downarrow NaOH})
\]

Effective degree of protonation:
Result-calcium ion measurement

Simulated hard water calibration in acetate buffer

$Ca^{2+}$ calibration in acetate buffer
Mg$^{2+}$ has no interfering effect in acetate buffer.
Calcium ionophore was sensitive to both $\text{Ca}^{2+}$ and $\text{Mg}^{2+}$ in Tris-Hcl buffer.

Control: 0.2g/L CaCl$_2$
Interfering: 0.2g/L CaCl$_2$ + 0.2g/L interfering ion
Result-total hard water measurement

Simulated hard water calibration in Tris-Hcl buffer
Response time and life time

Response time

Life time (Preserved at ambient temperature)
# Real sample measurement

<table>
<thead>
<tr>
<th>Sample</th>
<th>Commercial kit</th>
<th>Own designed device</th>
<th>ICPMS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total hardness (mg/L)</td>
<td>[CaCO3] (mg/L)</td>
<td>Total hardness (mg/L)</td>
</tr>
<tr>
<td><strong>Fountain water</strong></td>
<td>240.00</td>
<td>153.33</td>
<td>229.80±6.51</td>
</tr>
<tr>
<td><strong>Logan river</strong></td>
<td>193.33</td>
<td>100.00</td>
<td>171.51±4.91</td>
</tr>
<tr>
<td><strong>Tapping water</strong></td>
<td>246.67</td>
<td>160.00</td>
<td>216.35±6.98</td>
</tr>
<tr>
<td><strong>Drinking water</strong></td>
<td>33.33</td>
<td>20.00</td>
<td>26.51±1.85</td>
</tr>
</tbody>
</table>
Future work - Magnesium ionophore

- Acetate buffer
- Tris-HCl buffer
- Interfering ions

Calcium ionophore
Magnesium ionophore
Future work-Channel design & CFD

Mixing zone: optimize the mixability by adjust the inflow rate

Outlet: design the channel width to achieve the uniform pressure in each outlet
Conclusion

1. A novel colorimetric sensor was designed for hard water monitoring continuously and conveniently.
2. The sensing membrane is able to detect concentration of Calcium and Magnesium separately.
3. The linear range covered from soft water to very hard water (20mg/L to 800mg/L).
4. The smartphone based device is capable to be used in resource-limited area.
Acknowledgement

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Thanks for your attention and any questions?