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

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04-13-2017
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
Background

- 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

\[ 1 - \alpha_{eff} = \log \downarrow X_{\text{NaOH}} - \log \downarrow X_{\text{buffer}} - \log \downarrow X_{\text{NaOH}} \]

Effective degree of protonation:
Result-calcium ion measurement

Simulated hard water calibration in acetate buffer

Ca$^{2+}$ calibration in acetate buffer
Result-calcium ion measurement

Mg$^{2+}$ has no interfering effect in acetate buffer

Control: 0.2g/L CaCl$_2$

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

Calcium ionophore was sensitive to both Ca$^{2+}$ and 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**

- Graph showing intensity of red channel over time (s) for NaOH and 0.2g/L Ca²⁺.

**Life time (Preserved at ambient temperature)**

- Graph showing intensity of red channel over time (day) for 0.2g/L Ca²⁺.
### 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>Total hardness (mg/L)</td>
<td>[CaCO3] (mg/L)</td>
</tr>
<tr>
<td><strong>Fountain water</strong></td>
<td>240.00</td>
<td>229.80±6.51</td>
<td>174.73±9.71</td>
</tr>
<tr>
<td></td>
<td>153.33</td>
<td>174.73±9.71</td>
<td>230.79±23.60</td>
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<tr>
<td><strong>Logan river</strong></td>
<td>193.33</td>
<td>171.51±4.91</td>
<td>78.35±8.93</td>
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<tr>
<td></td>
<td>100.00</td>
<td>78.35±8.93</td>
<td>143.43±5.36</td>
</tr>
<tr>
<td><strong>Tapping water</strong></td>
<td>246.67</td>
<td>216.35±6.98</td>
<td>173.02±23.72</td>
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<tr>
<td></td>
<td>160.00</td>
<td>173.02±23.72</td>
<td>173.32±22.41</td>
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<tr>
<td><strong>Drinking water</strong></td>
<td>33.33</td>
<td>26.51±1.85</td>
<td>11.04±1.48</td>
</tr>
<tr>
<td></td>
<td>20.00</td>
<td>11.04±1.48</td>
<td>20.97±3.39</td>
</tr>
</tbody>
</table>

**Validation**

Real sample testing
Future work - Magnesium ionophore

Acetate buffer

Tris-HCl buffer

Interfering ions

Calcium ionophore

Magnesium ionophore

Glass cover

Ionophore membrane

Detection zone

Sample inlet

Plug layer
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

Thanks for the support from Utah Water Research Laboratory