

One Health: Use of wastewater for public and environmental surveillance



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Andy Weightman, Isabelle Durance & Pete Kille

Wastewater hits the media

.....for all the wrong reasons

NEWS

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Science & Environment

Sewage discharged into rivers 400,000 times in 2020

By David Brown
BBC News

31 March | Comments



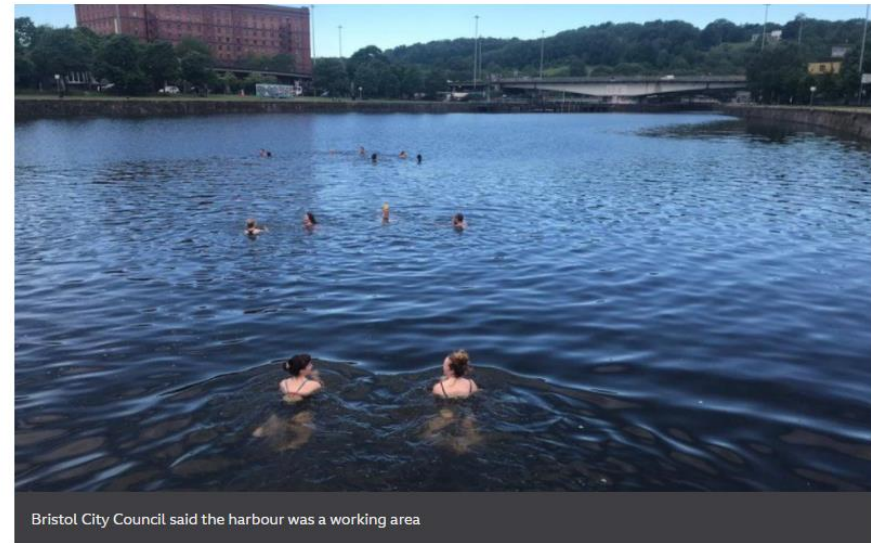
NEWS

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Swimmers protest against Bristol harbour's bathing ban

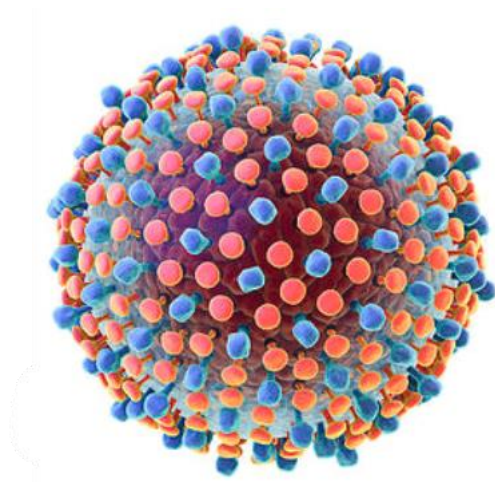
4 June



Viraaqua

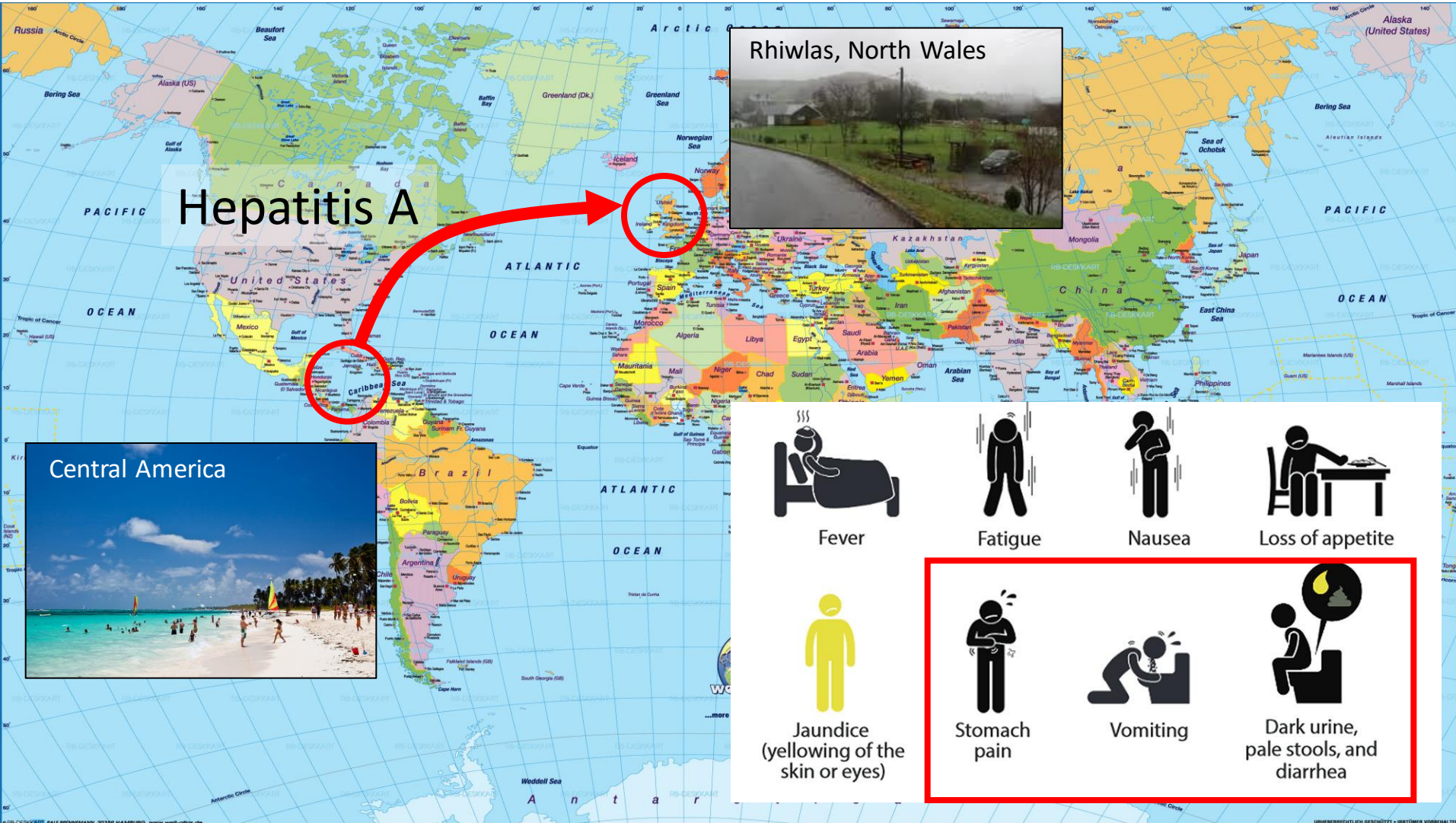
Tracing the fate and infectivity of
human pathogenic viruses through
the environment





.....a cautionary tale
of the power of viruses.....

The start of the viral journey





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Hep A

3^e Treated
CSO

Shellfishery

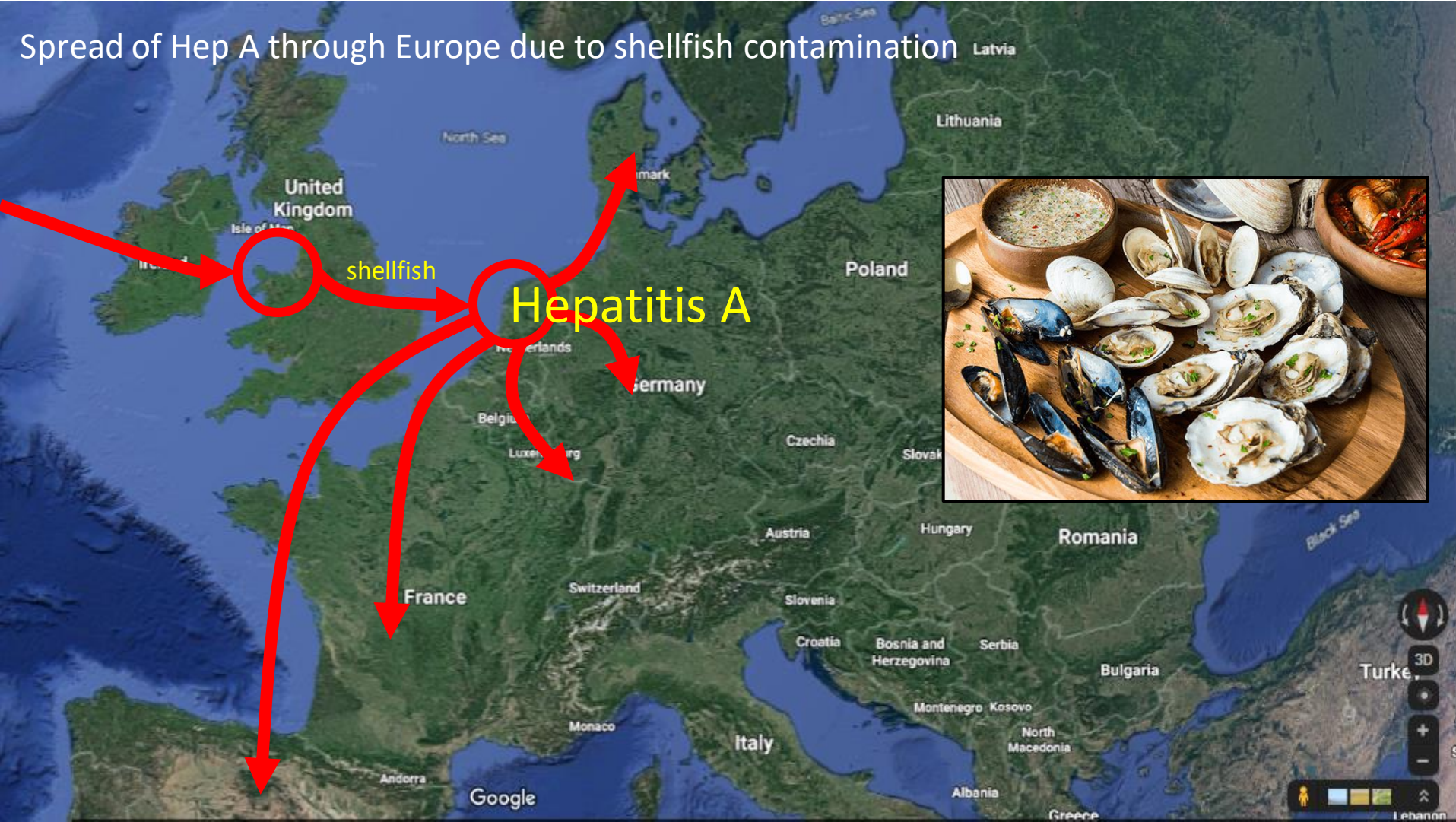


WWTP



The end of the viral journey

Spread of Hep A through Europe due to shellfish contamination



Winter vomiting bug alert over UK oysters as three-quarters are found to contain the norovirus

- Bug causes symptoms such as vomiting and diarrhoea
- Cooking kills virus but oysters are eaten raw

By **DAILY MAIL REPORTER**
UPDATED: 13:55, 29 November 2011

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More than three-quarters of British-grown oysters contain norovirus, known as the 'winter vomiting bug', experts have warned.

A study conducted on behalf of the Food Standards Agency found that 76 per cent of oysters tested from UK oyster growing beds had traces of the infectious bug.

Low levels of the virus, which causes symptoms such as vomiting and diarrhoea, were found in 52 per cent of the positive samples, according to the data.



sky ne
Home UK

180 hit as mussels cause outbreak of norovirus in hospital

A visitor bringing shellfish into a hospital in Northumberland has resulted in 180 people contracting the winter vomiting bug.



The outbreak has been traced back to mussels brought for an inpatient

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Norovirus outbreak from B.C. oysters makes dozens sick
Vancouver oyster bar owner expects his business to take a hit, as health officials issue warning
By Rafferty Baker, CBC News Posted: Jan 13, 2017 9:40 AM PT | Last Updated: Jan 13, 2017 2:20 PM PT

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News / Hepatitis crisis

San Diego waterways are not being tested for hepatitis amid health crisis

By **James DeHaven** - Contact Reporter

NO one is monitoring San Diego's surface water for hepatitis A, even amid a deadly, human waste-fueled outbreak of the disease that can spread through area waterways.

That's according to a letter from federal officials to U.S. Rep. Scott Peters, who last month asked the U.S. Environmental Protection Agency to take "the immediate steps necessary" to address potential waterborne transmission of the viral liver infection that has killed 18 people and sickened nearly 500 others since November.

The infection is spread when someone ingests even a tiny particle of feces, raising the possibility that it could spread from homeless encampments along city waterways toward the bays and inlets.

Top Stories

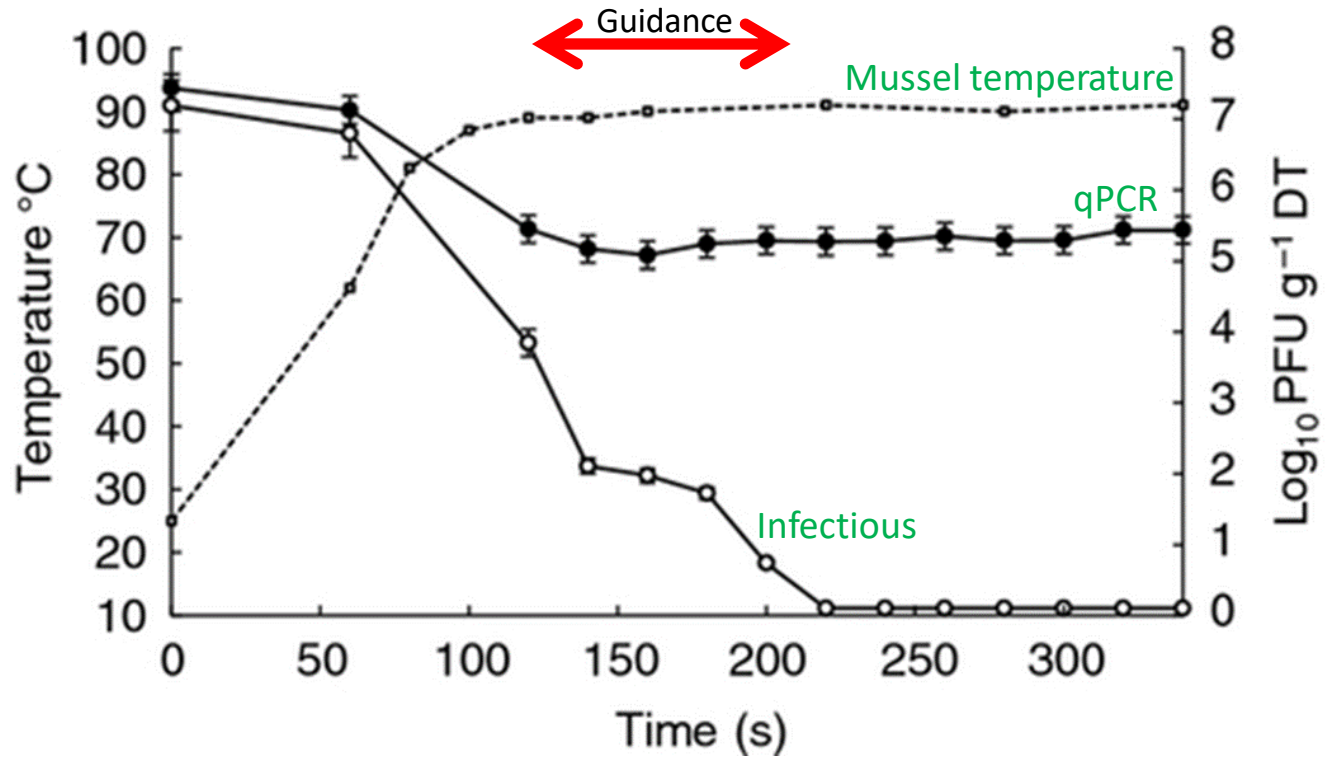
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Is it safe to eat shellfish? No

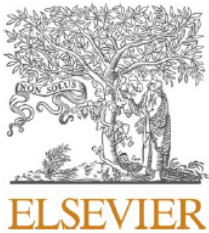
Raw oysters



Cooked mussels



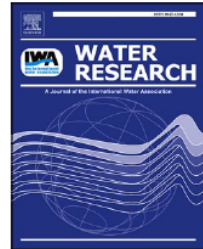




Contents lists available at [ScienceDirect](https://www.sciencedirect.com)

Water Research

journal homepage: www.elsevier.com/locate/watres



Tracing the fate of wastewater viruses reveals catchment-scale virome diversity and connectivity

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ARTICLE INFO

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viral diversity
wastewater viruses

ABSTRACT

The discharge of wastewater-derived viruses in aquatic environments impacts catchment-scale virome composition. To explore this, we used viromic analysis of RNA and DNA virus-like particles to holistically track virus communities entering and leaving wastewater treatment plants and the connecting river catchment system and

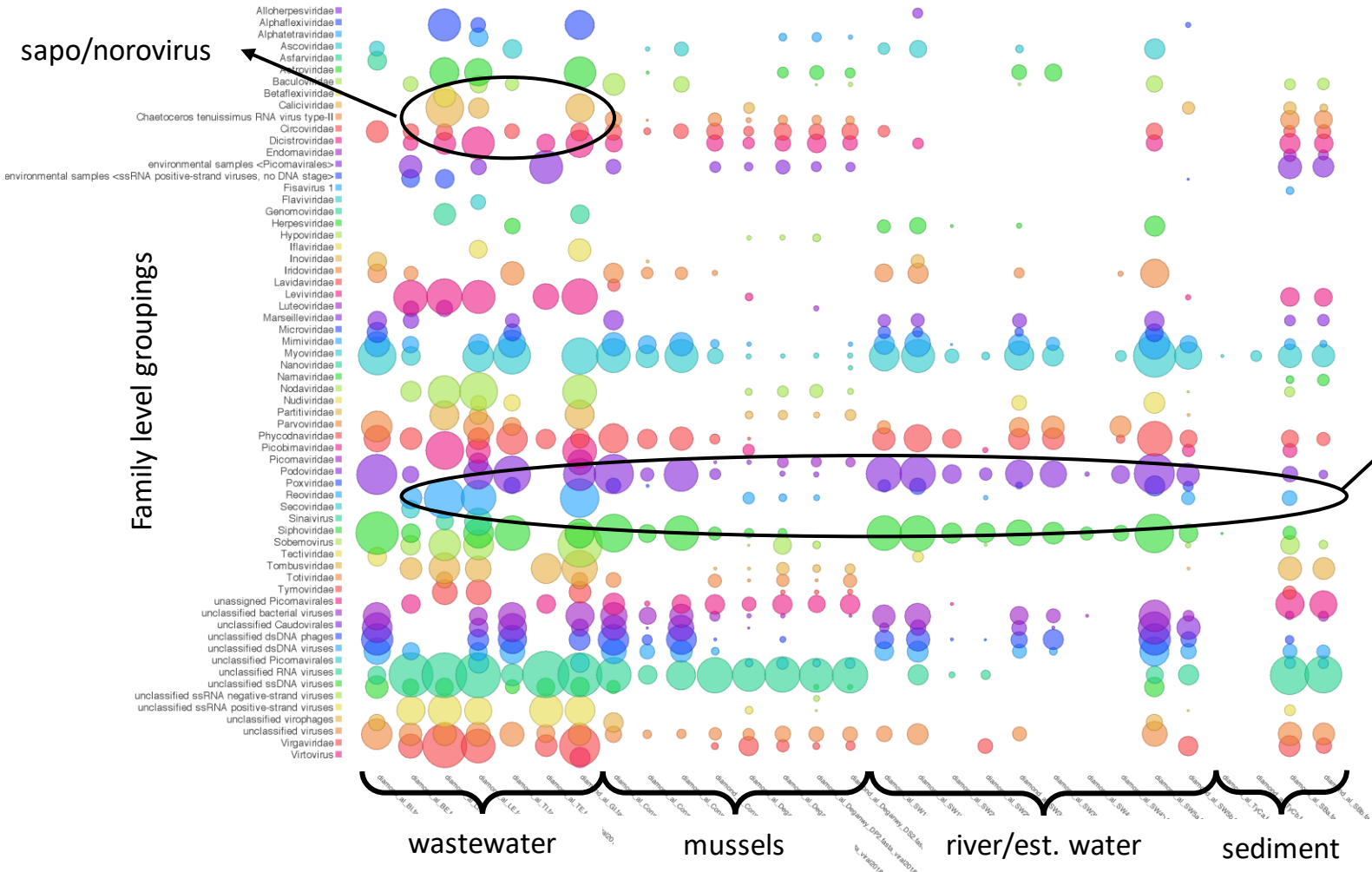


Taxonomy profile for Comparison_alreads_allsamples_viral2018_absolute.megan (rank=Family)

sapo/norovirus



Family level groupings

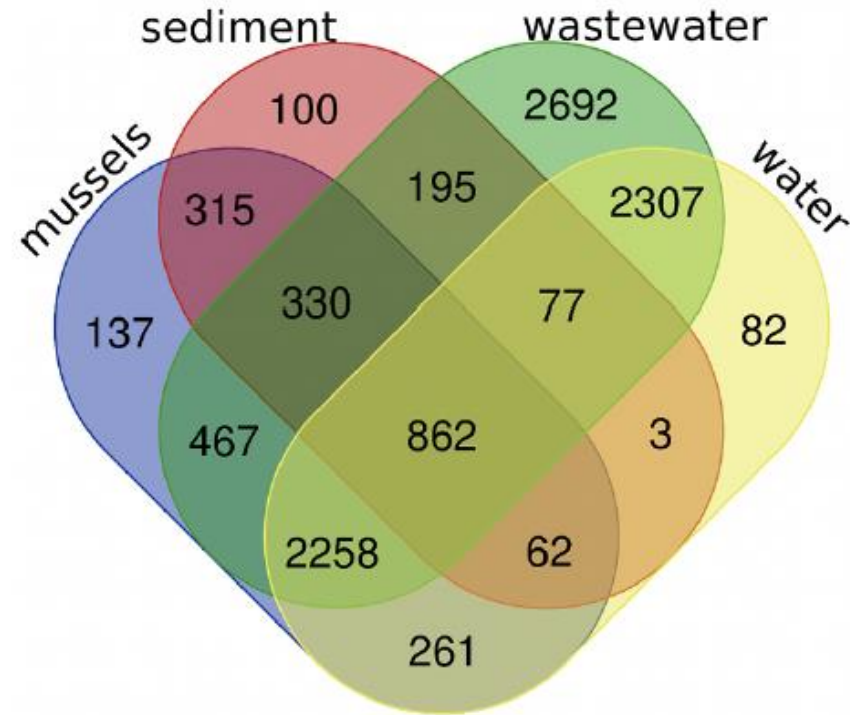


rotavirus

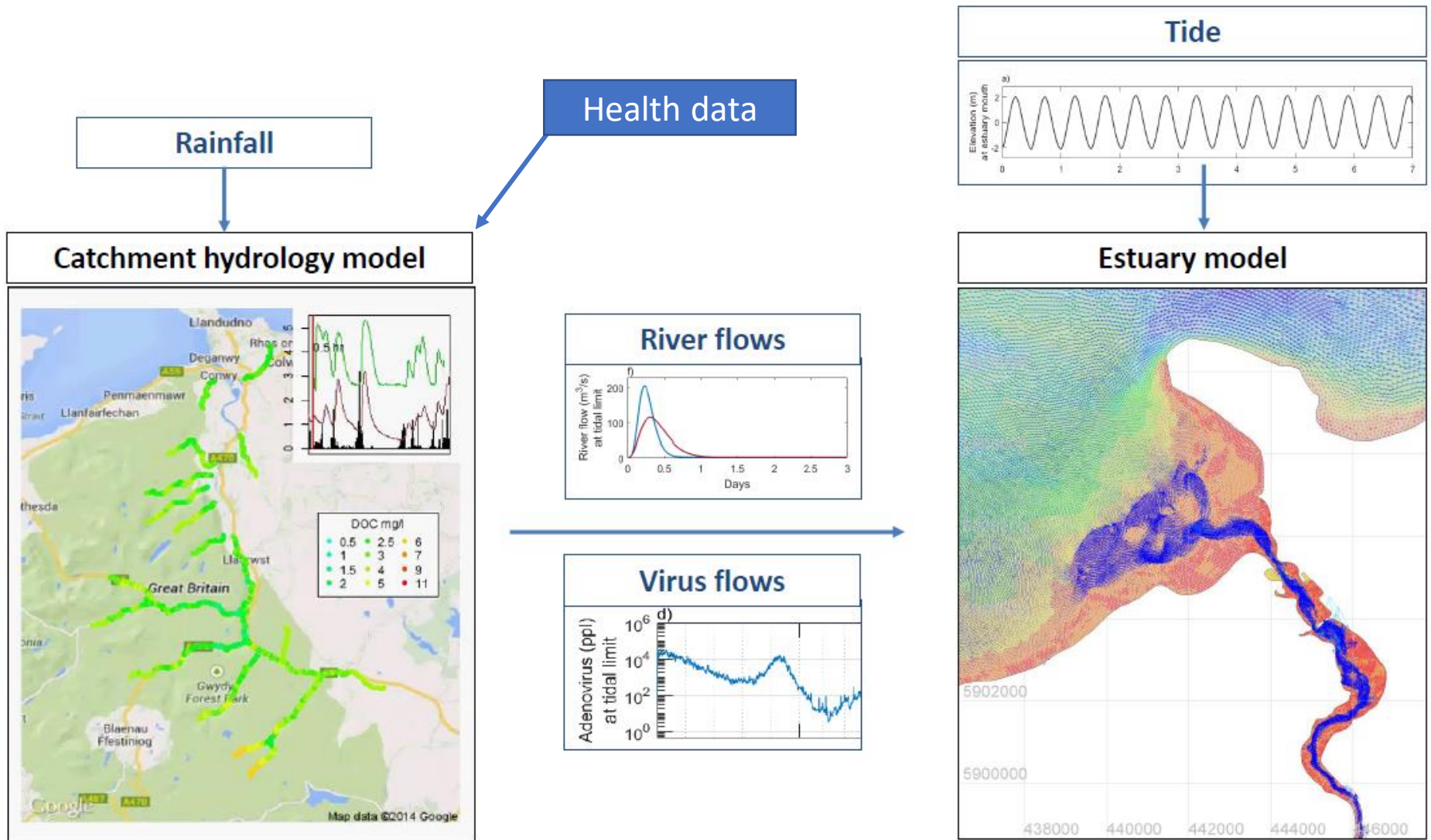
Metaviromes: Summary

- Lots of novel viruses identified
- Identification of novel strains circulating in the environment
 - Pathogens: norovirus G1
 - Indicators: picobirnaviruses
- Source tracking
- Epidemiology

Viral source tracking



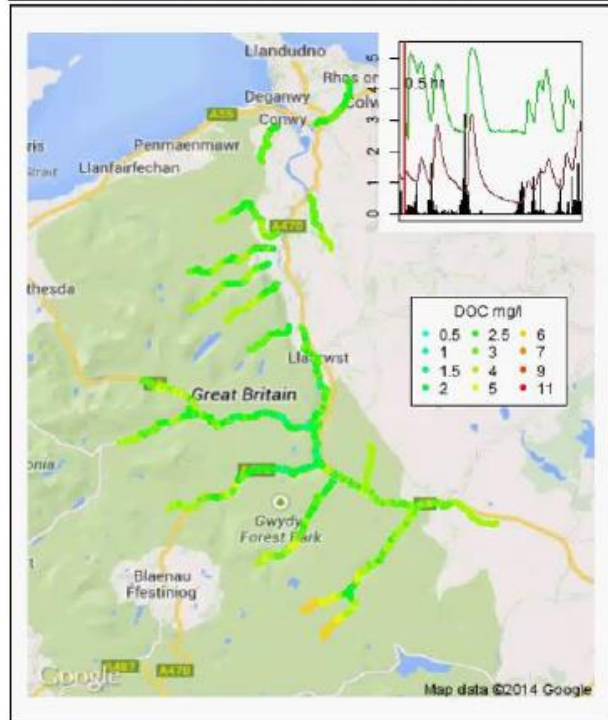
Active risk modelling



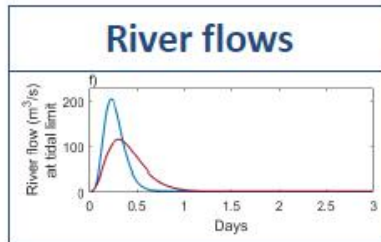
Rainfall

Health data

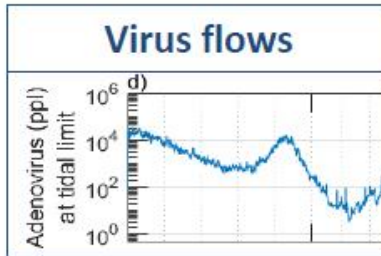
Catchment hydrology model



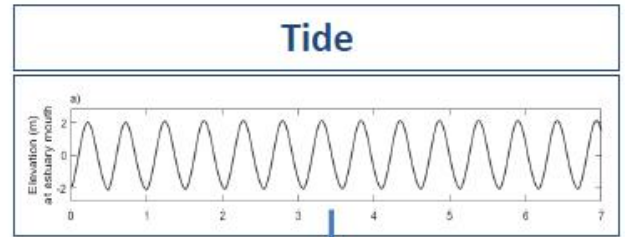
River flows



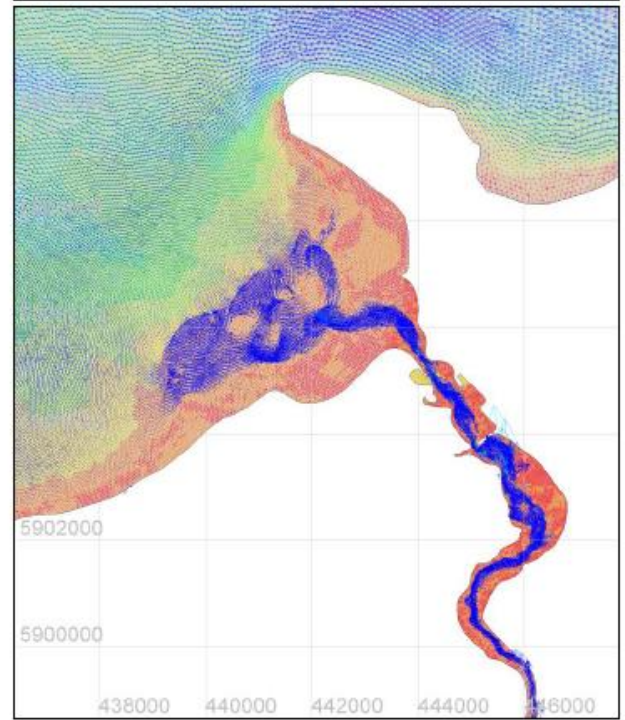
Virus flows



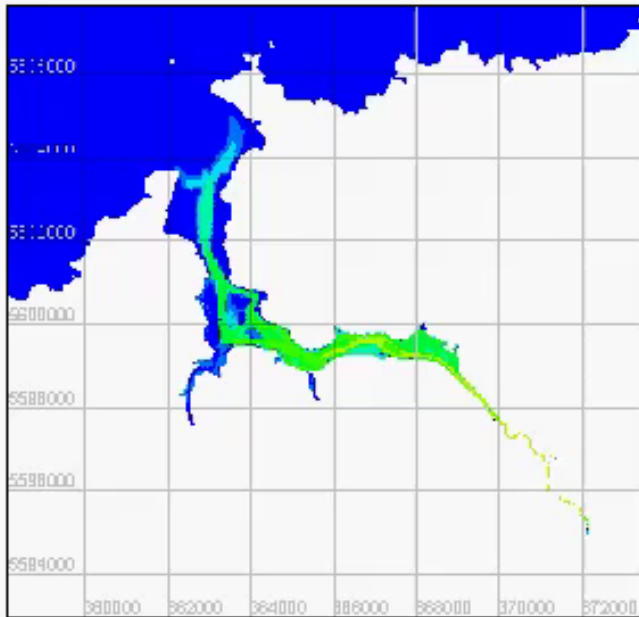
Tide



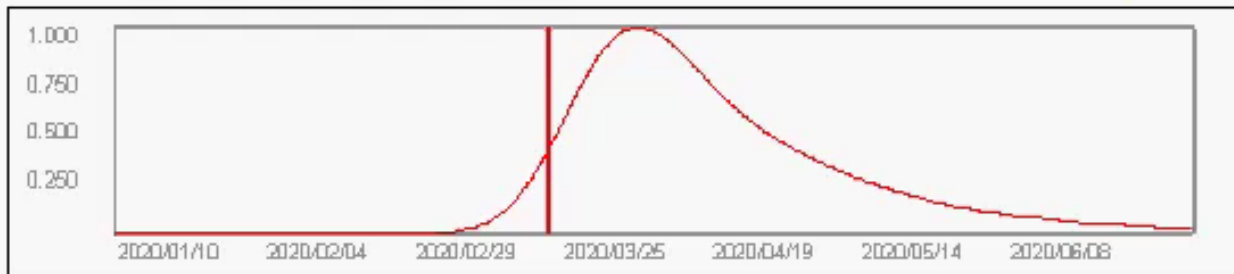
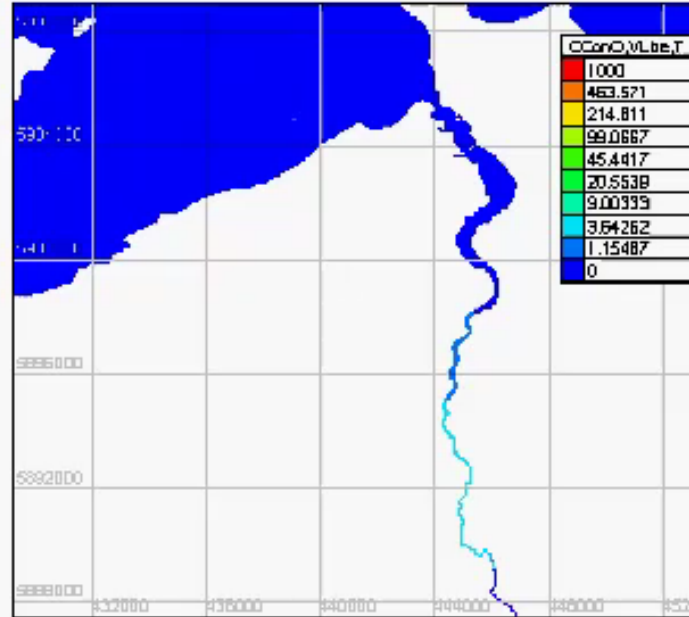
Estuary model



River Camel

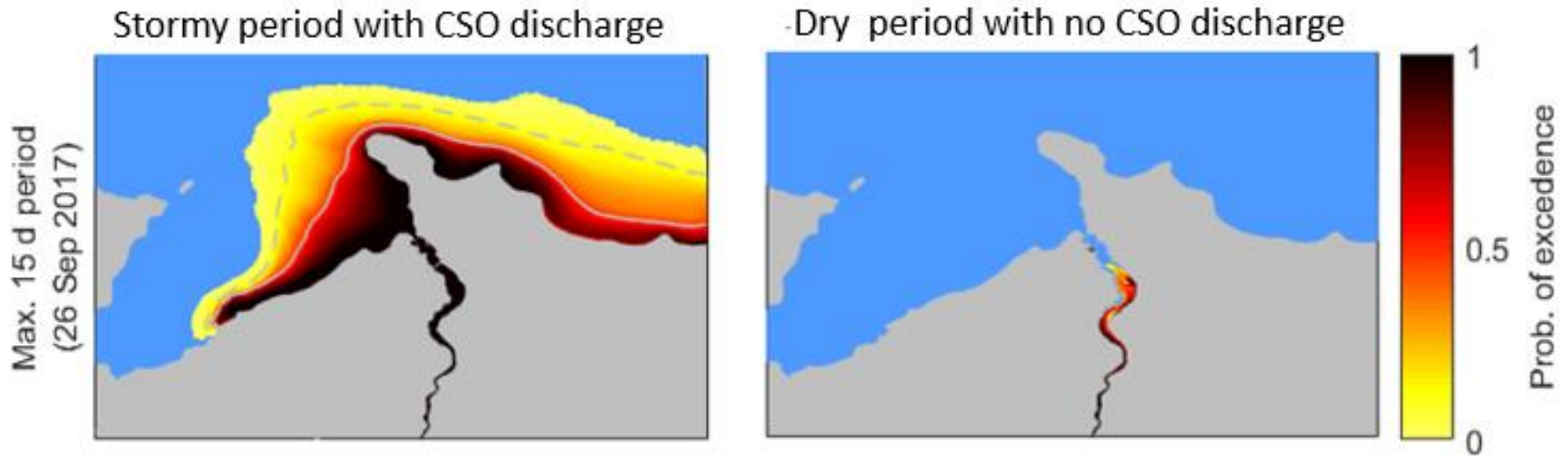


River Conwy



2020/03/13 15:00:00.000

We now have the potential to put 'active' management into practice



Tell people when it safe to use beaches, rivers, harvest shellfish etc



Take home messages

- 400,000 episodes of raw sewage being discharged into our rivers and coastal waters per year
- In the summer 20 to 50% of our rivers can be wastewater
- Viruses are far more persistent than bacteria
- Even treated wastewater contains many pathogenic viruses
- They easily flow through the environment
- They are known to cause large disease outbreaks via food, bathing waters, beaches, recreation
- Implementing active management is the next challenge
- **Don't eat oysters, mussels (or sushi)**

Tracking SARS-CoV-2 in the community using wastewater

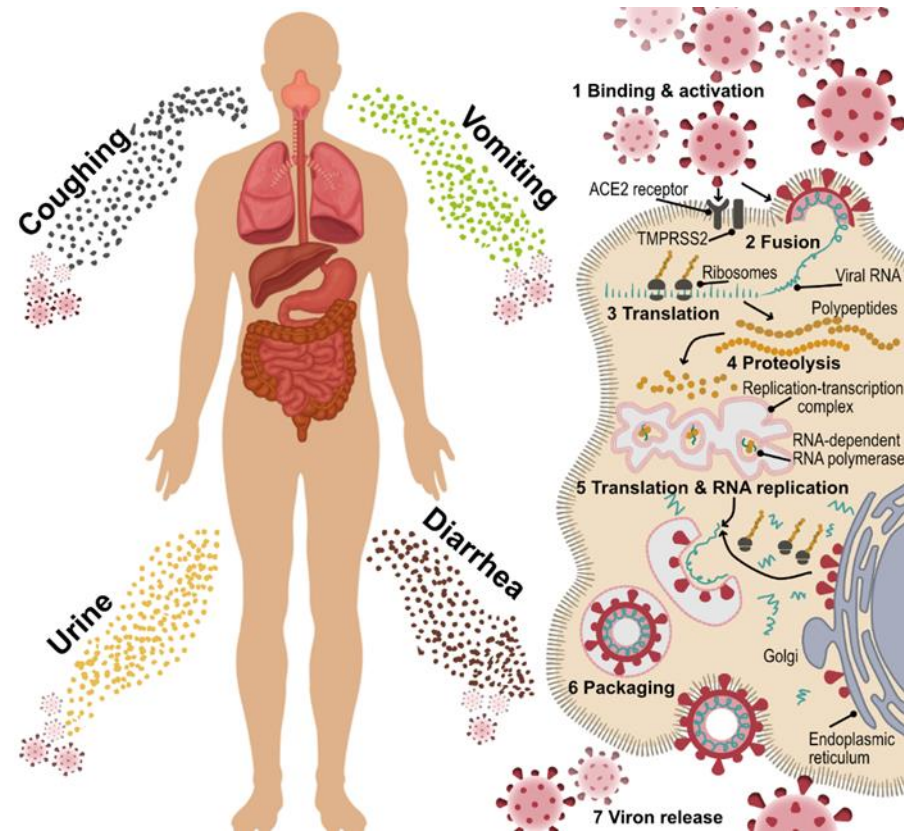
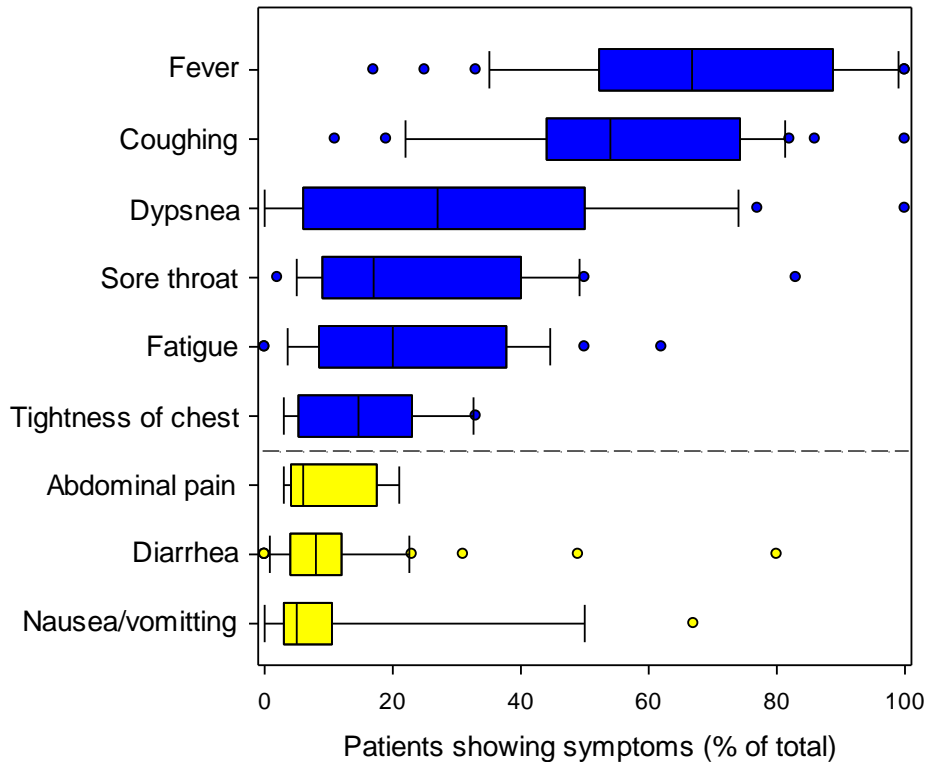


Wastewater-based epidemiology

- Measuring the waste products of society
- Prediction and status of ongoing outbreaks at a community level
- Snapshot of public health
- Inclusion of asymptomatic/presymptomatic cases
- Has been used for poliovirus epidemiology
- Data exists for enteric viruses (norovirus, enteroviruses, hepatitis A/E viruses)
- Does it work for the respiratory virus SARS-CoV-2?

Symptomatic SARS-CoV-2 infections

n = 50 studies



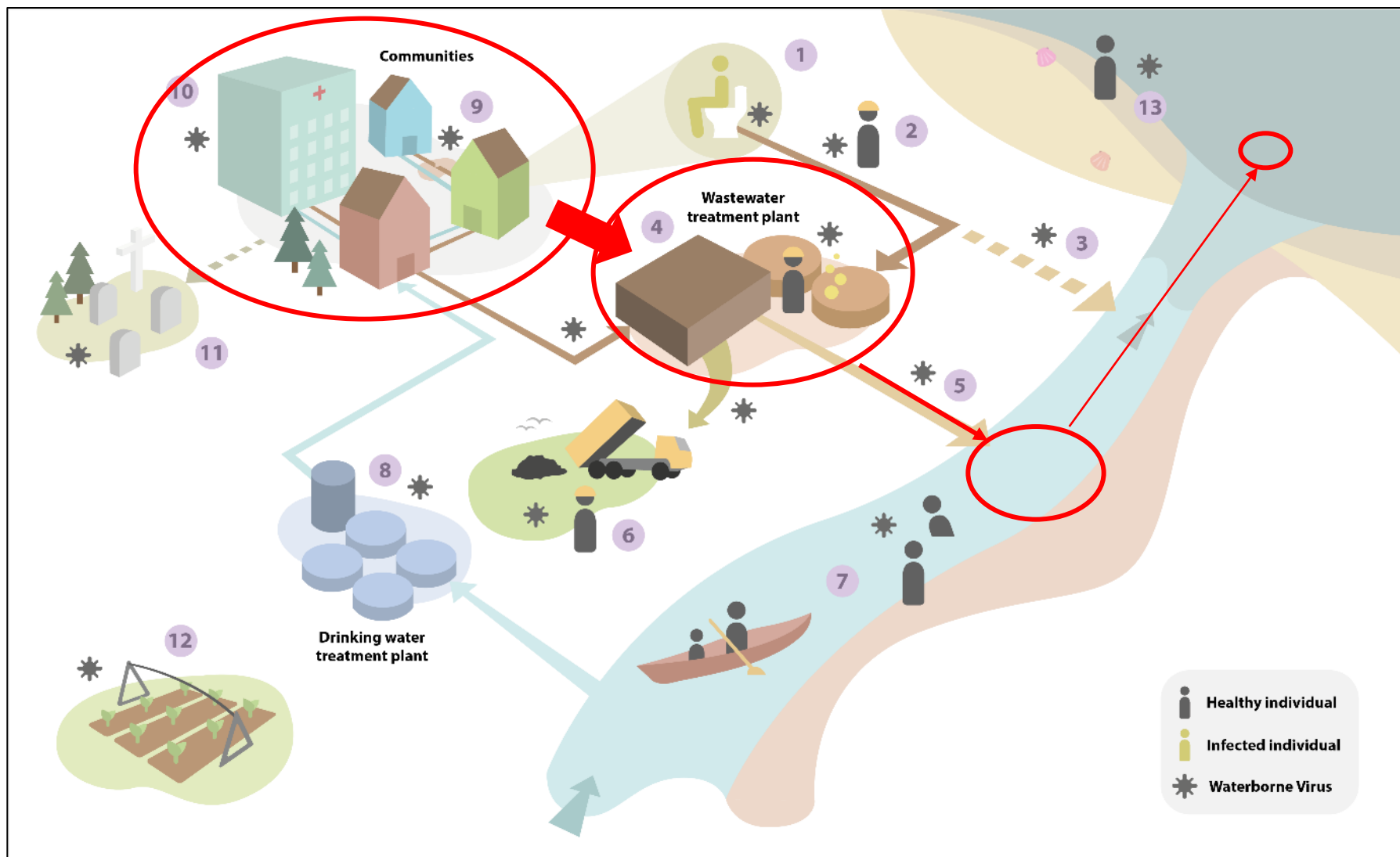
Faecal shedding of SARS-CoV-2

- Nasopharyngeal 10^5 - 10^{11} gc/ml
- Faeces 10^2 - 10^7 gc/ml
- Urine 10^2 - 10^5 gc/ml

- Respiratory release 9.1×10^{11} gc/person/d
- Faecal release 8.0×10^9 gc/person/d
 5.9×10^7 gc/l in sewerage

- Limit of quantification 10^3 gc/l
- Detection limit 1 case in 10,000

The basic principle of WBE

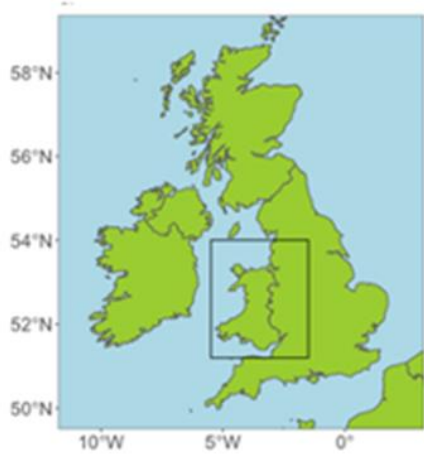


Cardiff

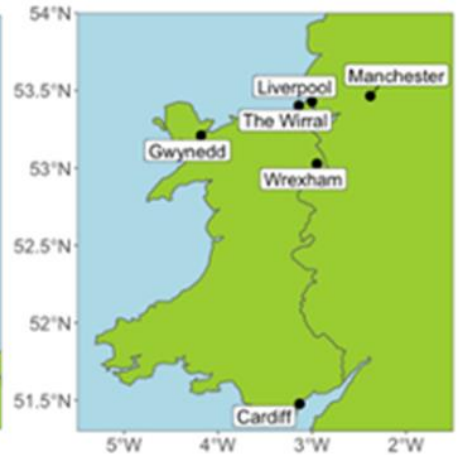


Wrexham

(a)



(b)

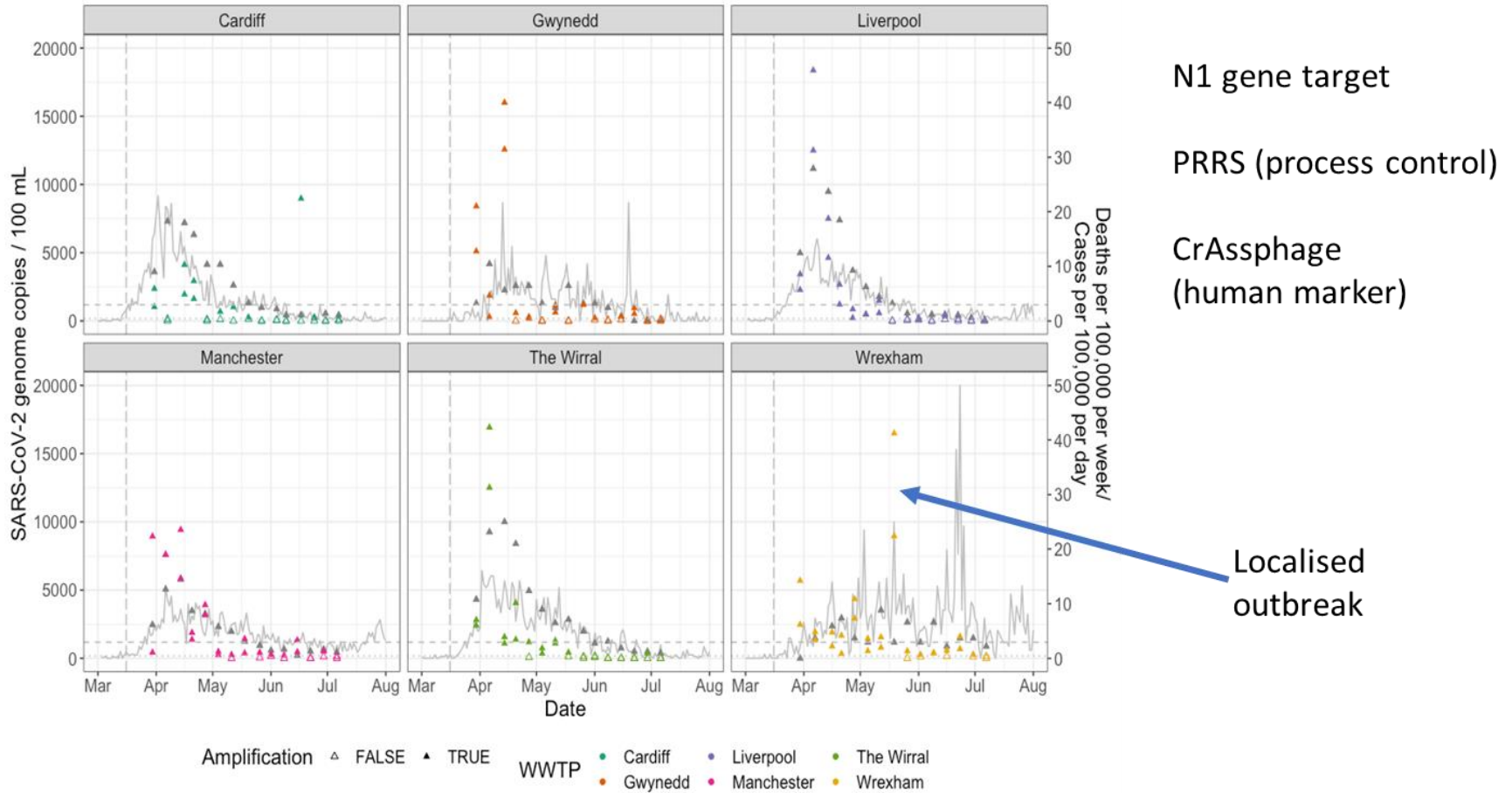


(c)

Location	Treatment	Population Equivalent
Cardiff	Sequential batch reactor	930,000
Gwynedd	Activated sludge plant	40,000
Liverpool	Activated sludge plant	628,000
Manchester	Activated sludge plant with tertiary treatment	1,170,000
The Wirral	Activated sludge plant with tertiary treatment	74,000
Wrexham	Oxidation ditch and biological filter bed	190,000



Examples of SARS-CoV-2 in wastewater in large UK cities



N1 gene target

PRRS (process control)

CrAssphage
(human marker)

Localised outbreak

Was SARS-CoV-2 in circulation prior to March 2020? **No**

News ▶ UK News

Covid outbreak in UK may have begun much earlier than we thought

There were many who suspect they may have had Covid-19 in early January 2020, or even December 2019



By Neil Shaw

06:57, 27 JAN 2021 | UPDATED 07:25, 27 JAN 2021

NEWS

Is SARS-CoV-2 infectious in wastewater? **No**

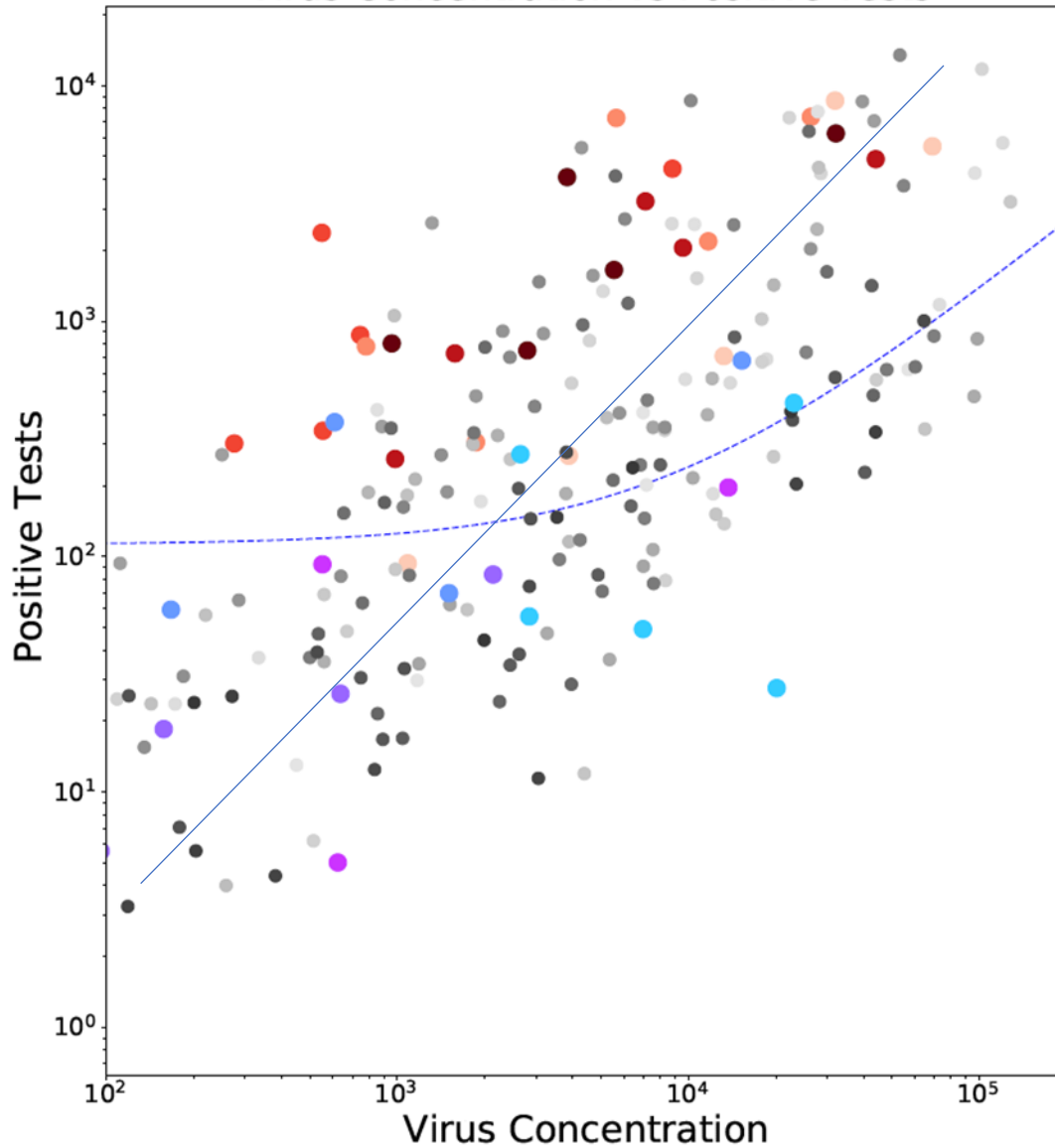


Imperial College
London

National Surveillance Programme

- 80 sites in England, Scotland and Wales
- Monitored 3 to 5 times a week
- SARS-CoV-2 and crAssphage
- Flow data
- Wastewater chemistry
- Prevalence of COVID in the population
- Published on the DHSC, WG and SG websites

Virus Concentration vs Positive Tests



- LONDON (Deepham STW)
- BOLTON STW
- DEWSBURY AND BATLEY STW
- DERBY STW
- HULL STW
- COLCHESTER STW
- BRISTOL STW
- BRADFORD ESHOLT STW
- HORDEN AND PETERLEE STW
- COVENTRY STW
- TROWBRIDGE STW
- STOKE BARDOLPH (Nottingham)
- LONDON (HOGSMILL Valley STW)
- LONDON (Crossness STW)
- ST IVES AND PENZANCE STW
- LONDON (Mogden STW)
- CREWE STW
- CAMBRIDGE
- LEIGH STW
- WASHINGTON STW
- LANCASTER (STODDAY) STW
- BARSTON STW
- MAIDSTONE AND AYLESFORD
- SOUTHAMPTON WEST (MILLBROOK) STW
- AYLESBURY, RABANS LANE, AYLESBU STW"
- BARROW IN FURNESS
- LEICESTER STW
- LEEDS (KNOSTROP) STW
- LITTLE MARLOW STW
- LONDON (Beddington STW)
- BASINGSTOKE, WILDMOOR, BASINGST STW"
- LUTON STW
- LONDON (Becton STW)
- LONDON (Riverside STW)
- LIVERPOOL (SANDON (NORTH LIVERPOOL DOCKS)) STW
- TOTTEN, MARCHWOOD, HYTHE, CADNAM STW"
- LINCOLN (Canwick works)
- WHITTLINGHAM (Norwich)
- PLYMOUTH CENTRAL
- PETERBOROUGH STW
- Hoylake (NORTH WIRRAL (MEOLS))
- WEYMOUTH STW
- BIRMINGHAM & BLACK COUNTRY NO. 1 (MINWORTH) STW
- CHATHAM AND GILLINGHAM STW

Using wastewater testing to support surge testing (in-network surveillance)

Liverpool



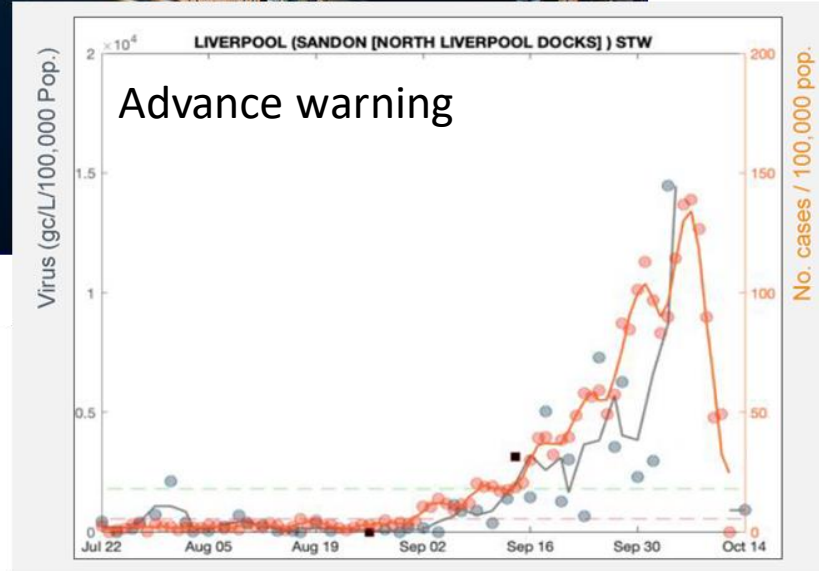
Draft document for discussion purposes only – not government policy



COVID-19 WASTEWATER PROGRAMME

LIVERPOOL UPDATE #17

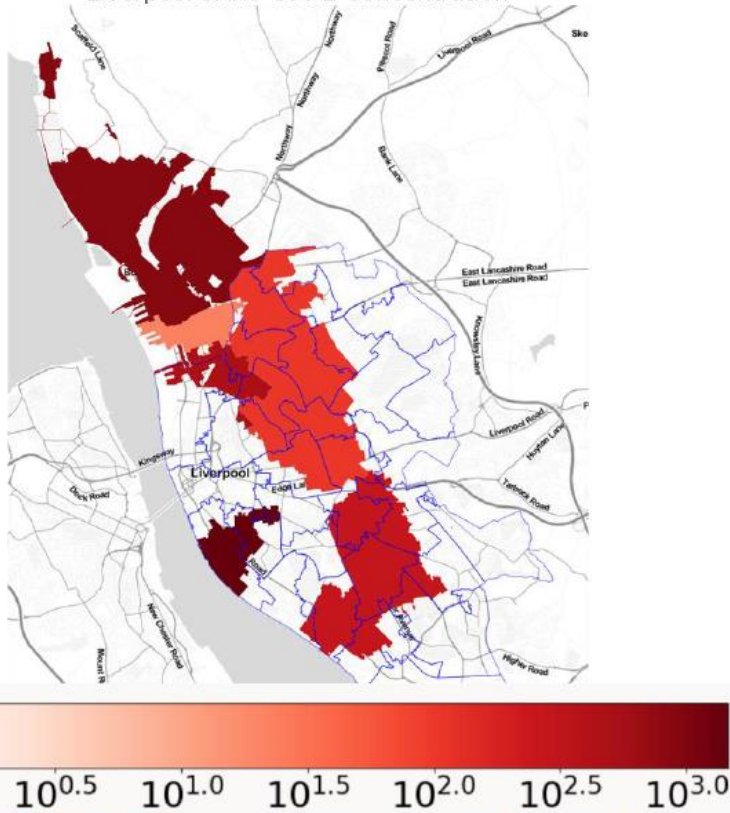
For the week commencing 11th January





Liverpool

Liverpool SARS-CoV-2 Concentration



Liverpool SARS-CoV-2 Concentration Change

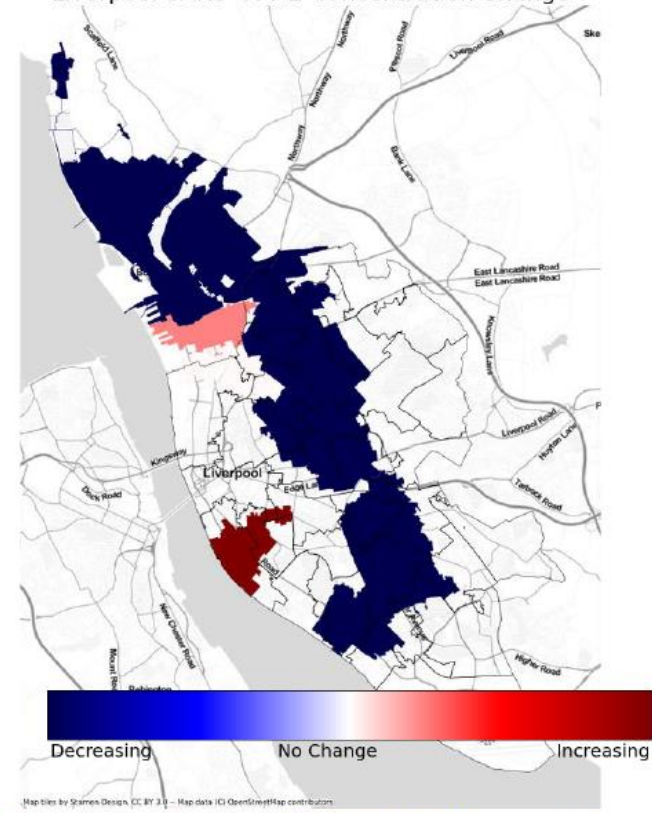
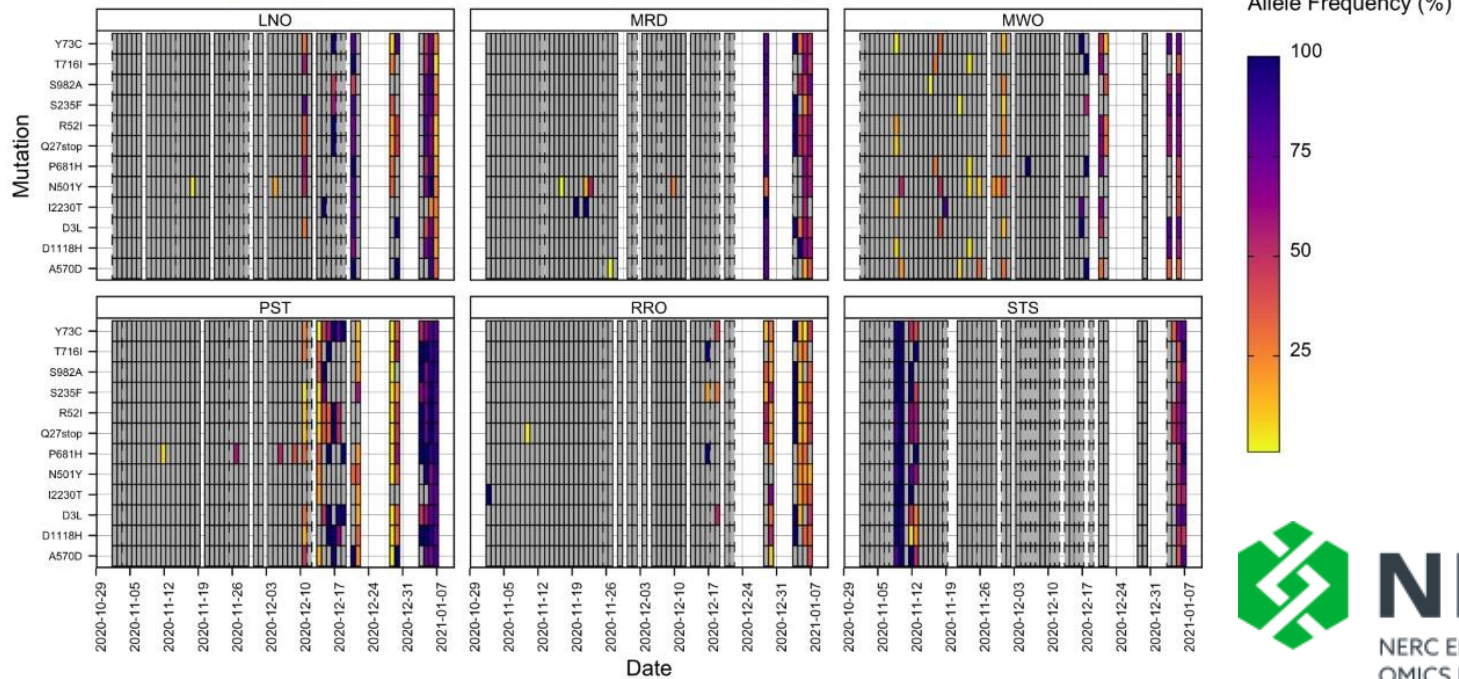
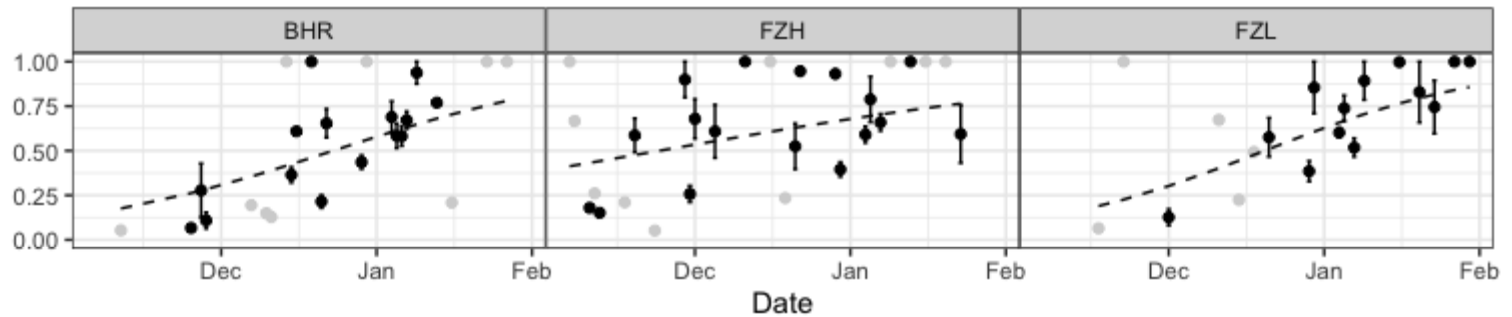


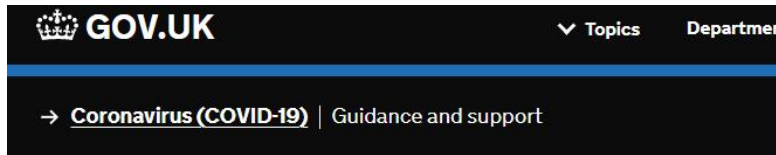
Figure 42: SARS-CoV-2 RNA concentration in wastewater. Darker shading indicate areas with a higher viral concentration. Higher concentration is associated with increased prevalence.

Figure 43: Change in weekly average SARS-CoV-2 RNA concentration in wastewater (scale is to maximum increase/decrease within the city).

Monitoring the spread of the alpha variant



Environmental Monitoring for Health Protection (3000 samples per week)



Home > Coronavirus (COVID-19) > Testing for coronavirus (COVID-19)

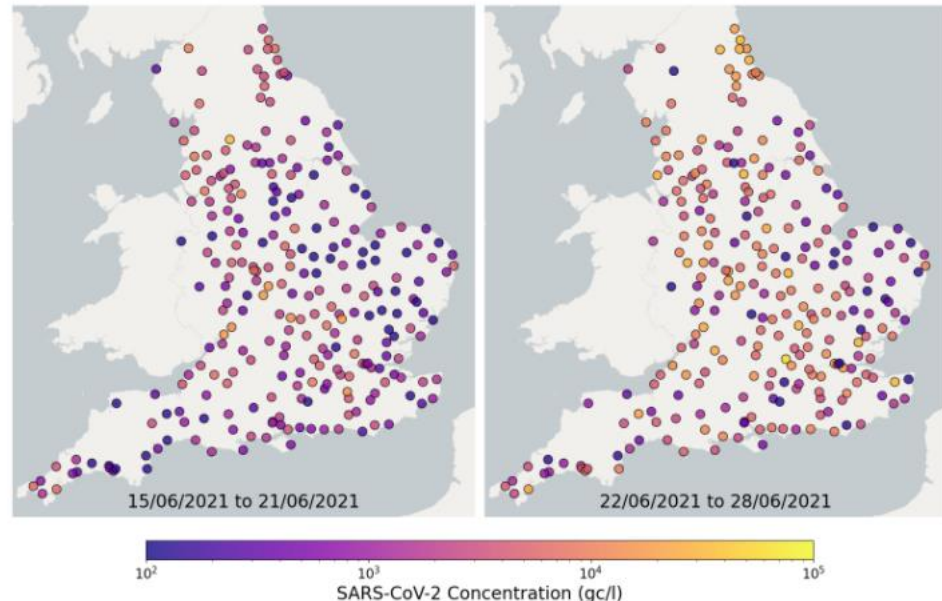
Press release

Testing and sequencing of sewage ramped up to help tackle COVID-19 outbreaks

The innovative programme to test wastewater for traces of coronavirus (COVID-19) has ramped up sequencing capacity to support variant detection.

From: [Department of Health and Social Care](#)

Published 22 May 2021



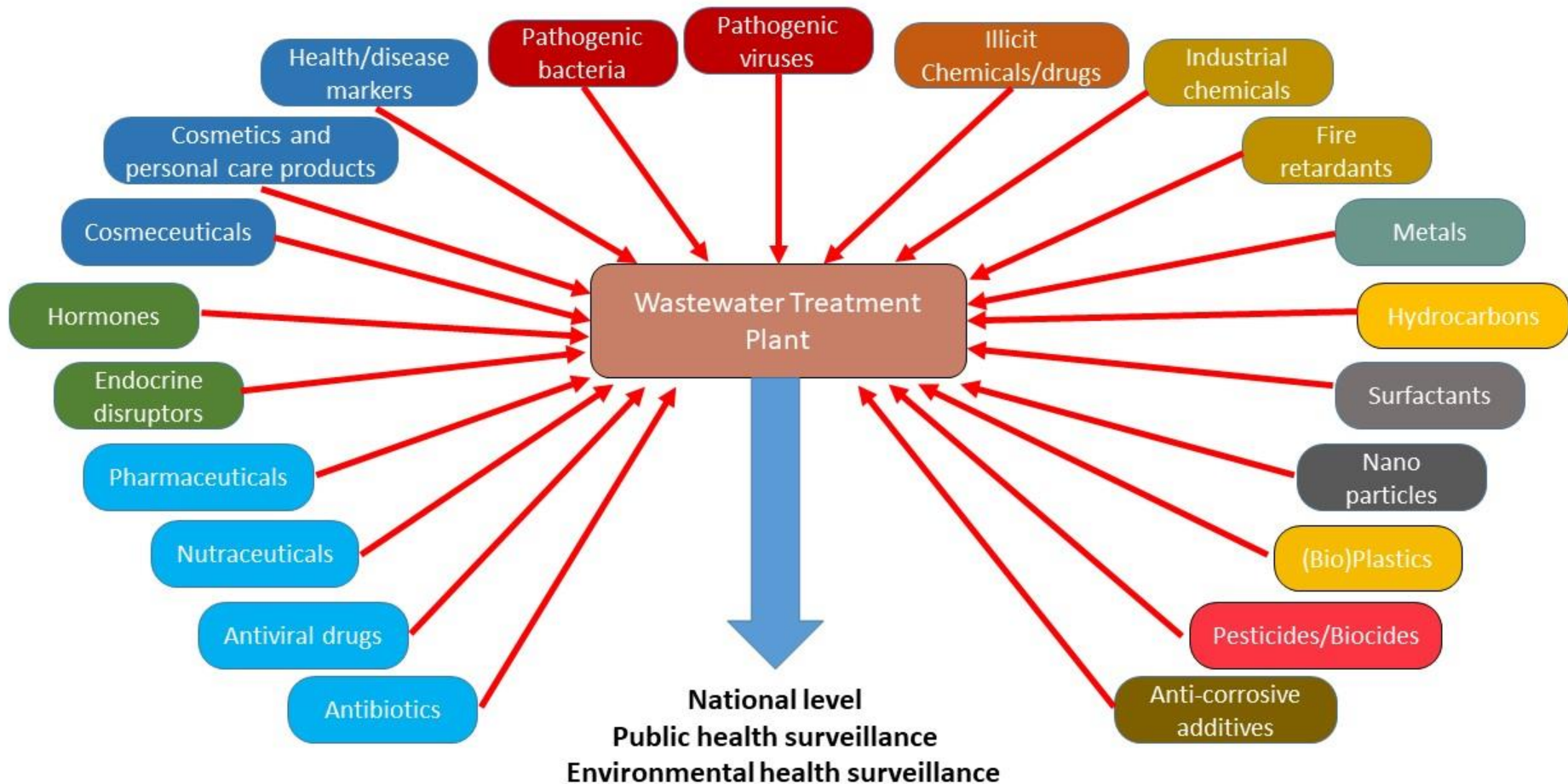


Natural
Environment
Research Council

- Started with the *Environmental & Human Health Programme*
- Provided the necessary skills and expertise in environmental virology (and AMR surveillance)
- Built capacity in the NERC Environmental Omics Facility
- Provided the NERC URGENCY award to test the SARS-CoV-2 community surveillance concept
- NERC funding created the national EMHP programme and infrastructure to enable WBE
- What next?

What is the future of wastewater-based epidemiology?

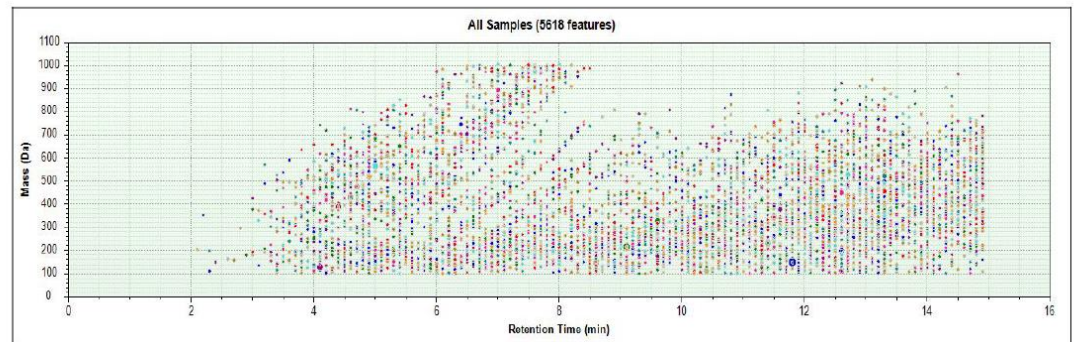
Wastewater tells no lies about our habits



Harnessing the power of analytical chemistry: pharmaceutical monitoring



Figure 3.4.1 – Sample Point 4 – Nant-Y-Ffin upstream of Nant-Y-Fendrod.



5-Aminosalicylic acid	Hydrocodone*	Venlafaxine*
Oxycodone	Cotinine	Paracetamol*
Diazepam	Phenyltoloxamine	Caffeine
Methylscopolamine	Irbesartan*	Tramadol*
Lamotrigine*	Benzoyllecgonine*	N,N-Diethyl-m-toluamide. DEET*
Nicotine*	MBDB	Hydroxycotinine*
Carbamazepine-10.11-epoxid*	Lidocaine	O-Desmethylvenlafaxine. Desvenlafaxine
Oxcarbazepine	Sertraline	Benzododecinium
Carbamazepine	Naproxen*	Citalopram*
Codeine	Dihydrocodeine*	

Monitoring drug use across Europe

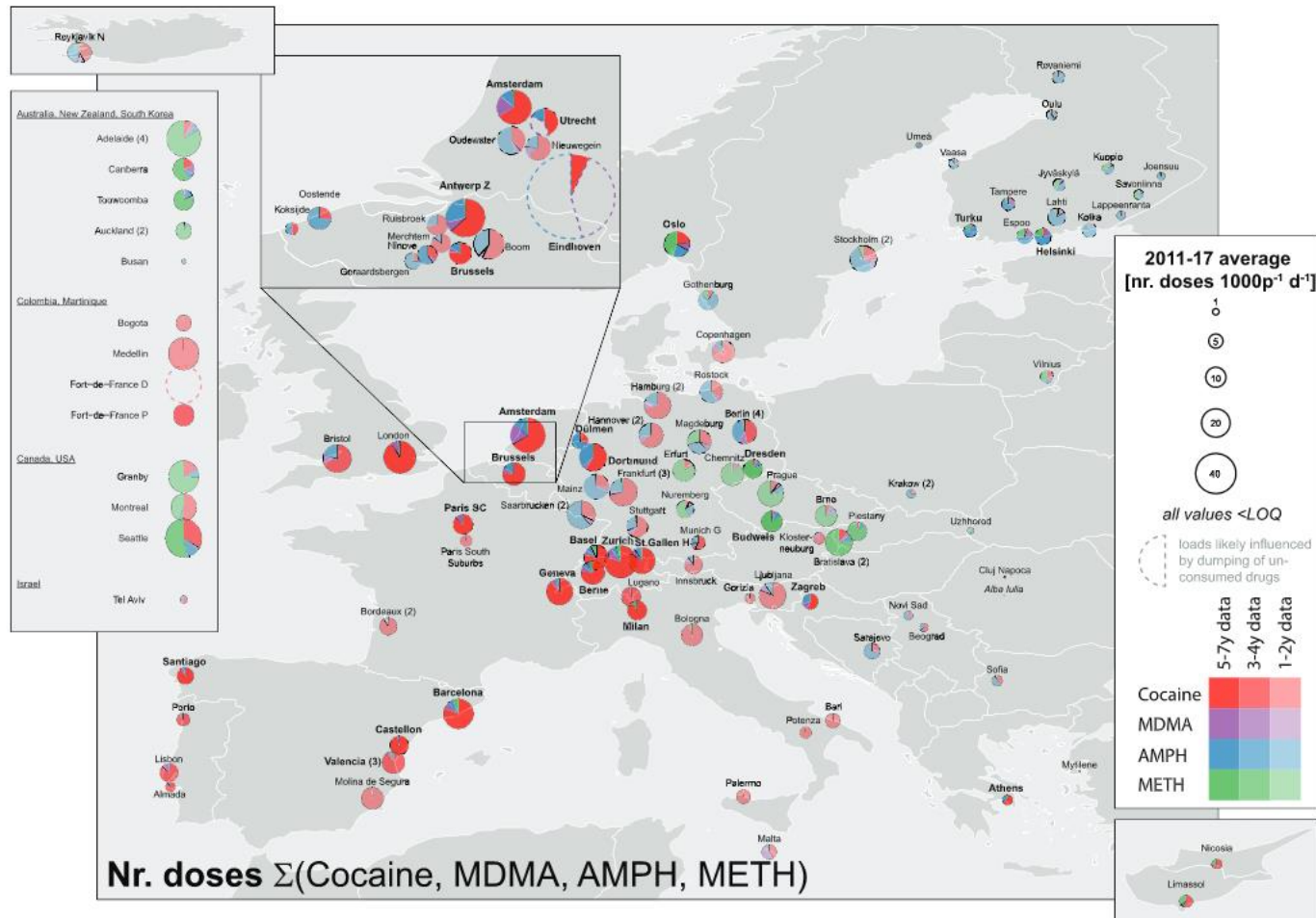


Figure 6 2011–17 total average number of doses/1000 people/day. [Colour figure can be viewed at wileyonlinelibrary.com]

Where
we are
now and
what is
the
vision..

- **Wastewater provides a perfect window to assess how we live**
- Wastewater-based surveillance for SARS-CoV-2 is now proven to work
- It has been used to guide national and local policy within 18 months
- We have the national infrastructure
- We need to greatly expand the portfolio
- WBE is truly multidisciplinary
- We need to better understand the downstream impacts – it is not just about public health
- It can make a valuable contribution to the health of the nation