Recent Advances in Microfluidic Device Applications for Environmental Monitoring and Toxicity Assessments

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- Advantages of Microfluidics
- Key Components of Microfluidics
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What is Microfluidics?

- Downsizing & Integrating Multiple Steps of Analysis (injection, separation, reaction, and detection) onto a Single Device
  → Micro Total Analysis System (μ-TAS) or Lab-on-a-chip (LOC)

- Handling fluids on the nanoliter and picoliter scale

- Laminar flow conditions (very low Reynold’s number)
  → diffusion controlled transport of molecules

*Microfluidics* is the science and technology of system that manipulate small amount of fluidics (nanoliter to picoliter) using channels measuring from tens to hundreds of micrometers.
What is Microfluidics?

μTAS or LOC

Miniaturization & Integration

Handling fluids in nanoliter to picoliter scale

→ Downsizing system volumes more than 1000 times

Volume of a Single Compartment

\[= 7.2 \times 10^{-8} \text{ L} = 72 \text{ nL} \]
What is Microfluidics?

Laminar flow condition provide “diffusion” controlled transport → Enable accurate control of fluids (e.g. formation of chemical gradient)

Advantages of Microfluidics

- Low reagent consumption (Cheaper !)
- Low waste production (Less Hazardous !)
- Rapid Analysis (Quicker !)
- Simple & Robust (Portable & Disposable)
Key Components of Microfluidics

- Sample Introduction
- Sample Pre-concentration
- Separation
  - Capillary Electrophoresis (CE)
  - Gas Chromatography (GC)
- Detection
  - Optical Method – Fluorescence/Absorbance …
  - Electrochemical Method – Amperometric/Conductivity
  - Mass Spectrometry Method
Key Components of Microfluidics

✿ Separation

Capillary Electrophoresis (CE) → well suited for miniturization w/o loosing separation efficiency & analysis speed
Key Components of Microfluidics

‧ Separation
  ✤ Capillary Electrophoresis (CE)

Key Components of Microfluidics

Detection

- Optical Method – Fluorescence (Off-chip approach)

**Key Components of Microfluidics**

**Detection**

* Optical Method – Fluorescence (On-chip approach)

## Application of Microfluidics for Monitoring of “Real” Environmental Samples

<table>
<thead>
<tr>
<th>Sample</th>
<th>Detection Limit</th>
<th>Detection Method</th>
<th>Real Sample</th>
<th>Ref.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cd$$^{2+}$$</strong></td>
<td>6 µg/L</td>
<td></td>
<td></td>
<td>Deng G. et al. (2003)</td>
</tr>
<tr>
<td><strong>Pb$$^{2+}$$</strong></td>
<td>1.8 µg/L</td>
<td>Absorbance</td>
<td>Water</td>
<td>J. Chromatogr. A</td>
</tr>
<tr>
<td><strong>Co$$^{2+}$$</strong></td>
<td>0.15 µg/L</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Ni$$^{2+}$$</strong></td>
<td>0.48 µg/L</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sulfite, nitrite</td>
<td>0.4-1 µg/L</td>
<td>LIF</td>
<td>River, Pond and Rain water</td>
<td>Fujii S. et al. (2004) Anal. Sci.</td>
</tr>
<tr>
<td>Nitrite, fluoride, phosphate</td>
<td>0.5-0.7 µg/L</td>
<td>Conductivity</td>
<td>River, Tap, Mineral water</td>
<td>Bodor R. et al. (2001) J. Chromatogr. A</td>
</tr>
</tbody>
</table>
There are urgent needs for high-throughput (HTS) & high content (HCS) screening biological assays, due to the increasing numbers of new chemicals, such as manufactured nanomaterials.

However, current in-vitro cytotoxicity assay methods using multiwell plate systems are labor-intensive, expensive and have limited capability to meet current needs.

Microfluidics may solve this problem by providing high-throughput & high contents screening methods for in-vitro toxicity assessments with much reduced costs.
Cells on Chips

Downsizing & Integrating Multiple Steps of Biological Assay Protocols onto a Single Chip

Microfluidic Cell Culture for High-Throughput Cell-based Assay - Under Continuous Perfusion Flow

Microfluidic Cell Culture for High-Throughput Cell-based Assay - Under Continuous Perfusion Flow
Microfluidic System for High-Throughput Cell-based Assay

King et al. Lab on a Chip (2007)
Microfluidic System for High-Throughput Cell-based Assay

King et al. Lab on a Chip (2007)
# Microfluidic System for High-Throughput Cell-based Assay

![Image of cell culture](image-url)

## Table 1 Comparative cell cytotoxicity: microfluidic array vs. 96 well tissue culture plate

<table>
<thead>
<tr>
<th>% Viability (S.D.)</th>
<th>Microfluidic array</th>
<th></th>
<th>96 Well culture plate</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>HeLa</td>
<td>BALB/3T3</td>
<td>Bov. endo.</td>
<td>HeLa</td>
</tr>
<tr>
<td>PBS</td>
<td>99.3 ± 0.8</td>
<td>100</td>
<td>98.8 ± 1.1</td>
<td>100</td>
</tr>
<tr>
<td>Dig(H)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Dig(L)</td>
<td>69.4 ± 2.3</td>
<td>69.9 ± 2.9</td>
<td>71.1 ± 2.3</td>
<td>73.7 ± 1.2</td>
</tr>
<tr>
<td>Sap(H)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Sap(L)</td>
<td>74.5 ± 2.4</td>
<td>77.8 ± 5.1</td>
<td>80.4 ± 2.0</td>
<td>75.7 ± 2.1</td>
</tr>
<tr>
<td>CoCl₂(H)</td>
<td>80.8 ± 4.4</td>
<td>80.4 ± 3.3</td>
<td>82.5 ± 3.9</td>
<td>85.6 ± 2.6</td>
</tr>
<tr>
<td>CoCl₂(L)</td>
<td>89.3 ± 3.4</td>
<td>89.4 ± 1.7</td>
<td>88.9 ± 2.9</td>
<td>91.0 ± 2.2</td>
</tr>
<tr>
<td>NiCl₂(H)</td>
<td>80.1 ± 3.5</td>
<td>80.6 ± 3.1</td>
<td>78.8 ± 5.4</td>
<td>80.6 ± 1.7</td>
</tr>
<tr>
<td>NiCl₂(L)</td>
<td>88.3 ± 5.3</td>
<td>91.0 ± 2.8</td>
<td>89.4 ± 2.5</td>
<td>89.3 ± 2.5</td>
</tr>
<tr>
<td>Acrol(H)</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Acrol(L)</td>
<td>84.9 ± 3.8</td>
<td>85.4 ± 3.0</td>
<td>83.3 ± 3.1</td>
<td>82.3 ± 1.5</td>
</tr>
</tbody>
</table>
Other Applications of Microfluidics
- Greener Synthesis of Quality Controlled Nanomaterials
Other Applications of Microfluidics
- Greener Synthesis of Nanomaterials
Summary - Benefits of Microfluidics

- Low reagent consumption & waste production
  ➔ Provide eco-friendly environmental monitoring and biological assay methods

- Portability due to simple & robust design
  ➔ Generate large amount of temporal & spatial information for on-line monitoring of environment

- Fast analysis time & Accurate Control of Fluids
  ➔ Enable High Throughput Measurements of Environmental Samples and Biological Assays
Thanks for your attention !!