Paper Microfluidic Device for Rapid and On-Site Wastewater Surveillance

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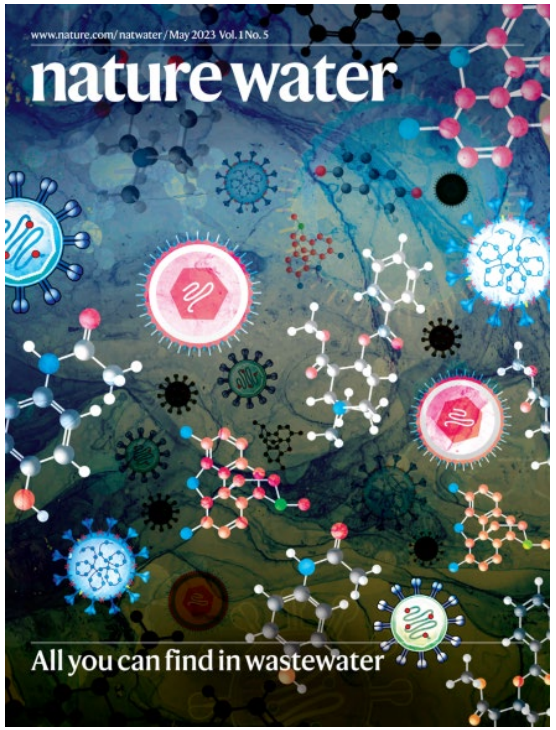
Challenges: Biomarkers detection in wastewater

- **Complex wastewater samples**
  - Low concentration, many interferants (“cocktail”)

- **Conventional methods for microbial detection**
  - Culture: time-consuming (**days/weeks**), less sensitive
  - Molecule method: e.g., qPCR: central laboratories, well-trained persons

- **Chemical biomarkers detection**
  - LC-MS/MS, sensitive but need centrale laboratory and well-trained personnel

Need low-cost, rapid, sensitive and portable sensing platform

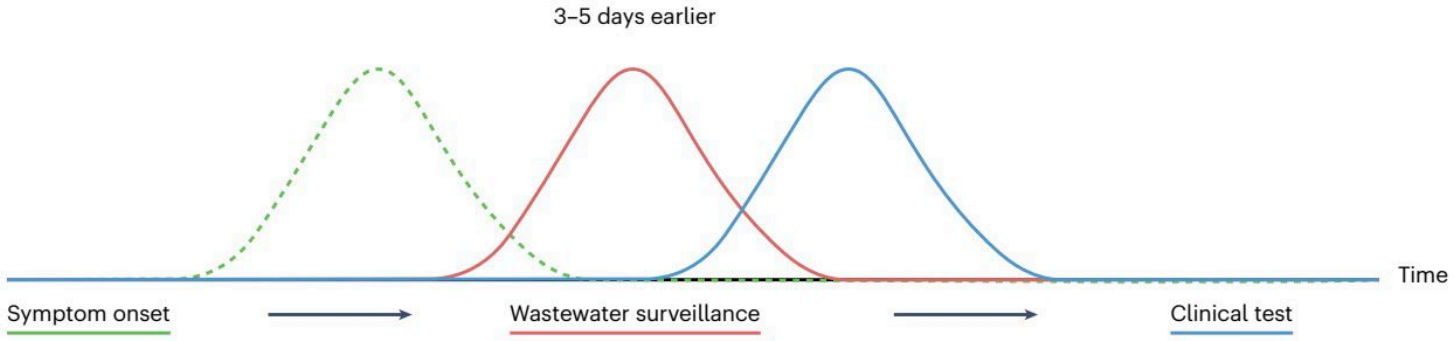


https://doi.org/10.1038/s44221-023-00080-x

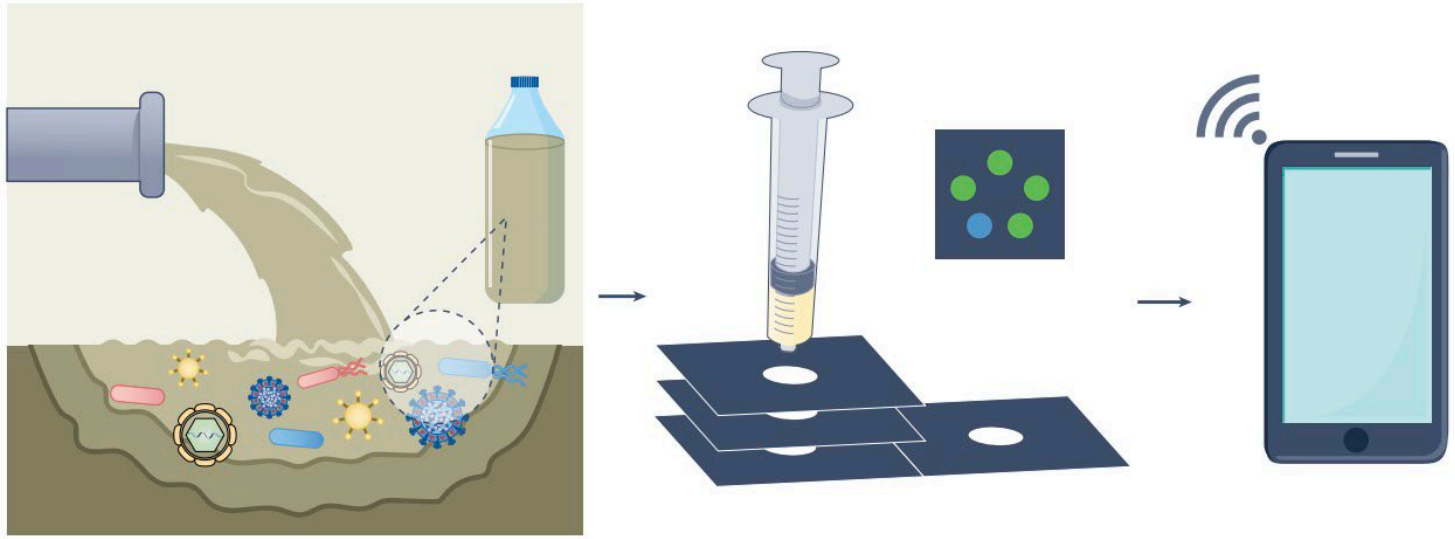
Low-cost and rapid sensors for wastewater surveillance at low-resource settings

Zhugen Yang

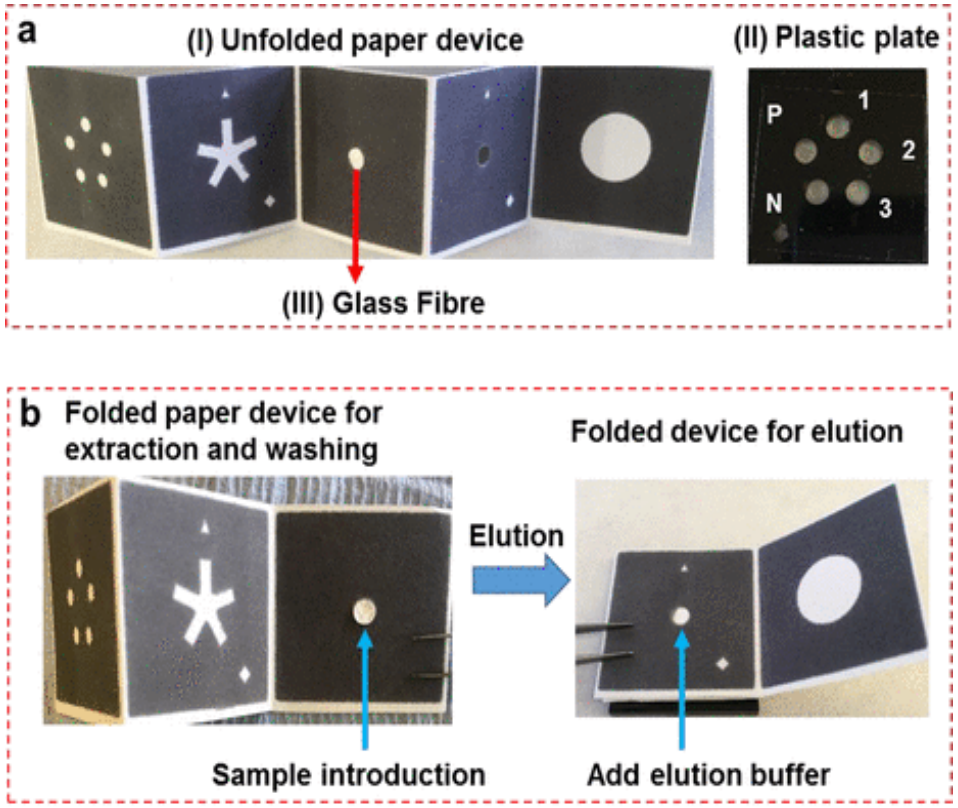
2023, 1, 405



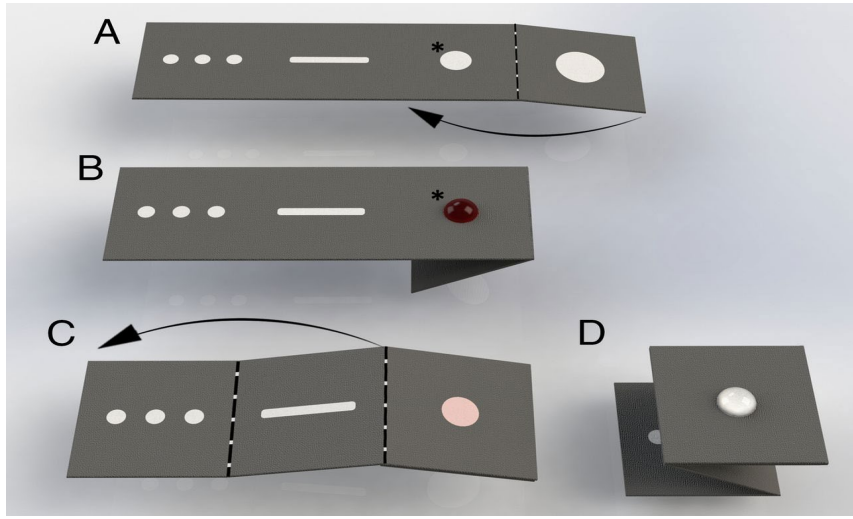
- Early warning
- Tracking down the source
- Understanding the circulation



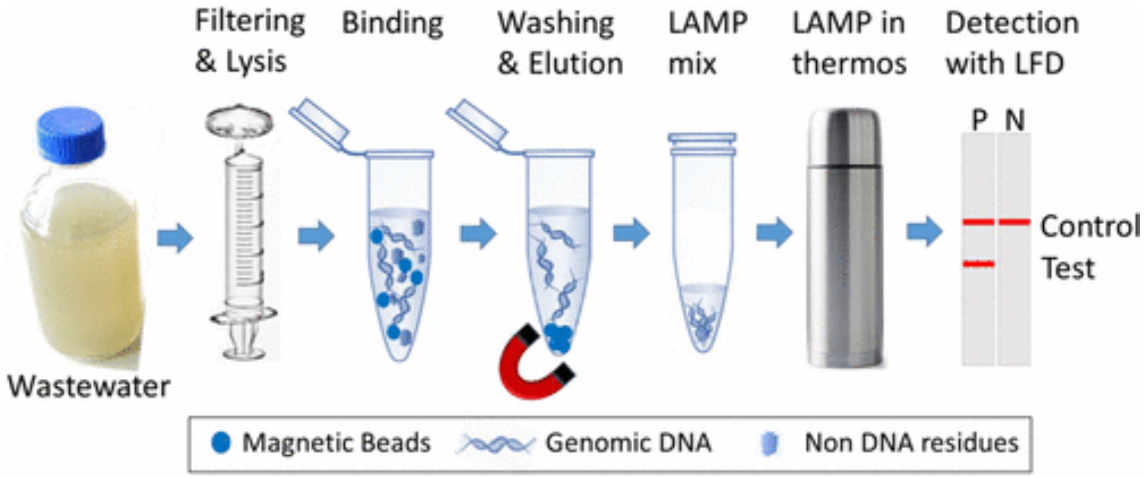
Origami-Paper device for Rapid and Onsite Pathogen Detection



Yang *et al.* ***ACS Sensors*** 2018 **3** (2): 403



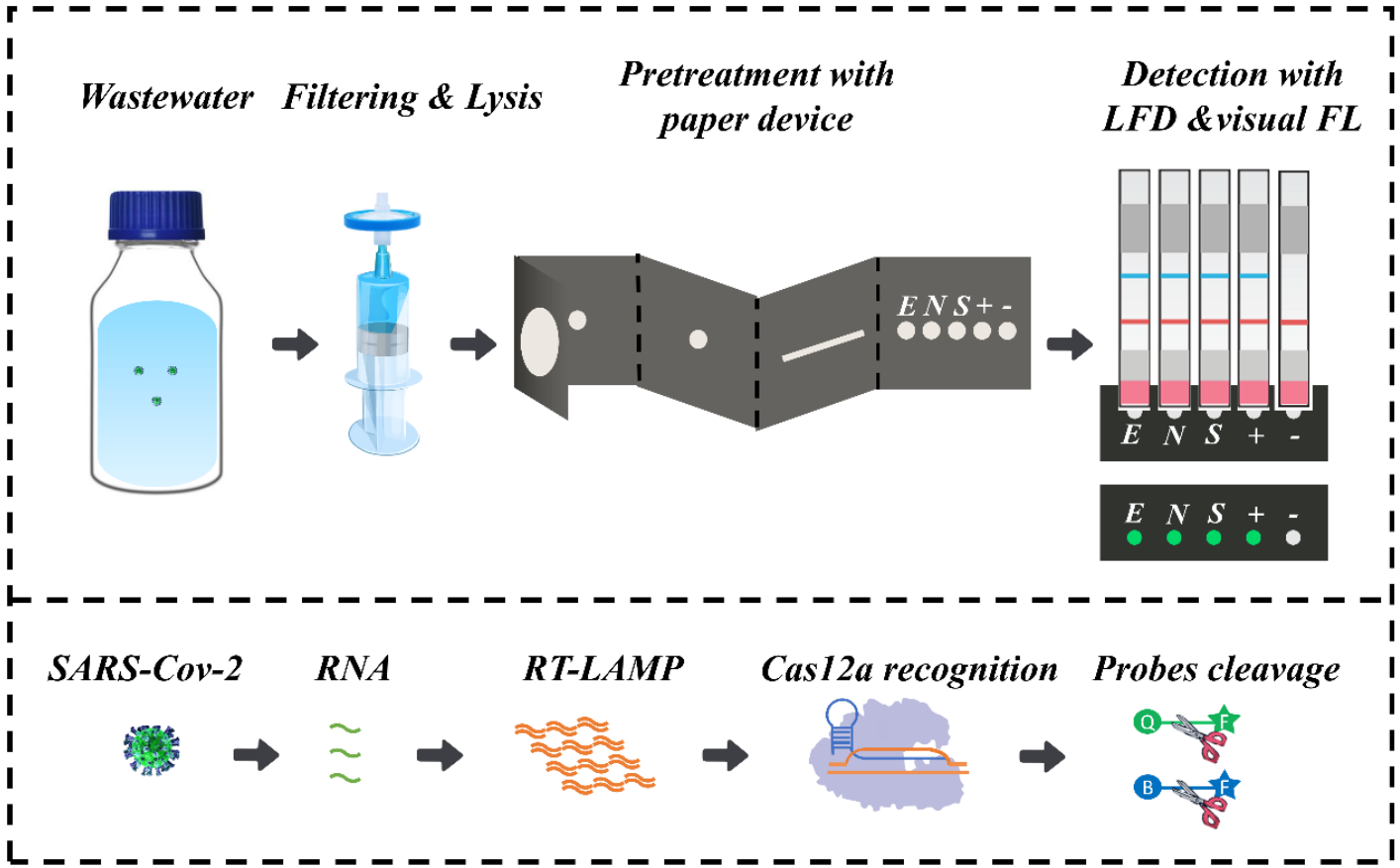
PNAS 2019, 16(11), 4834

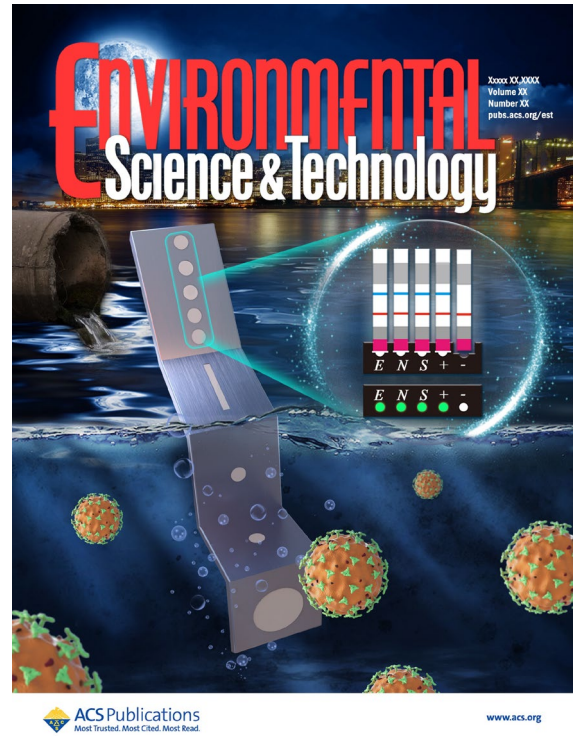


Anal. Chem., 2017, *89*: 99415

Paper-based device with CRISPR/Cas - LAMP for SARS-CoV-2 detection in Wastewater

CRISPR/CAS - LAMP assay for SARS-CoV-2



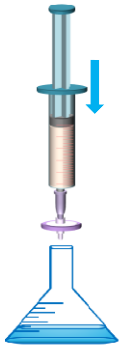


ACS ES&T, 2022, 56, 13245

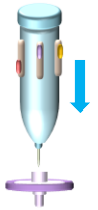
Origami-paper device for field-testing of SARS-CoV-2 in quarantine hotel in London

Test a cohort of sewage samples at lab-scale & validated with RT-qPCR

Wastewater



Filter sediment



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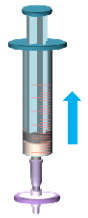
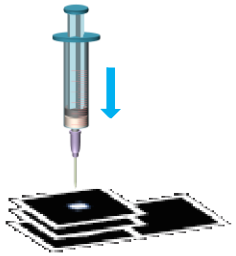
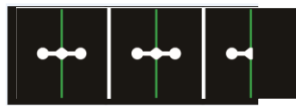


Take lysed sample

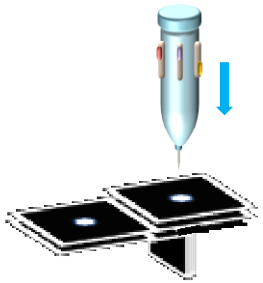


Introduce sample to paper device

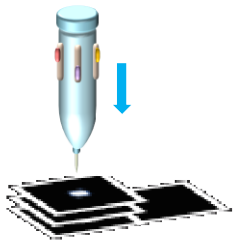
Visual LAMP reaction



Add primers and LAMP mix

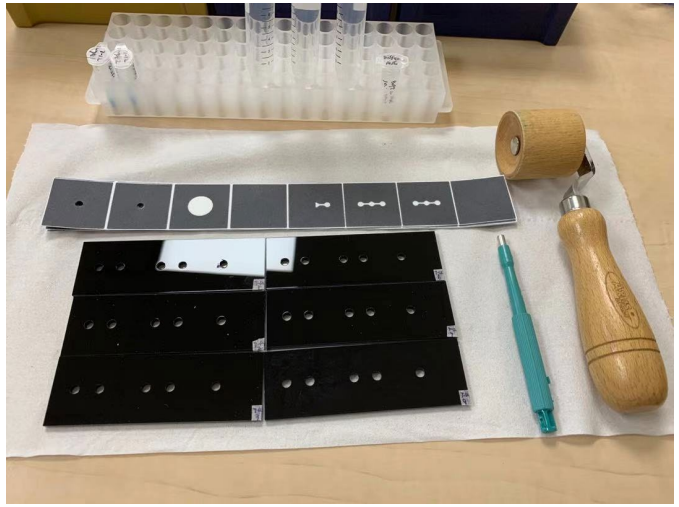


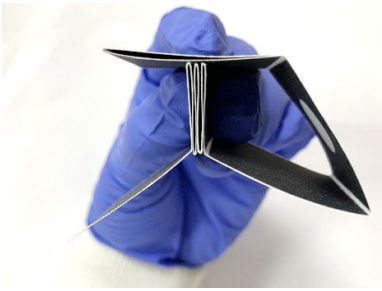
Elution

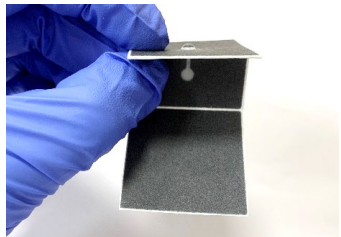


Washing

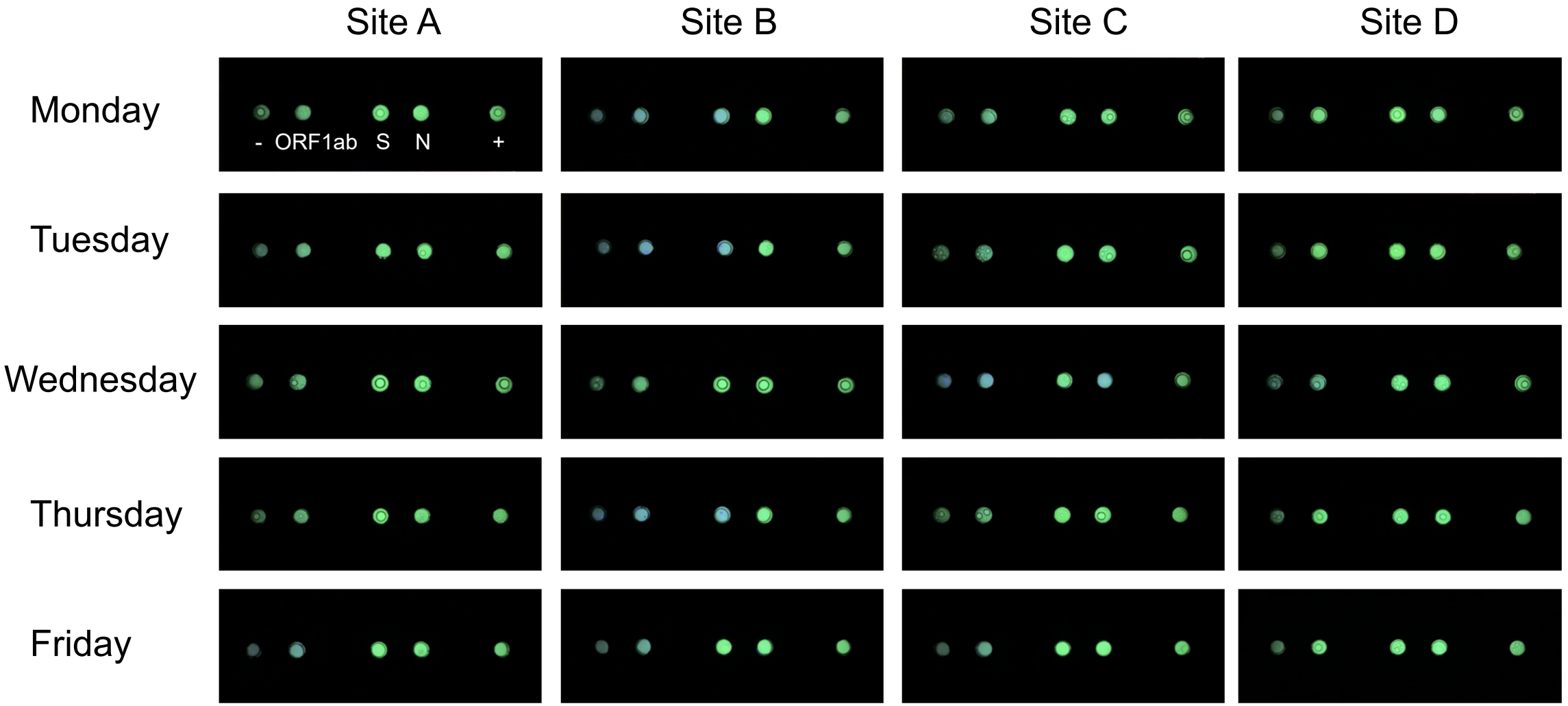
- Field-based enrichment
- Sensitive amplification
- Fast turnround (2-3h)
- Internal control
- Multiplexed detection







Field-testing of wastewater in quarantine hotel in London



Chemical Sensors for Chemicals (illicit drugs detections)

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Community Sewage Sensors for Monitoring Public Health

Zhugen Yang*†‡, Barbara Kasprzyk-Hordern†, Christopher G. Frost*†, Pedro Estrela‡, and Kevin V. Thomas§

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Cite this: *Environ. Sci. Technol.* 2015, 49, 10, 5845–5846
Publication Date: May 8, 2015
https://doi.org/10.1021/acs.est.5b01434

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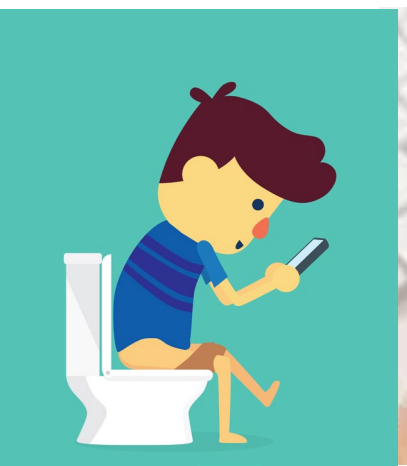

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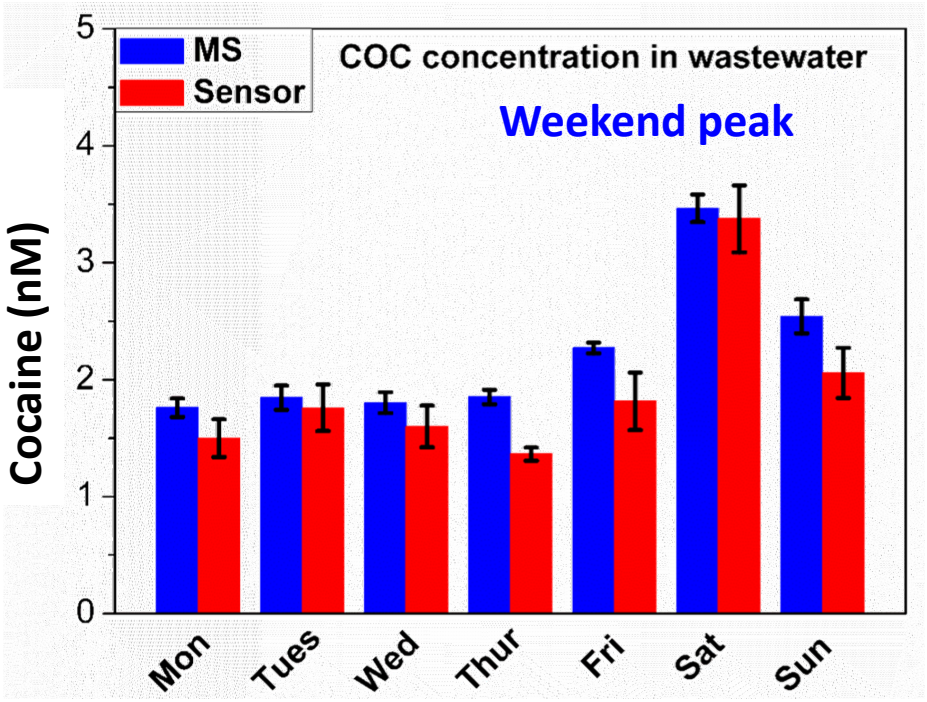
NEWS · 16 JULY 2018

China expands surveillance of sewage to police illegal drug use

Privacy concerns and cultural differences make some researchers sceptical that the method could work in other countries.

Example 1: Electrochemical sensors for quantification of cocaine to evaluate illicit drug use trends

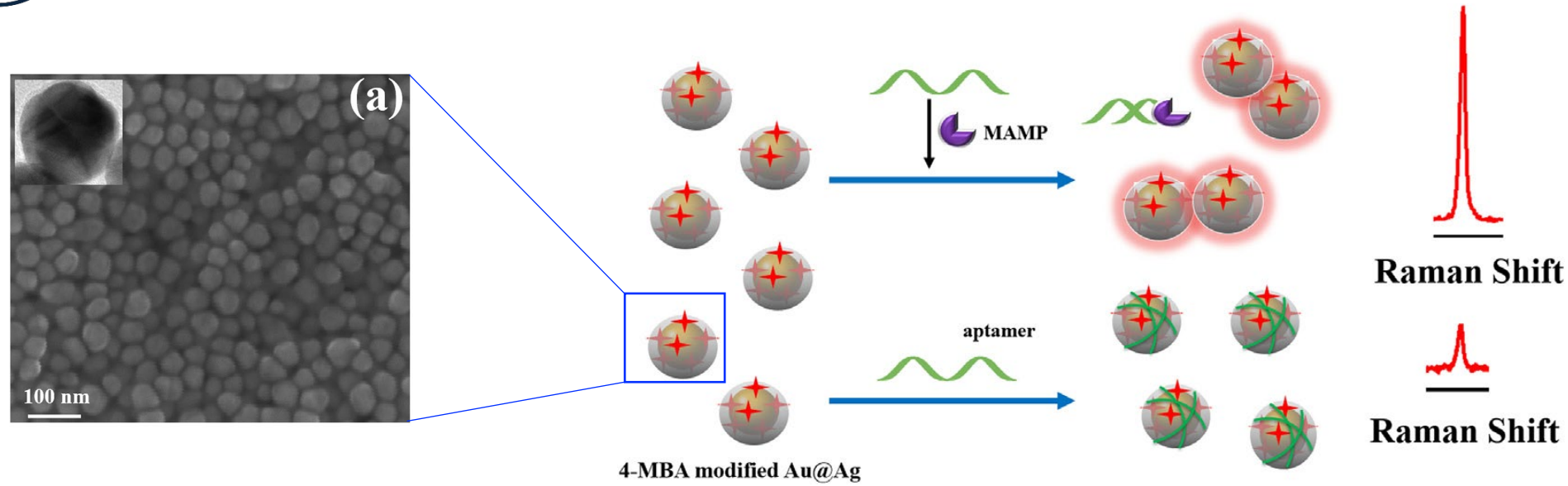
Sewage analysis using cocaine sensors

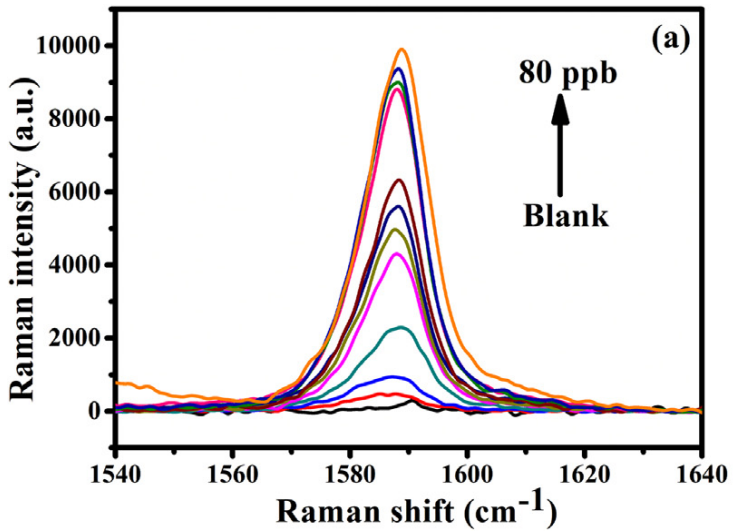


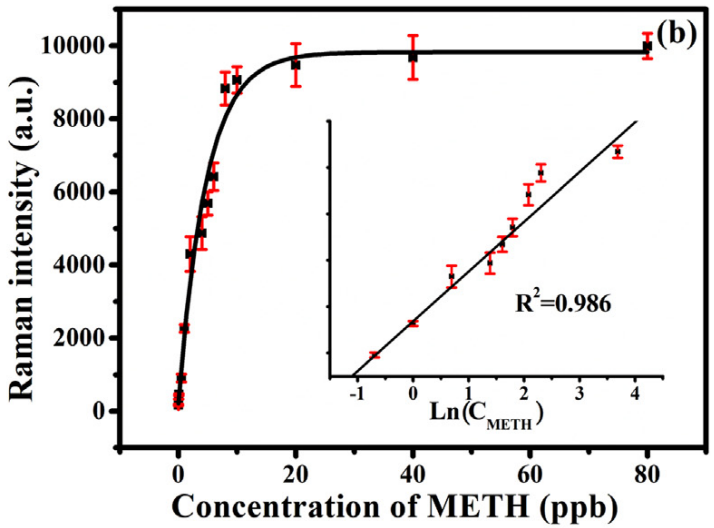
- improve the sensitivity from 300 ng/ml (current commercial paper strip) to **0.3 ng/ml** (1000 times)

Yang *et al* **Sci Reports 2016** (6), 21024

Example 2: Rapid detection of **methamphetamine** using Surface Enhanced Roman Scattering (SERS)



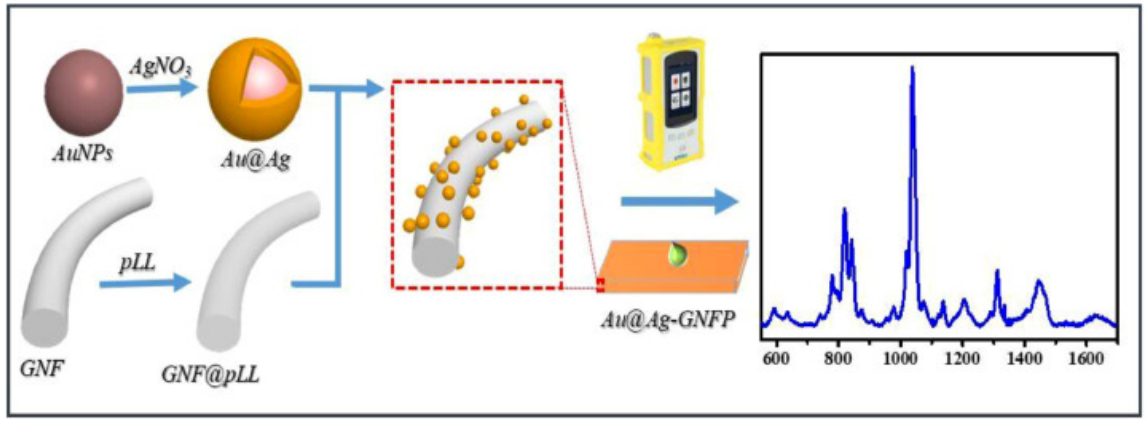


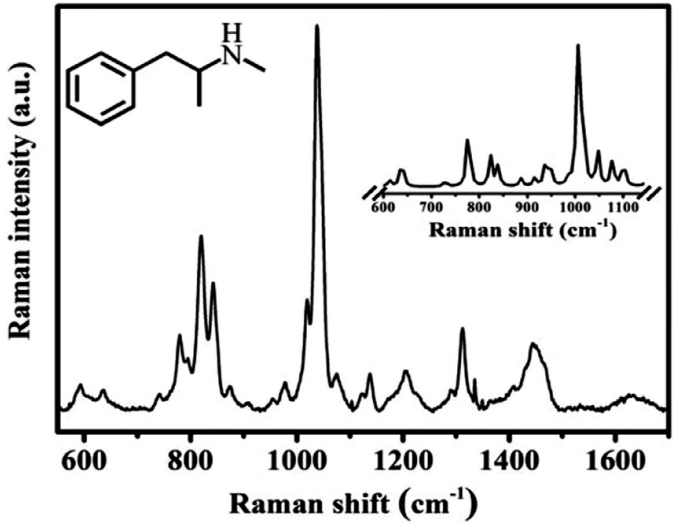


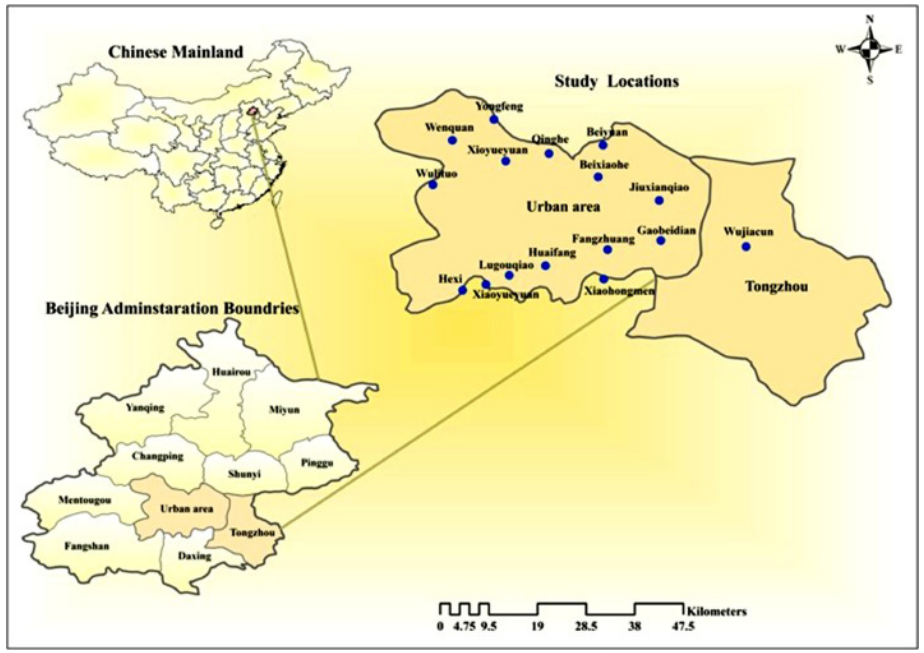
- LOD: 0.1 ppb
- Potential for portable assay

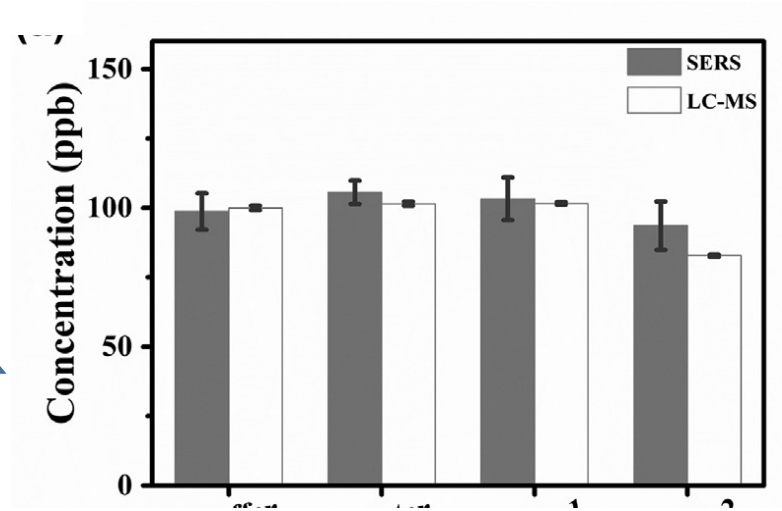
Talanta 2018,190, 263

Example 3: Paper-based nano-sensors (SERS) to evaluate community-wide illicit drug of abuse







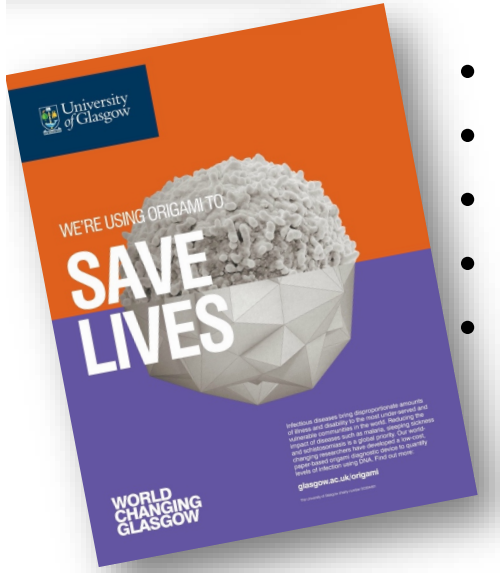


Yang *et al* ***Water Res*** 2021**, 189,** 116559, **ES&T** 2015, 49,5609

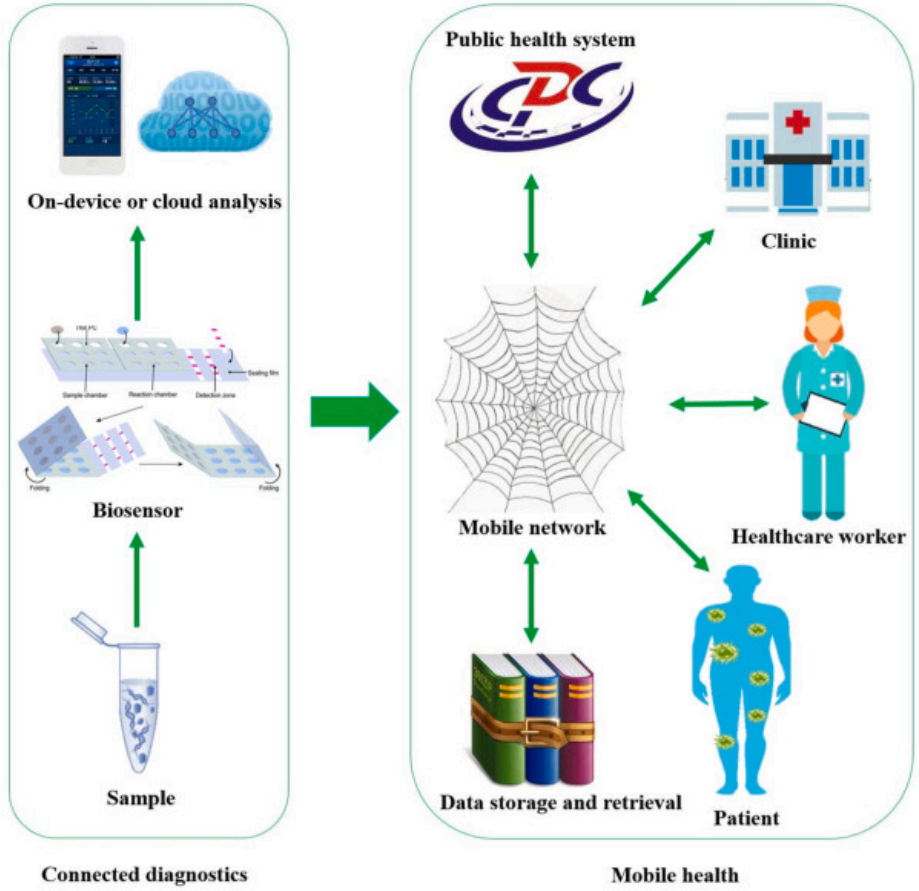
Origami-Paper Devices for Public Health

- Blood
- Semen
- Water
- Wastewater
- Soil

- Chemicals
- SARS-CoV-2
- Influenza A/B
- E.coli
- Salmonella
- Brucella
- Leptospira
- Malaria
- TB
- AMR



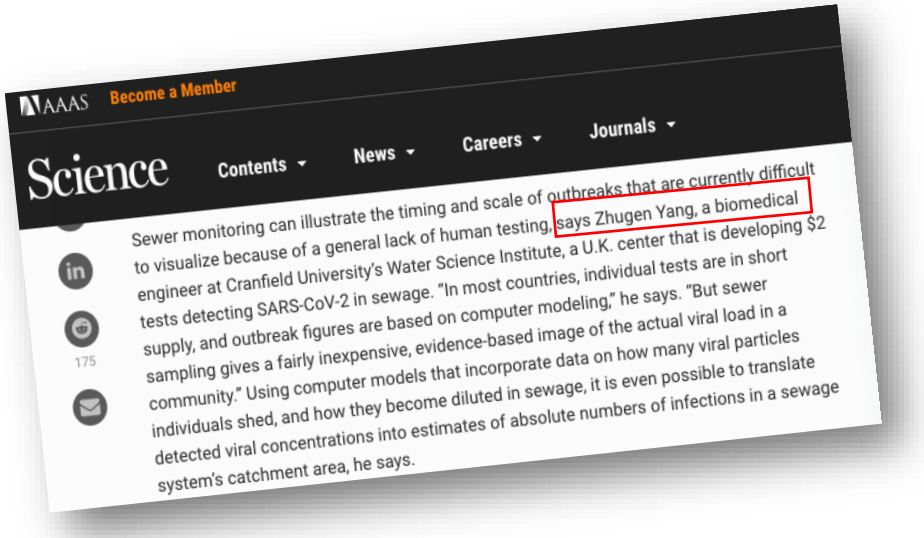
- Low-cost
- Rapid (~45min)
- Species-specific
- Point-of-Care
- Multiplexed



Nat Commun 2022, 13, 1937
Nat Commun 2021,12, 6994.
Water Res 2021, 191, 116787
PNAS 2019, 116 (11) 4834

Nat Water 2023, 5, 1-3
Adv Funct Mat 2023, 3, 202212081
ES&T, 2022, 56, 18, 13245
ACS Nano, 2020, 14, 7783

Our contribution to wastewater surveillance for early warning of pandemic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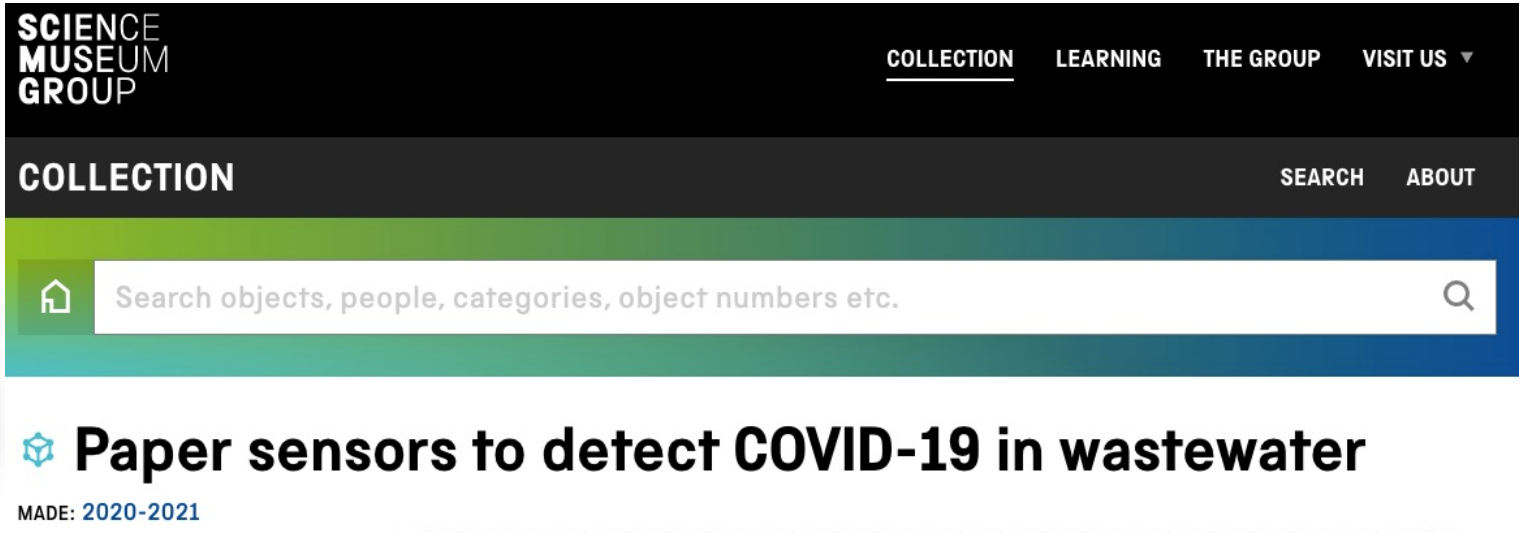
Sewer monitoring can illustrate the timing and scale of outbreaks that are currently difficult to visualize because of a general lack of human testing, says Zhugen Yang, a biomedical engineer at Cranfield University's Water Science Institute, a U.K. center that is developing $2 tests detecting SARS-CoV-2 in sewage. "In most countries, individual tests are in short supply, and outbreak figures are based on computer modeling," he says. "But sewer sampling gives a fairly inexpensive, evidence-based image of the actual viral load in a community." Using computer models that incorporate data on how many viral particles individuals shed, and how they become diluted in sewage, it is even possible to translate detected viral concentrations into estimates of absolute numbers of infections in a sewage system's catchment area, he says.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Paper sensors to detect COVID-19 in wastewater

MADE: 2020-2021

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Can a Paper-Based Device Trace COVID-19 Sources with Wastewater-Based Epidemiology?

Kang Mao, Hua Zhang*, and Zhugen Yang*

Cite this: *Environ. Sci. Technol.* 2020, 54, 7, 3733–3735

Publication Date: March 23, 2020

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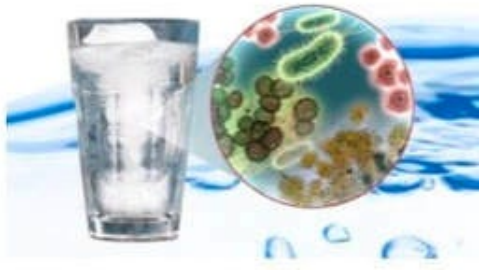

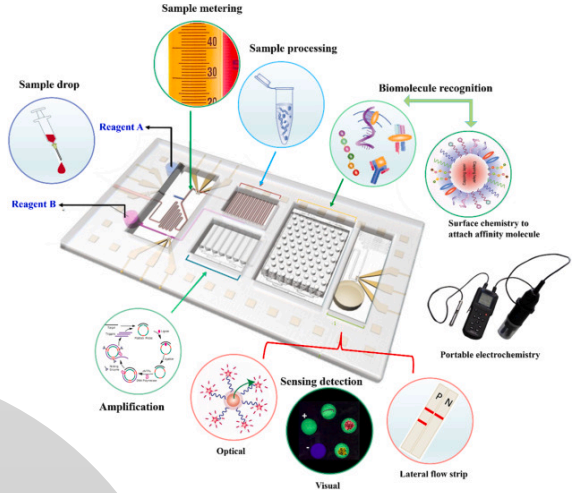

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Biosensing & Microfluidics

Public health

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Environ Sci Technol, 2020, 54, 3733
Biosens Bioelectron 2020,169,112617

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