Abwasser und resistente Keime: Kann das überwacht werden?

Alan Elena, Uli Klümper, David Kneis, Magali del Cruz Barron, Faina Tskhay, Diala Konyali

Thomas Berendonk

Institut für Hydrobiology

Technische Universität Dresden

Relevanz

RICHTLINIE (EU) 2024/3019 DES EUROPÄISCHEN PARLAMENTS UND DES RATES

vom 27. November 2024

über die Behandlung von kommunalem Abwasser

(Neufassung)

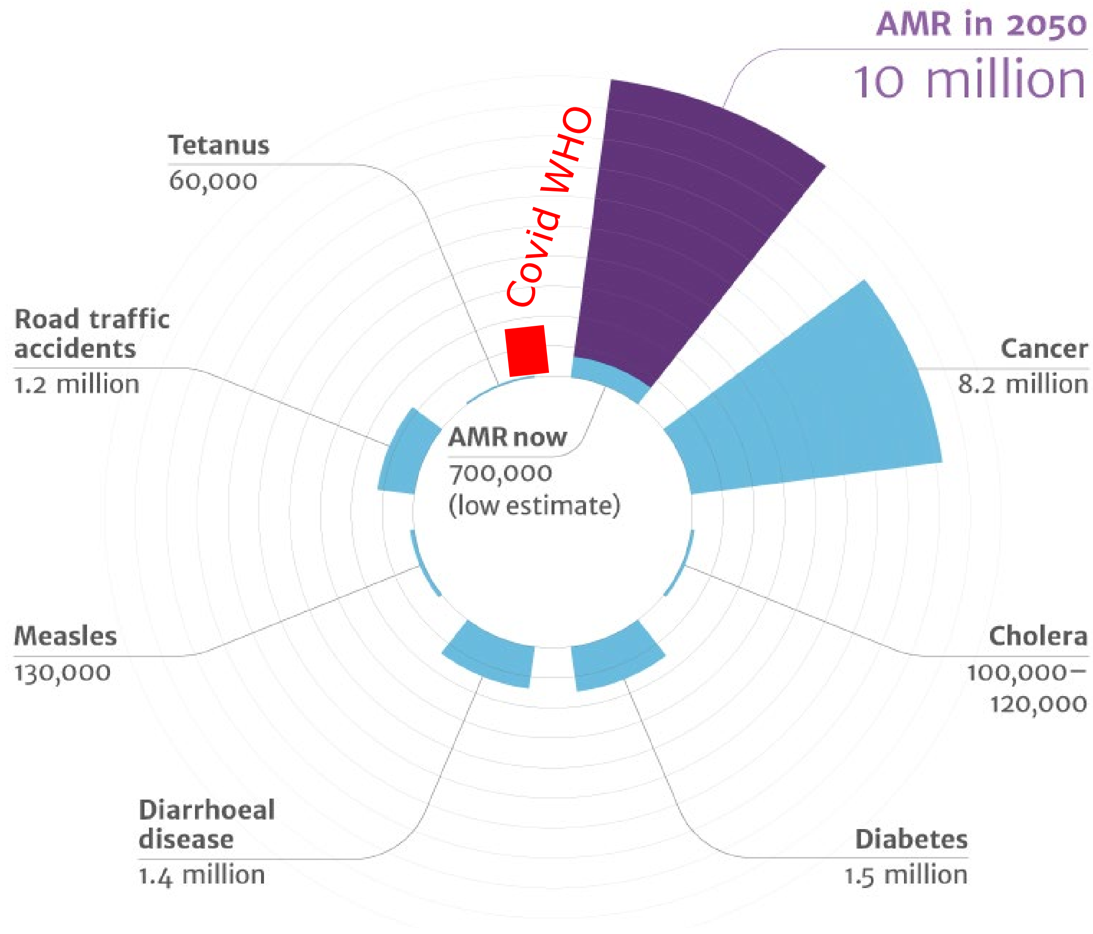
Artikel 17

Überwachung von kommunalem Abwasser

(3) Für Siedlungsgebiete mit 100 000 EW und mehr stellen die Mitgliedstaaten bis zum letzten Tag des zweiten Jahres nach Erlass des Durchführungsrechtsakts im Sinne von Unterabsatz 2 sicher, dass antimikrobielle Resistenzen im kommunalen Abwasser überwacht werden.

Zur Erweiterung des Wissens über die wichtigsten Quellen antimikrobieller Resistenzen sollte eine Verpflichtung zur Überwachung des Vorhandenseins antimikrobieller Resistenzen im kommunalen Abwasser eingeführt werden, um unsere wissenschaftlichen Erkenntnisse auszubauen und möglicherweise in Zukunft angemessene Maßnahmen zu ergreifen.

Prognose Anzahl Sterbefälle durch antibiotikaresistente Erreger (AMR) pro Jahr

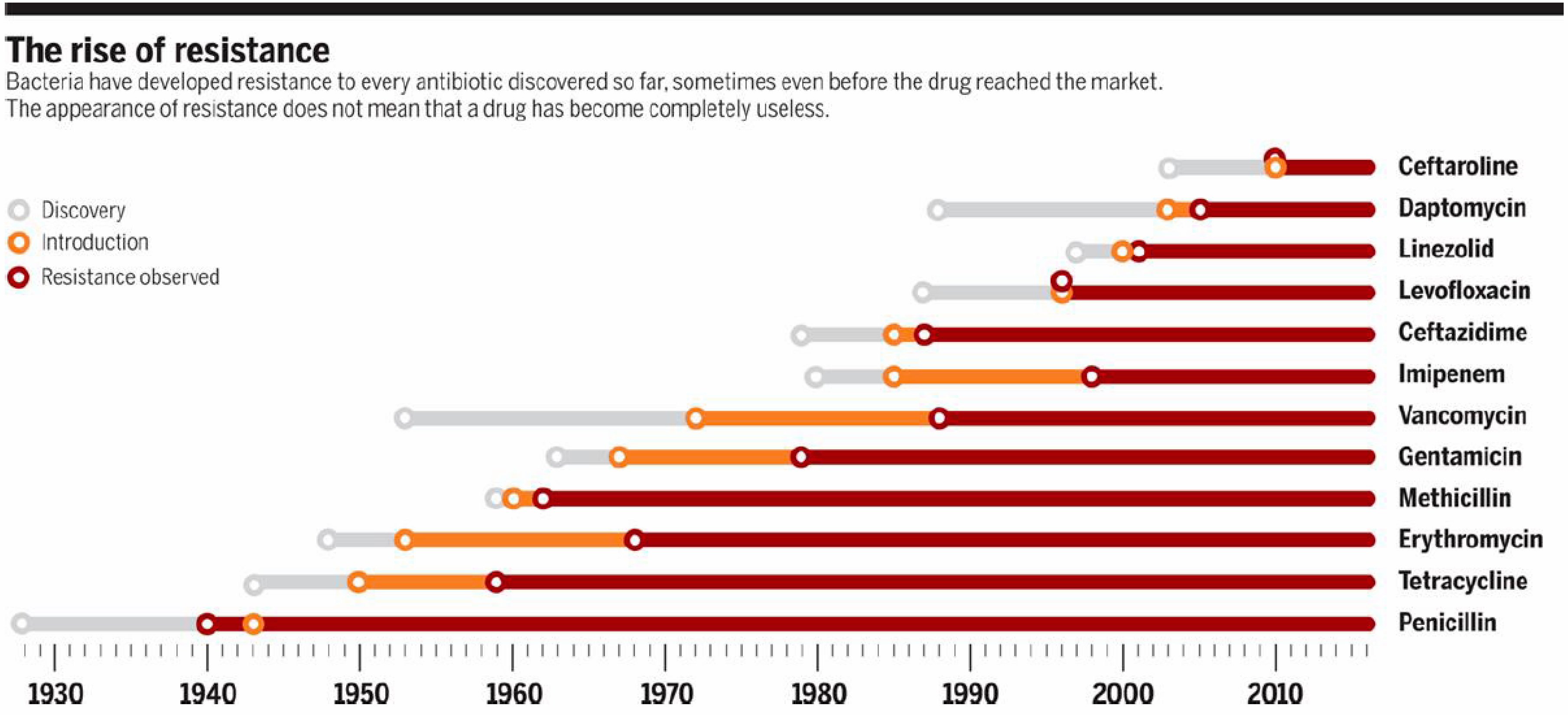


Sources:
Diabetes: www.whi.int/mediacentre/factsheets/fs312/en/ Cancer: www.whi.int/mediacentre/factsheets/fs297/en/
Cholera: www.whi.int/mediacentre/factsheets/fs107/en/ Diarrhoeal disease: www.sciencedirect.com/science/article/pii/S0140673612617280
Measles: www.sciencedirect.com/science/article/pii/S0140673612617280 Road traffic accidents: www.whi.int/mediacentre/factsheets/fs358/en/
Tetanus: www.sciencedirect.com/science/article/pii/S0140673612617280

Review on Antimicrobial Resistance

Zeitspanne zwischen Einführung der Antibiotika und der Beobachtung erster Resistenzen

„Die Stille Pandemie"



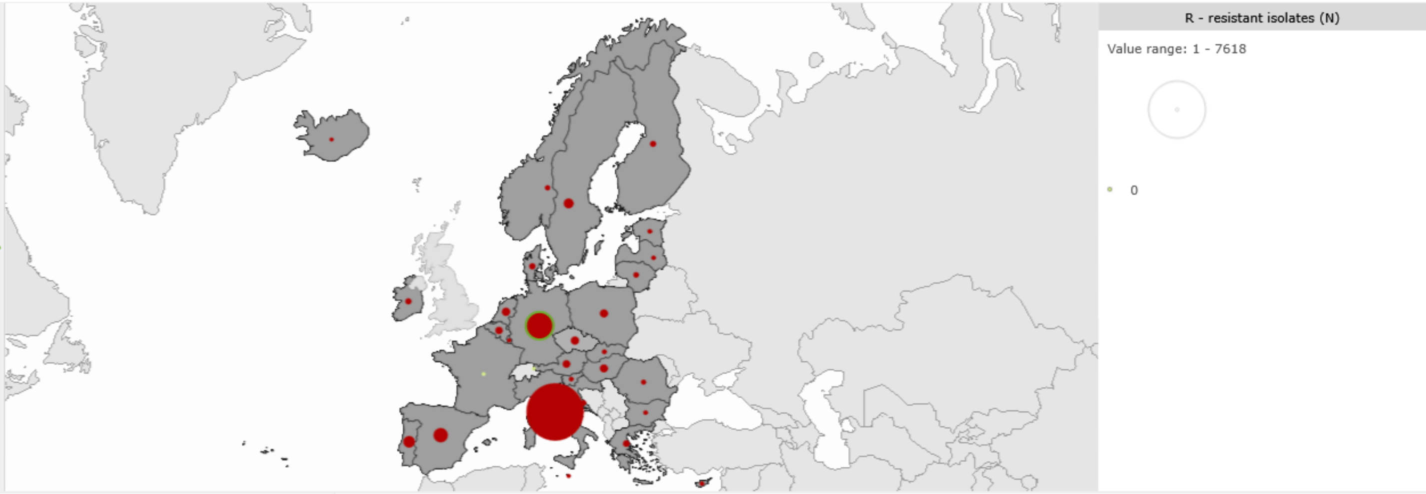
Kai Kupferschmidt Science 2016;352:758-761

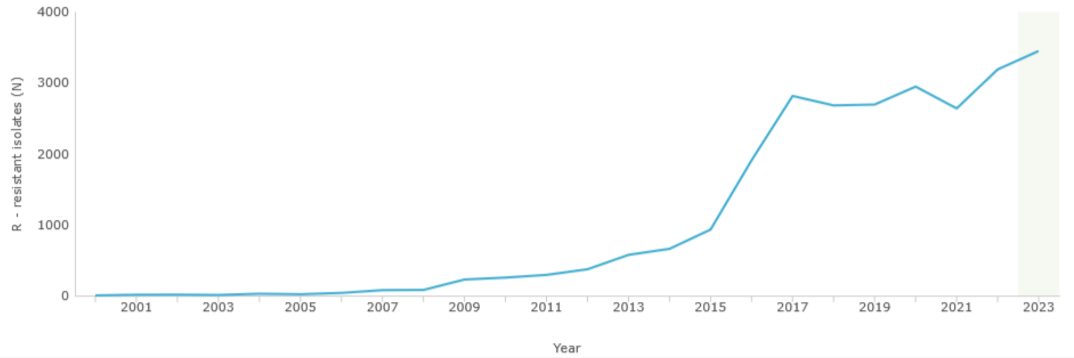
Europäische Datenbank zu klinischen Resistenzen

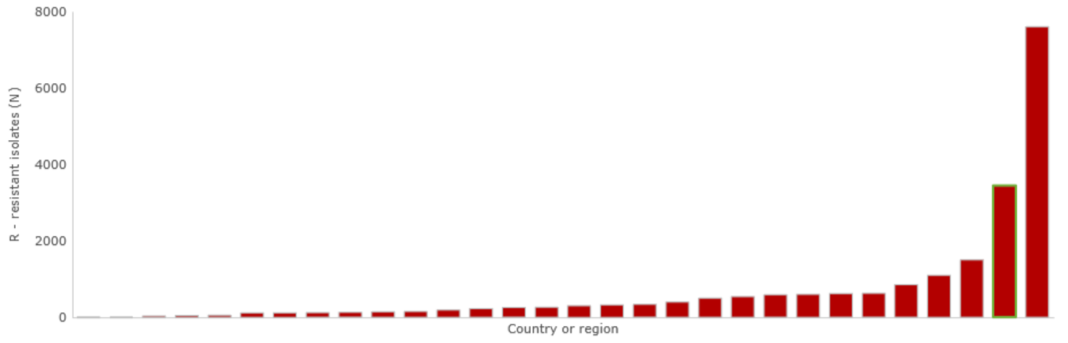
Surveillance Atlas of Infectious Diseases

Antimicrobial resistance | Escherichia coli | Third-generation cephalosporins | R - resistant isolates | 2023

Region	R - resistant isolates (N)
Austria	541
Belgium	500
Bulgaria	114
Croatia	262
Cyprus	115
Czechia	618
Denmark	333
Estonia	124
Finland	302
France	0
Germany	3451
Greece	397
Hungary	588
Iceland	31
Ireland	325
Italy	7618

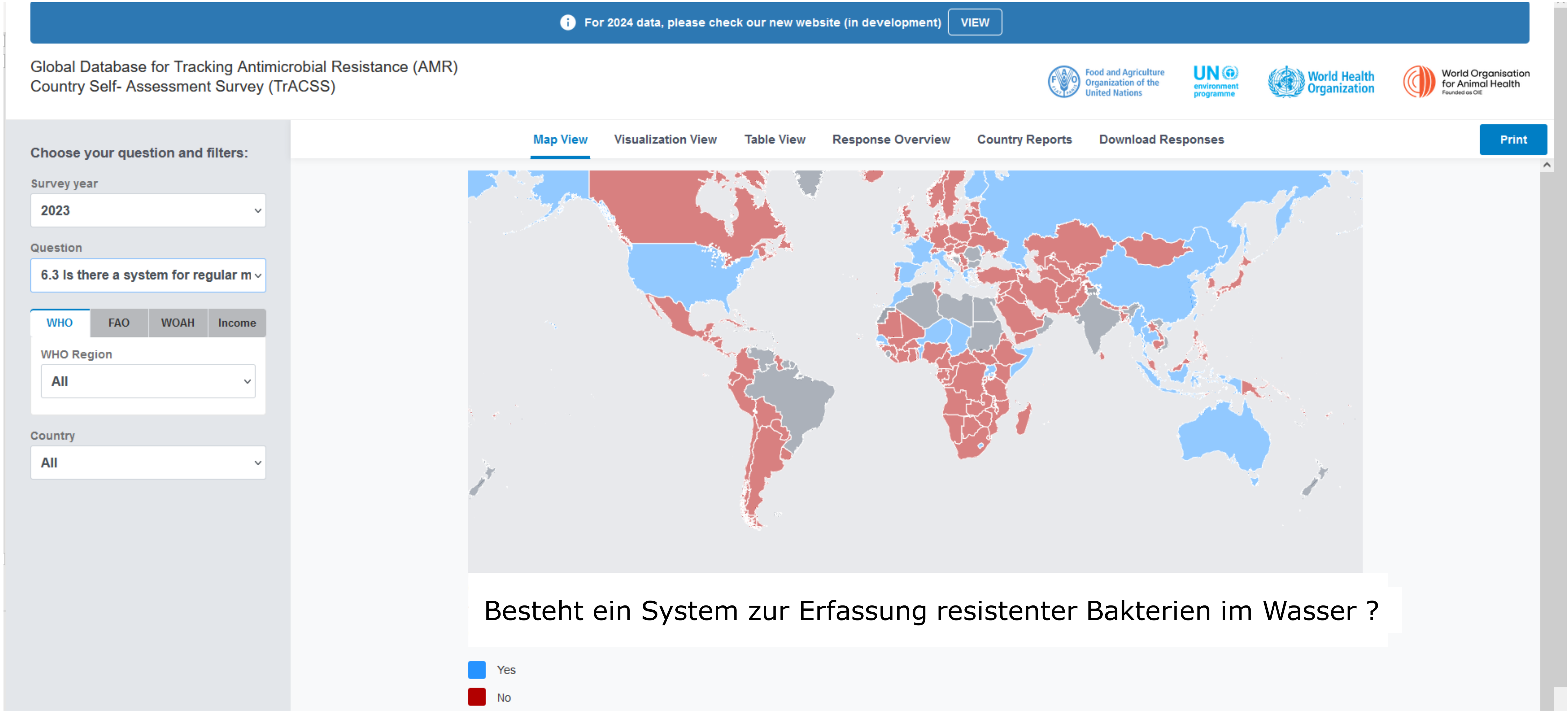






Germany

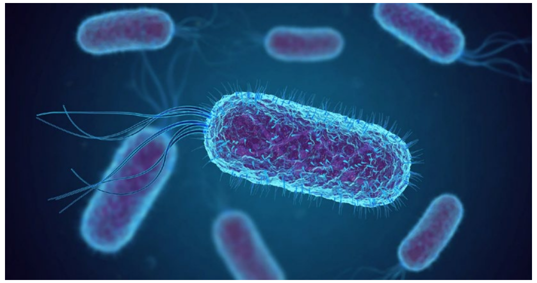
Weltweite Datenbank zur Nachverfolgung von Antibiotikaresistenzen

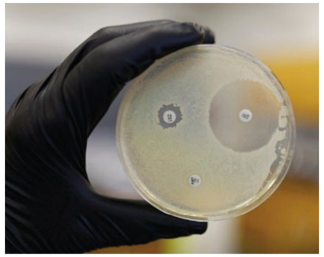


Besteht ein System zur Erfassung resistenter Bakterien im Wasser ?

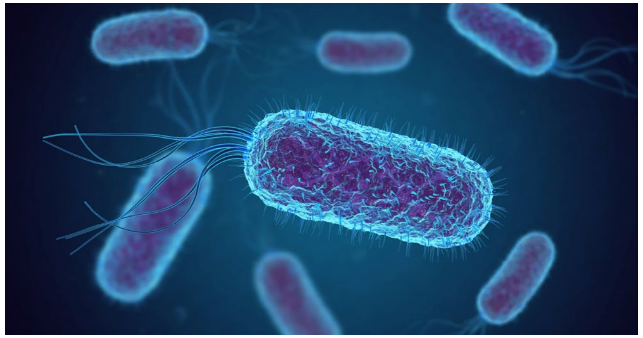
Abwasser Epidemiologie - Monitoring der Resistenzen im Abwasser

- Virus monitoring ist als Konzept vergleichweise "einfach"
  - ⇨ Covid Viren zeigen im Abwasser bzw. der Umwelt keine Dynamik
- Antibiotika Resistenz zeigt eine wesentlich komplexere Dynamik
- Epidemiologische Studien beruhen im Wesentlichen auf kulturbasierten Ansätzen
- Aber nur 10% der Umweltbakterien können kultiviert werden

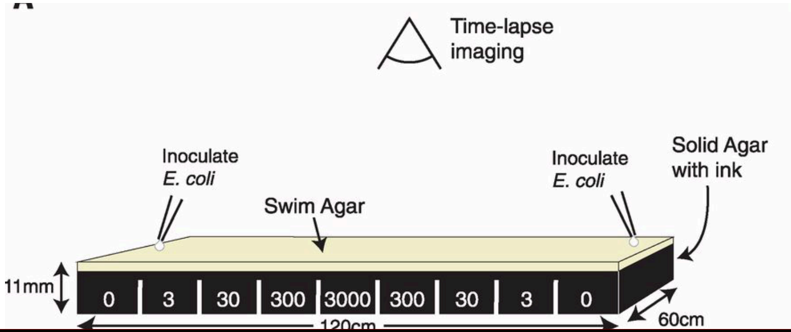


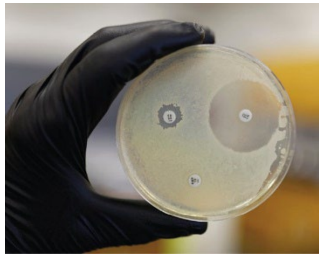


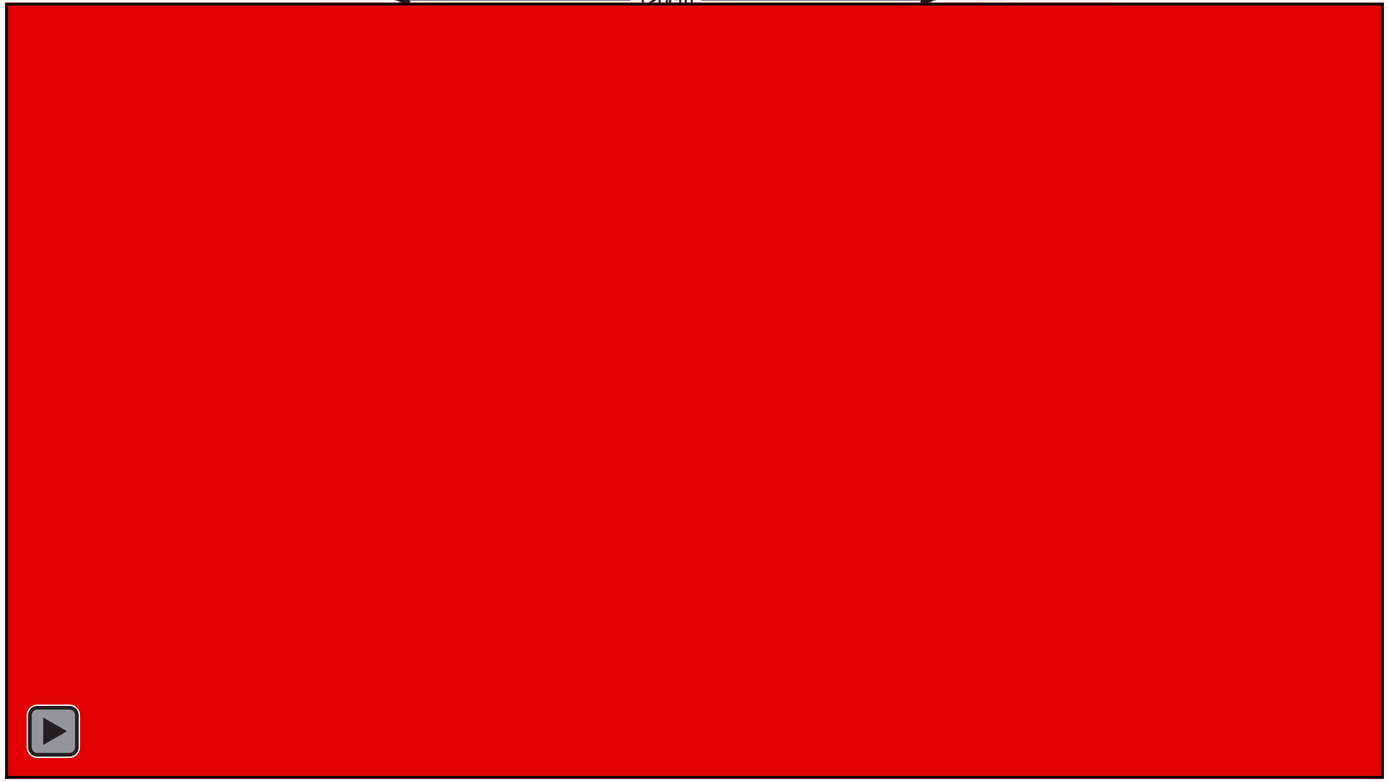
Berendonk et al. Nature Microbiology Review 2015



Evolution eines Bakteriums (*E. coli*)

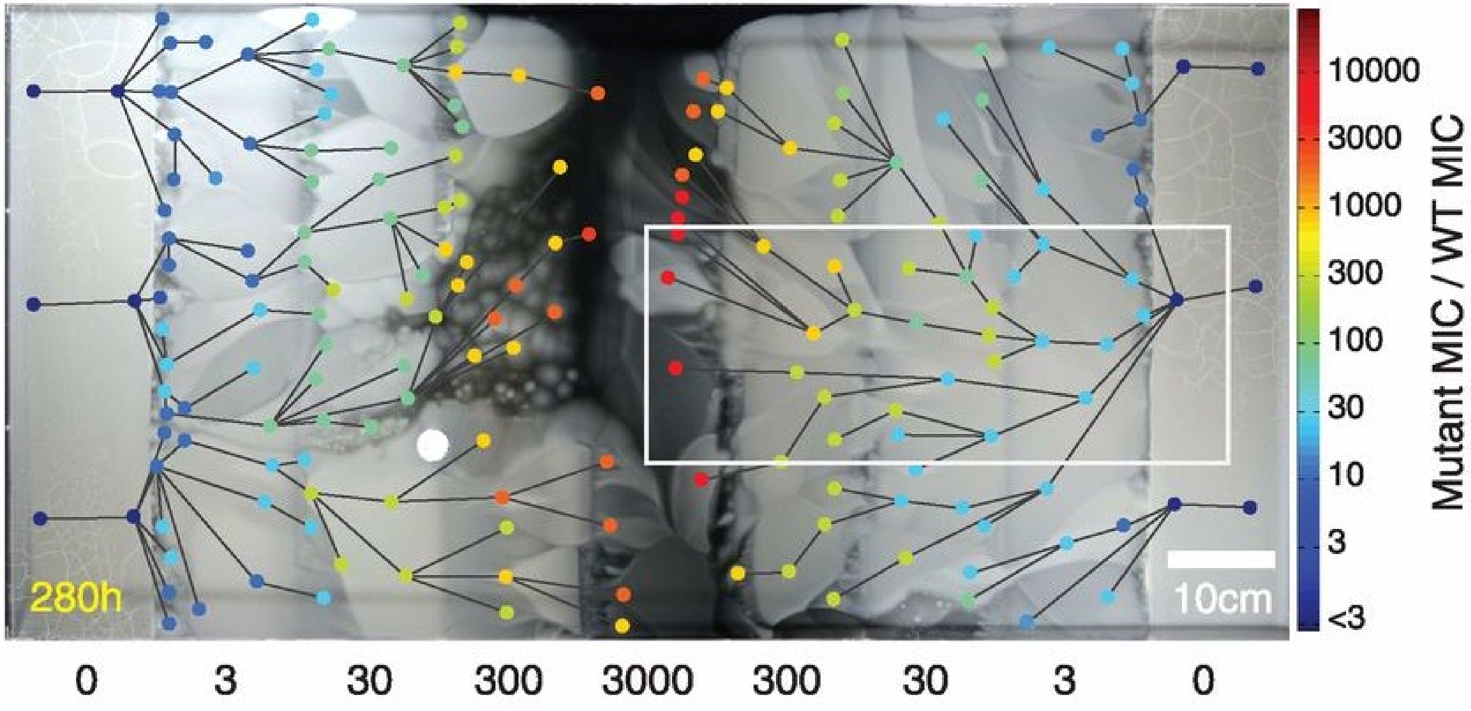






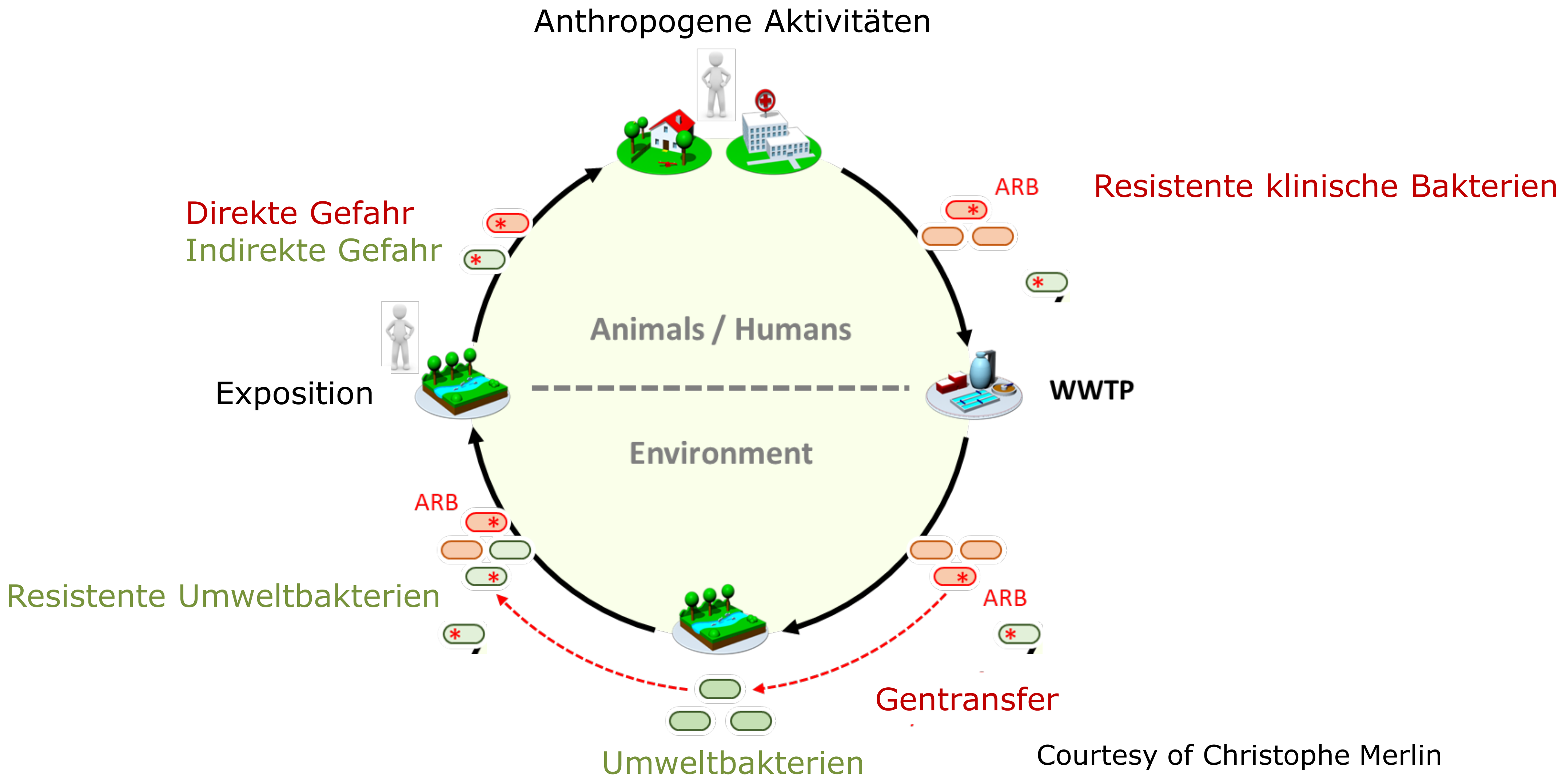
Michael Baym et al. Science 2016;353:1147-1151

Evolution eines Bakteriums (*E. coli*)



Michael Baym et al. Science 2016;353:1147-1151

Resistente Bakterien und Gentransfer



Courtesy of Christophe Merlin

Mögliche Methoden des AMR monitoring

Problembeschreibung

JOURNAL ARTICLE

Antibiotic resistant bacteria and resistance genes in the bottom sediment of a small stream and the potential impact of remobilization

S Heß, T U Berendonk, D Kneis

FEMS Microbiology Ecology, Volume 94, Issue 9, September 2018, fiy128, https://doi.org/10.1093/femsec/fiy128

Published: 30 June 2018 **Article history**

SCIENTIFIC REPORTS

OPEN **High genomic diversity of multi-drug resistant wastewater *Escherichia coli***

Received: 27 November 2017
Accepted: 18 May 2018

Norhan Mahfouz[1], Serena Caucci[2,3], Eric Achatz[1], Torsten Semmler[4], Sebastian Guenther[4,5], Thomas U. Berendonk[2] & Michael Schroeder[1]

Water Research
Volume 162, 1 October 2019, Pages 320-330

Antibiotic resistance genes in treated wastewater and in the receiving water bodies: A pan-European survey of urban settings

Damiano Cacace[a], Despo Fatta-Kassinos[b], Celia M. Manaia[c], Eddie Cytryn[d], Norbert Kreuzinger[e], Luigi Rizzo[f], Popi Karaolia[b], Thomas Schwartz[g], Johannes Alexander[g], Christophe Merlin[h], Hemda Garelick[i], Heike Schmitt[j], Daisy de Vries[j], Carsten U. Schwermer[k], Sureyya Meric[l], Can Burak Ozkal[l], Marie-Noelle Pons[m], David Kneis[a], Thomas U. Berendonk[a]

Sewage from Airplanes Exhibits High Abundance and Diversity of Antibiotic Resistance Genes

Stefanie Heß*, David Kneis, Tobias Österlund, Bing Li, Erik Kristiansson, and Thomas U. Berendonk

Cite this: *Environ. Sci. Technol.* 2019, 53, 23, 13898–13905
Publication Date: November 12, 2019
https://doi.org/10.1021/acs.est.9b03236

Article Views 2348 | Altmetric 106 | Citations 31

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FEMS MICROBIOLOGY ECOLOGY
Leading research in the microbial ecology community

FEMS Microbiol Ecol. 2023 Apr; 99(4): fiad031. PMCID: PMC10054912
Published online 2023 Mar 20. doi: 10.1093/femsec/fiad031 PMID: 36941120

Quantification of the mobility potential of antibiotic resistance genes through multiplexed ddPCR linkage analysis

Magali de la Cruz Barron, David Kneis, Alan Xavier Elena, Kenyum Bagra, Thomas U Berendonk, and Uli Klümper

Antibiotic Resistance Genes in River Biofilms: A Metagenomic Approach toward the Identification of Sources and Candidate Hosts

David Kneis*, Thomas U. Berendonk, Sofia K. Forslund, and Stefanie Hess

Cite this: *Environ. Sci. Technol.* 2022, 56, 21, 14913–14922
Publication Date: April 25, 2022
https://doi.org/10.1021/acs.est.2c00370

Article Views 4931 | Altmetric 7 | Citations 2

LEARN ABOUT THESE METRICS

Science of The Total Environment
Volume 904, 15 December 2023, 166661

Environmental stress increases the invasion success of antimicrobial resistant bacteria in river microbial communities

Kenyum Bagra[a,b], Xavier Bellanger[c], Christophe Merlin[c], Gargi Singh[b], Thomas U. Berendonk[a], Uli Klümper[a]

Environment International 144 (2020) 106035

Contents lists available at ScienceDirect

Environment International

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

A global multinational survey of cefotaxime-resistant coliforms in urban wastewater treatment plants

Roberto B.M. Marano[a,b,1], Telma Fernandes[c,1], Célia M. Manaia[c], Olga Nunes[d], Donald Morrison[x], Thomas U. Berendonk[e], Norbert Kreuzinger[f], Tanel Tenson[g], Gianluca Corno[h],

BRIEF RESEARCH REPORT article

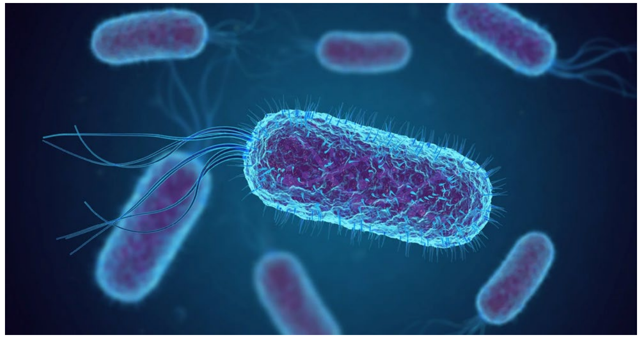
Front. Public Health, 27 December 2023
Sec. Infectious Diseases: Epidemiology and Prevention
Volume 11 - 2023 | https://doi.org/10.3389/fpubh.2023.1271594

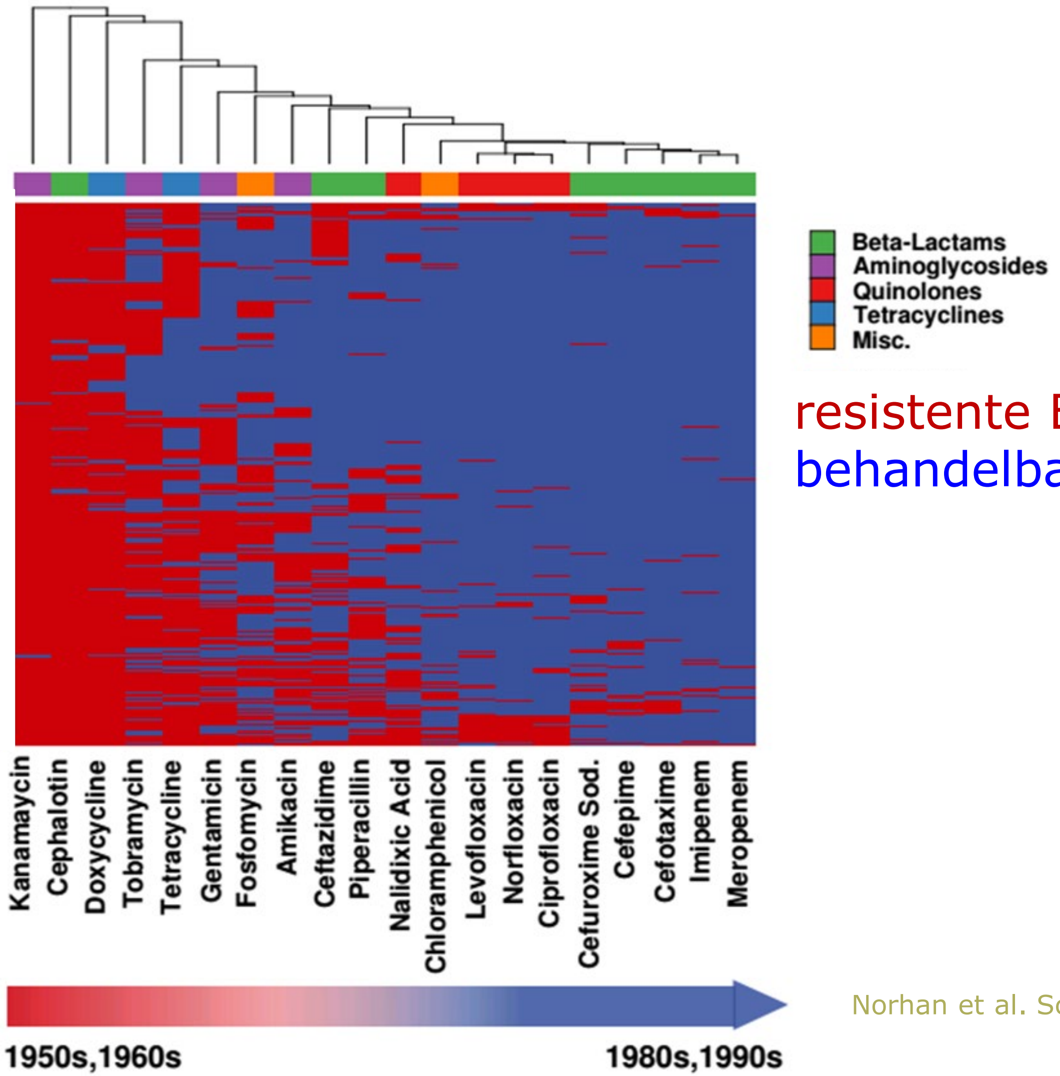
Evaluating the sensitivity of droplet digital PCR for the quantification of SARS-CoV-2 in wastewater

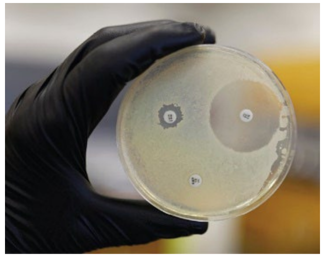
Magali de la Cruz Barron[1*†], David Kneis[1], Michael Geissler[2], Roger Dumke[2], Alexander Dalpke[2,3], Thomas U. Berendonk[1*†]

Beispiel

1100 Antibiotikaresistente individuelle Bakterien (E. coli) des Abwassers







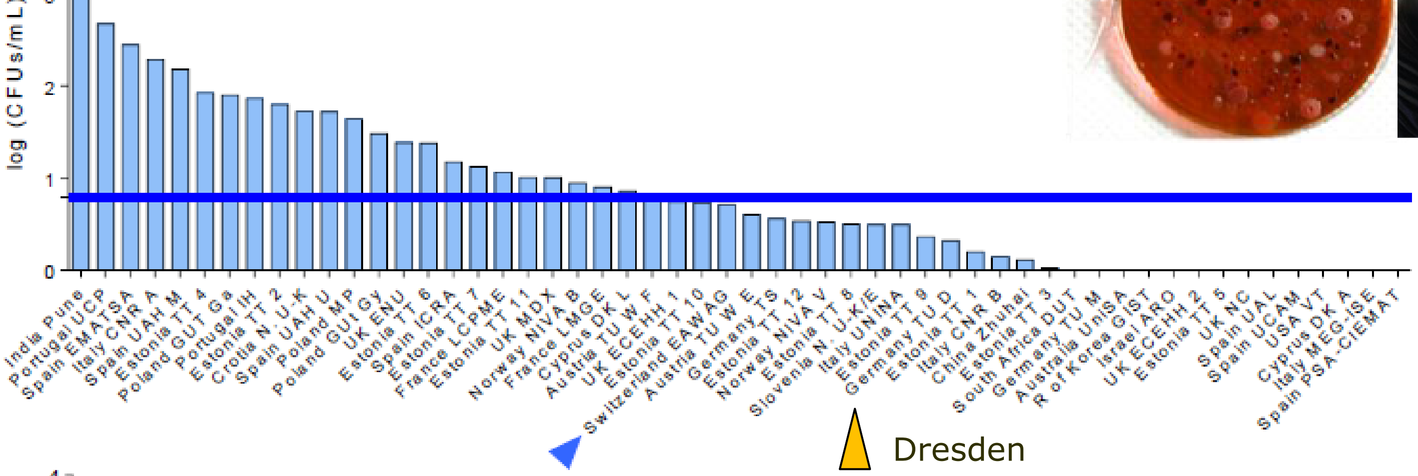
resistente Bakterien

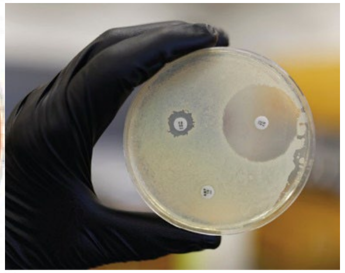
behandelbare Bakterien

Norhan et al. Scientific Reports 2018

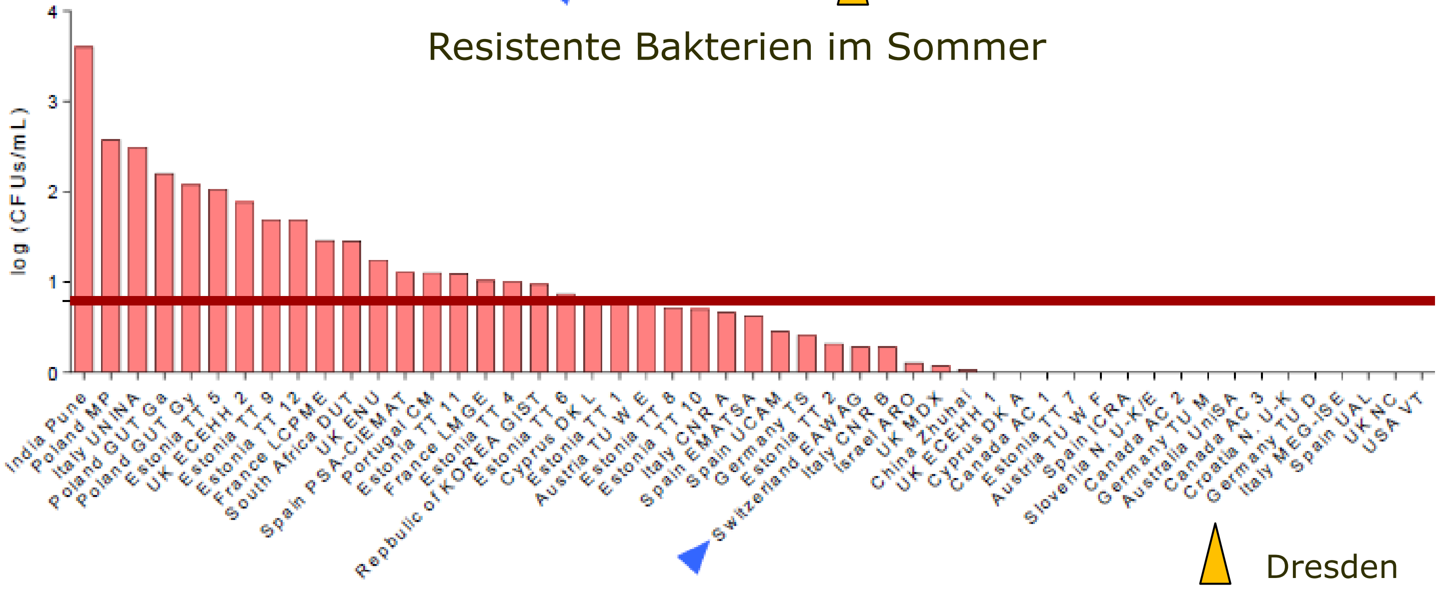
Mögliche Methoden des AMR monitoring

Resistente Bakterien im Winter



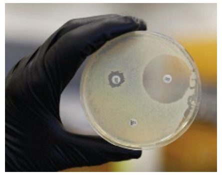


Resistente Bakterien im Sommer



Marano et al. 2020 Environment International

Mögliche Methoden des AMR monitoring



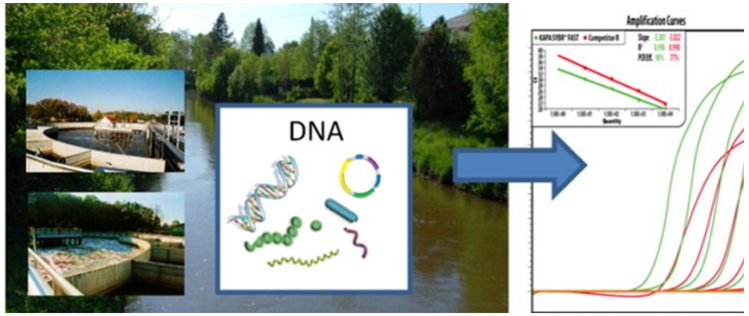
- Kulturbasiert (langsam) ✓

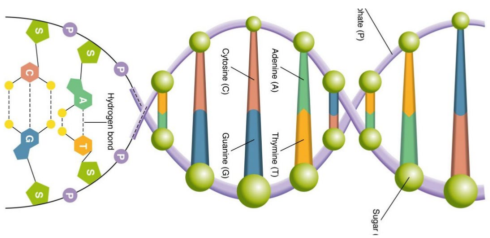
- Molekular

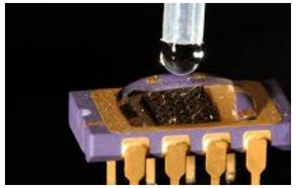
  ⇨ Quantifizierungsanalysen (schnell)

  - Quantifikation Resistenzgene
  - Q-PCR – high throughput qPCR
  - digitale PCR

  - Sequenzierungstechnologien (hoher bioinformatischer Aufwand)
  - Metagenomik (long or short read)
  - Epic-PCR
  - Hi-C linkage







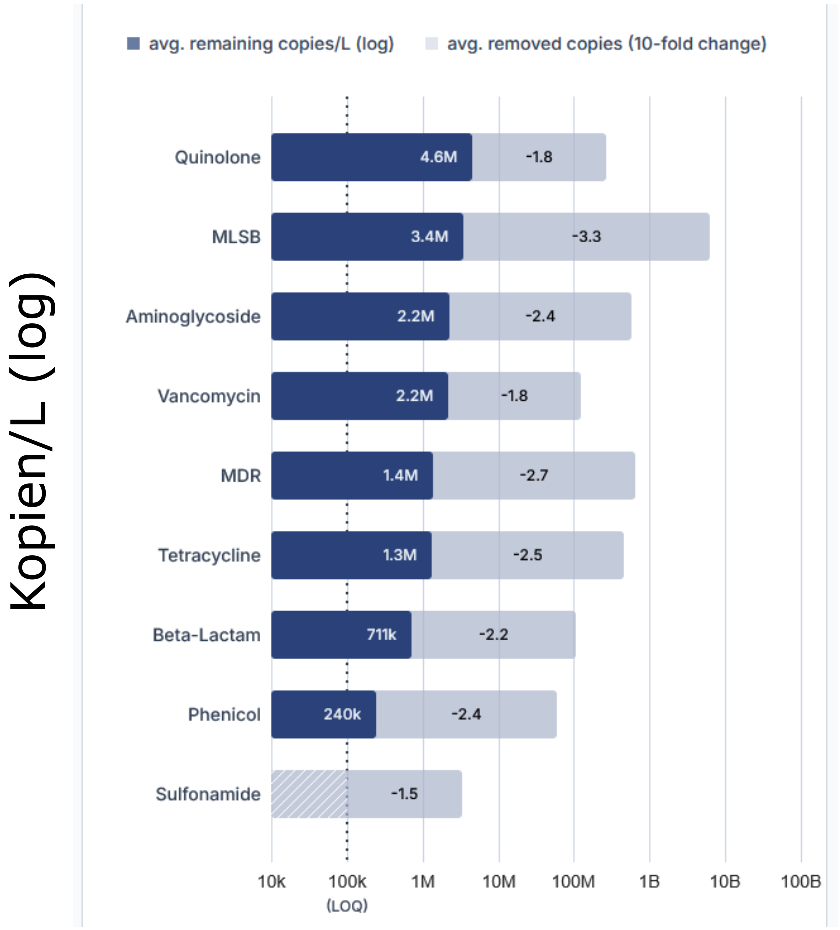
- Sensor Technologien (erst am Anfang)

  ⇨ Optical, DNA or Proteinbased

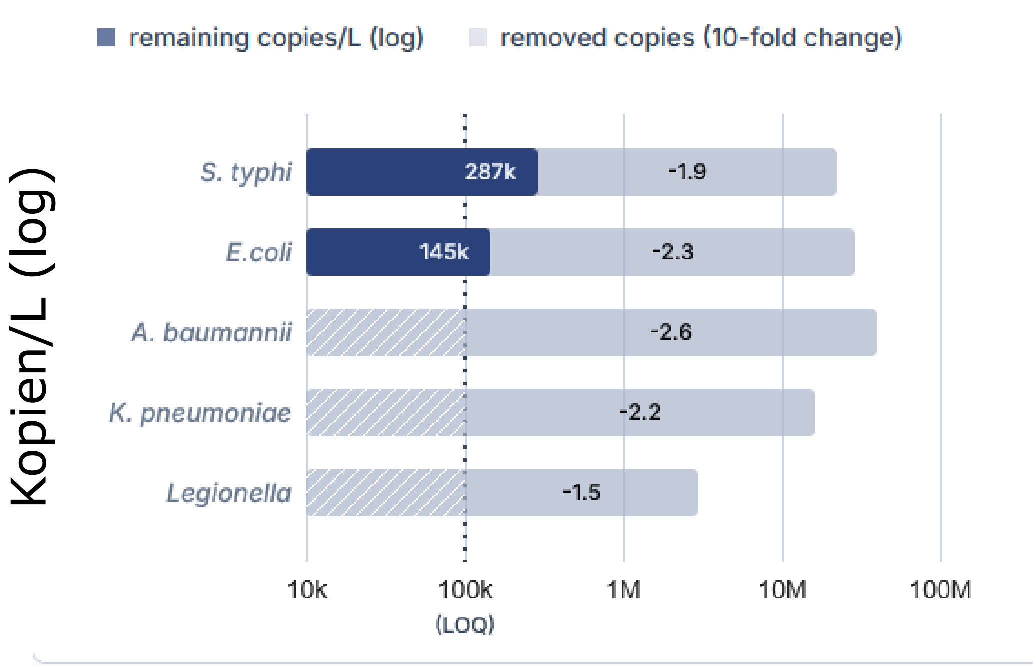
Nochmal:

Quantifizierung der Resistenzgene und der Pathogene

Reduktion der Resistenzgene



Pathogene Bakterien



Zeitplan

ChatGPT →

Die Richtlinie trat am 1. Januar 2025 in Kraft.
Die Mitgliedstaaten müssen die Bestimmungen bis spätestens 31. Juli 2027 in nationales Recht umsetzen.

Die Kommission erlässt bis zum 2. Juli 2026 Durchführungsrechtsakte, um eine Mindesthäufigkeit für Probenahmen und eine harmonisierte Methode zur Messung antimikrobieller Resistenzen im kommunalen Abwasser festzulegen, wobei sie mindestens alle verfügbaren Daten der nationalen Gesundheitsbehörden und der für die Überwachung antimikrobieller Resistenzen zuständigen nationalen Behörden berücksichtigt. Diese Durchführungsrechtsakte werden gemäß dem in Artikel 28 Absatz 2 genannten Prüfverfahren erlassen.

Artikel 22

Informationen über die Überwachung der Durchführung

a) bis zum 31. Dezember 2028 einen Datensatz mit Informationen, die gemäß Artikel 21 erhoben wurden, einschließlich Informationen über die Parameter gemäß Artikel 21 Absatz 1 Buchstabe a und die Prüfergebnisse in Bezug auf die in Anhang I Teil C festgelegten Kriterien für die Erfüllung/Nichterfüllung der Anforderungen, und aktualisieren diesen Datensatz danach jährlich, ???

h) bis zum 31. Dezember 2030 einen Datensatz mit den in Artikel 17 Absätze 1 und 3 genannten Überwachungsergebnissen und aktualisieren diesen Datensatz danach jährlich,

The End

Zusammenfassung - Ausblick

- Das Monitoring antimikrobieller Resistenzen wird auf kulturbasierten und molekularen Methoden basieren.
- Eine Standardisierung der Methoden ist unerlässlich
- (dringender) Bedarf an einem einheitlichen AMR-Datenmanagementsystem für den Umweltbereich, das eine sektorübergreifende Datenintegration ermöglicht und Forscher, Aufsichtsbehörden und Betreiber von Kläranlagen unterstützt.

My group

GEFÖRDERT VOM

Bundesministerium
für Bildung
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Deutsche
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JPI AMR EMBARK
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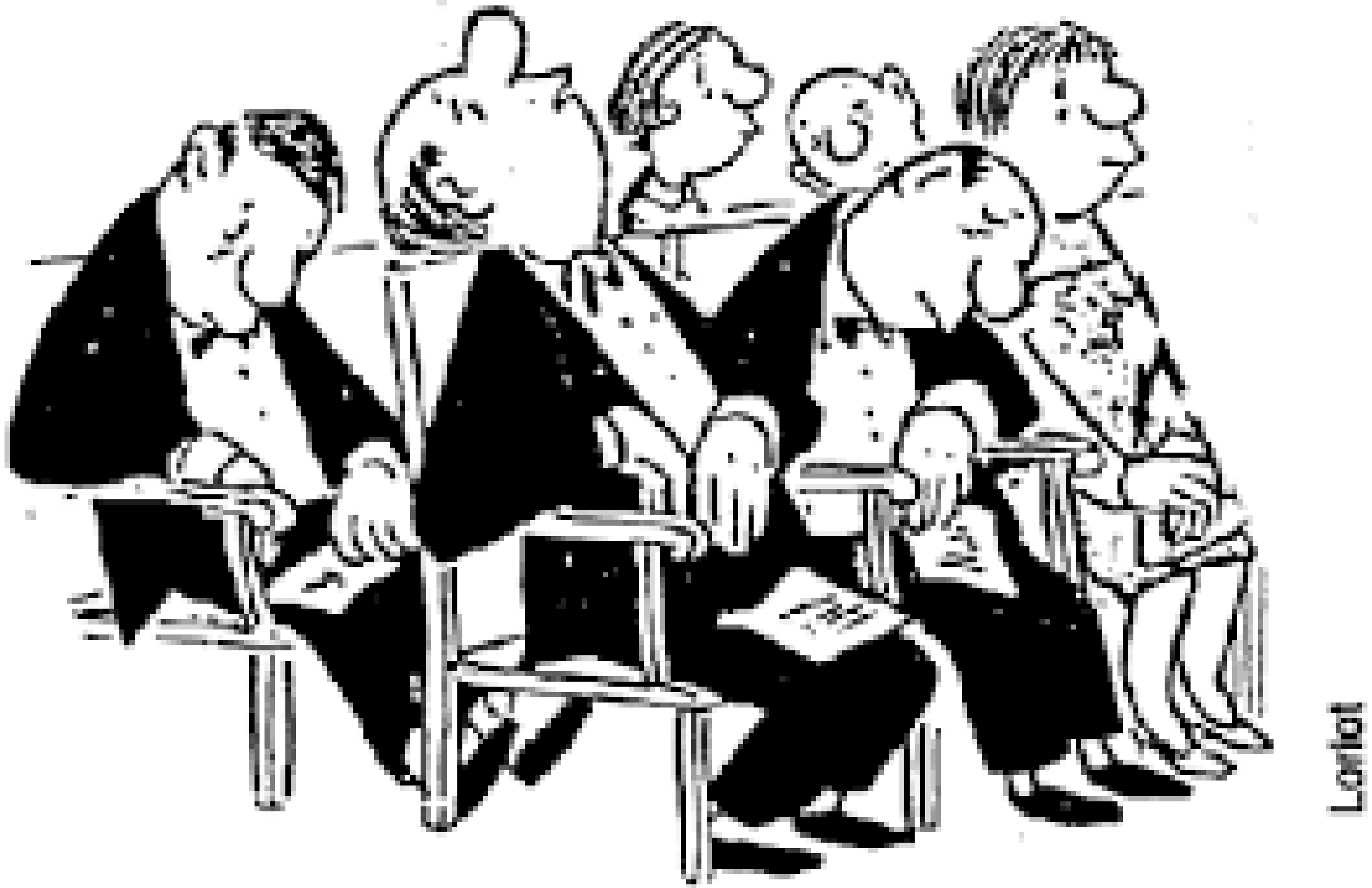
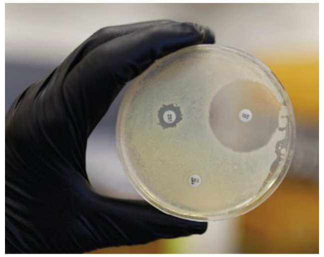
SCAN ME

Danke für die Aufmerksamkeit

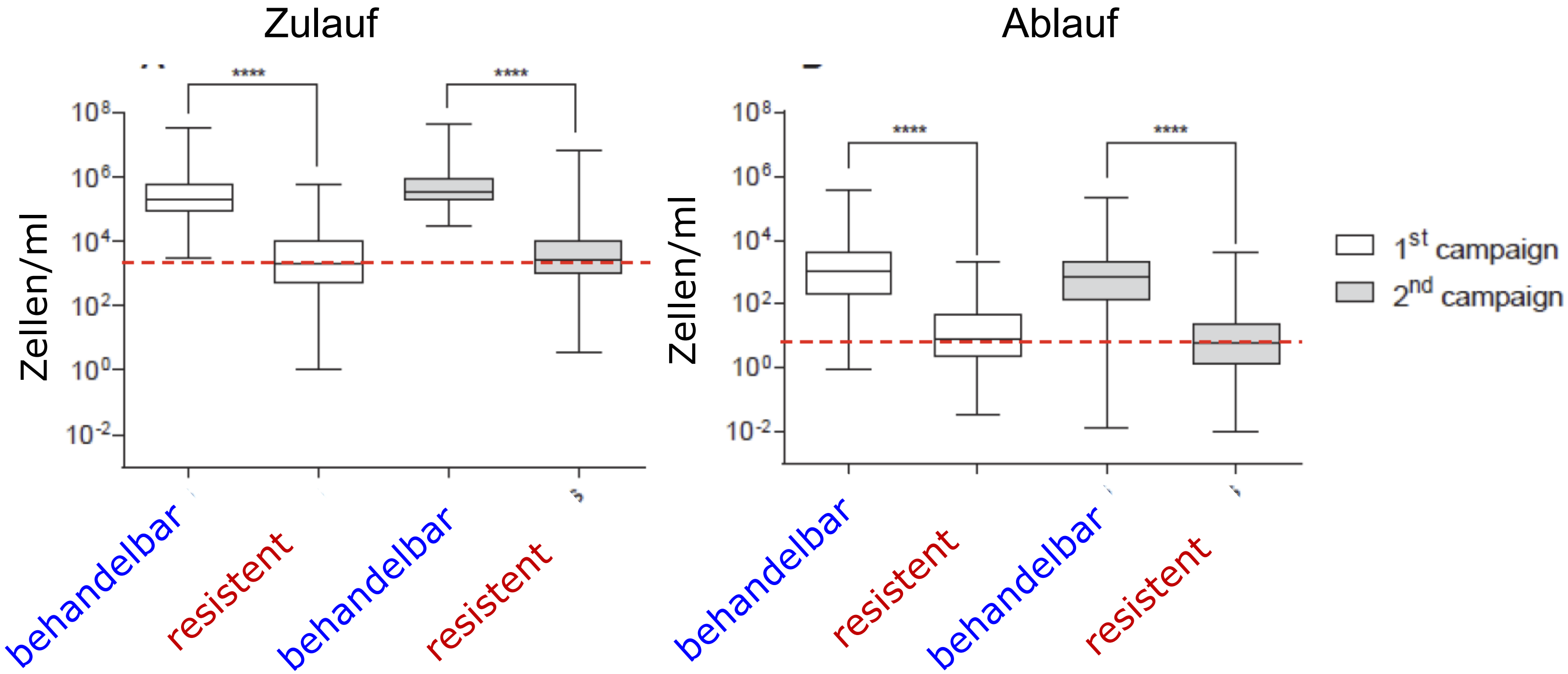


Mögliche Methoden des AMR monitoring



- Kulturbasiert

  ⇨ Cefotaxim Resistente Bakterien (Coliforme) – WWTP globale Studie (54 WWTP)



Marano et al. 2020 Environment International

The End

ISME

The ISME Journal, 2024, **18(1)**, wrae243
https://doi.org/10.1093/ismejo/wrae243
Advance access publication: 10 December 2024
Original Article

Bacteria of the order *Burkholderiales* are original environmental hosts of type II trimethoprim resistance genes (*dfrB*)

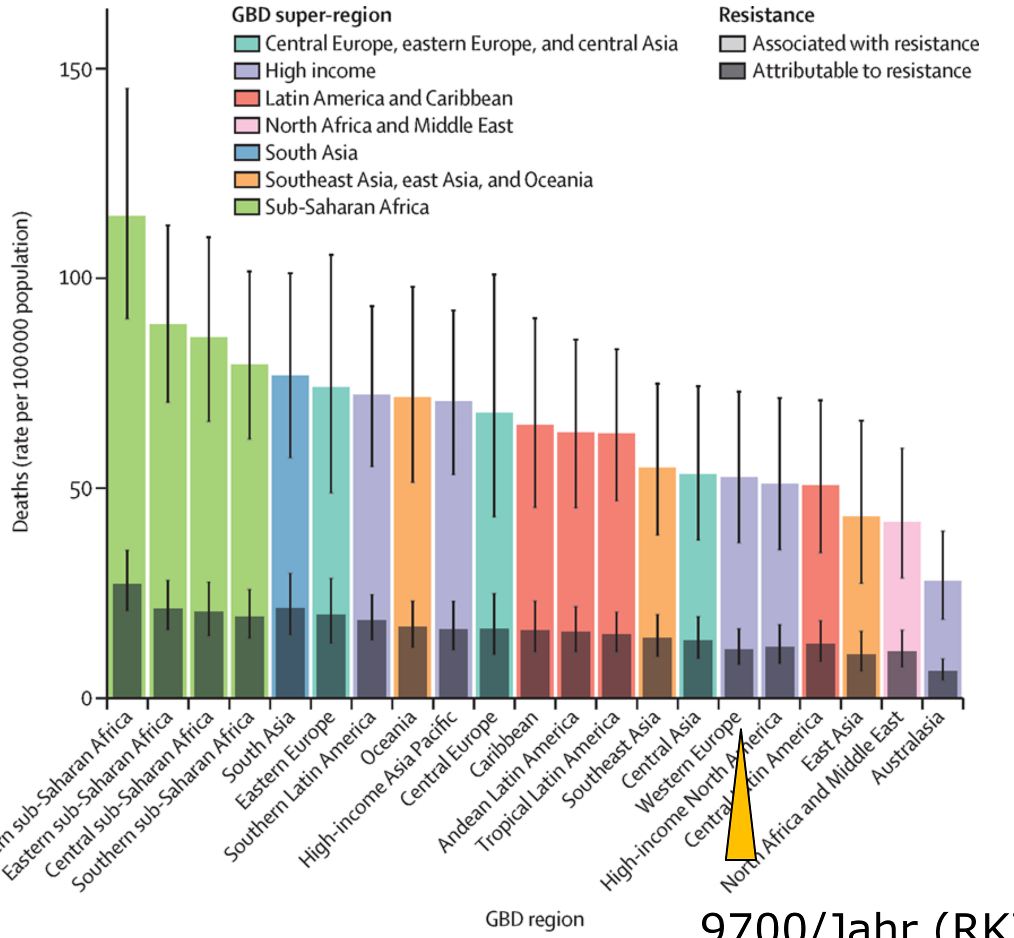
David Kneis*, Faina Tskhay, Magali de la Cruz Barron, Thomas U. Berendonk

Dresden University of Technology, Institute of Hydrobiology, 01062 Dresden, Saxony, Germany

https://doi.org/10.1093/ismejo/wrae243

The End

„Die Stille Pandemie“



9700/Jahr (RKI)

The Lancet 2022 399629-655DOI: (10.1016/S0140-6736(21)02724-0)

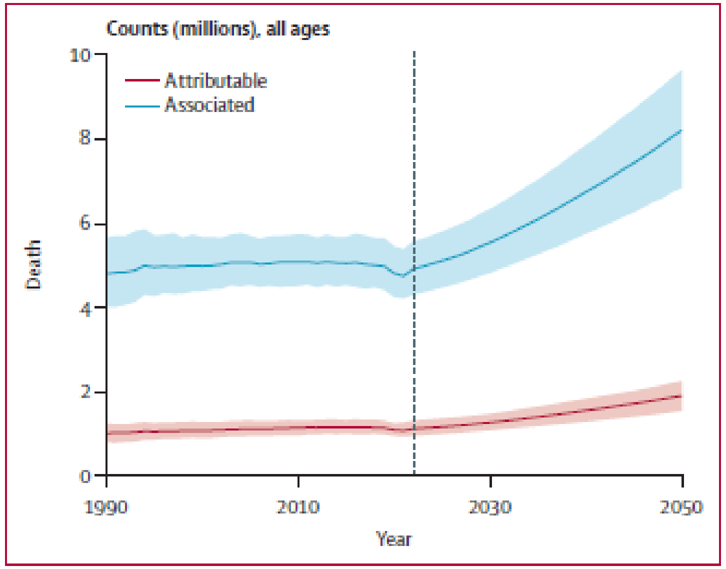


Figure 6: Global attributable and associated AMR burden in the reference scenario, 2022–2050
Shading represents the 95% uncertainty interval. The vertical line is placed at 2021 to distinguish estimates from forecasts.

Global burden of bacterial antimicrobial resistance 1990–2021: a systematic analysis with forecasts to 2050

GBD 2021 Antimicrobial Resistance Collaborators*

www.thelancet.com Published online September 16, 2024 https://doi.org/10.1016/ S0140-6736(24)01867-1

Mögliche Methoden des AMR monitoring

- Kulturbasiert

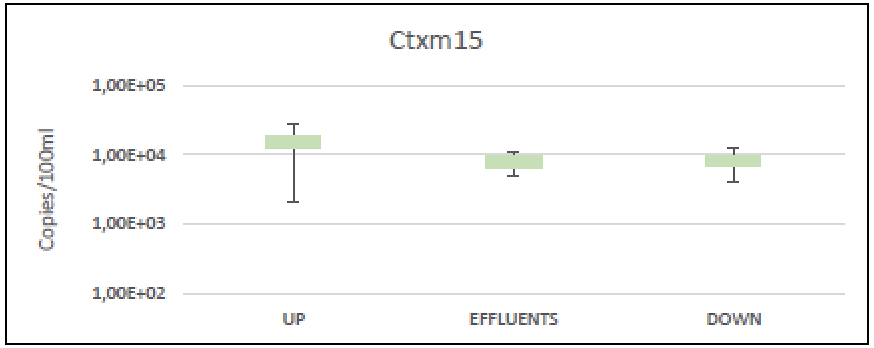
- Molekular
  - ⇨ Quantifikation Resistenzgene
  - ⇨ Q-PCR – high throughput qPCR
  - ⇨ digitale PCR

  - ⇨ Sequenzierungstechnologien (+Einzellzellsequenzierung)
  - ⇨ Metagenomik (long or short read)
  - ⇨ Epic-PCR
  - ⇨ Hi-C linkage

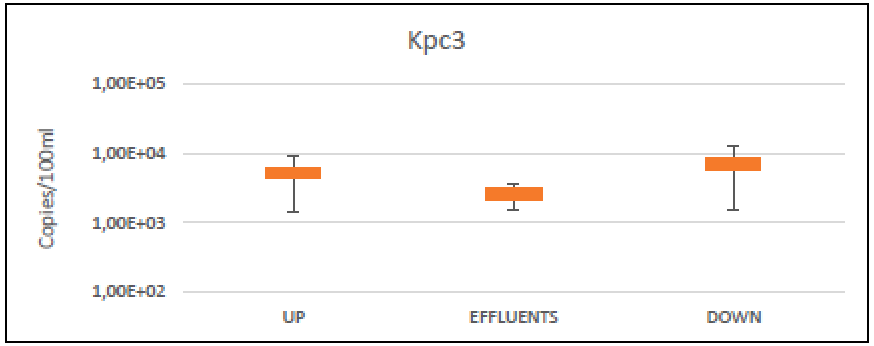
- Sensor Technologien
  - ⇨ Optical, DNA or Proteinbased

Surveilance of resistance in the environment
The receiving water

ß-Lactamase - Penicillin



ß-Lactamase – Penicillin *K. pneumoniae*



Mögliche Methoden des AMR monitoring

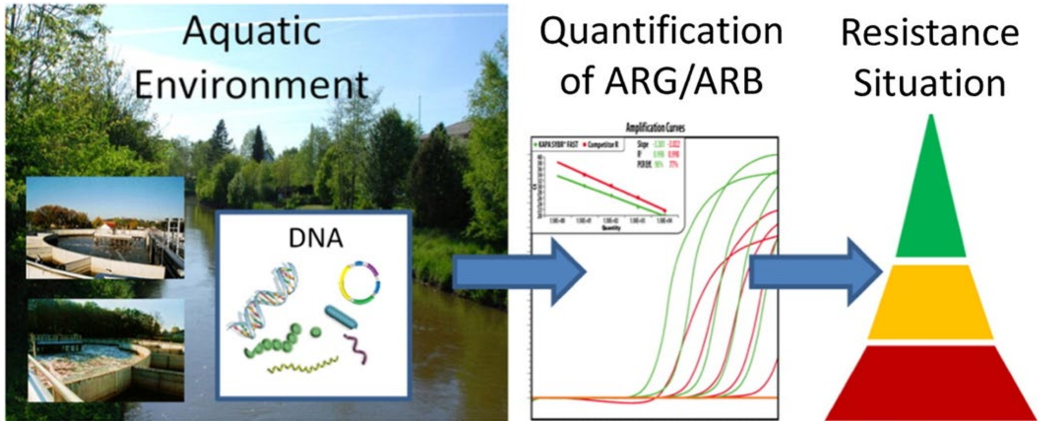
- Kulturbasiert

  ⇨ Bsp.: Escherichia coli

  - DIN EN ISO 9308-2:2014 DE MPN
  - Ursprüngliche Motivation eine Fäkalverunreinigung zu detektieren
  - Geeignet um eine *E.coli* – Coliforme Belastung abzuschätzen ?
  - Resistenten Anteil abschätzen ?

Mögliche Methoden des AMR monitoring

- Molekular
  - ⇨ Quantifikation Resistenzgene
- Quantifizierung als Anzahl der Genkopien pro 16S („Bakterienmasse“)
  - ⇨ „relative Anzahl der Resistenzgene“
- Quantifizierung als Anzahl der Genkopien per Volumen
  - ⇨ „Absolute Anzahl der Resistenzgene“ (Konzentration)



Rocha et al. 2018 J. Environ. Chem. Eng

Relevanz

nature communications

Article

https://doi.org/10.1038/s41467-022-34312-7

Genomic analysis of sewage from 101 countries reveals global landscape of antimicrobial resistance

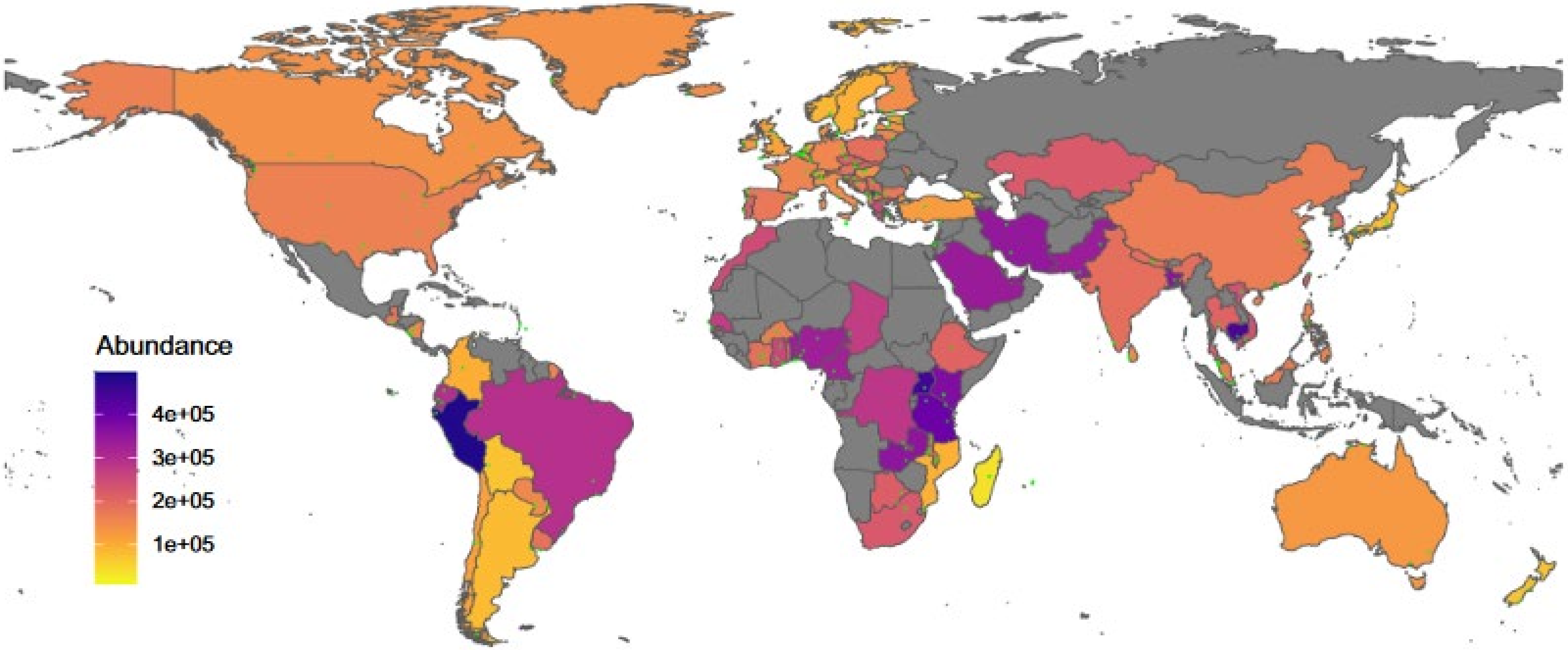
Received: 25 July 2022

Accepted: 20 October 2022

Published online: 01 December 2022

Patrick Munk[1], Christian Brinch[1], Frederik Duus Møller[1], Thomas N. Petersen[1], Rene S. Hendriksen[1], Anne Mette Seyfarth[1], Jette S. Kjeldgaard[1], Christina Aaby Svendsen[1], Bram van Bunnik[2], Fanny Berglund[3], Global Sewage Surveillance Consortium*,

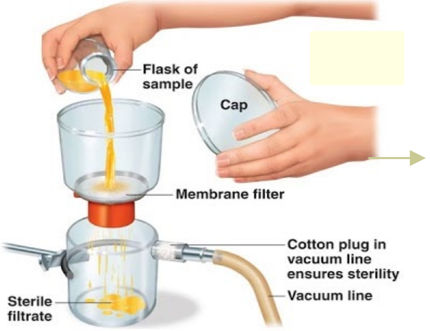
a

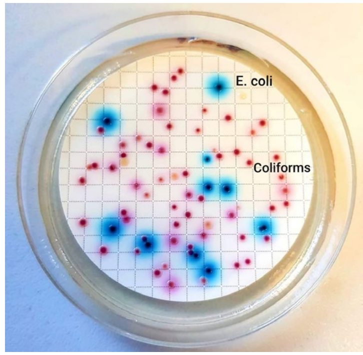


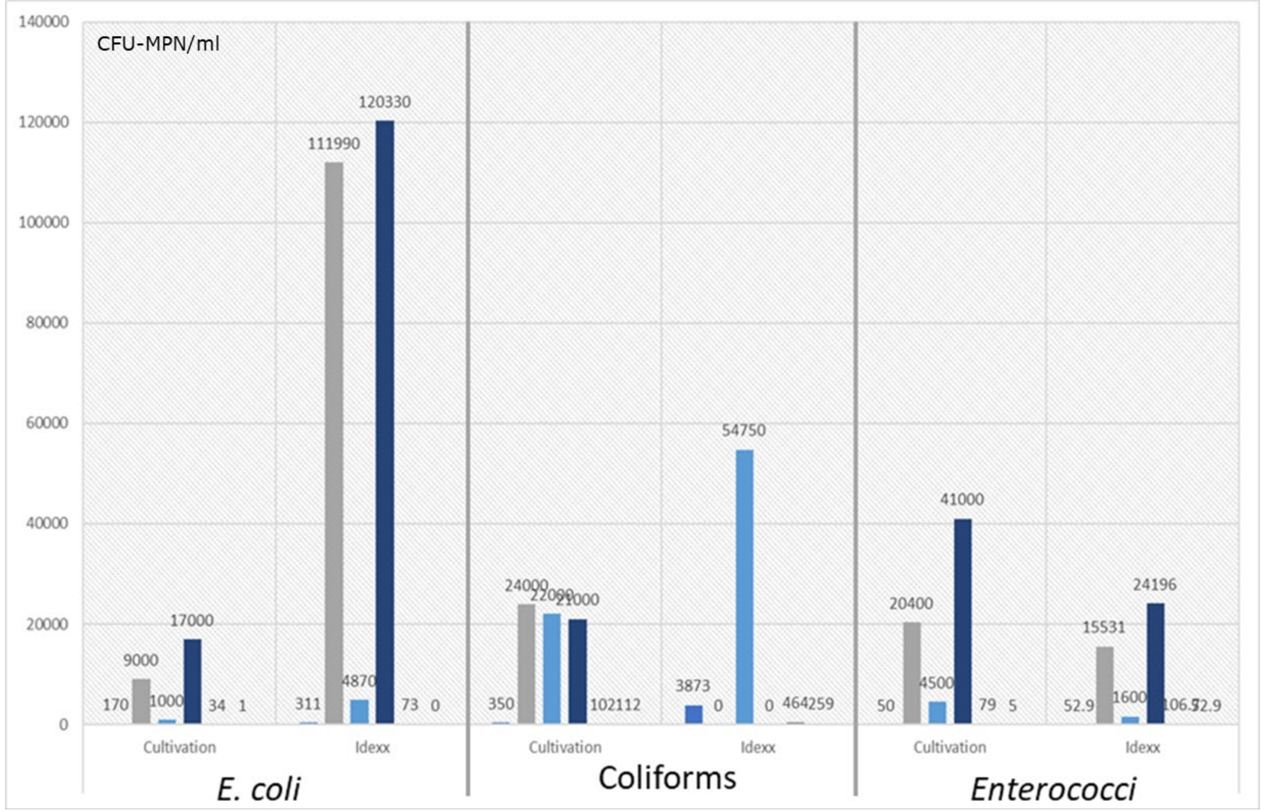
b

Mögliche Methoden des AMR monitoring

- Kulturbasiert
  - ⇨ Escherichia coli – coliforme
  - ⇨ Vergleich Chomagar - Colilert







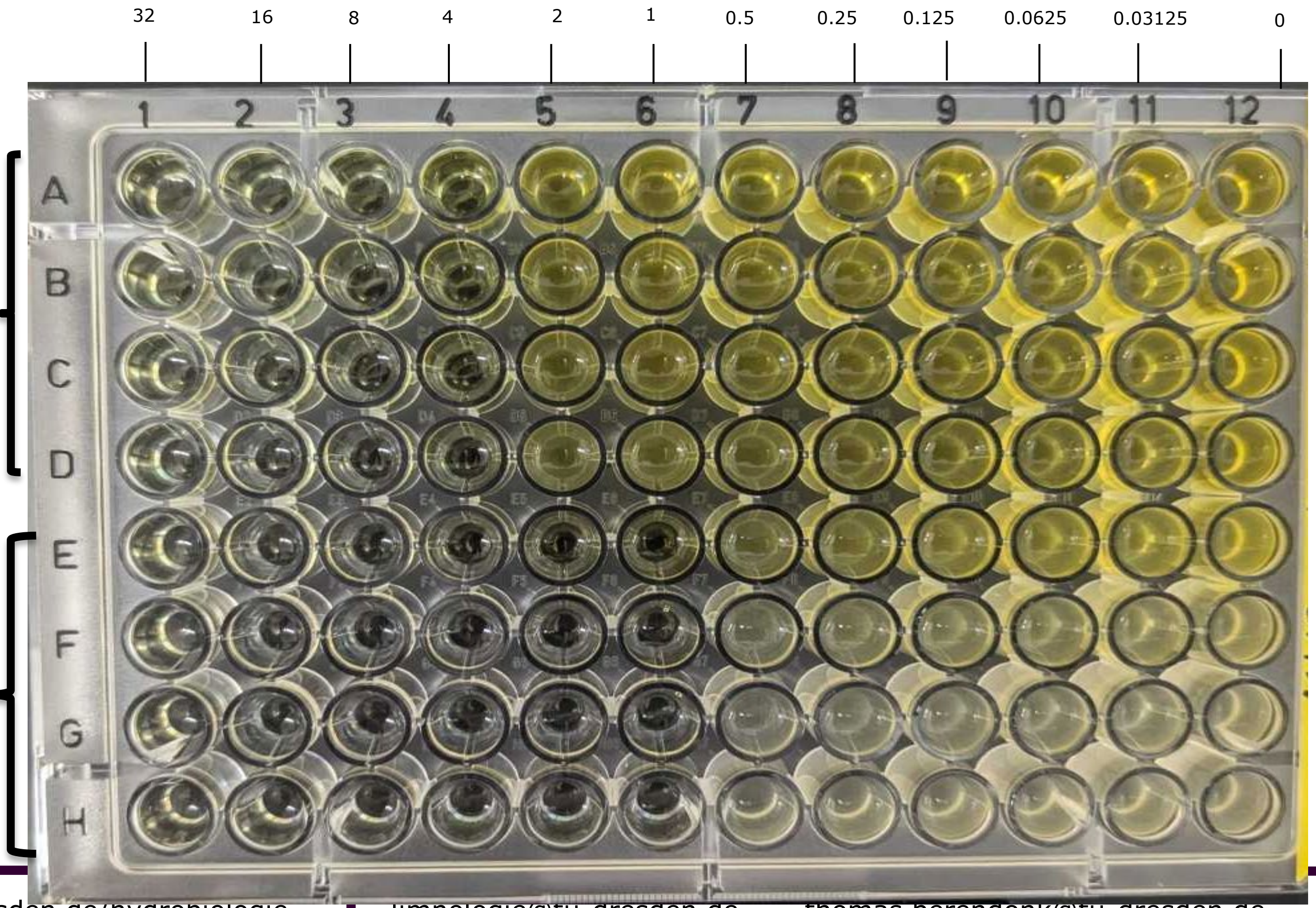
Unterschiedliche Farben sind verschiedene Probenahmestellen an der Kläranlage

Mögliche Methoden des AMR monitoring

- Kulturbasiert
  - ⇨ Anpassung des Colilert an AMR Detektion schlug fehl

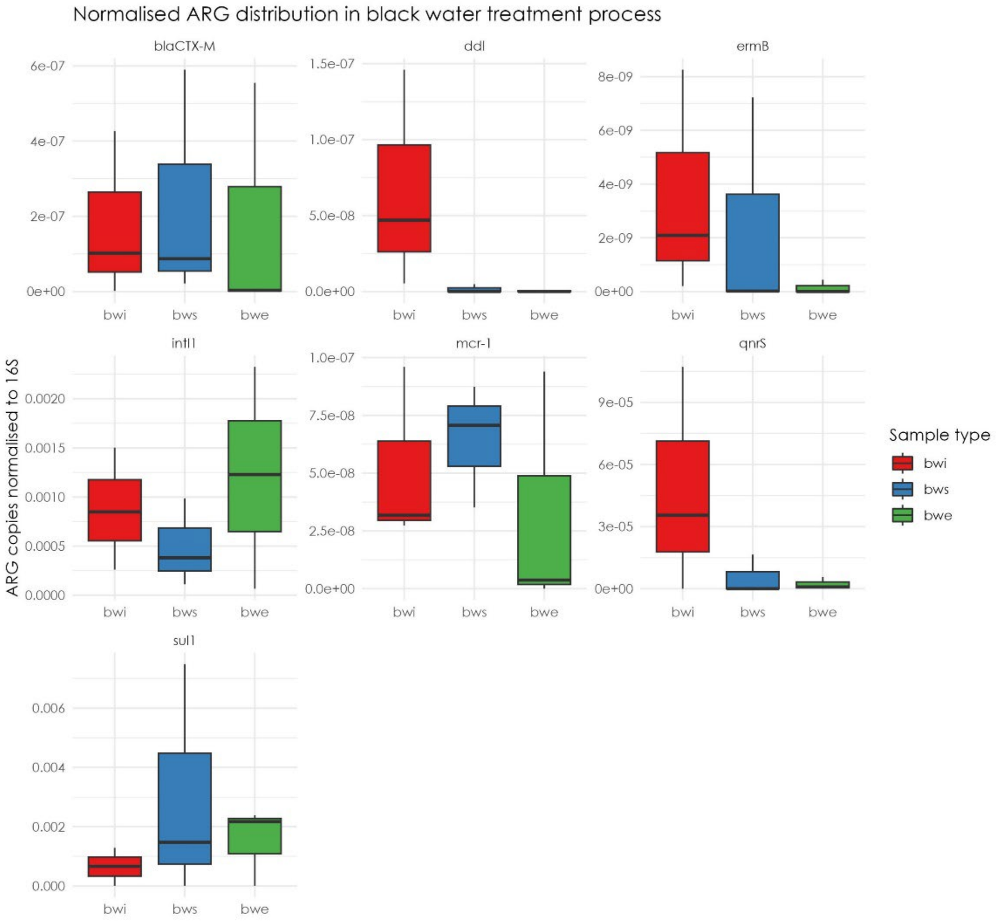
IDEXX Colilert

Mueller–Hinton



Mögliche Methoden des AMR monitoring

- Molekular
  - ⇨ Quantifikation Resistenzgene
- Beispiel: Anaerobic MBR Spanien



BW	
gene	Removal (%)
bla$_{CTX-M}$	50
ddl	~100
ermB	62
*intI*1	Increase
mcr-1	37
qnrS	95
sul1	Increase

relevante Parameter für die öffentliche Gesundheit zu ermitteln, die zumindest im Zulauf kommunaler Abwasserbehandlungsanlagen zu überwachen sind, unter Berücksichtigung der verfügbaren Empfehlungen unter anderem des Europäischen Zentrums für die Prävention und die Kontrolle von Krankheiten (ECDC), der Europäischen Behörde für die Krisenvorsorge und -reaktion bei gesundheitlichen Notlagen (HERA) und der Weltgesundheitsorganisation (WHO),

Mögliche Methoden des AMR monitoring

Kontrollen - Behandlungstechnologien

DSWAP Removal Efficiency Datal ×

limno-live.hydro.tu-dresden.de/dkneis/prototypes/dswap/

DSWAP Removal Efficiency Database

Start page | High-level summaries | Tabular views | SQL mode | Impressum | Legal aspects

This is the web interface to the database of removal efficiencies observed in wastewater treatment. It represents the knowledge reported in the scientific literature as of 2022 with regard to selected chemical or biological contaminants and treatment technologies.

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Contaminant group	Reported value	Unit	Definition
Chemical	Percentage removal efficiency	%	$PRE = (C_{in} - C_{out}) / C_{in} * 100$
Biological	Log removal value	-	$LRV = log_{10}(C_{in} / C_{out})$

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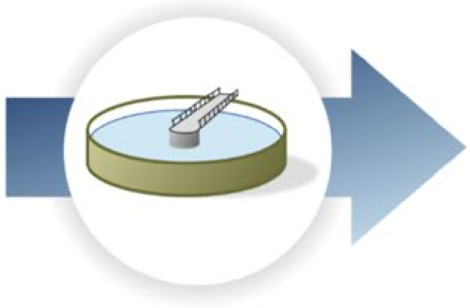

DSWAP

SCAN ME

Mögliche Methoden des AMR monitoring

Kontrollen - Behandlungstechnologien

DSWAP Removal Efficiency Data

limno-live.hydro.tu-dresden.de/dkneis/prototypes/dswap/

DSWAP Removal Efficiency Database

Start page | High-level summaries | Tabular views | SQL mode | Impressum | Legal aspects

Numbers of records | Ranges per contaminant | Ranges per technology group

Select criterion for building the summary

TechnologyGroup

TechnologyGroup	Records
Conventional activated sludge treatment	114
Fenton treatment	5
Forward Osmosis	3
Free Chlorine	25
Granular activated carbon treatment	22
Membrane Bioreactor	46
Microfiltration	6
Nano Filtration	7
Ozonation treatment	68
Ozonation/H2O2 treatment	4
Photo Fenton treatment	47
Reverse Osmosis	36
Sand Filtration	15
Sewage treatment plants	36
UV combined with H2O2 treatment	94

https://limno-live.hydro.tu-dresden.de/dkneis/prototypes/dswap/#tab-4270-2

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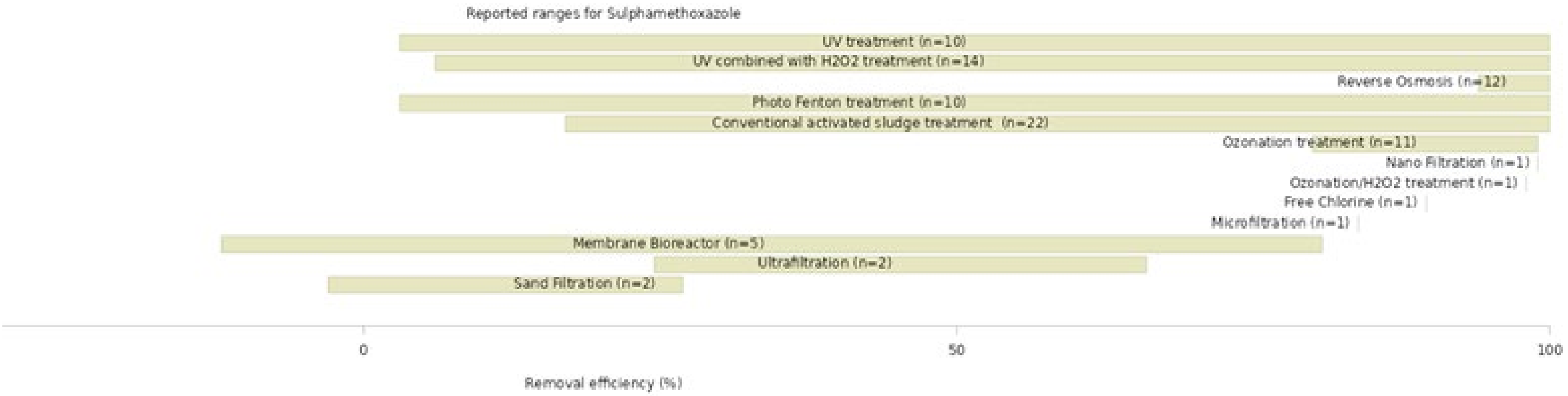
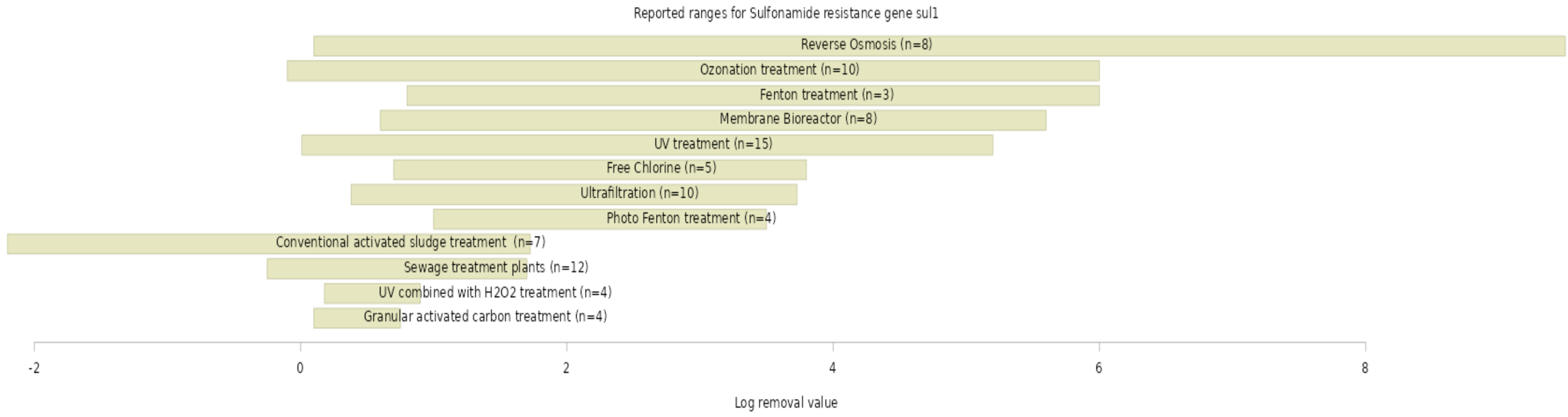
Mögliche Methoden des AMR monitoring

Kontrollen - Behandlungstechnologien





Zusammenfassung und Schlussfolgerungen

- Antibiotikaresistenz im Abwasser ist ein relevantes Problem

- Zum Monitoring bestimmter Kontrollmaßnahmen (e.g. Aktivkohle, Membran, Ozon) stehen unterschiedliche Werkzeuge zur Verfügung
  - ⇨ Datenlage zu Maßnahmen ist noch unübersichtlich

- Kulturbasierte Ansätze (Leitl. EU-Verordnung 2020/741, EU WasserWVVO 2022/C 2989/01)
  - ⇨ enstprechende Indikatorsysteme existieren (ABER müssen evtl. angepasst werden)
  - ⇨ Wirt – Resistenzgen Verhältnis am besten dargestellt
  - ⇨ Im klinischen Bereich existieren Normierungen

- Q-PCR (real time,chip, dd-PCR) Berendonk et al. 2015, Abramova et al. 2023 Alygizakis et al. 2024
  - ⇨ Analytisch schnellster Ansatz
  - ⇨ gut zu normieren (e.g. ISO)
  - ⇨ Beste Sensitivtät für “niedrige” Konzentrationen

- Metagenomik

Monitoring – (passive ?) Surveillance

Was nun ?

- Derzeit am wahrscheinlichsten das sich entweder ein kulturbasierter oder ein mit q-PCR kombinierter Ansatz durchsetzt.
- In den USA scheint die EPA aufgrund der Covid-Analysen eine q-PCR System zu etablieren.

The End

DANKE an meine AG, besonders Dr. Klümper, Dr. Kneis, Dr. De LaCruz, Mrs. Faina Tskhay

NORMAN-network

JPI-Water - PRESAGE
JPI AMR EMBARK, SEARCHER
JPI Biodiversa - ANTIVERSA

norman

ANSWER

PRIMA
PARTNERSHIP FOR RESEARCH AND INNOVATION IN THE MEDITERRANEAN AREA

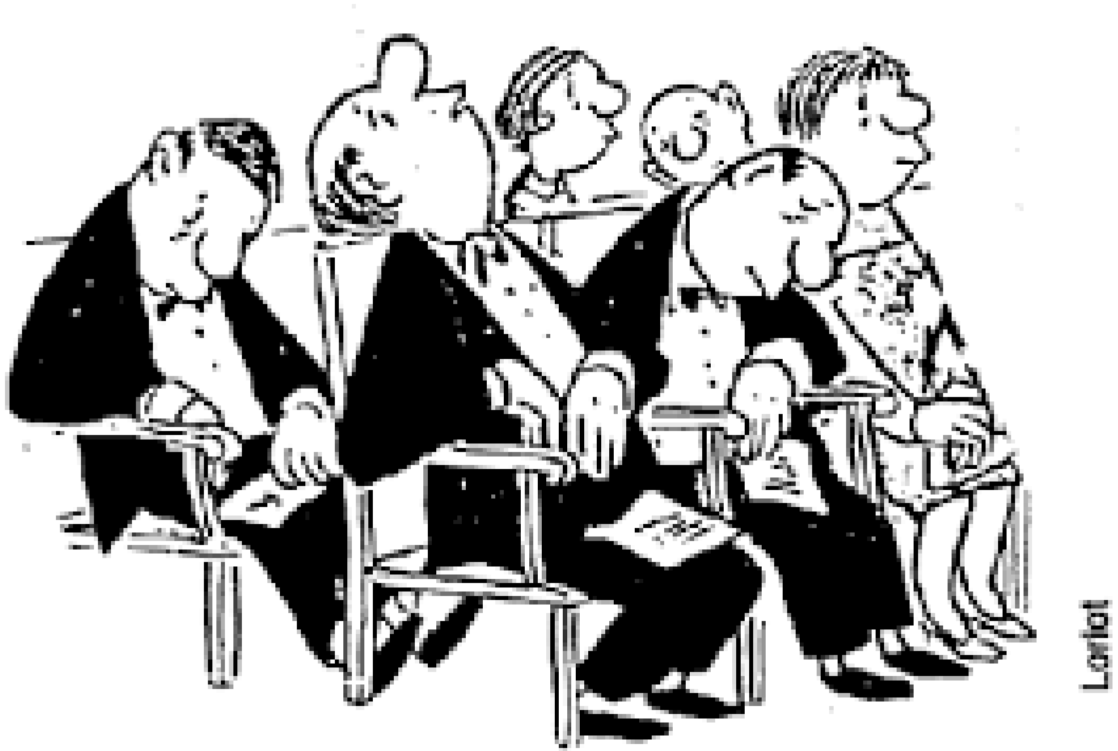
GEFÖRDERT VOM
Bundesministerium für Bildung und Forschung

DFG
Deutsche Forschungsgemeinschaft

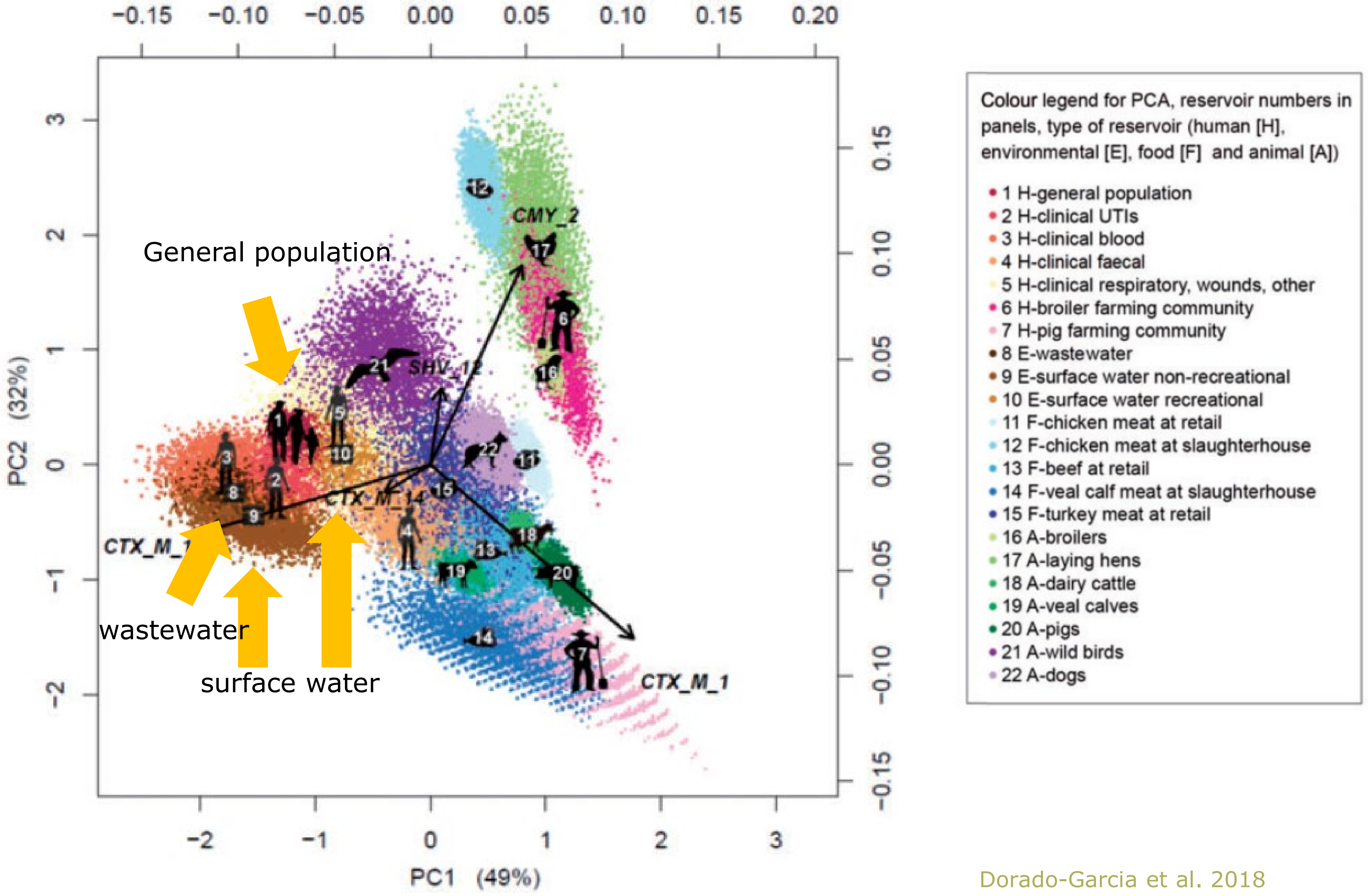
StARE

SCAN ME

Danke für Ihre Aufmerksamkeit



Resistant Escherichia coli and their genome association



Dorado-Garcia et al. 2018

Was bedeuten 10^{-3} resistance gene /16S/ml ?
Jedes 1000 te Bacterium besitzt ein Resistenzgen (ARG)

Bakterienkonzentration im Ablauf : ~10^{6} Zellen/ml
-> 10^{3} Zellen mit einem Resistenzgen/ml (10^{6}/L)

Volumen des Ablaufs: ~ 10^{8} L/d (10^{5} m^{3})
-> 10^{14} Zellen mit einem Resistenzgen /d

Bacterium mit ARG	: Umweltbakterium
1	: 10 – 10000

oder
10^{4} Resistenzgene (ARG) pro ml im Kläranlagenablauf ?

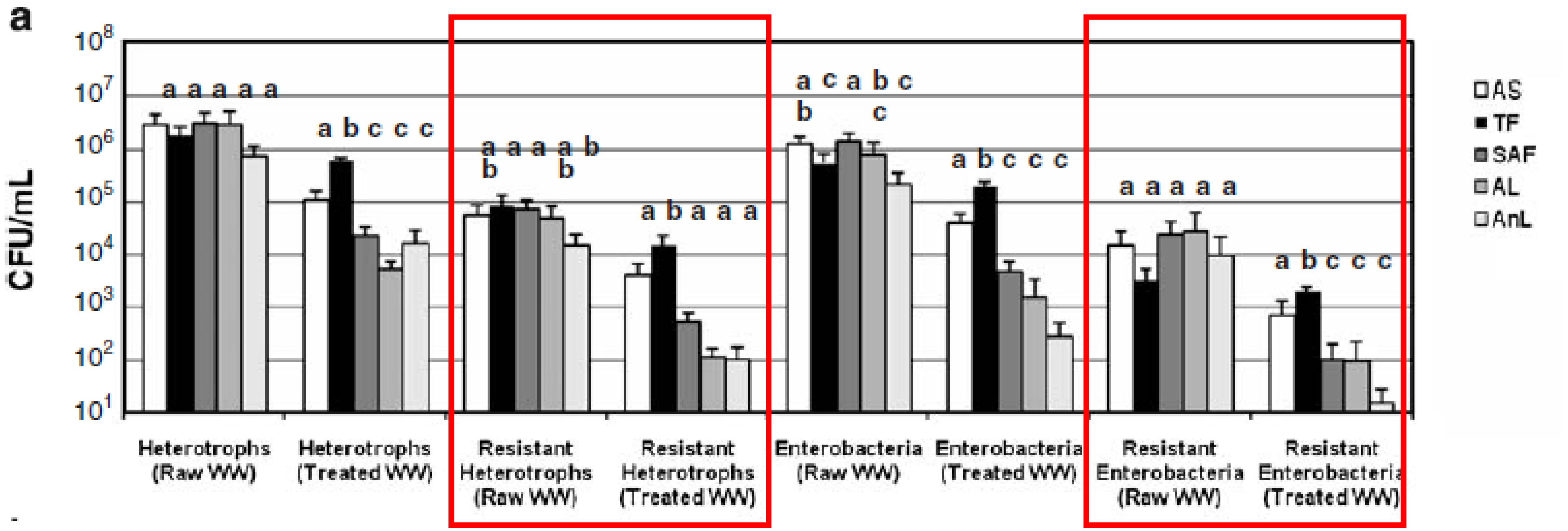
c. 10^{15} Resistenzgenkopien (pro Gentyp) pro Tag verlassen die Kläranlage

Voolaid, Donner, Vasileiadis, and Berendonk 2017

Ciprofloxacin Resistance in Domestic Wastewater Treatment Plants

Celia M. Manaia · Ana Novo · Bruno Coelho · Olga C. Nunes

Water Air Soil Pollut (2010) 208:335–343 339



„ Independently of the size or type of treatment used domestic wastewater treatment plants discharged per day at least 10^{10}–10^{14} colony forming units of ciprofloxacin-resistant bacteria“

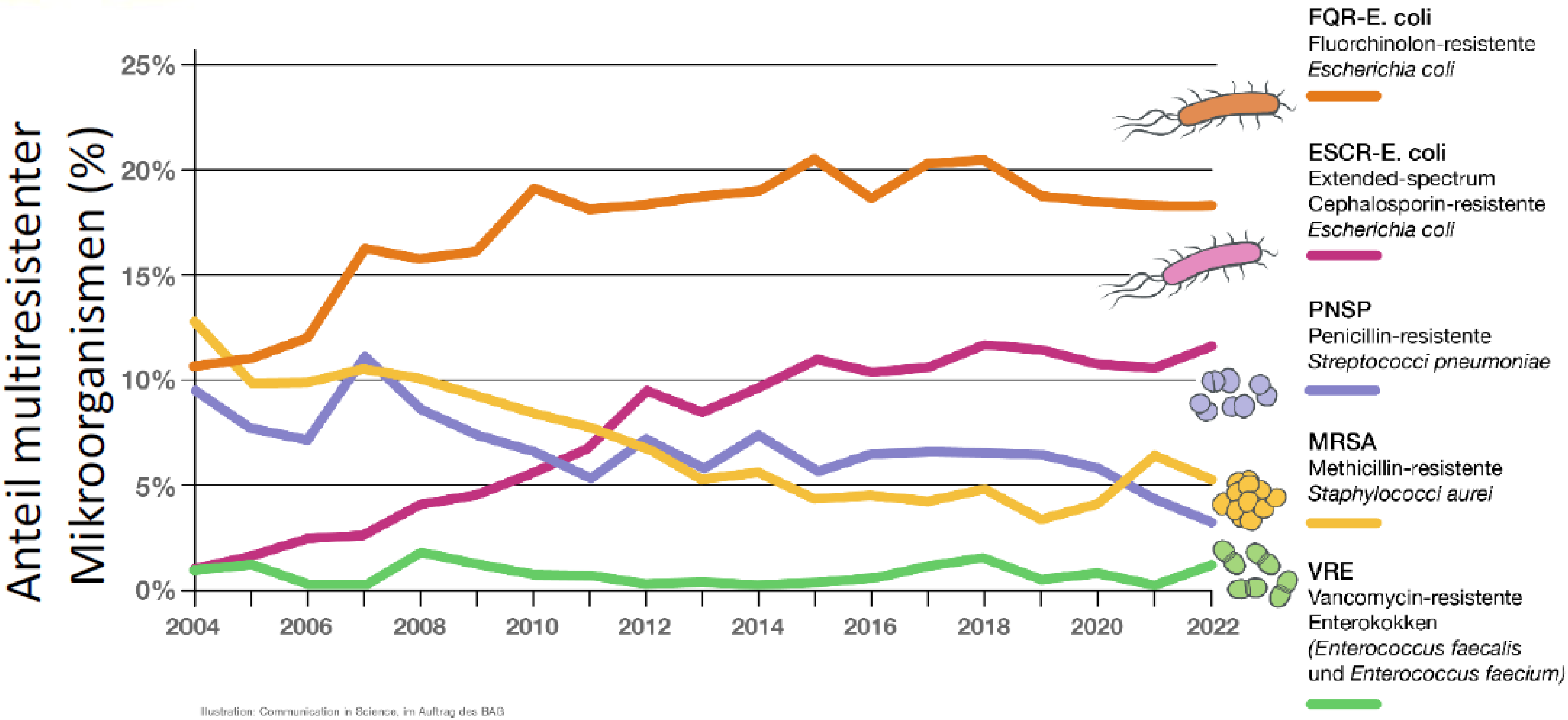


Illustration: Communication in Science, im Auftrag des BAG

The End

B. ***Surveillance and monitoring of AMR and antimicrobial consumption (AMC)***

HEREBY ENCOURAGES MEMBER STATES TO:

5. Close existing surveillance and monitoring gaps and ensure completeness of data, including real-time data and timely access to data where appropriate by 2030, on both AMR and AMC at all levels (*e.g.* community, hospitals and long-term care facilities) to support the prudent use of antimicrobials in human health, by:

   a. ensuring, in coordination with ECDC, that surveillance of AMR in bacteria from humans encompasses not only bloodstream and cerebrospinal fluid isolates (invasive isolates) but also all other isolates from clinical microbiology laboratories, and that the corresponding data are regularly reported to the ECDC to rapidly detect and better gauge the scale and spread of antimicrobial resistant pathogens within and across Member States;

   b. requiring, taking into account any methodology established at EU level, that infections caused by critical (high negative health impact) multidrug-resistant organisms resistant to last line treatments, *e.g.* carbapenem-resistant *Acinetobacter baumannii*, carbapenem-resistant Enterobacteriaceae (*e.g. Klebsiella pneumoniae*, *Escherichia coli*) and *Candida auris*, are notifiable diseases under national legislation. Member States can decide if other resistant organisms are notifiable, according to the national situation and need;

   c. expanding surveillance of AMR in humans to pathogens with emerging or established AMR, due to their exposure to substances in the environment, in particular those used in plant protection products or biocidal products;

   d. collecting data on AMC, in humans at the appropriate levels to allow the monitoring of antimicrobial prescribing and to provide timely feedback on prescription trends and patterns involving, among others, prescribers, pharmacists and other parties collecting such data, and where possible and appropriate using EU level digital infrastructure.

   e. developing integrated systems for the surveillance of AMR and AMC encompassing human health, animal health, plant health, food, wastewater and the environment (in particular water and soil), taking into account the Commission feasibility study on integrated systems, the work of the Quadripartite QTS-AIS expert group on Integrated Surveillance ([56]) as well as other initiatives already launched, such as the WHO Tricyle protocol for an integrated global surveillance on ESBL-producing E. coli across the human, animal and environmental sectors. Such integrated and continuous intersectorial monitoring should be designed to efficiently and rapidly detect emerging resistant infections and outbreaks but equally as regards soil and water bodies to determine the presence of AMR genes and antimicrobials, the trends and their toxicity. The results of this surveillance should inform effective strategies to tackle AMR across sectors and at appropriate administrative levels.

Commission Notice Guidelines to support the application of Regulation 2020/741 on minimum requirements for water reuse 2022/C 298/01

C/2022/5489

OJ C 298, 5.8.2022, p. 1–55 (BG, ES, CS, DA, DE, ET, EL, EN, FR, GA, HR, IT, LV, LT, HU, MT, NL, PL, PT, RO, SK, SL, FI, SV)

6. **Additional requirements (KRM6)** - the outcomes of the risk assessment might identify additional or stricter water quality and monitoring requirements than those from Section 2 of Annex I of the Regulation.

If additional parameters or limits are included, this should be based on the outcomes of the risk assessment and supported by scientific evidence that they originate from the water reuse system and not from other sources.

These additional parameters may also include the following pollutants: heavy metals, pesticides, disinfection by-products, pharmaceuticals, substances of emerging concern, bacteria that exhibit anti-microbial resistance.

(23) The Union recognises the importance of tackling the issue of antimicrobial resistance (AMR) and adopted in 2017 the European One Health Action Plan against AMR[55]. According to the World Health Organisation (WHO), wastewater is recognised and documented as major sources of antimicrobial agents and their metabolites, as well as antimicrobial-resistant bacteria and their genes. In order to increase the knowledge on the main sources of AMR, it is necessary to introduce a monitoring obligation for the presence of AMR in urban wastewaters to further develop our scientific knowledge and potentially take adequate action in the future.

Proposal for a

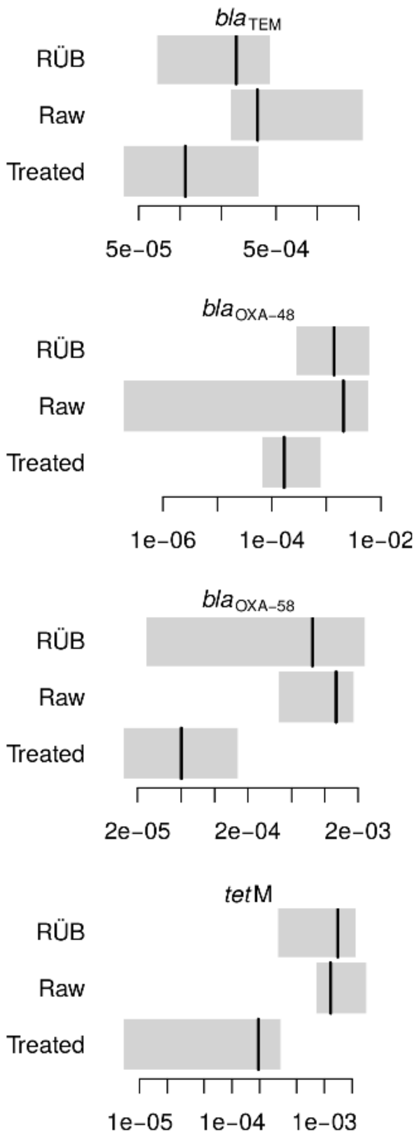
DIRECTIVE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL

concerning urban wastewater treatment (recast)

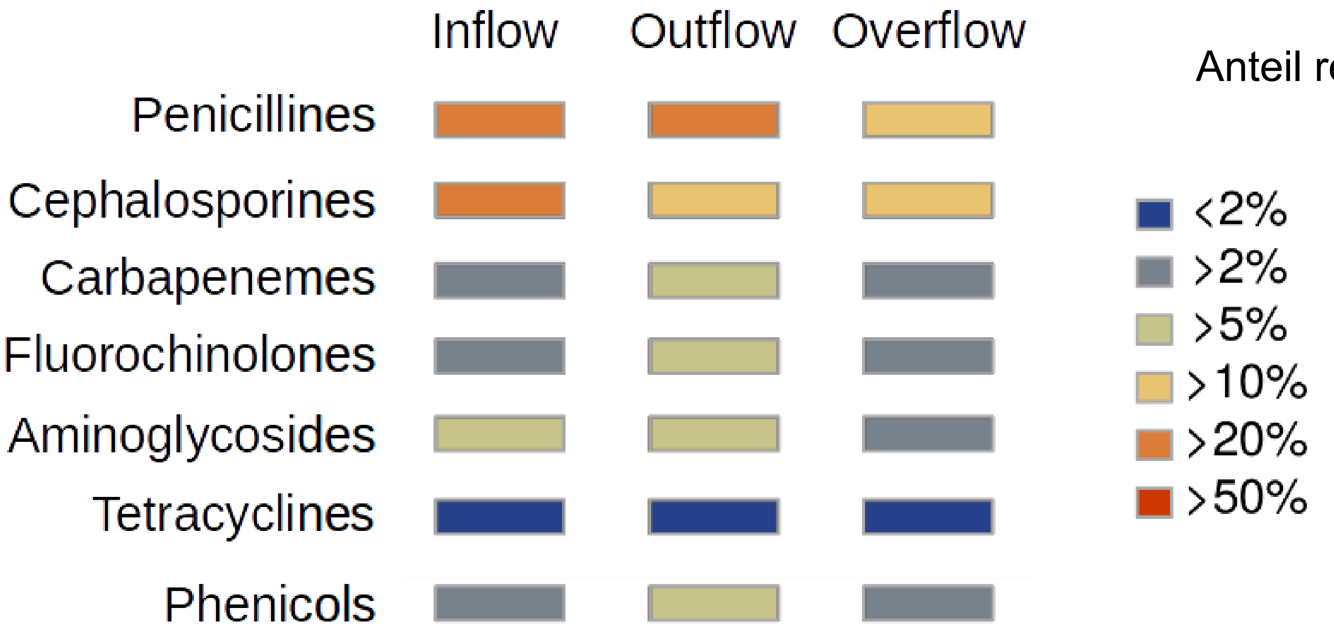
4. For agglomerations of 100 000 p.e. and above, Member States shall, by 1 January 2025, ensure that antimicrobial resistance is monitored at least twice a year at the inlets and outlets of urban wastewater treatment plants and, when relevant, in the collecting systems.

The Commission shall adopt implementing acts in accordance with the procedure referred to in Article 28 to ensure an uniform application of this Directive by establishing a harmonised methodology for measuring antimicrobial resistance in urban wastewaters.

Ergebnisse – Mischwasserentlastung Dresden



Mischwasserentlastung Dresden *Escherichia coli*



Trends:

- Resistenzniveau in der Entlastung ist entweder gleich oder geringer als im Ablauf der Kläranlage

- Resistenzniveau im Ablauf der Kläranlage entweder gleich oder größer als im Zulauf zur Kläranlage (einzige Ausnahme: FOX)

Wiederbelebung eines „alten“ Themas

Applied and Environmental Microbiology, Dec. 1982, p. 1395–1403 Vol. 44, No. 6
0099-2240/82/121395-09$02.00/0
Copyright © 1982, American Society for Microbiology

R-Plasmid Transfer in a Wastewater Treatment Plant

PATRICK A. MACH† and D. JAY GRIMES‡*
River Studies Center and Department of Biology, University of Wisconsin-La Crosse, La Crosse, Wisconsin

ELSEVIER

FEMS Microbiology Ecology 4[illegible] (2003) 325–335

FEMS MICROBIOLOGY Ecology
www.fems-microbiology.org

Detection of antibiotic-resistant bacteria and their resistance genes in wastewater, surface water, and drinking water biofilms

Thomas Schwartz [a,*], Wolfgang Kohnen [b], Bernd Jansen [b], Ursula Obst [a]

Antibiotika , Resistenzen und Bakterien in Kläranlagen LUA NRW, 2006, Dr. Eichler

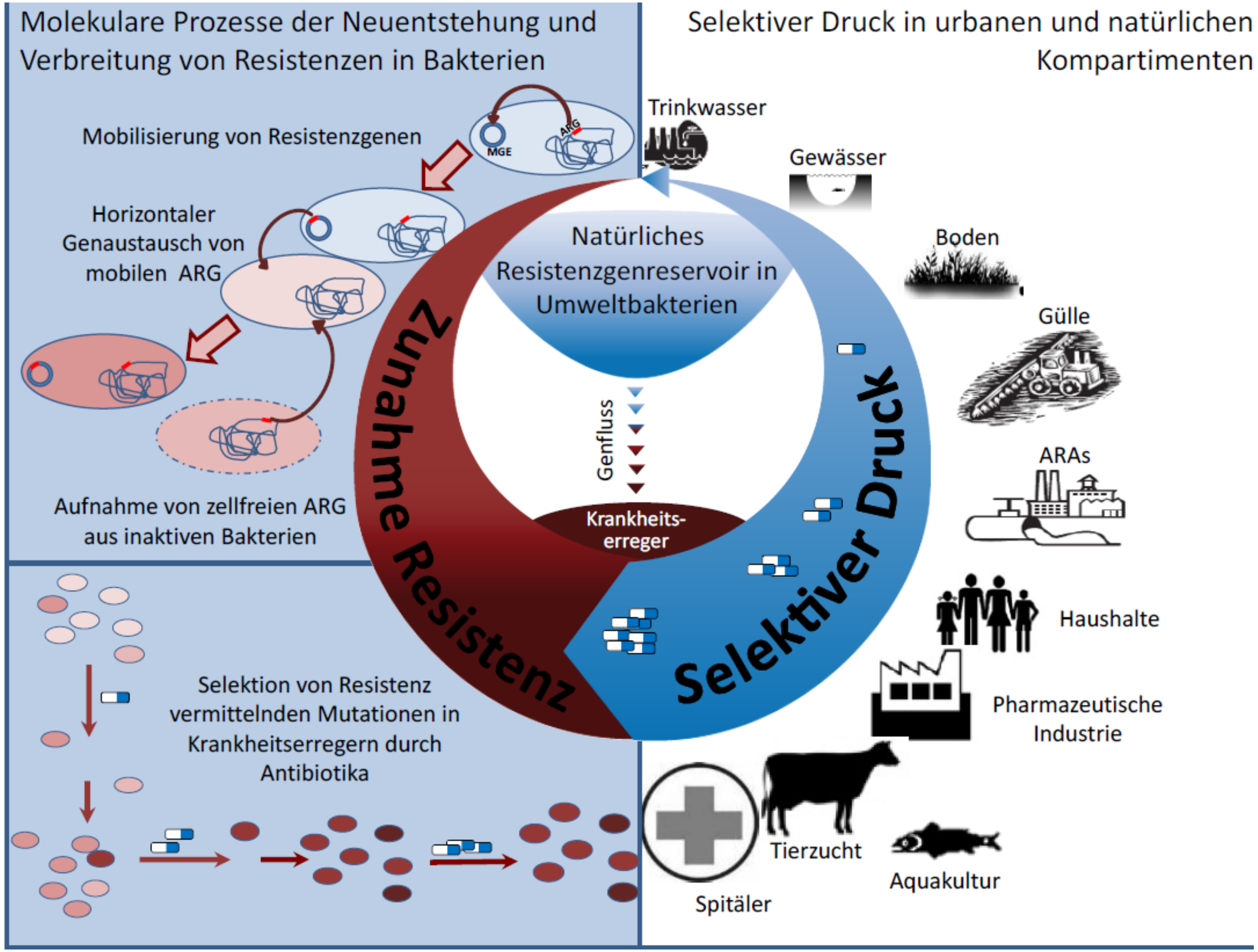
TZW-Schriftenreihe
Bedeutung von Antibiotikaresistenzen für die Rohwasserqualität: Vorkommen, Transport und natürliche Eliminationsprozesse
(2009) ISSN 1434-5765

The End

Estimated total incidence of bloodstream infections with resistance phenotype (n per 100 000 population) and trend, 2019-2023, as well as the percentage change 2019-2023, by bacterial species and antimicrobial group/agent, Germany

Bacterial species	Antimicrobial group/agent	Estimated incidence[a] of isolates from bloodstream infections with resistance phenotype (n per 100 000 population)						
		2019	2020	2021	2022	2023	Trend 2019-2023[b]	Change 2019-2023 (%)[c]
E. coli	Aminopenicillin (amoxicillin/ampicillin) resistance	50.64#	48.94#	44.66#	45.75#	47.05#	↓	-7.1
	Third-generation cephalosporin (cefotaxime/ceftriaxone/ceftazidime) resistance	12.02#	10.74#	9.07#	9.58#	10.23#	-	-14.9
	Carbapenem (imipenem/meropenem) resistance	0.01#	0.02#	0.04#	0.04#	0.05#	↑	+400.0
	Fluoroquinolone (ciprofloxacin/levofloxacin/ofloxacin) resistance	18.28#	17.14#	14.61#	15.40#	17.47#	-	-4.4
	Aminoglycoside (gentamicin/netilmicin/tobramycin) resistance[d]	8.53#	7.41#	5.28#	4.95#	5.33#	↓	-37.5
	Combined resistance to third-generation cephalosporins, fluoroquinolones, and aminoglycosides[d]	3.20#	2.71#	2.11#	1.80#	2.03#	↓	-36.6
K. pneumoniae	Third-generation cephalosporin (cefotaxime/ceftriaxone/ceftazidime) resistance	2.57#	2.38#	2.33#	2.32#	2.32#	-	-9.7
	Carbapenem (imipenem/meropenem) resistance	0.20#	0.11#	0.18#	0.23#	0.25#	-	+25.0
	Fluoroquinolone (ciprofloxacin/levofloxacin/ofloxacin) resistance	2.76#	2.54#	2.41#	2.61#	2.69#	-	-2.5
	Aminoglycoside (gentamicin/netilmicin/tobramycin) resistance[d]	1.52#	1.17#	0.93#	0.90#	0.86#	↓	-43.4
	Combined resistance to third-generation cephalosporins, fluoroquinolones, and aminoglycosides[d]	0.99#	0.77#	0.57#	0.65#	0.63#	↓	-36.4
P. aeruginosa	Piperacillin-tazobactam resistance	1.08#	1.12#	1.30#	1.31#	1.33#	↑	+23.1
	Ceftazidime resistance	0.94#	0.96#	1.04#	0.96#	0.98#	-	+4.3
	Carbapenem (imipenem/meropenem) resistance	1.21#	1.35#	1.46#	1.25#	1.27#	-	+5.0
	Fluoroquinolone (ciprofloxacin/levofloxacin) resistance	1.26#	1.03#	0.98#	0.93#	0.92#	↓	-27.0
	Aminoglycoside (gentamicin/netilmicin/tobramycin) resistance[e]	0.38#	0.17^#	0.17#	0.20#	0.16#	NA	-57.9
	Combined resistance to ≥3 antimicrobial groups (among piperacillin-tazobactam, ceftazidime, carbapenems, fluoroquinolones and aminoglycosides)[e]	0.58#	0.59^#	0.60^#	0.60#	0.60#	NA	+3.4
Acinetobacter species	Carbapenem (imipenem/meropenem) resistance	0.04#	0.07#	0.09#	0.08#	0.08#	-	+100.0
	Fluoroquinolone (ciprofloxacin/levofloxacin) resistance	0.10#	0.11#	0.12#	0.11#	0.11#	-	+10.0
	Aminoglycoside (gentamicin/netilmicin/tobramycin) resistance[d]	0.08#	0.09#	0.08#	0.09^#	0.06#	-	-25.0
	Combined resistance to carbapenems, fluoroquinolones and aminoglycosides[d]	0.03#	0.04^#	0.05#	0.05^#	0.04#	-	+33.3
S. aureus	MRSA[f]	3.56#	2.91#	2.64#	2.24#	2.44#	↓	-31.5
S. pneumoniae	Penicillin non-wild-type[g]	0.50#	0.29#	0.32#	0.44#	0.63#	-	+26.0
	Macrolide (azithromycin/clarithromycin/erythromycin) resistance	0.67#	0.35#	0.27#	0.47#	0.65#	-	-3.0
	Combined penicillin non-wild-type and resistance to macrolides[g]	0.25#	0.10#	0.09#	0.20#	0.27#	-	+8.0
E. faecalis	High-level gentamicin resistance	1.25^#	1.38^#	1.33^#	1.37^#	1.40^#	-	+12.0
E. faecium	Vancomycin resistance	3.28#	3.18#	3.51#	2.71#	1.86#	↓	-43.3

Resistente Bakterien, Gentransfer und Selektionsdruck



Thomas U. Berendonk | https://tu-dresden.de/hydrobiologie | limnologie@tu-dresden.de thomas.berendonk@tu-dresden.de | TECHNISCHE UNIVERSITÄT DRESDEN | Institut für Hydrobiologie

Mögliche Methoden des AMR monitoring

Kontrollen - Behandlungstechnologien

DSWAP Removal Efficiency Datal ×

limno-live.hydro.tu-dresden.de/dkneis/prototypes/dswap/

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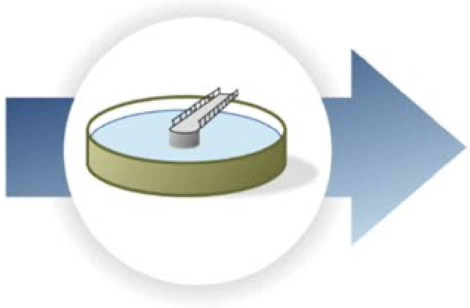

DSWAP

SCAN ME

Mögliche Methoden des AMR monitoring

Kontrollen - Behandlungstechnologien