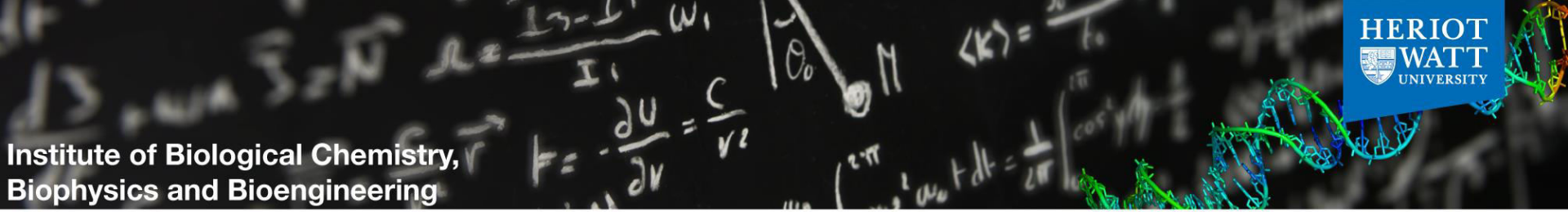



# Applications of Microfluidics in Waterborne Pathogen Monitoring

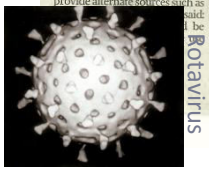
Dr Helen Bridle

# Monitoring for Waterborne Pathogens

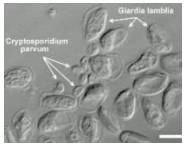
Why?
Health and economic impacts
Outbreaks
Endemic disease
Food production

What?

| | Pathogen | Equivalent diameter nm |
|---|---|---|
| VIRUS | ***Enteroviruses*** | 20-30 |
| | ***Hepatitis E*** | 27-34 |
| | ***Rotaviruses*** | 60-80 |
| | ***Adenoviruses*** | 70-100 |
| BACTERIA | ***Campylobacter spp*** | 310-1800 |
| | ***Shigella spp*** | 510-2100 |
| | ***E. coli*** | 720-1000 |
| | ***Vibrio Cholera*** | 810-1400 |
| | ***Samonella spp*** | 1100-2600 |
| PROTO. | ***Giardia Lamblia*** | 2800-4600 |
| | ***Cryptosporidium*** | 3600-7400 |


Rotavirus


Shigella



Protozoa


SATURDAY 25 AUGUST 2012 THE SCOTSMAN 17

**Private water supplies 'expose children to Third World risks'**

HELEN BRIDLE

HALF of the private water supplies in the UK fail to meet safety standards, risking the health of young children, according to new research.

Youngsters who drink from these sources suffer diarrhoeal disease to the same extent as children in developing countries. Scotland is the region in the UK with the most private supplies and 150,000 people obtain their water from sources other than the mains supply.

Professor Paul Hunter, of the University of East Anglia, said: "This is a serious concern. As well as children being more at risk, they also suffer the most from an episode of diarrhoea – with greater rates of hospitalisation and higher mortality rates."

Prof Hunter recommends that parents ensure adequate, well-maintained treatment such as chlorination or filtration, or provide alternate sources such as

One in 100 people in the UK are served by private supplies

John Cowden, of Health Protection Scotland, said: "If appropriately maintained and run, then private water supplies are fine."

However, according to the Drinking Water Quality in Scotland 2010 Annual Report, many private supplies have disinfection systems which are incorrectly installed or operated, or are not adequately maintained.

A spokesperson for the Drinking Water Quality Regulator for Scotland said: "In 2010, there were 19,177 registered private water supplies in Scotland. While some of these supplies are well managed, the quality of water from many is of concern.

"To help improve the quality of these supplies, there is a non-means-tested grant scheme in Scotland. Owners and users of private water supplies are encouraged to make use of this grant and further information can be obtained from local authorities."

Adults and older children are less susceptible to disease caused by bacteria in water, while those under ten can suffer five bouts of sickness per year.

"My advice to parents would be boil the water or treat it"
*Professor Paul Hunter*

The scientists said: "We found a particularly high incidence of diarrhoea in children under ten – a risk of illness similar to that reported in developing countries. You get people saying, 'I have been drinking this for 40 years and it has never done me any harm'. But we have shown for the first time that the risk is mainly to young children whose immune systems have not had time to build up. In the past, researchers have tended to look at the general population."

Mr Cowden said that exposure to contaminated water to build up immunity was not a good idea: "You wouldn't use a vaccine which made many people ill, and some fatally so."

The study followed more than 600 consumers in Norfolk, Suffolk and Herefordshire for 12 weeks and found drinking from contaminated supplies increased the risk of infection, particularly among young children.

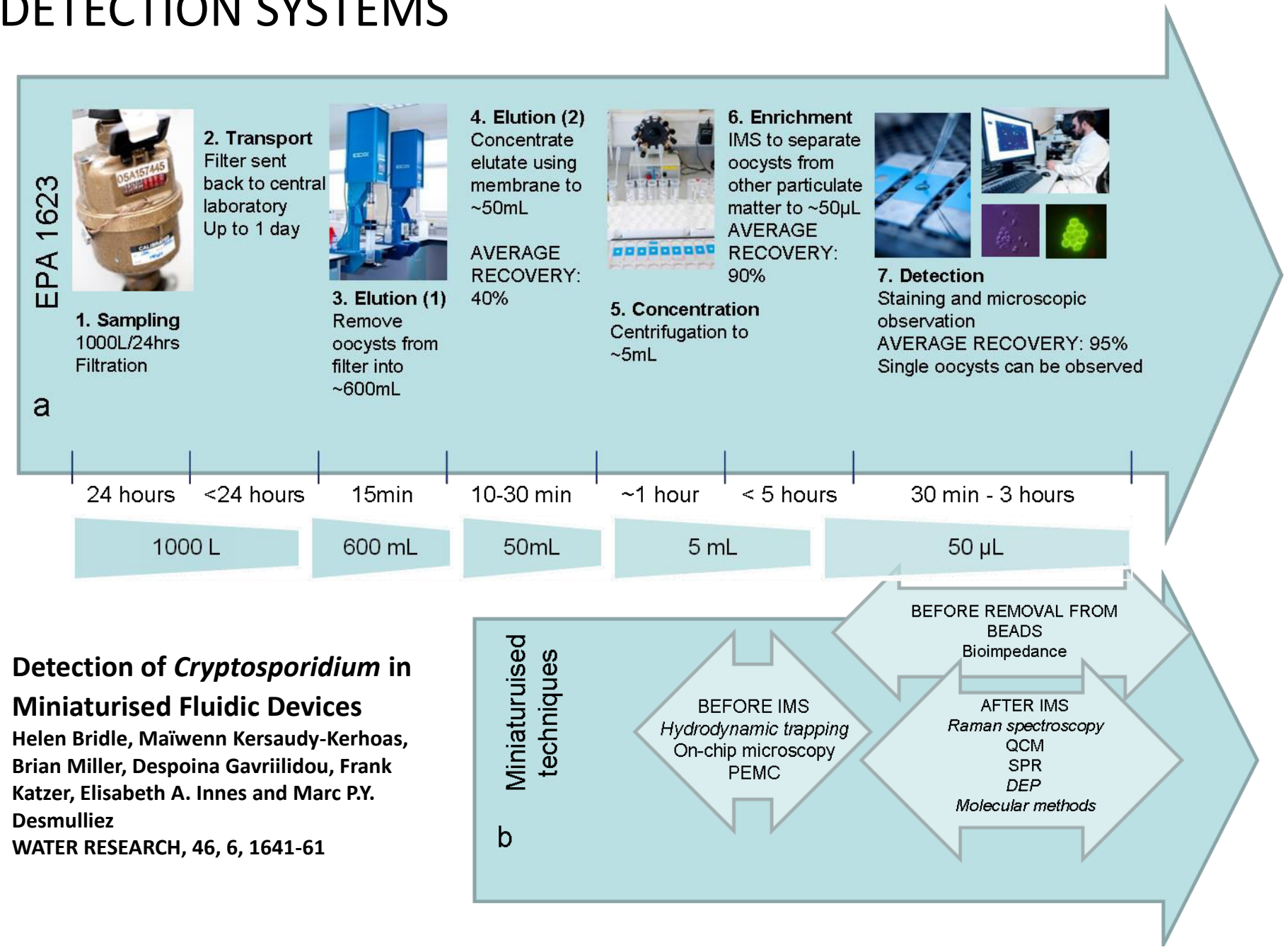
The researchers tested the water for the presence of bacteria and the consumers studied kept a diary of symptoms including diarrhoea, vomiting, stomach pains, nausea, headache and fever.

Around one in 100 people in the UK – and one in ten in Europe – is served by private supplies such as wells and boreholes. And many more drink from them as visitors and while on holiday.




Cryptosporidium Oocyst

# DETECTION SYSTEMS




**Detection of *Cryptosporidium* in Miniaturised Fluidic Devices**

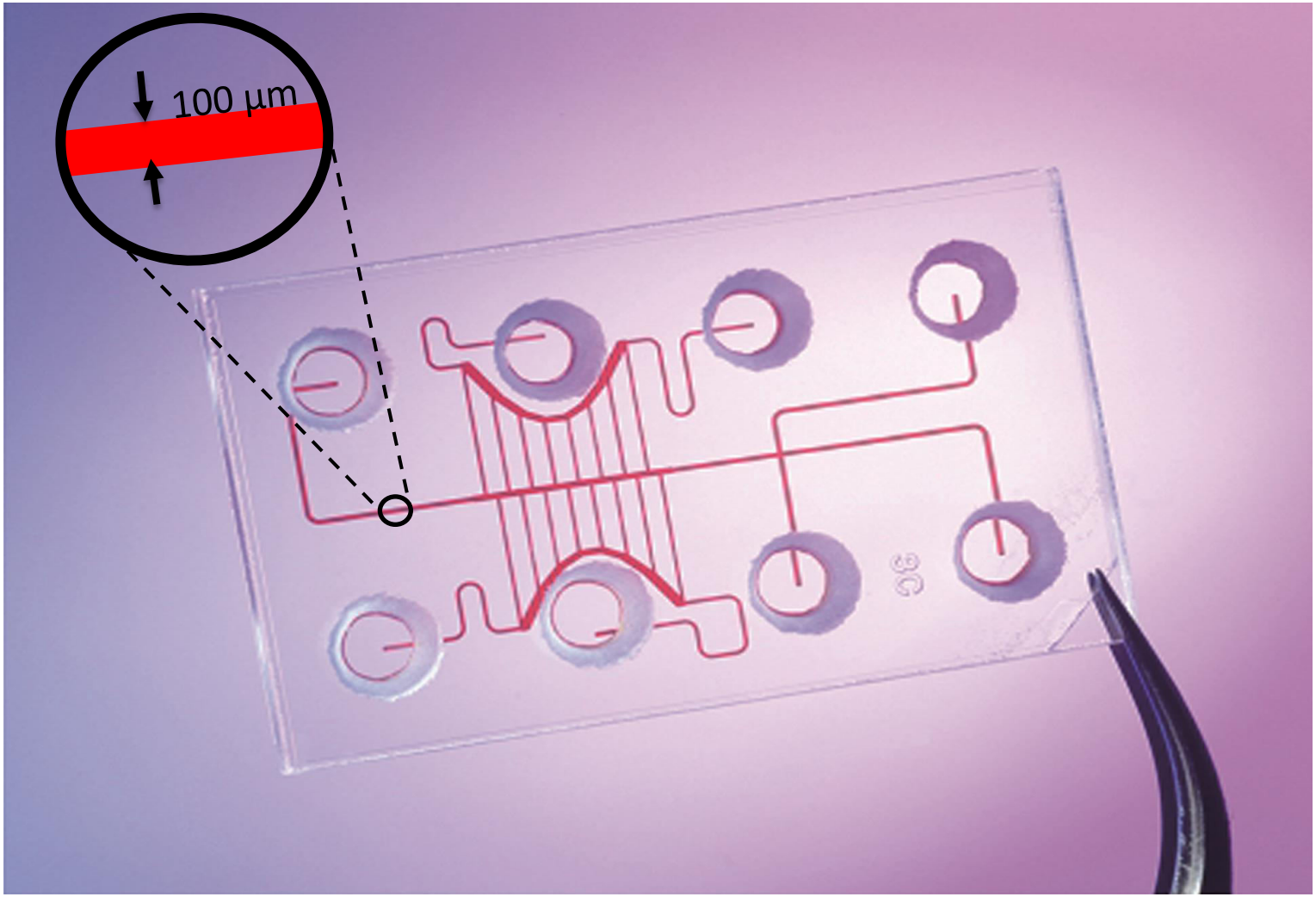
**Helen Bridle, Maïwenn Kersaudy-Kerhoas, Brian Miller, Despoina Gavriilidou, Frank Katzer, Elisabeth A. Innes and Marc P.Y. Desmulliez**

**WATER RESEARCH, 46, 6, 1641-61**

# Challenges and Solutions

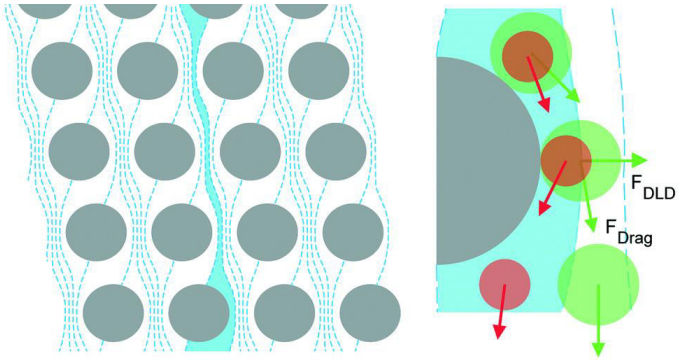
| Challenges in Monitoring | Our Research |
|---|---|
| Recovery rates – sample processing challenge | Filtration systems – automated systems |
| | Filters – new materials |
| | **Microfluidic approaches** |
| Information obtained from detection | **Active microfluidic separations** |
| | Cantilever sensors |
| | Molecular methods |
| | Raman spectroscopy |
| Rapid online testing | **Microfluidic early warning system** |

# Microfluidics – Sample Processing and Detection

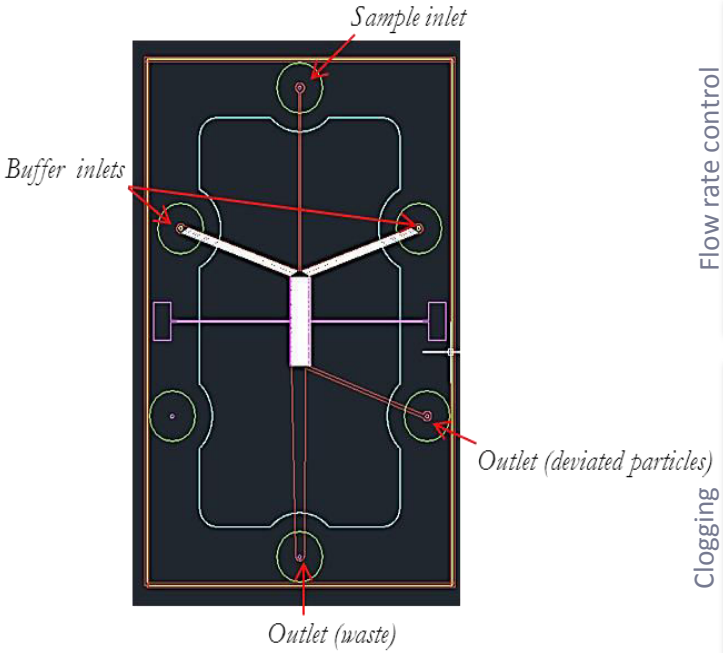


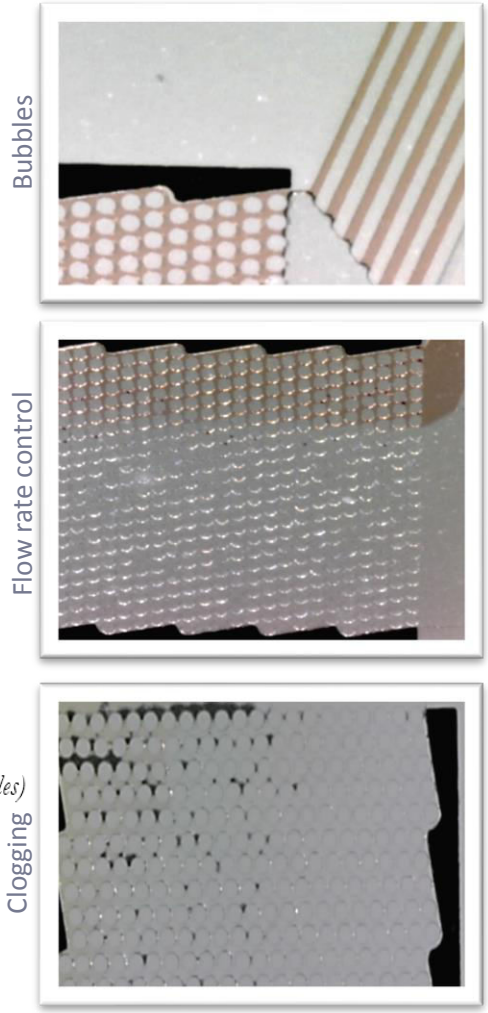

**Bridle, H.,** Miller, B. and Desmulliez, M.P.Y. (2014) Application of microfluidics in waterborne pathogen monitoring: A review. *Water Research*, 55, 265-271.

# Passive Microfluidic Sample Processing




Beech et al, Lab Chip, 2009,
**DOI:** 10.1039/B823275J




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

# Passive Microfluidic Sample Processing

ALTERNATIVE SYSTEM – several scales of performance

<u>Protozoan Concentration Device</u>
5mL input volume
Up to ~1mL/min
Run with spiked DI water, tap water, concentrate from tap water filtration and surface water filtration

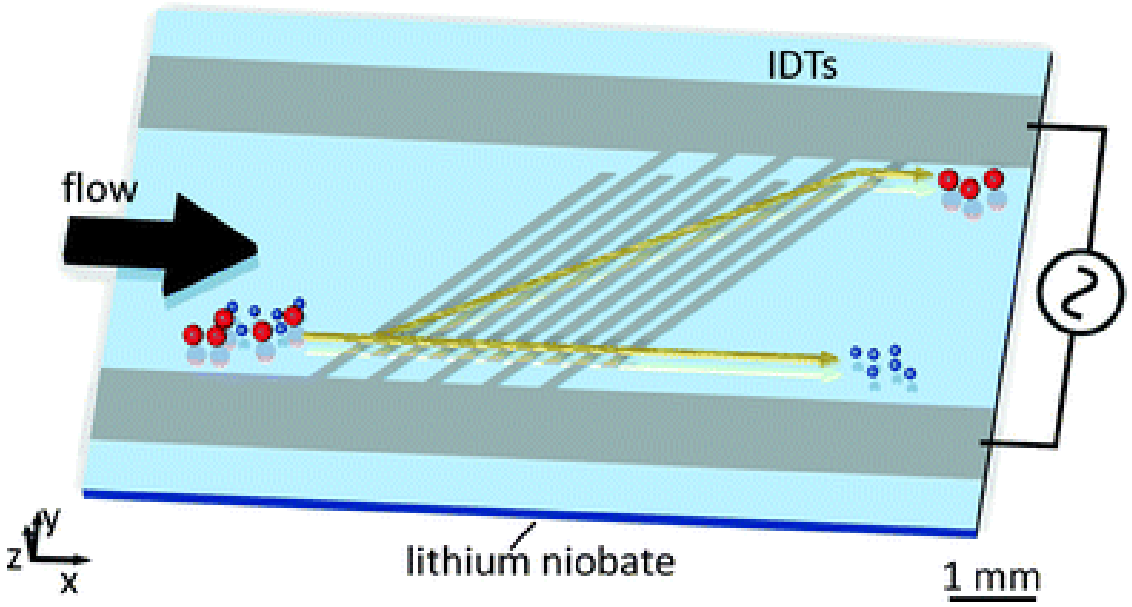
Concentration factor equals number of outlets (2 outlets gives 2.5mL and 4 outlets gives 1.25mL from 5mL)

Increase concentration by recirculation and device stacking: 50mL to 1mL in ~10mins with a stack of 10 4 outlet devices recirculating 3 times

<u>Filtration Type Systems</u>
Stack of 20 larger systems operated at 1L/min
Filtered out larger particles (above ~75µm)
Single devices tested with tap and surface water

Brian Miller
PATENT about to be filed

# ACTIVE FORCES FOR SEPARATIONS



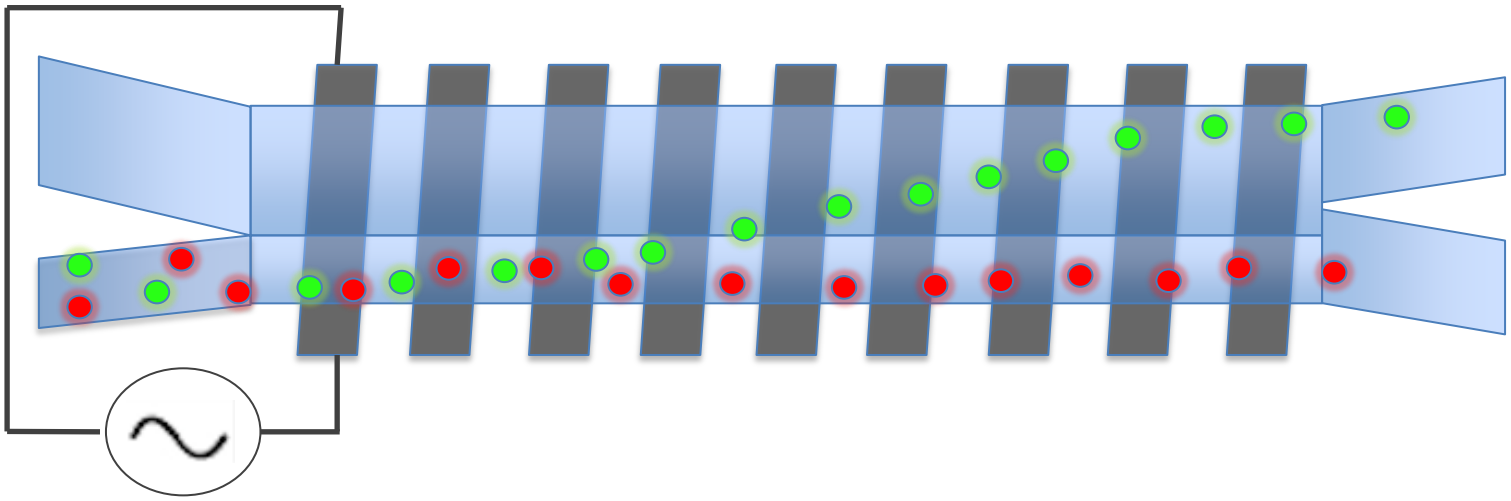

- Generate an acoustic force in the channel
- Size based separations

Collins, et al, Lab Chip, 2014, **DOI:** 10.1039/C3LC51367J

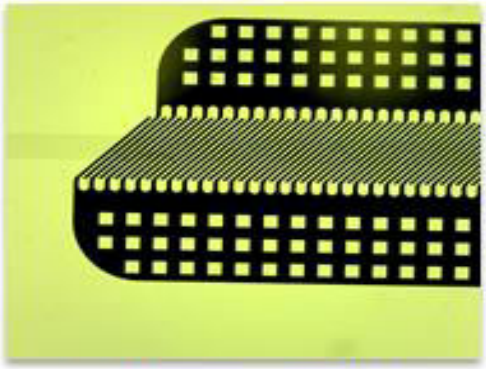
- Trialled the system with protozoa but encountered problems of sticking to the electrodes so a redesign has been produced and is awaiting testing

John McGrath
Dr Adrian Neild, Monash University

# ACTIVE FORCES FOR SEPARATIONS



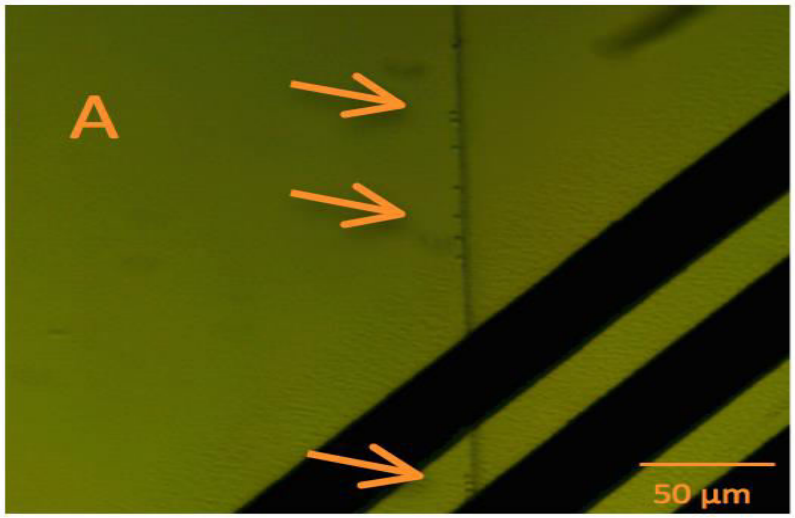
**A.** Wide buffer inlet enables focusing of sample inlet stream

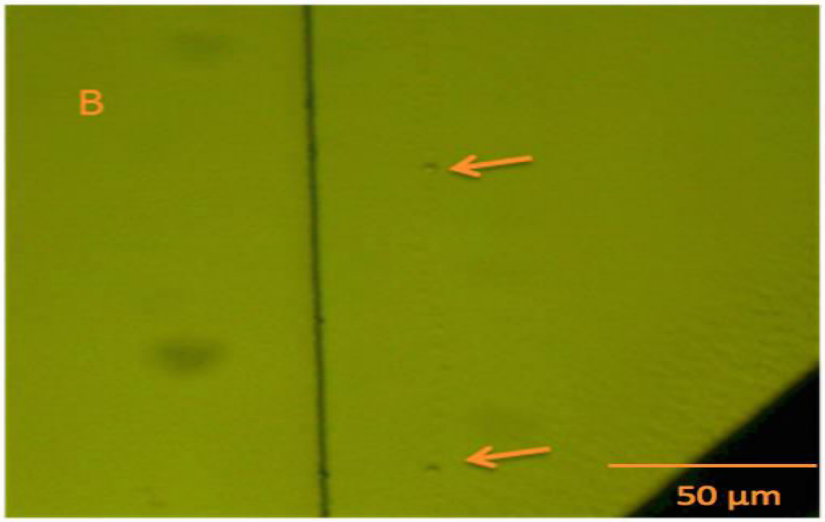


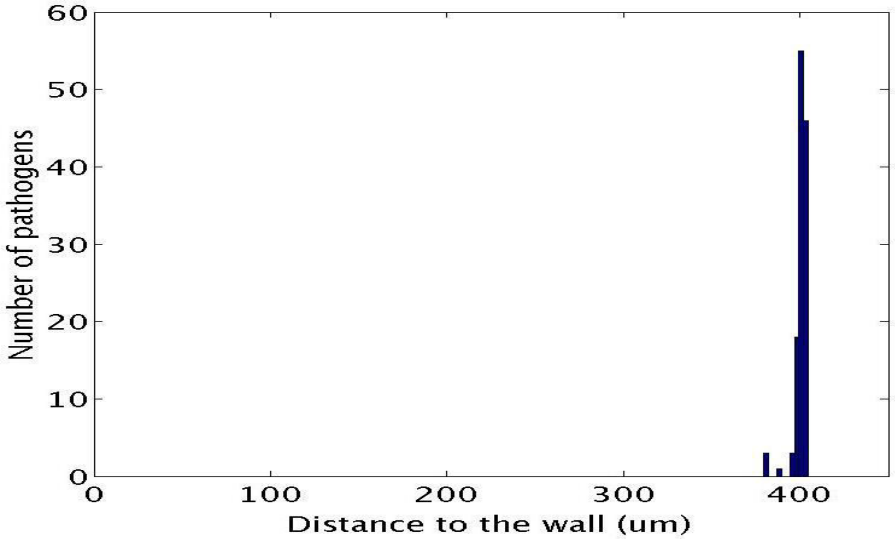
**B.** Electrodes at 45° to allow separation in main channel

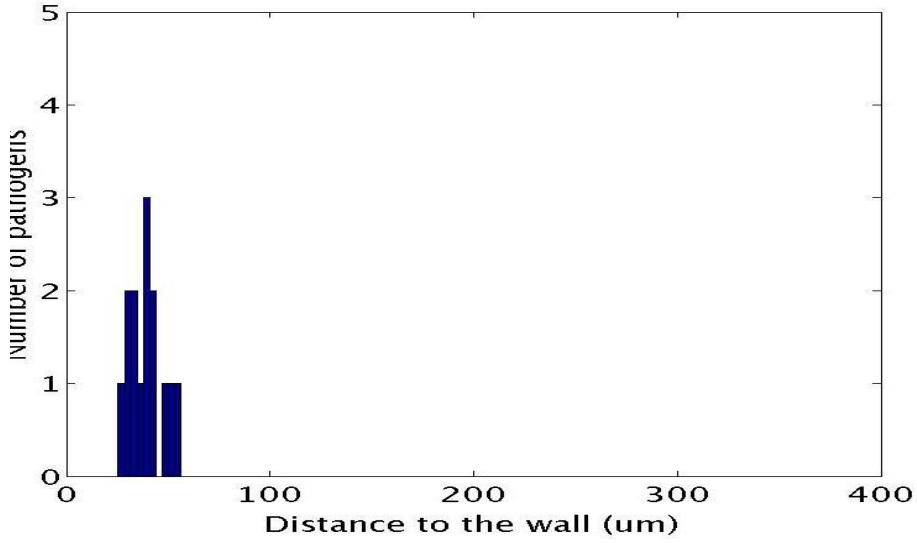
**C.** Main channel separates into two equal divisions

# ACTIVE FORCES FOR SEPARATIONS



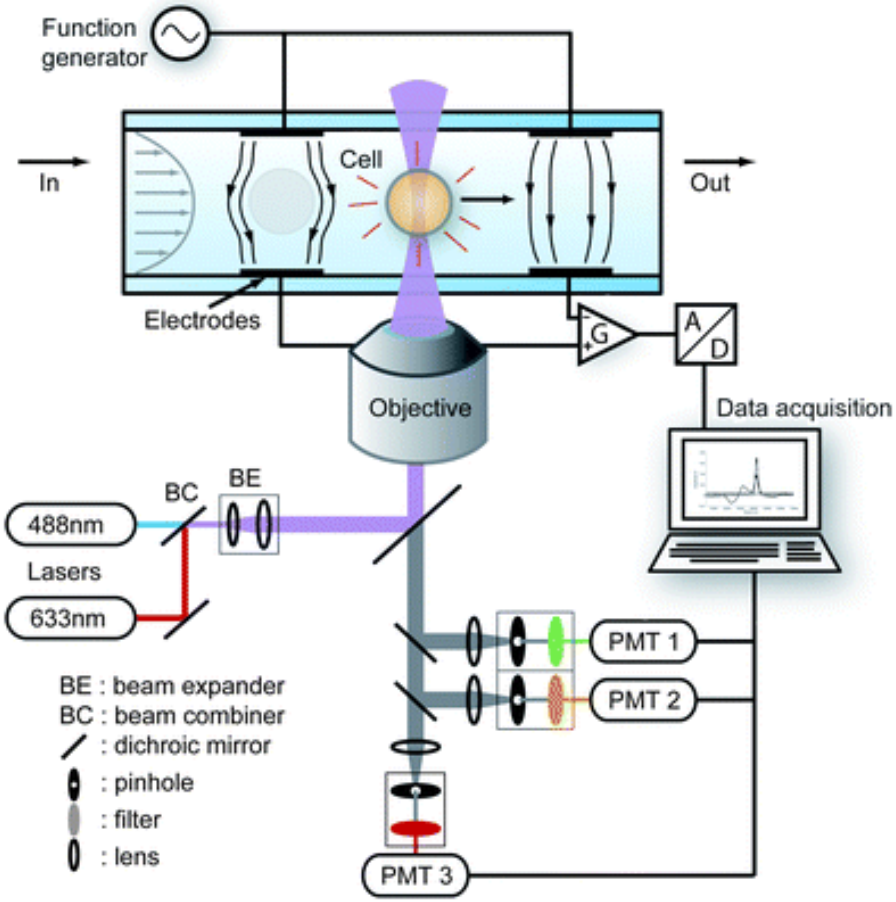



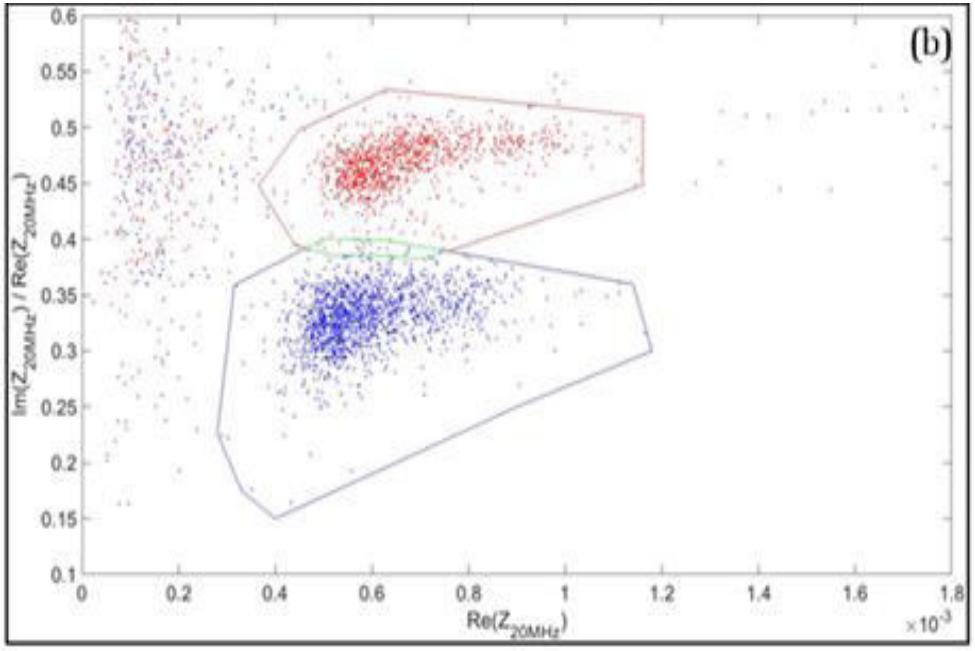

Displacement at 14 - 15 MHz, 12V

Sample and buffer introduced at 1 µl $min^{-1}$ and 10µl $min^{-1}$, respectively

# IMPEDANCE CYTOMETRY

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



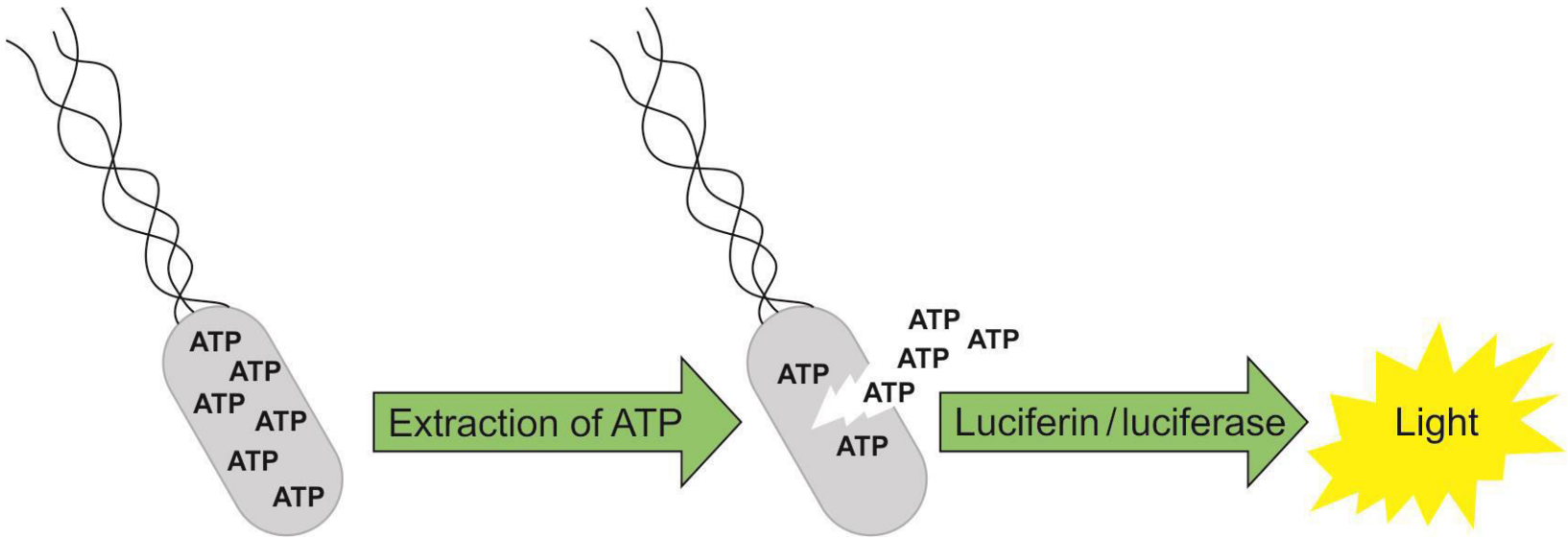




Discriminate viable and non-viable *C. parvum* (99% accuracy)

Discriminate between *C. parvum*, *C. muris* and *Giardia*

John McGrath
Professor Hywel Morgan, University of Southampton

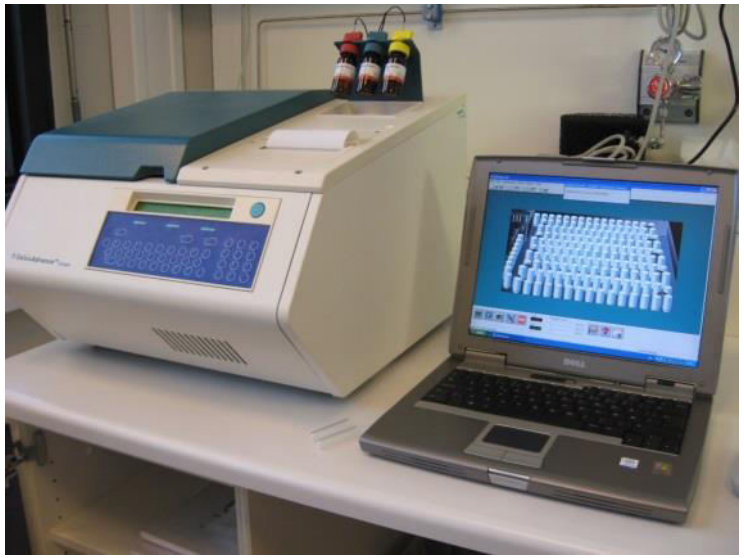
# Early Warning System




- 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 M ATP, 0.2 pg/mL

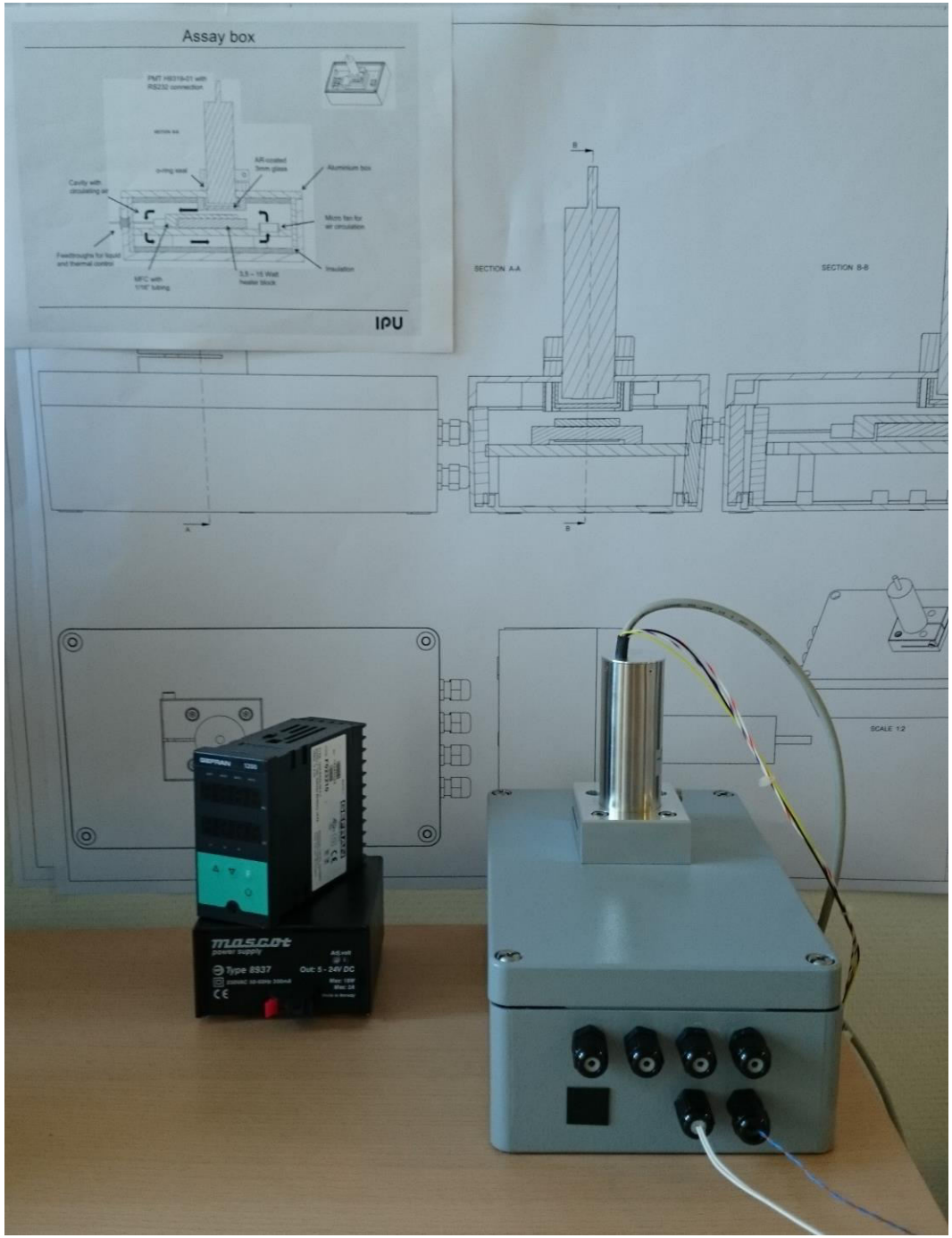
Vang Ó.K., C.B. Corfitzen, C. Smith & H.-J. Albrechtsen, 2014: Evaluation of ATP measurements to detect microbial ingress in drinking water by waste water and surface water **Water Research**, 64, 309-320.

# Early Warning System

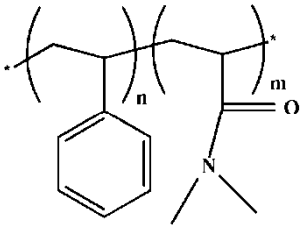


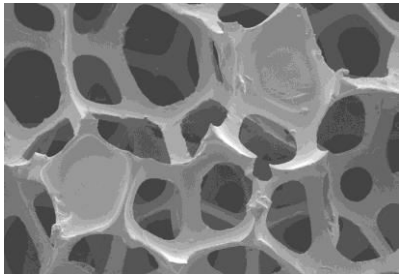
From lab equipment to online testing unit

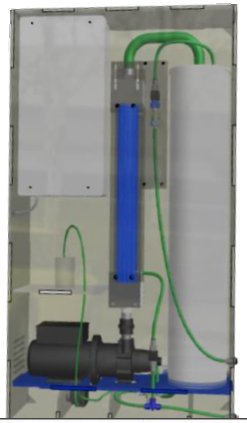
Abdelfateh Kerrouche
In collaboration with Epigem and Claus Barholm-Hanson (DTU Environment)



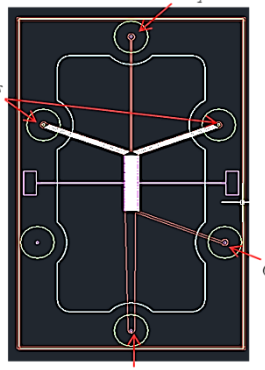
# SUMMARY

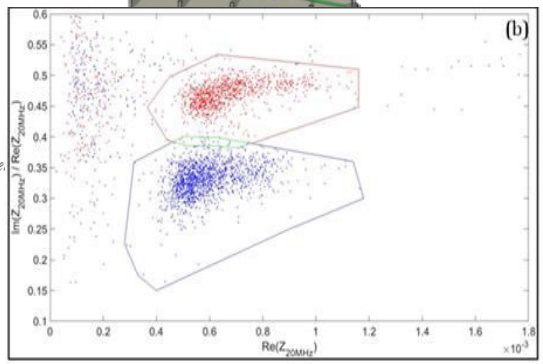


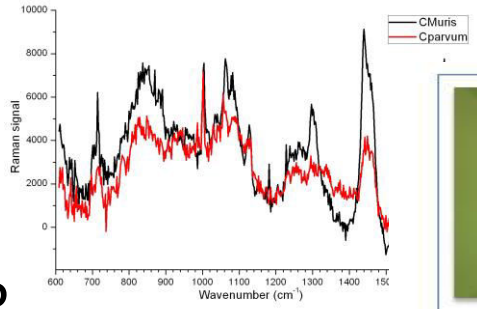


SAMPLE PROCESSING – automated filtration units, novel filter materials and **microfluidic solutions**

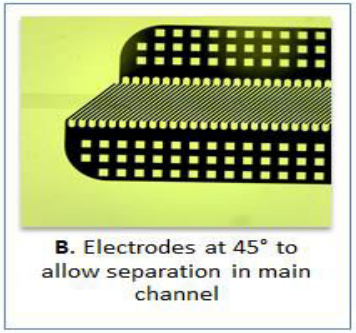


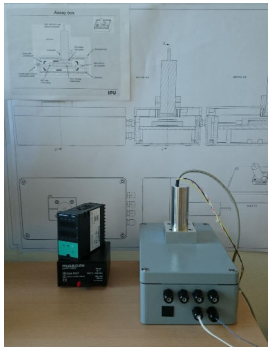




INFORMATION RICH DETECTION – **microfluidics**, molecular methods and Raman spectroscopy




EARLY WARNING – **microfluidic** online ATP

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

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**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**