NOVEL WIRELESS SYSTEM FOR IN-SITU LAB-ON-A-DISC MULTI-PARAMETER WATER QUALITY ANALYSIS

22/8/12
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@ cyrusmekon #SESEH
Contents

Centrifugal microfluidic analysis system: CMAS

- The desire for CMAS.
- Design of CMAS.
- Nitrite determination
- Conclusions.
About Clarity

Vision: Sensing Mind, Body & Place

- Brings together fundamental materials science, functional polymers, device prototyping, energy management, adaptive middleware, wearable sensors, distributed environmental monitoring.

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The need for sensors.
HP's Peter Hartwell: "one trillion nanoscale sensors and actuators will need the equivalent of 1000 internets: the next huge demand for computing!"
The need for sensors.

Sensing Systems: $70 B global market by 2013 (Frost & Sullivan)

Sensing Services: $290 B Global market by 2013 (Harbour research)
The need for sensors.

Similar strategies proposed by IBM, INTEL, Nokia....
Brief introduction: The desire for CMAS.

- Existing analytical methods are very costly and time consuming, therefore simple, accurate sensing devices capable of multiple analysis would be of great benefit.

- portable
- cheap
- single probe
- no data saving

- hand-held device
- multiprobe (temperature, cond., pH, redox, DO, turbidity (TSS), Nitrate, Ammonium, Sodium, Fluoride, etc.)

• ~14,000$
Brief introduction: The desire for CMAS.

- Existing analytical methods are very costly and time consuming, therefore simple, accurate sensing devices capable of multiple analysis would be of great benefit.

- The availability of optical components like light emitting diodes (LEDs) or photodiodes in particular has opened the potential of optical sensing approaches to be widely employed in platforms for wireless sensor networks (WSNs).
The desire for CMAS.

Why centrifugal platform?

• Elimination of large power supplies and external pump.

• Provides forces across the entire length of a fluid element.

• Multiple individual micro-fluidic systems can be placed on a single CD.

• Potential to include multi-parameter assays and / or multiple replicate assays with calibration.

• Potential for multi-stage assays involving several fluidic sub-compartments.
The desire for CMAS.

Microfluidic Devices market in M$

Yole Development: Large projected markets for microfluidics
Current CD platforms.

*Abaxis Piccolo Xpress*

“The Piccolo xpress is a convenient and compact clinical chemistry system developed for the on-site testing of patients.

In size, it is almost like a shoebox. The easily understandable color touch screen commands enable health care providers to carry out everyday multi-chemistry

**COST: $8500 USD**
Current CD platforms.

Samsung Blood Analyser

IVD-A10A compact blood tester. The company claims that its blood tester is smaller, faster and more accurate compare to traditional blood testing devices.

COST: $8500 USD
Current CD platforms.

LaMotte Waterlink Spin

<table>
<thead>
<tr>
<th>Test Factor</th>
<th>Range</th>
<th># Tests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Free Chlorine DPD</td>
<td>0-15.0 ppm</td>
<td>100</td>
</tr>
<tr>
<td>Total Chlorine DPD</td>
<td>0-15.0 ppm</td>
<td>100</td>
</tr>
<tr>
<td>Bromine DPD</td>
<td>0-33.0 ppm</td>
<td>100</td>
</tr>
<tr>
<td>pH</td>
<td>6.3-8.6 pH</td>
<td>100</td>
</tr>
<tr>
<td>Calcium Hardness</td>
<td>0-1200 ppm</td>
<td>100</td>
</tr>
<tr>
<td>Total Alkalinity</td>
<td>0-250 ppm</td>
<td>100</td>
</tr>
<tr>
<td>Cyanuric Acid</td>
<td>5-150 ppm</td>
<td>100</td>
</tr>
<tr>
<td>Copper</td>
<td>0-3.0 ppm</td>
<td>100</td>
</tr>
<tr>
<td>Iron</td>
<td>0-3.0 ppm</td>
<td>100</td>
</tr>
</tbody>
</table>

COST: $1000 USD
Current CD platforms.

LaMotte Waterlink Spin

<table>
<thead>
<tr>
<th>Test Factor</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Biguanide</td>
<td>0-70 ppm</td>
</tr>
<tr>
<td>Biguanide Shock</td>
<td>0-250 ppm</td>
</tr>
<tr>
<td>pH</td>
<td>6.3-8.6 pH</td>
</tr>
<tr>
<td>Calcium Hardness</td>
<td>0-1200 ppm</td>
</tr>
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COST: $1000 USD

Abaxis Piccolo Xpress

COST: $8500 USD

Samsung Blood Analyser
The design of CMAS

Fluid Manipulation (CD Spinning)

Colorimetric Analysis
The design of CMAS

Fluid Manipulation (CD Spinning)

Colorimetric Analysis

Spinning + Colorimetric Analysis
The design of CMAS

1. Modular LED unit
2. Centrifugal Disc
3. LED Detector Intensity
4. Wixel Shield for Arduino
5. Model Motor Size H
6. Two 9V, Li battery
7. Support unit

• Patent application no. GB 1207239.3
The design of CMAS

- Low cost colourmetric detector.
- Multiple samples analysis in a single micro-fluidic chip.
- Multiplexing capabilities (pH, turbidity, nitrite,...).
- Portable system: sample analysis at the point of need.
- Wireless communication system.
The design of CMAS
The design of CMAS

The design of CMAS

Manual alignment

Alignment Emitter LED

CD alignment window

Optical Cuvette

CD

Alignment Detector LED
The design of CMAS

A versatile Modular Point of Care / Need device

A) Environmental  B) Physiological  C) Biological
Cost.....

- LED’s € 2.00
- Batteries € 18.60
- Misc Electronics € 40.00
- Custom PCB Board € 59.94
- Printed ABS case € 100.11
Cost.....

LED's € 2.00
Batteries € 18.60
Misc Electronics € 40.00
Custom PCB Board € 59.94
Printed ABS case € 100.11
Software development-Beta testing

In collaboration with Prof Smeaton, School of Computing, DCU.
Software development-Beta testing

CMAS system

Android Tablet
Software development - Beta testing

![Image of a software interface with options: Start new Experiment, Search, Configuration Settings]
Software development-Beta testing

Experiment Details Form

Location: 630-672 Collins Avenue Extension, Dublin
Date and Time: Aug 16, 2012 5:00:35
Person: John Doe
Field Trial Name: test
Experiment Number: 1

Next
Software development - Beta testing
Experiment finished.
Data saved to SD Card successfully.

- Take Photo of the Disk
- Start New Experiment
Nitrite detection in freshwater: CMAS
Nitrite detection in freshwater: CMAS

CD design

- Top PMMA (Inlets; 1.5mm)
- Top PSA (Bonding; 80µm)
- Middle PMMA (Reservoirs; 1.5mm)
- Bottom PSA (Channels; 80µm)
- Bottom PMMA (Valves; 1.5mm)
Nitrite detection in freshwater: CMAS

- Standard solution/Sample reservoir - 31.5 uL
- Air vent (bubble prevention)
- Griess Reagent reservoir - 2.1 uL
- Microchannels - 1000 um width
- Mixing/Detection area - 33.5 uL
Nitrite detection in freshwater: CMAS

![Image of nitrite detection experiment](image_url)

Levels: 0.0 mg/L, 0.2 mg/L, 0.4 mg/L, 0.6 mg/L, 0.8 mg/L, 1.0 mg/L, 1.2 mg/L

Wednesday, 22 August 12
Nitrite detection in freshwater: CMAS

Reagent A

\[
\begin{align*}
    &\text{HO}_3\text{S} &\text{NH}_2 \\
    &\text{H}_3\text{PO}_4 &\rightarrow \\
    &\text{HO}_3\text{S} &\text{N}_2
\end{align*}
\]

Reagent B

\[
\begin{align*}
    &\text{NH(CH}_2\text{)}_2\text{NH}_2 \\
    &\rightarrow \\
    &\text{HO}_3\text{S} &\text{N} = \text{N} &\text{NH(CH}_2\text{)}_2\text{NH}_2
\end{align*}
\]

Griess reaction method: Nitrite detection\([3]\)

Azo dye \((\lambda_{\text{max}} \, 547 \, \text{nm})\)

\[\text{[3]} \text{ M. O'Toole and R. Shepherd, K. Lau and D. Diamond, (2007) Advanced Environmental, Chemical, and Biological Sensing Technologies V, 10 September 2007, Boston, MA, USA.}\]
Nitrite detection validation: UV-Vis

Absorbance
Nitrite detection validation: UV-Vis

Kinetic profile of colour formation between NO$_2^-$ and Griess reagent

![Graph showing the kinetic profile of colour formation between NO$_2^-$ and Griess reagent. The x-axis represents time in minutes (0 to 35), and the y-axis represents normalized absorbance (0 to 2.5). There are curves for different concentrations: 0.2 mg/L, 0.4 mg/L, 0.6 mg/L, 0.8 mg/L, 1.0 mg/L, and 1.2 mg/L. Each curve reaches a plateau at different absorbance levels, indicating the formation of colour over time.]
Nitrite detection validation: UV-Vis

Absorbance after 20 mins

\[ y = 1.6458x + 0.0736 \]

\[ R^2 = 0.99321 \]
Sequence of the Experiment: CMAS

A. Loading the samples and reagent

B. Spinning of the CD (1800 rpm, 180 s)

C. Alignment of CD

D. Detection
Sequence of the Experiment: CMAS

A. Loading the samples and reagent

B. Spinning of the CD (1800 rpm, 180 s)

C. Alignment of CD

- Nitrite standard solution
- Griess Reagent
- Air Vent
- Mixing/Detection area
- Alignment hole

D. Detection
Nitrite detection validation: CMAS
Nitrite detection validation: CMAS

![Graph showing nitrite detection over time for different concentrations.](image)
Nitrite detection validation: CMAS

Limit of Detection: 40 ppb nitrite
Nitrite detection in freshwater: CMAS

Water nitrite analysis using a bench-top UV-VIS spectrometer and the CMAS device and a map of the sampling places (n = 3).
CMAS: Conclusions

Design

• A portable system for *in-situ* colorimetric water quality analysis has been developed.
• Integration of a wireless communication device allows data acquisition according to individual needs.
• Cloud Integration / data management via Android tablet.

Functionality

• System shows the huge potential for the CMAS to be a cheap and versatile alternative as point-of-need optical detector for lab-on-a-disc applications.
• LoD for Nitrite: 40 ppb

• Patent application no. GB 1207239.3
CMAS: Acknowledgments

Materials
Monika Czugala
Fernando Benito-Lopez

Engineering
Damien Maher
Fiachra Collins

Software
Frank Hopfgartner
Yang Yang
Jiang Zhou
Alan Smeaton
CMAS: Acknowledgments

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Software
Frank Hopfgartner
Yang Yang
Jiang Zhou
Alan Smeaton

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Thanks for your attention

QUESTIONS?

Presentation available for download