MONITORING FOR WATERBORNE PATHOGENS

SWIG 28/1/15
Dr Helen Bridle
Monitoring for Waterborne Pathogens

Why?
Health and economic impacts
Outbreaks
Endemic disease
Food production

What?

<table>
<thead>
<tr>
<th>Pathogen</th>
<th>Equivalent diameter (nm)</th>
</tr>
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<tbody>
<tr>
<td>Enteroviruses</td>
<td>20-30</td>
</tr>
<tr>
<td>Hepatitis E</td>
<td>27-34</td>
</tr>
<tr>
<td>Rotaviruses</td>
<td>60-80</td>
</tr>
<tr>
<td>Adenoviruses</td>
<td>70-100</td>
</tr>
<tr>
<td>Campylobacter spp</td>
<td>310-1800</td>
</tr>
<tr>
<td>Shigella spp</td>
<td>510-2100</td>
</tr>
<tr>
<td>E. coli</td>
<td>720-1000</td>
</tr>
<tr>
<td>Vibrio Cholera</td>
<td>810-1400</td>
</tr>
<tr>
<td>Salmonella spp</td>
<td>1100-2600</td>
</tr>
<tr>
<td>Giardia Lamblia</td>
<td>2800-4600</td>
</tr>
<tr>
<td>Cryptosporidium</td>
<td>3600-7400</td>
</tr>
</tbody>
</table>
DETECTION SYSTEMS

Detection of *Cryptosporidium* in Miniaturised Fluidic Devices
Helen Bridle, Maiwenn Kersaudy-Kerhoas, Brian Miller, Despoina Gavriilidou, Frank Katzer, Elisabeth A. Innes and Marc P.Y. Desmulliez
WATER RESEARCH, 46, 6, 1641-61
Challenges and Solutions

<table>
<thead>
<tr>
<th>Challenges in Monitoring</th>
<th>Our Research</th>
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<tr>
<td>Recovery rates – sample processing challenge</td>
<td>Filtration systems – automated systems</td>
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<td>Filters – new materials</td>
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<td>Microfluidic approaches</td>
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<td>Information obtained from detection</td>
<td>Active microfluidic separations</td>
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<td></td>
<td>Cantilever sensors</td>
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<td></td>
<td>Molecular methods</td>
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<tr>
<td>Rapid online testing</td>
<td>Raman spectroscopy</td>
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<td></td>
<td>Microfluidic early warning system</td>
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</tbody>
</table>
Filters – New Materials


Dr Pagona Pavli
Collaboration with Professor Mark Bradley and Sesh Venkateswaran, University of Edinburgh
Filters – New Materials

- PA6 better than PA531 and better than the control 😊
- PBST is a more efficient elution buffer
- Explore optimal polymer loading
- Test performance within assembled units
- Other materials and pathogens

<table>
<thead>
<tr>
<th></th>
<th>Recovery rate (Elution PBS)</th>
<th>Recovery rate (Elution PBST)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Foam disc uncoated</td>
<td>18%</td>
<td>29%</td>
</tr>
<tr>
<td>Foam disc coated with PA6</td>
<td>31%</td>
<td>49%</td>
</tr>
<tr>
<td>Foam disc coated with PA531</td>
<td>16%</td>
<td>35%</td>
</tr>
</tbody>
</table>

Submitted to Chemosphere
Microfluidics – Sample Processing and Detection

Passive Microfluidic Sample Processing


Jimenez and Bridle (OUTREACH) Lab Chip, 2014, DOI: 10.1039/C4LC00944D

McGrath, Jimenez and Bridle (REVIEW) Lab Chip, 2014 DOI: 10.1039/C4LC00939H

John McGrath, Melanie Jimenez Collaboration with Andras Laki, PPKE, Budapest
Active Microfluidics

Holmes et al, Lab Chip 2009
DOI: 10.1039/B910053A

John McGrath
Professor Hywel Morgan, University of Southampton
Active Microfluidics

- 40 μL min\(^{-1}\) and focus particles to central region of microchannel
- Measure ratio of voltage to current – particle disturbs field
- Data reflects the AC electrical properties of the particle
- Custom electronics and lock-in amplification used to separate out the response at each frequency at the output
Active Microfluidics

Above graph
Beads (top box)
Viable and non-viable *Giardia*

Graph to the right
Beads (top box)
Viable and non-viable *C. muris*
$x = Re1$
$y = Im1/ Re1$

$x = \log_{10}(\text{frequency})$
$y = Z(\text{pathogen})/Z(\text{beads})$ at test frequency
Active Microfluidics

Beads (top box)
From L-R: C. parvum, C. muris and Giardia

\[ x = Re1 \]
\[ y = Im1/ Re1 \]

- Observe clear difference between species and viable/non-viable
- FACS was not equally successful
- Still analysing all the data!
Microfluidic Cantilever Sensors

Collaboration with Dr Will Shu
Submitted to Journal of Micromechanics and Microengineering

- Photoresist
- Gold coated polyimide
- Exposed to UV and developed
- Sealed with polyimide tape

Diagram showing the setup of a microfluidic cantilever sensor with solutions, valve, waste, laser diode, cantilever, thermally insulating box, microscope, and PSD.
Raman Spectroscopy for Pathogen Detection

Interactions with molecular vibrations
Identification of molecules and even whole cells

Raman spectra of a single layer of Graphene. Taken and adapted from A. C. Ferrari, Solid State Communications 143, 47 (2007)

Shona Stewart; Lindy McClelland and John Maier
Raman Spectroscopy for Pathogen Detection

Thanks to Dr Andy Downes (UoE) for assistance with the Raman spectroscopy
Raman Spectroscopy for Pathogen Detection

Wavelength to time conversion converts single pixel to entire spectrometer

Multiplex gains using multicore fibre!

Rapid acquisition of spectra
Raman Spectroscopy for Pathogen Detection
Raman Spectroscopy for Pathogen Detection
Early Warning System

- Established method of detection which is applied for monitoring within the Netherlands
- Has been tested with drinking water spiked with wastewater samples achieving sensitivity comparable to total direct counts
- Sensitivity? $10^{-14} \text{ M ATP}, 0.2 \text{ pg/mL}$

Early Warning System

From lab equipment to online testing unit

Abdelfateh Kerrouche
In collaboration with Epigem and Claus Barholm-Hanson (DTU Environment)
Next steps:
Test with known bacteria concentrations
Validation with real water samples in comparison to other techniques
SUMMARY

SAMPLE PROCESSING – automated filtration units, novel filter materials and microfluidic solutions

INFORMATION RICH DETECTION – microfluidics, molecular methods and Raman spectroscopy

EARLY WARNING – microfluidic online ATP

=> Range of easy to use high performance monitoring technologies for safe drinking water
ACKNOWLEDGEMENTS

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Collaborators
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Professor Marc Desmulliez, Dr Robert Thomson, Dr Will Shu (HWU)
Dr Claus Barholm Hanson, Professor Hans-Jørgen Albrechtsen (DTU)
Andras Laki, PPKE, Budapest
Professor Hywel Morgan, University of Southampton
Scottish Water, IDEXX, Renishaw and Epigem

Dr Frauke Izdebski
Harikumar Chandrasekharan

Brian Miller (PhD at UoE)
Sesha Venkateswaran (PhD at UoE, Bradley Group)