Microbes: The Good, the Bad, and the Environmental Impact

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Chief Scientist's Group

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Environment Agency & its Chief Scientist's Group

- The Environment Agency was established in 1996 to protect and improve the environment in England. It is the Department for Environment, Food & Rural Affairs (Defra) largest non-departmental public body with around 10,600 employees.
- The Environment Agency's remit covers about 13 million hectares of land, 22,000 miles of river, 3,100 miles of coastline and 2 million hectares of coastal waters.
- Our main duties include: environmental permits, regulating major industry and waste, and the management of water quality and resources, including the National Flood and Coastal Erosion Risk Management.
- Within the Chief Scientist's Group, we have around 150 scientist and our work involves research, evaluation, data analysis and reporting, horizon scanning and innovation for the Environment Agency. Our Chief Scientist is Rob Bradburne, and you can find out more of what we do at our annual Chief Scientist's Annual Review 2023 on gov.uk

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The microbial world

Aquatic animals
Fish have microbial communities that support their health.

Soil
Soil microbial communities differ: fungi form spider webs in the soil to connect plants, bacteria are near plant roots.

Plants
Microbes are on and in plants, supporting plant health.

Animals and disease
Potentially harmful microbes are often part of the natural host microbial community and attack when immunity is weak. The animal food chain may also spread anti-microbial resistances.

Microbes on food
Foods like yoghurt and sauerkraut are rich in beneficial bacteria that outnumber those microbes which cause food go rotten. In food production, yeasts are often used for bread and beer.

Water bodies
Microbes in phytoplankton communities are food for fish.

Humans
Humans have many beneficial microbial communities: our gut bacteria is influenced by the food we eat.

Shellfish and disease
Some microbial compounds accumulate in shellfish and cause food poisoning.

Humans and disease
Microbial infections are common when immune systems are weak.

Single celled algae
Single-celled algae are a food source for us.

Agriculture
Some bacteria help crop growth and defend plants against diseases.

Plants and disease
Some microbes can cause plant disease and food losses, in the right environment.

Animals
Animals have microbial communities that are supportive of the animal's health.

Microbes in foods
Wrong food storage causes food to go rotten as moulds take over the microbial community. These microbes often cause food poisoning.

Food waste
Rotting of food means microbes recylce food leftovers so that nutrients can be released back into the environment.

The project MicrobiomeSupport (www.microbiomsupport.eu) has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 818116.

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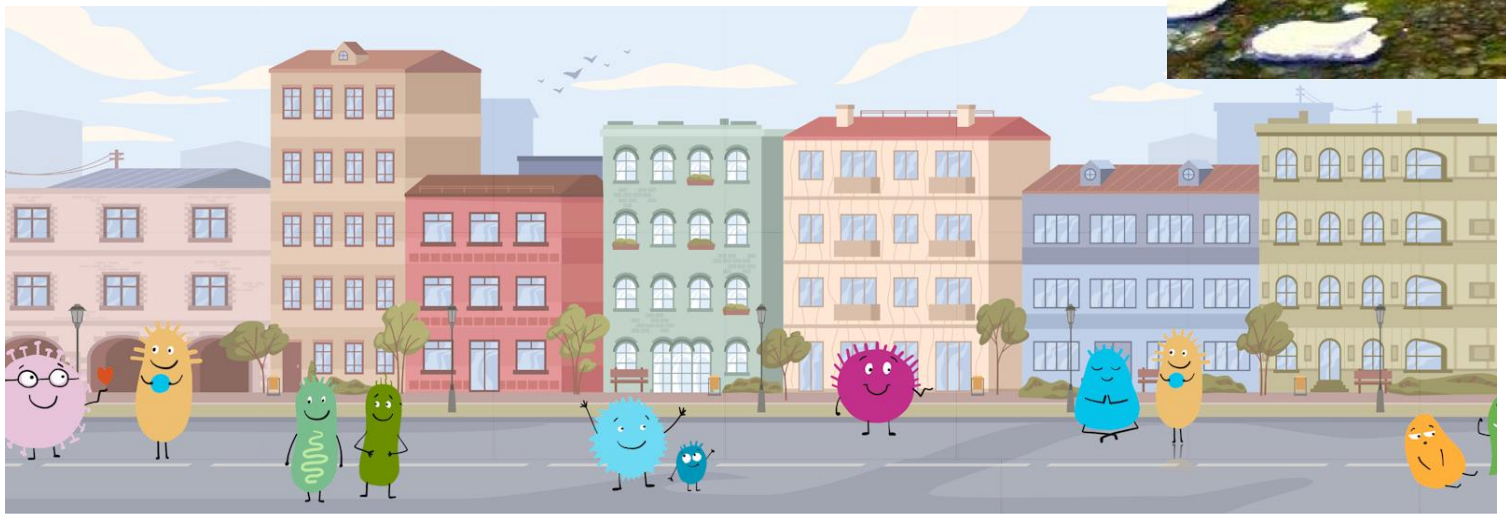
Microbes in river biofilms

- Microbial ‘cities’ of river systems
- Important metabolic processes
- Large knowledge gaps as we currently do not monitor for microbes



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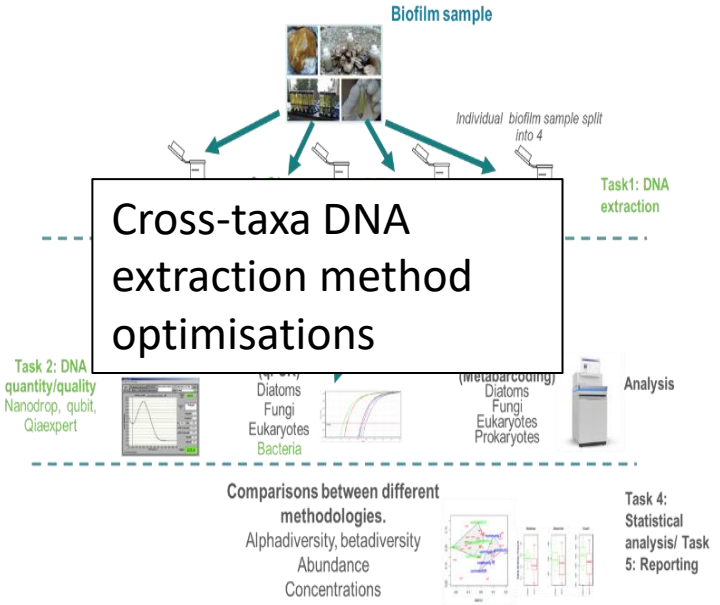
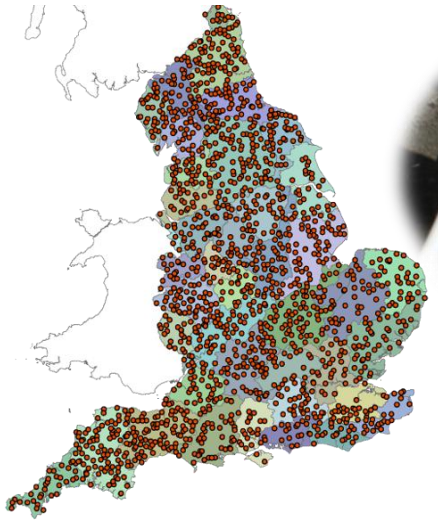
Underpinning data & information



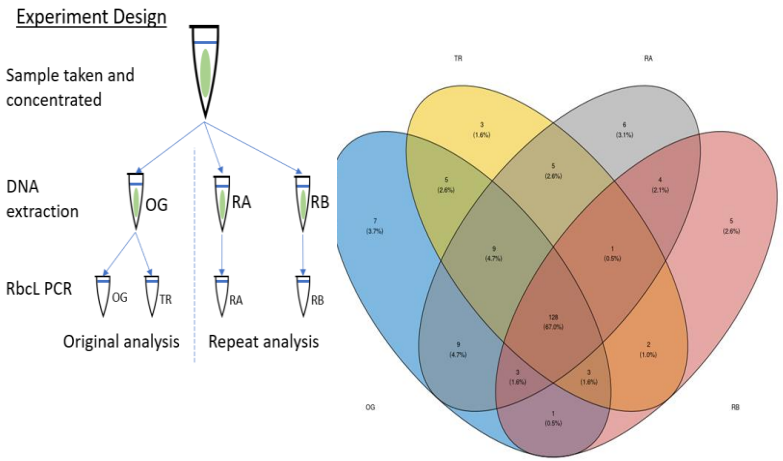
Cross-taxa DNA extraction method optimisations



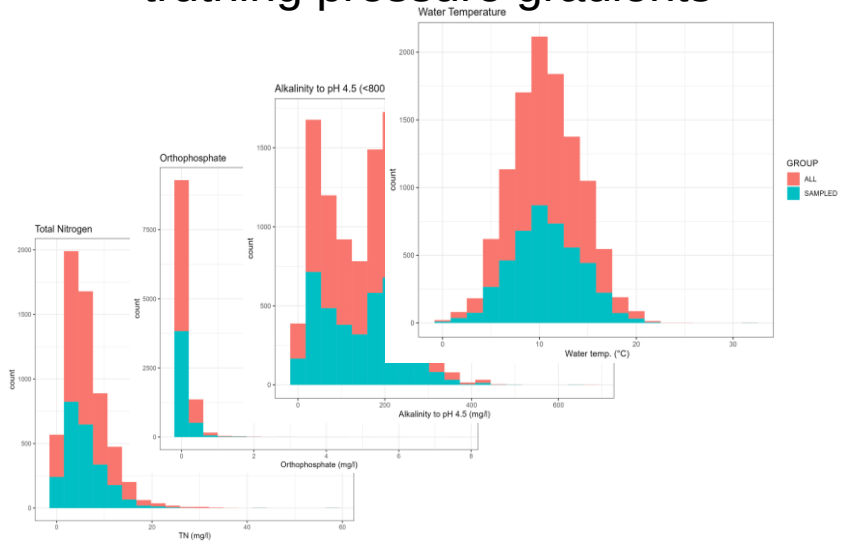
Data & information scoping

-ML workshop
-Ecological network science (ENS) think pieces

Assessing eDNA degradation



Collating abiotic data and ground-truthing pressure gradients



Biobanking

-Storage system to biobank samples
-Allows reanalyse from single samples (INNS, pathogens, additional data for trend analysis)

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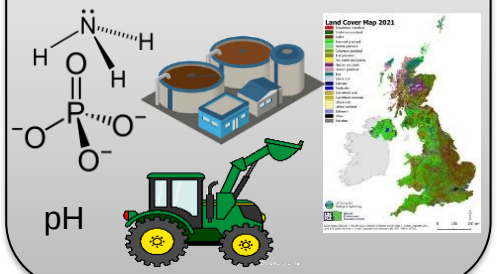
Are microbes valuable bioindicators of ecosystem health and change?

Biofilm

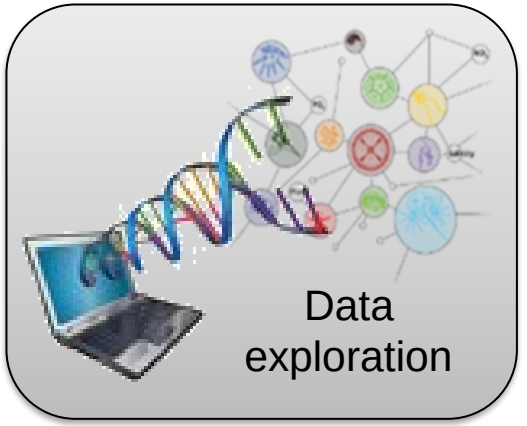
RSN

Abiotic datasets



~1600 samples
699 sites
3 years

Microbiome
Bacteria, fungi, diatoms, micro-eukaryotes



? Ecologically important species

? Response to pressures

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UK National Action Plan on AMR

The 20-year vision for Antimicrobial Resistance (AMR) outlines how the UK will contribute to containing and controlling AMR by 2040. To support the 20-year vision, there are 5-year national action plans setting out key areas of tackling AMR: action plan for AMR 2019 to 2024 and action plan for AMR 2024 to 2029.

Over the past years, the Chief Scientist's Group has worked to gain a scientific and evidence-based understanding of the nature and extent of AMR in the environment and the drivers that influence this.

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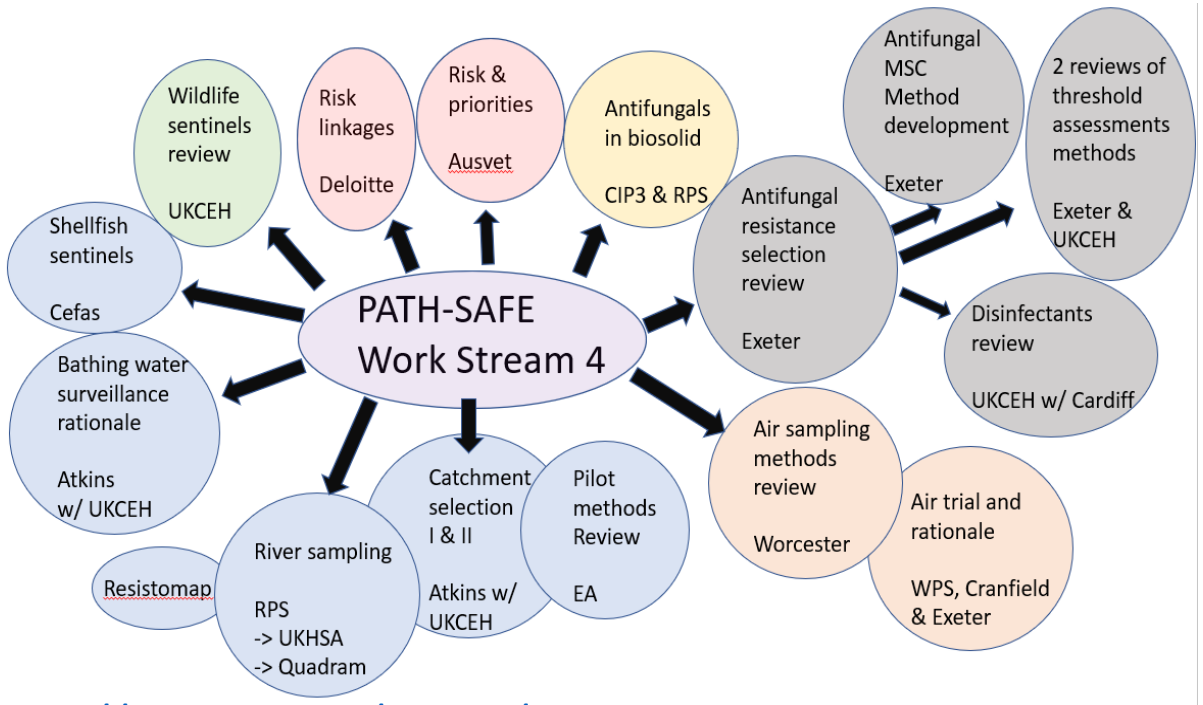
Environmental surveillance methods

- In 2021, HM Treasury funded the '**Path**ogen, **S**urveillance in **A**griculture, **F**ood, and the **E**nvironment (PATH-SAFE)' programme.
- As part of this the Environment Agency, Defra and UK HSA bid for funding to address the NAP commitments (awarded £2.16 million of the £19.2 PATH-SAFE programme; Oct 2021-June 2023)

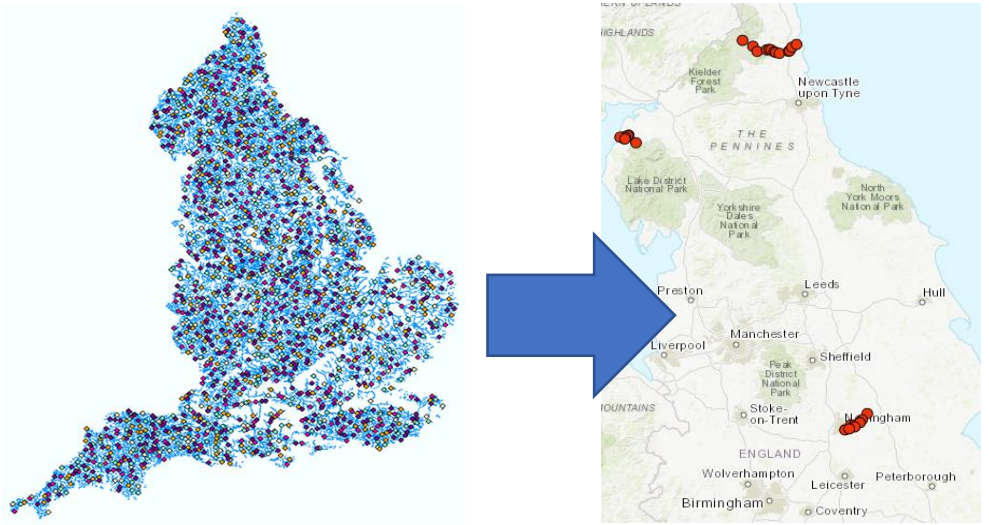


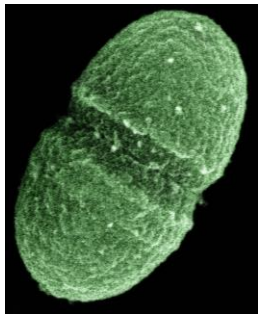
https://www.gov.uk/search/research-and-statistics?parent=environment-agency&keywords=AMR&content_store_document_type=research&organisations%5B%5D=environment-agency&order=relevance

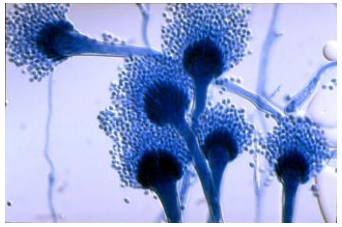
Food Standards Agency | Food Standards Scotland | Department for Environment Food & Rural Affairs | UK Health Security Agency | Veterinary Medicines Directorate | Department of Health & Social Care | Environment Agency

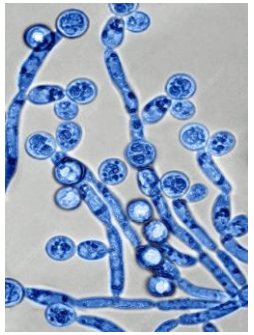
Pilot Surveillance of AMR in River Catchments

1. We selected three pilot river catchments that exhibit a range of land uses and inputs.
2. Sampled river surface waters from May 2022 to Feb 2023 at different times, frequencies and locations within a catchment.
3. We applied a range of testing methodologies:





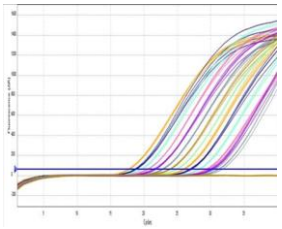




Phenotypic Indicator Organisms

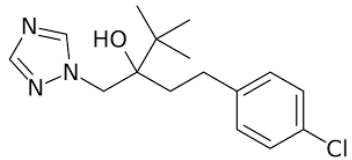
Metagenomic sequencing of water samples to identify and detect microbial composition within the samples

Antimicrobial Susceptibility Testing of isolates



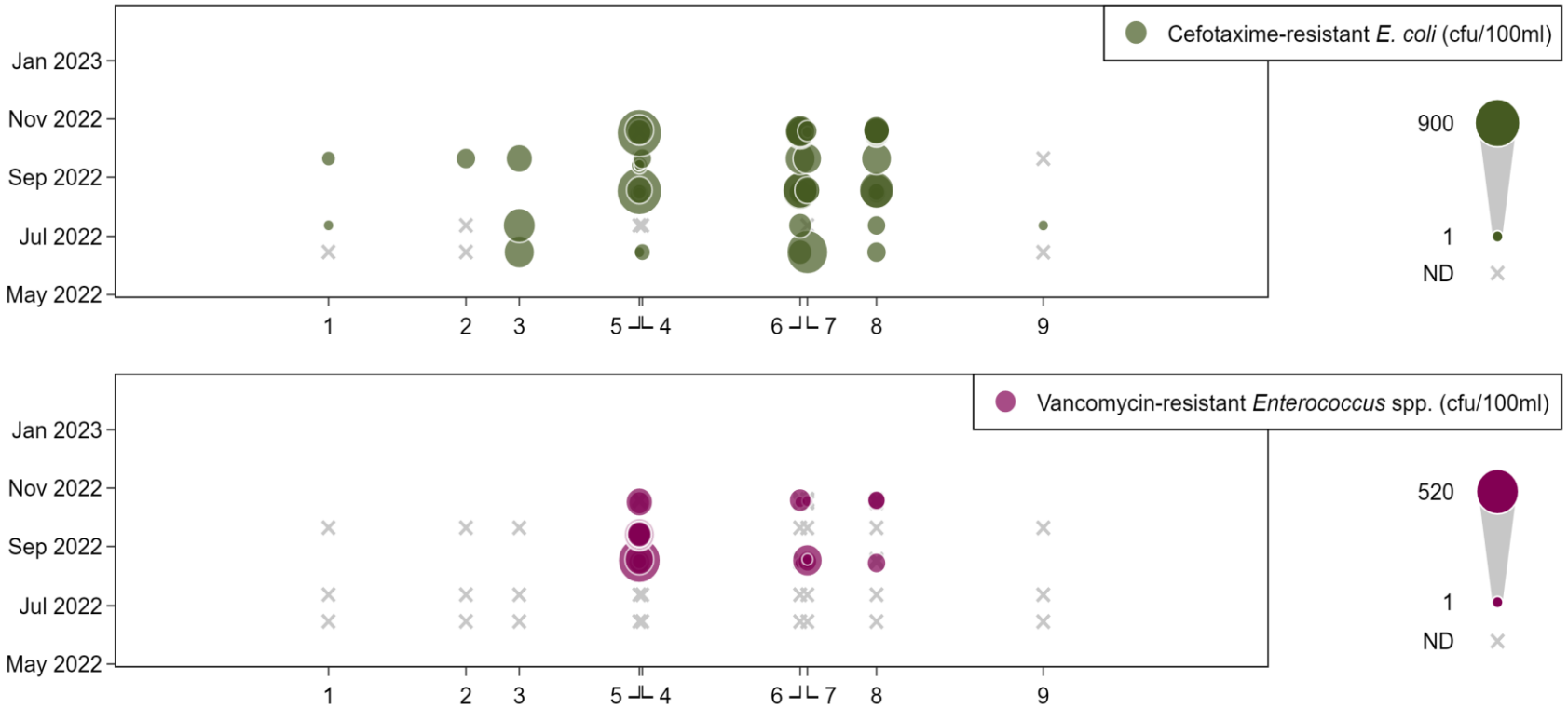
qPCR for High Throughput Detection and Quantification of Antibiotic Resistance Genes

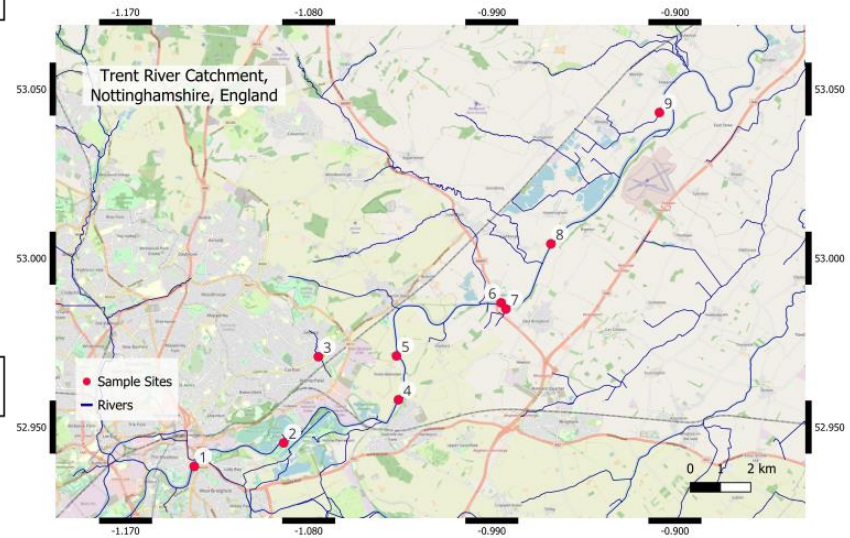
Whole-genome sequencing of isolates



Chemical analysis of a range of antimicrobial substances, covering antibiotic classes, antifungals, disinfectants and heavy metals

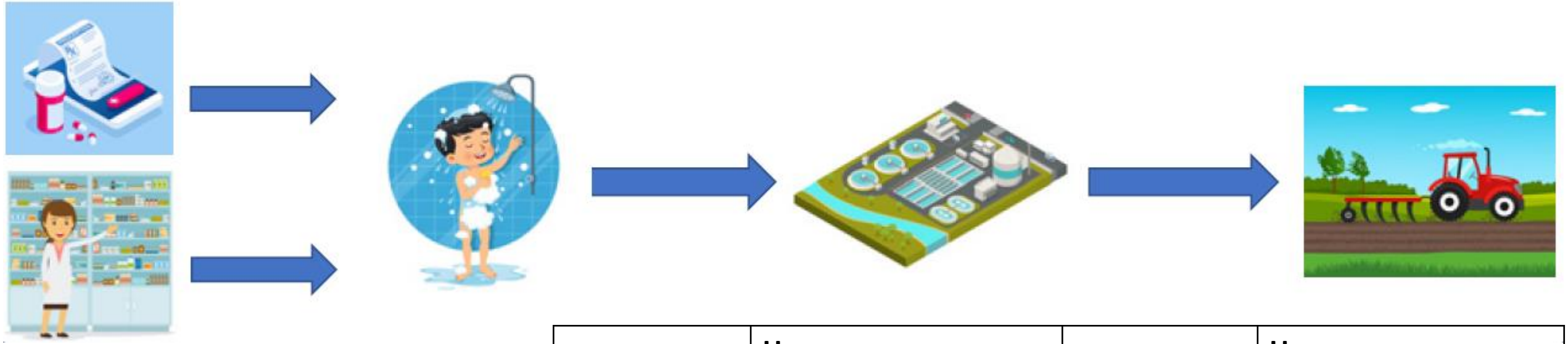
Pilot Surveillance of AMR in River Catchments II





	Trent	Coquet	Crookhurst
Cefotaxime-resistant *E. coli*	81%	51%	24%
Vancomycin-Resistant *Enterococcus* spp.	26%	14%	24%

Clinical antifungals in biosolids



Samples from 11 Sludge Treatment Centres in England and Wales were collected over a 12-month were tested for 14 selected antifungals

Antifungals	**Use systemic (S), topical (T)**	**Antifungals**	**Use systemic (S), topical (T)**
Amorolfine	Clinical: T	Miconazole	Clinical: S, T
Clotrimazole	Clinical: T	Posaconazole	Clinical: S
Enilconazole	Veterinary: T	Terbinafine	Clinical: S, T
Fluconazole	Clinical: S	Voriconazole	Clinical: S
Griseofulvin	Clinical: S, T	Climbazole	Preservative
Itraconazole	Clinical: S	Flucytosine	Clinical: S
Ketoconazole	Clinical: S, T	Nystatin	Clinical: S, T

Clinical antifungals in biosolids II

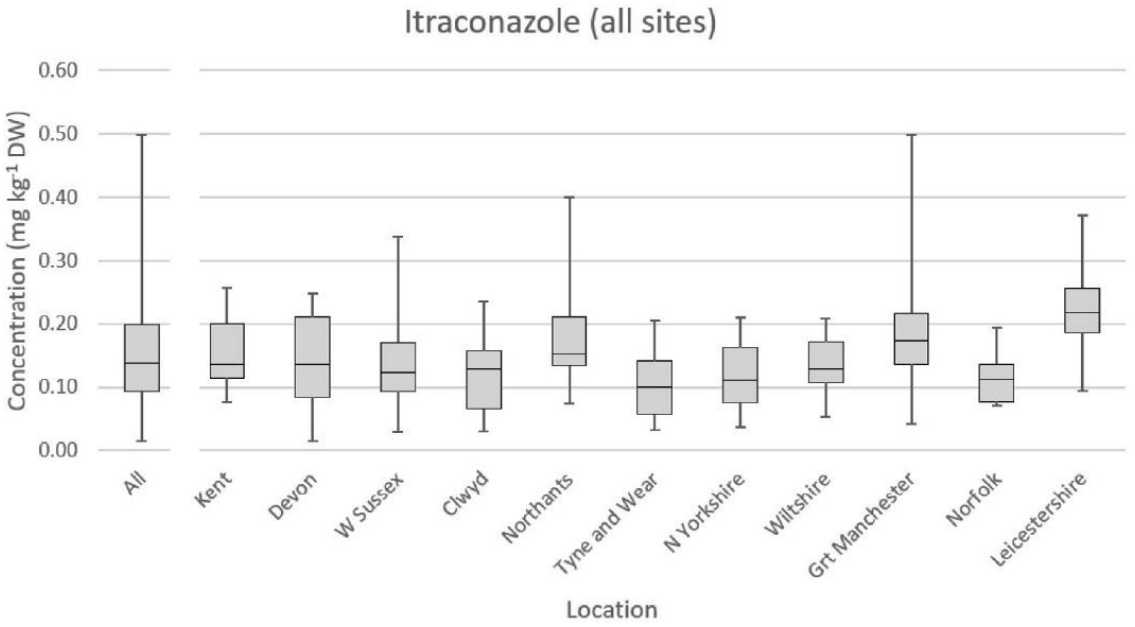
http://dx.doi.org/10.1016/j.scitotenv.2023.161999

Table 2
Levels of antifungals determined in biosolids with samples from all sites combined (n = 201 unless stated). Detection frequency is based on a method LOD of 0.01 mg kg^{-1} AR (0.01–0.05 mg kg^{-1} DW).

	Detection frequency (%)	Median mg kg^{-1} DW	Mean mg kg^{-1} DW	Std. dev. mg kg^{-1} DW	Range mg kg^{-1} DW
Clotrimazole					
All sites (n = 201)	80	0.94	0.89	0.72	<0.03–2.59
7 sites (n = 133)[a]	100	1.32	1.32	0.47	0.39–2.59
Climbazole	76	0.06	0.07	0.05	<0.01–0.27
Enilconazole	17	0.04	0.04	0.02	<0.01–0.19
Itraconazole	99	0.14	0.15	0.08	<0.01–0.5
Ketoconazole	100	0.87	1.03	0.71	0.16–4.33
Miconazole	100	0.54	0.60	0.34	0.09–2.88
Posaconazole	64	0.09	0.15	0.19	<0.01–1.62
Terbinafine	80	0.06	0.06	0.03	<0.01–0.19

[a] Four of the eleven sites were known to have THP as a pretreatment for sludge prior to digestion and were associated with the lowest clotrimazole levels found across all sites (see text).

THP= thermal hydrolysis process



The biosolid levels of itraconazole found in this study were two orders of magnitude higher than an indicative Predicted No Effect Concentration for resistance selection (PNEC-R) in soil.

Antimicrobial substance & selective pressures

- There are not many values available that inform us at which concentration of an antimicrobial substance, resistant microbes have an advantage compared to non-resistant microbes.
- Most values that exist are based on estimations and mainly for antibiotics.
- Exposing *Candida glabrata* strains to a range of concentrations of antifungals and explored their growth over time.

- Development of experimental approaches for determining concentrations of antifungals that select for resistance
- Determining selective concentrations for antibiotics and antifungals in natural environments
- Determining concentrations of substances which influence development of AMR
- Potential impact of disinfectants on AMR development

The atmosphere

https://environmentagency.blog.gov.uk/2024/09/26/shifting-perspectives-from-clean-air-to-healthy-air/

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

Review

A systematic review of the public health risks of bioaerosols from intensive farming

Philippa Douglas[a,1], Sarah Robertson[b,1], Rebecca Gay[b], Anna L. Hansell[a,c,*], Timothy W. Gant[b,**]

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

Bioaerosol exposure from composting facilities and health outcomes in workers and in the community: A systematic review update

Sarah Robertson[a,b,1], Philippa Douglas[b,c,1,*], Deborah Jarvis[c], Emma Marczylo[a,b]

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Sampling strategy and assessment options for environmental antimicrobial resistance in airborne microorganisms

Chief Scientist's Group report

Summary

- It is a microbial world, and the environmental microbiome plays a vital role in the maintenance of a healthy ecosystem.
- There are some microbes that can cause harm to human, animal and plant health.
- Currently the environmental microbiome is not assessed/ monitored for its benefits/ potential harm.
- The Chief Scientist's Group is working on how we can identify the composition and function of microbes in the environment (air, land & water). Furthermore, the group explores how we can assess the risk of environmental exposure to harmful microbes for human health.

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Thank you for listening

"It is the microbes,
who will have the last word."

- Louis Pasteur

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