



Natalie Lamb: Water – Sewage – Microbes

England's river system has for decades been used as an extension of our sewerage system – diluted sewage was discharged into rivers over 200,000 times in 2019 alone. This is a scandal which is finally now receiving the media and public attention it deserves. What is to be done? While massive investment will be required to end this practice by our water companies, the first requirement is to properly police them, by monitoring water quality – which is a massive task beyond the resources of a demoralized and underfunded Environmental Protection Agency. In this lecture, Natalie will put the problem in context before exploring how technology can assist.









Q: Do you understand this?

E. coli

Bacteria



Scientific name: Escherichia coli

Domain: Bacteria

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Escherichia coli, also known as E. coli, is a Gramnegative, facultative anaerobic, rod-shaped, coliform bacterium of the genus Escherichia that is commonly found in the lower intestine of warm-blooded organisms. Wikipedia

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Naming microorganisms

- All organisms have two names-the first signifies the genus and the second signifies the species
- E.g. Escherichia coli or E. coli
- Note the use of capital and lower case letters and the italics

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How to categorise microorganisms

- The Gram Reaction was developed in 1884 by Danish physician Christian
- Gram positive cells retain the stain so stain purple and Gram negative do not, staying pink
- The difference is due to differences in cell wall composition



Only bacteriamore on this in a sec!

There's more than just bacteria!



Bacteria

• Can have "good bacteria" or pathogenic bacteria

Antibiotics kill them



Viruses

• Parasites (need a host to reproduce)

100 times smaller than bacteria



Fungi

Include mold, yeast and mushrooms
Do not photosynthesise (like plants do)



Algae

Photosynthesise like plants

- An informal name for a large number of diverse organisms that are not always
- genetically closely related



Protozoa

- Are not animals but have animal-like behaviours (being able to move)
- Feed on organic matter (other microorganisms)



Archaea

Survive in extreme environments

Similar in size and shape to bacteria

How to categorise microorganisms

- In viruses, we look at their genomes, on their RNA or DNA, whether it is single or double stranded
 - Both DNA and RNA are macromolecules essential for all known forms of life and both made up of similar things
 - But RNA is often single-stranded, contains a different sugar and has one different base (the connecting bits of the "ladder")
- In fungi, we look to see if there is one cell carrying out all functions or many cells
 - For instance, humans have blood cells , skin cells, fat cells etc.





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Microorganisms adapt

- Aerobic bacteria need oxygen to survive, anaerobic bacteria do not
- A facultative anaerobic organism is an organism that will make ATP by aerobic respiration if oxygen is present, but is also capable of switching to fermentation if oxygen is absent.
- Microorganisms require different food sources / environmental factors to grow e.g. carbon, nitrogen, phosphorus, sulfur, pH, temperature



Everything is in balance



Everything is in balance

- There is only so much food
- There are only so many niches
- Everything is in competition to survive
- Environmental conditions really matter



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Microorganisms come in many shapes

Rods/Bacilli Spirochete Diplococi

Strepto cocci Vibrios Cocobacili

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Why focus on coliforms?

- Coliform bacteria are a type of gram-negative bacteria that can be frequently found in the faeces of warm-blooded animals as they are known to inhabit the gastrointestinal system
- They do not normally cause serious illness
- They are easy to culture
- Their presence is used to infer that other pathogenic organisms of faecal origin may be present in a sample, or that said sample is not safe to consume



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Some final tips from me

- Don't panic!
- Think of microorganisms like plants or animals- they need food, a place to live, they compete, they are very stubborn, they are everywhere
- There's a lot more microorganisms than just bacteria
- They are not all bad! They can be helpful!





An overview of wastewater challenges and technologies



DAILY POST TUESDAY, NOVEMBER 29, 2022

ûû♠ InYo

Raw sewage dumped 6,952 times in North Wales tourism hotspot

www.northwales-live.co.uk NEWS @dailypostwales

By ANDREW FORGRAVE Countryside and Tourism Editor

WHEN public health warnings were issued for Anglesey and Pembrokeshire in late August, not everyone got the mes-

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extent of sewage contamination. Latest figures suggest the problem is at its worst in three Welsh parliamentary

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overwhelmed. It also has the longest coastline, pro-portionately, and so seawater contamispills Rive nation is more likely.

TOP THREE SEWAGE IS

failure to stop sewage pollution Under-fire water firms, criticised for their part in the scandal, have

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from Lla

And the second s

pointed the finger at the authorities in newly revealed letters



UK government U-turns on sewage after Tory MPs threaten rebellion

Water companies will have duty to reduce impact of sewage discharges from storm overflows



What is a storm overflow?



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Nant Brisgyll, from

Llanllyfni storm

Llanffestiniog treatment

Efailnewydd treatment

River Erch, from

182 sewage spills

179 sewage spills

works - 189 sewage spills

Abererch storm overflow

Barmouth long sea outfall

Cardigan Bay, from

River Glaslyn, from

Beddgelert treatment

works - 174 sewage spills



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Image Credit: Daily Post Wales

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- Most is screened to 6mm
- Can be settled in tanks to reduce suspended solid matter



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Llanllvfni storm overflow - 195 sewage



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'Dumping' implies an activity that is:

- Irresponsible
- Illegal
- Choice to do the wrong thing.



Where are the storm overflows?

There are about 15,000 storm overflows in England



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Image Credit: Rivers Trust. Map Link: https://experience.arcgis.com/experience/e834e261b53740eba2fe6736e37bbc7b?org=theriverstrust

What is the impact of storm overflows?

- We don't currently know the real time impact storm overflows have on water quality.
- It is possible that a storm overflow that discharges for a couple of hours could discharge less harmful sewage than a storm overflow that discharges for just 30 minutes. It all depends on the contents of the combined sewer at the time of heavy rainfall.

How can we stop this?

- Stop building new combined sewers
 - We have been building separate sewer systems in the UK since the 1960s
- Construct large storage tanks to contain storm water during heavy rainstorms
 - Carbon consequences, cost billions of pounds and would be disruptive
- Treat the storm overflow discharge. In some cases, nature-based solutions such as reed-beds

Barriers





How can water companies stop this?

What are we doing about storm overflows right now?



Since 2000, we have invested £181 million upgrading more than 582 storm overflows. From 2022 to 2025, we plan to spend a further £150 million on storm overflows to reduce their impact on the environment.

Our <u>storm overflows improvement plan 2022-25</u>, sets out how we aim to address storm overflows over the next three years. In summary, our plan means we are taking the following actions:

- Investing £3 million a month to tackle storm overflows, with work already underway.
- Between 2020 and 2025, we are carrying out 54 investigations into storm overflows that spill most frequently or have environmental impact.
- There are 13 improvement projects in Bath, Bristol, Dorset, Somerset, South Gloucestershire and Wiltshire that are currently being designed or in progress as part of our priority programme. These will be completed by March 2025.
- Sewage treatment upgrades at 42 water recycling centres to increase capacity and with more nature-based, low carbon methods introduced.
- A 25% reduction in the number of hours of storm overflow discharges by 2025.
- Increased environmental and public health monitoring at key locations.
- Use of artificial intelligence to manage sewerage network and provide real time bathing water information.



How can you stop this?

- Help by stopping unnecessary stress on our sewer network:
- Only flush the three Ps: poo, paper and pee. Sanitary items, such as wet wipes, don't break down properly in our sewers and cause blockages.
- Don't put FOGs (fats, oils and grease) down the sink. Instead, allow them to cool and scrape them into the bin so that they don't solidify in your pipes.
- Install a water butt to collect rainwater. This water can be used to maintain your garden during summer and will also reduce the volume of water going down the drain.

How am I trying to stop this?

SENTRY can be used upstream and downstream of CSOs to monitor discharges into the environment



Populations in Watersheds Protected by SENTRY

26,250,000



be monitored like a speed camera but for water quality Microbial activity is low and the water quality is good

This water course is best avoided right now

What do you think this is?



Image Credit: University of Sheffield Pipe Dreams (2012)

What do you think this is?









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What is a biofilm?

Biofilms are when microorganisms, organic matter and inorganic matter attach to surfaces













An overview of drinking water challenges and technologies





There are problems with our use of chemicals as an industry



How are chemicals used to treat and distribute drinking water?



Image Credit: eSchool Today

Chlorine

- Taste and odour concerns- <0.5mg/l is dosed to not impact on taste and smell but there still must be enough to provide protection
- Chlorine has the potential to form disinfection by-products, which, in high concentrations, could have a health impact¹
- Accidents happen- Graniteville, South Carolina in 2005 ~60 tons chlorine leak due to a train derailment, leading to the deaths of 9 people respiratory difficulties in 554 people and the evacuation of 5,400 people within a 1-mile radius for several days²



References

¹International Agency for Research on Cancer 2004 International Agency for Research on Cancer 1995 Richardson, et al. 2007 ²National Transportation Safety Board 2005

Phosphate

- Expense- in 2008 the UK used >12,000 tonnes of phosphate, which came to a total cost of £12.24 million, a figure far above other chemicals dosed³
- Under The Urban Waste Water Treatment Directive phosphate must be removed at sewage treatment works, with further costs⁴
- Phosphate is a finite resource- some sources say it will be gone in as little as 50 years
- Difficult dose optimisation- cannot be adjusted for specific water conditions
- If accidents happen, phosphate can cause eutrophication of water bodies and encourage toxic algal blooms

References ³Knowledge Transfer Network 2008 ⁴European Commission 2016

Image Credit: Robert Wyatt/Alamy

Fluoride

- The decision about whether to add fluoride to the water supply is made and paid for by individual local authorities
- Fluorosis is discolouration of the teeth caused by overexposure to fluoride during the first eight years of life, when most permanent teeth are being formed
- Although the dose used in water (~1mg/l) is controlled, it cannot be controlled how much fluoridated water people are consuming or from other sources they are intaking it
- There are alternative methods of dosing fluoride



Are there any countries that are chemical free and compliant?



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Country	Source Water Type	Pipe Length and Material	Pipe Replacement Rate	Leakage	Lead Presence	Phosphate Dosing	"Normal" Chlorine Use
Denmark (VCS)	100% Ground	1026km PVC	1.1% 20.5km/year	< 5%	0	None	None
The Netherlands (PWN)	78% Surface 22% Ground	9995km Cement	0.4% 40km/year	<4%	0	None	Residual Chlorine
Germany (Stadtwerke Düsseldorf)	75% Surface 25% Ground	1800km Cement	0.4% 7.2km/year	6%	0	1 mg/l	None
UK (Anglian Water)	60% Surface 40% Ground	38000km Cast Iron	0.27% 103km/year	12%	~15%	0.5-2 mg/l	Primary Disinfection Residual Chlorine



- Customer culture alterations e.g.: adopting boil notices, more efficient water usage, tap cleaning practises, the use of approved plumbers and approved materials and pipe replacement responsibilities
- Regulation changes with less of a focus on punishment and greater collaboration with industry and academia

If we had this perfect network today, could we turn off the chemicals?



If we had this perfect network today, could we turn off the chemicals?



- 1 x biologically stable site
- 1 x less biologically stable site

If we had this perfect network today, could we turn off the chemicals?



- Clostridium perfingens
- Enterococci
- E. coli confirmed
- Coliforms confirmed
- DNA Sequencing

How much is there?

- Total cell count
- Intact cell count
- 2 day colony count (37°c)
 - 3 day colony count (22°c)
 - Biofilm total cell count

What has the potential to be there?

- BDOC/DOC
- Phosphate
- Sulphate
- Nitrate
- Filtered/Total iron
- Filtered/Total manganese
- Filtered/Total lead



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- Two identical 20" shipping containers
- Per shipping container there are two 14m long 90mm external diameter butt-fusion welded pipe loop systems
- The pipes are made from grade PE100 SDR17 High-Density Polyethylene (HDPE)

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SEM Images – 28 day biofilm development, 16°C, different hydraulic regimes

"Biofilm" microorganisms, organic matter and inorganic matter are attached to the inside of pipes

The biofilm protects the microorganisms within, resulting in greater resilience

Acc.V Spot Magn Det WD Exp ______ 50 μm 20.0 kV 3.0 400x SE 8.7 2 BMS Sheffield



- How to understand the microbiology of water and wastewater
- An overview of wastewater challenges and technologies
- An overview of drinking water challenges and technologies