ARHAI Scotland

Antimicrobial Resistance and Healthcare Associated Infection

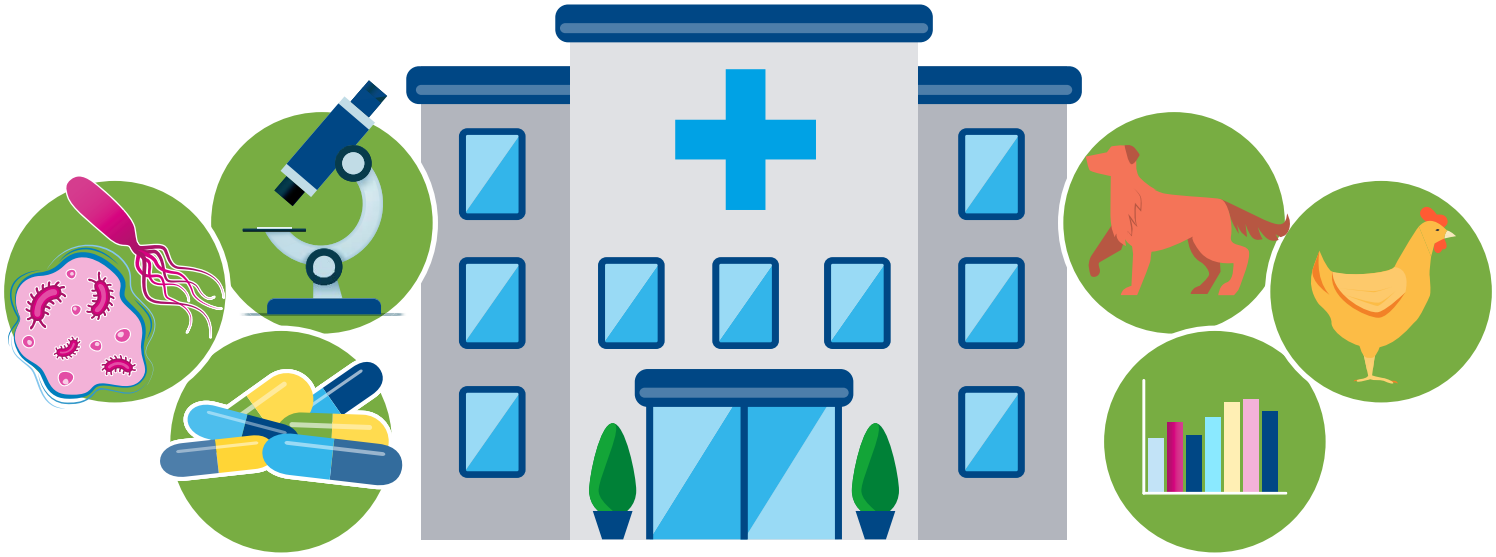
NHS National Services Scotland

Scottish One Health Antimicrobial Use and Antimicrobial Resistance in 2022

Annual Report

Publication date:
21 November 2023

Contents



Alternative formats
If you require this document in an alternative format, please contact **nss.communications@nhs.scot**

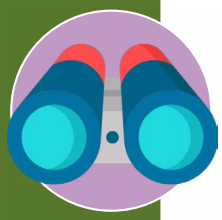
Contact
William Malcolm
Pharmaceutical Adviser and Clinical Lead for Scottish One Health Antimicrobial Use and Antimicrobial Resistance programme
NHS National Services Scotland
Email: **NSS.ARHAIsonaar@nhs.scot**

Reference this document as:
Antimicrobial Resistance and Healthcare Associated Infection Scotland. Scottish One Health Antimicrobial Use and Antimicrobial Resistance in 2022. ARHAI Scotland, Glasgow 2023 [Report]

About ARHAI Scotland

ARHAI Scotland's overall vision is to

Enable Scotland to have a world leading approach to reducing the burden of infection and antimicrobial resistance (AMR).



Our mission is to

Improve the health and wellbeing of the population by reducing the burden of infection and antimicrobial resistance within Scottish care settings.

We will do this by

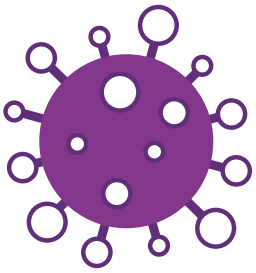
Establishing a robust evidence base for practice and building mechanisms for monitoring key priority areas, connecting with the wider health and social care and public health system and collaborating with key delivery partners including NHS boards, care providers and other national bodies as commissioned by the Scottish Government.

The work of ARHAI Scotland is underpinned by delivering a wide range of functions, working with stakeholders across health and care, and beyond to fulfil these functions. The Scottish One Health Antimicrobial Use and Antimicrobial Resistance (SONAAR) programme is one of six priority programmes that contributes to ARHAI Scotland's mission to improve the health and wellbeing of the population by reducing the burden of infection and AMR.

The SONAAR programme aims to:

- Take an internationally recognised 'One Health' approach to tackling AMR which acknowledges that the health of humans, animals and the environment are interconnected.
- Provide intelligence and evidence for action, informing the development of local and national interventions and initiatives to tackle AMR.
- Sustain actions to preserve antimicrobials, reduce drug resistant infections and reduce our service users' risk from infections caused by micro-organisms that are resistant to antimicrobials.

The impact of the COVID-19 pandemic



The COVID-19 pandemic impacted healthcare delivery in both hospital and community settings. Priorities were adjusted to respond to the pandemic, leading to changes to delivery of services and to the patient population, including a new cohort of patients being treated for COVID-19. This makes comparisons with previous years difficult, therefore results presented in this report must be interpreted in the context of the pandemic and with due caution.

For further information on how COVID-19 has impacted healthcare delivery please see the **ARHAI Scotland 2022 Annual Report.**

What is antimicrobial resistance and what is being done to control it?

Antimicrobial resistance (AMR) occurs when micro-organisms, such as bacteria, change over time and no longer respond to treatments which can increase the risk of disease spread, severe illness and death. As a result of AMR, antibiotics and other antimicrobial treatments become ineffective and infections become increasingly difficult or impossible to treat.

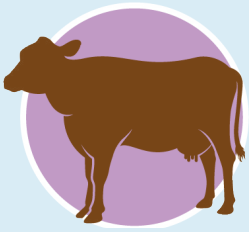
Antimicrobial use (AMU) and spread of micro-organisms in humans, animals and the environment contribute to the development of resistant infections. Development of AMR is a complex evolutionary process. The main causes of AMR are shown below:

Causes of Antibiotic Resistance

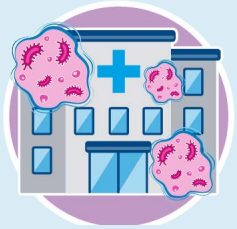
AMR happens when bacteria change and become resistant to the antibiotics used to treat the infections they cause

Over-prescribing of antibiotics

Patients not finishing their treatment



Over-use of antibiotics in livestock and fish farming

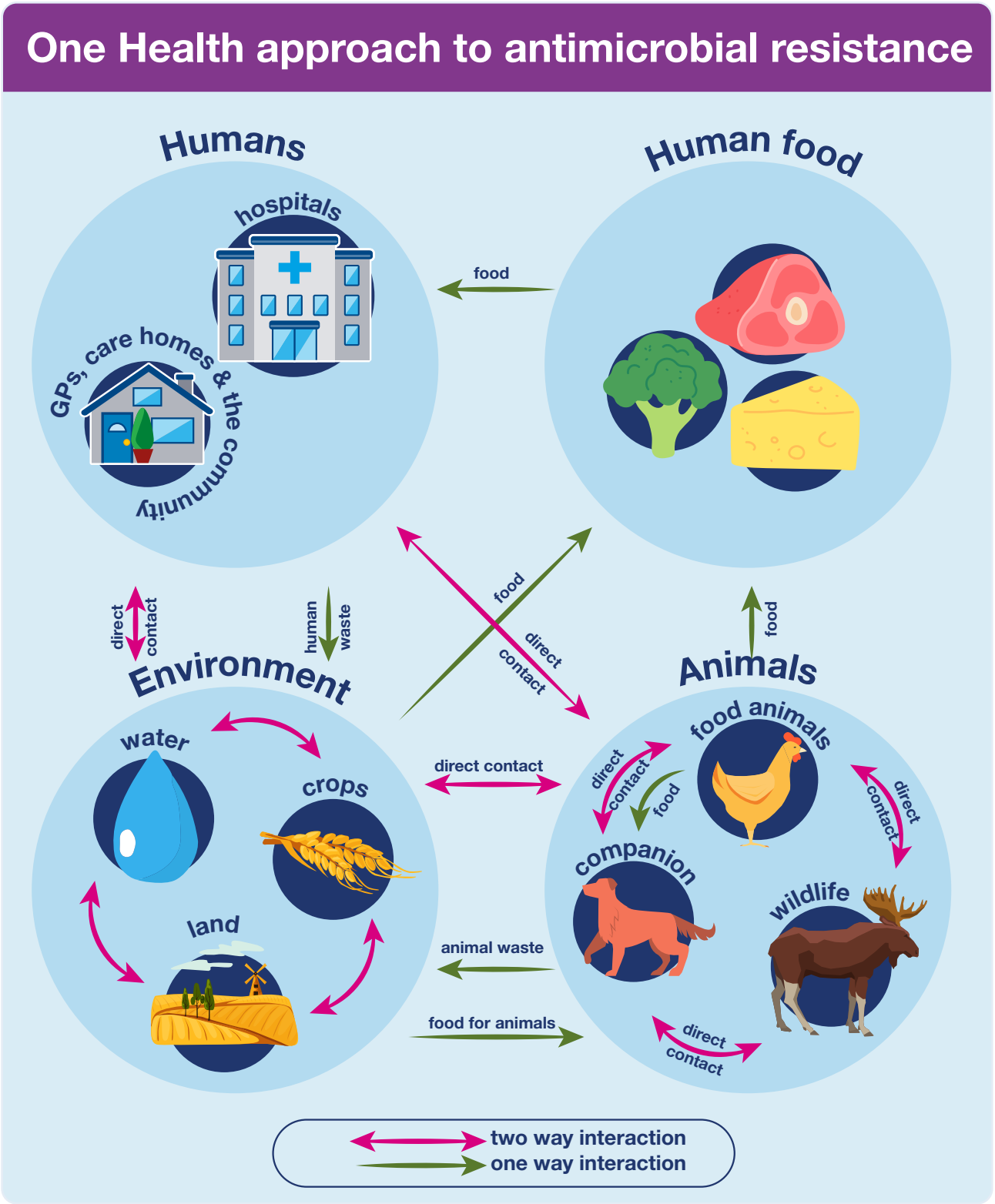


Poor infection control in hospitals and clinics

Lack of hygiene and poor sanitation

Lack of new antibiotics being developed

A co-ordinated cross sectoral response is needed to address the threat from AMR. This is called a ‘One Health’ approach, which recognises that many of the same bacteria infect humans and animals and may be found in the environment as they share the same ecosystem. The links and transmission between different species and parts of the ecosystem are complex (see graphic below) and so efforts in all sectors are required to reduce the threat from AMR.



AMR is a global concern. Actions to tackle AMR in Scotland, within the UK and internationally are underway with ARHAI Scotland playing its part. In January 2019, the UK Government published a vision for AMR in 20 years '**Contained and controlled: The UK's 20-year vision for antimicrobial resistance**' and a five-year national action plan '**Tackling antimicrobial resistance 2019–2024**'.

ARHAI Scotland is actively contributing to the development of the next five-year AMR UK action plan (2024-2029) and will have a continued role in providing intelligence and evidence to support optimisation of antibiotic use and containment and control of AMR across all sectors. This will be delivered through ongoing development of epidemiological evidence on trends in AMU and AMR to inform local and national interventions and initiatives in human and animal health.

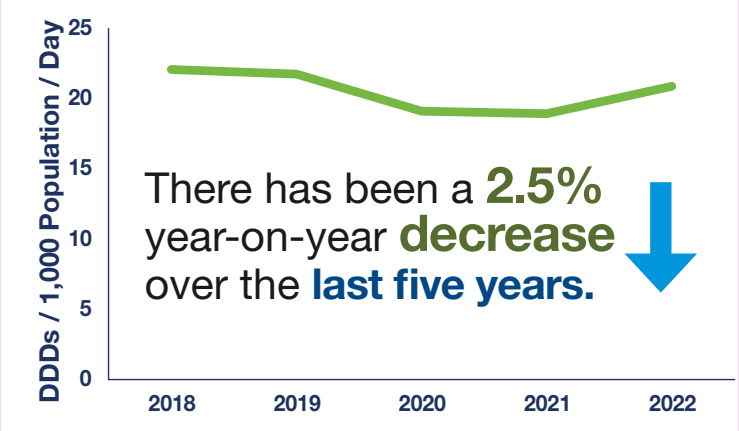
Antimicrobial use in humans

Total antibiotic use in humans

Total use of antibiotics in humans

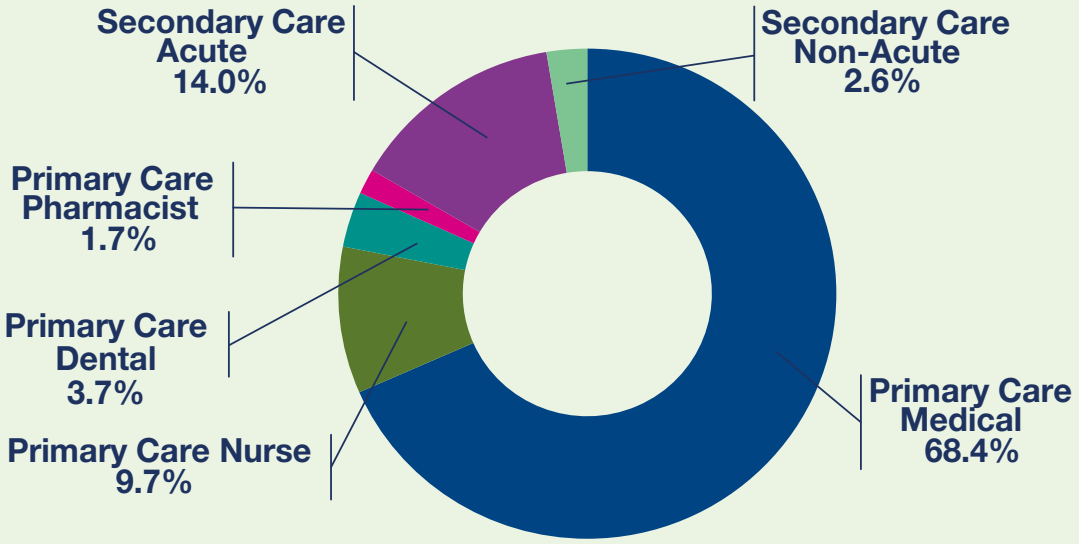
In **2022, 21.0 defined daily doses (DDDs)** per 1,000 population per day (DDDs/1,000/day) were used.

There has been a **10.2% increase** in the rate between **2021** and **2022.**



Antibiotic use in Scotland by prescriber type

Optimisation of antibiotic use by all clinicians in all settings is required. In **2022**, **83.4%** of antibiotic use (DDDs) was in primary care. Antibiotic use in acute hospitals accounted for **14.0%** of antibiotic use (DDDs) with non-acute hospitals accounting for **2.6%**.



Percentage of all antibiotics in Scotland that belonged to the Access group

To avoid unnecessary use of broad-spectrum antibiotics an adapted version of the **World Health Organization (WHO) Access, Watch, Reserve (AWaRe)** classification of antibiotics is used to monitor antibiotic use in Scotland. Access antibiotics should be used as first line treatment for most common infections.

In **2022, Access antibiotics** accounted for **64.3%** of total antibiotic use, compared to **62.4%** in **2021**.

There has been a **1.9%** year-on-year **increase** over the **last five years**.

This may reflect increasing compliance with prescribing policies.

ARHAI Scotland will continue to make available clinically meaningful intelligence on antibiotic use in humans through **Discovery dashboards**. This enables NHS boards to track local progress against Scottish Government standards on antibiotic use and to identify areas for targeted local improvement activity.

For detailed information on use of different antibiotics see **Supplementary Data**.

For further information on Discovery Dashboards see **Public Health Scotland.**

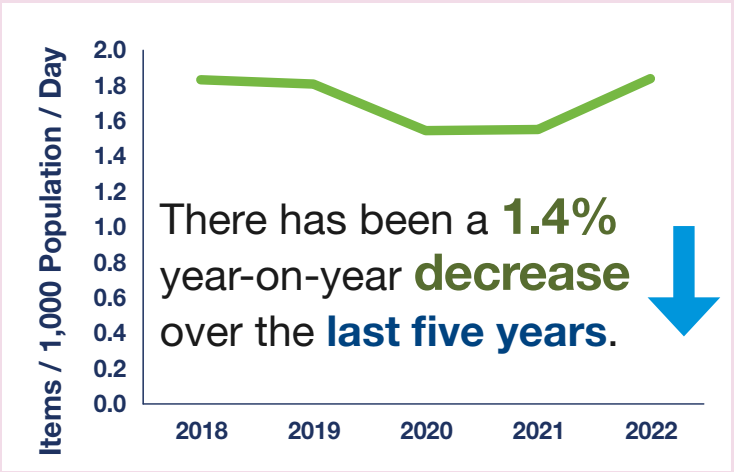
Antibiotic use in primary care

A key approach to optimising antibiotic use in primary care is to minimise use for symptoms such as coughs, colds, sore throats, and earache in otherwise fit and healthy people. Resistance is a natural consequence of using antibiotics, but overuse and inappropriate use can unnecessarily increase the rate of development of resistance.

Antibiotic use in primary care (excluding dental)

In **2022**, **1.8 items** per 1,000 population per day were used.

There has been an **18.4% increase** in the rate between **2021** and **2022**.

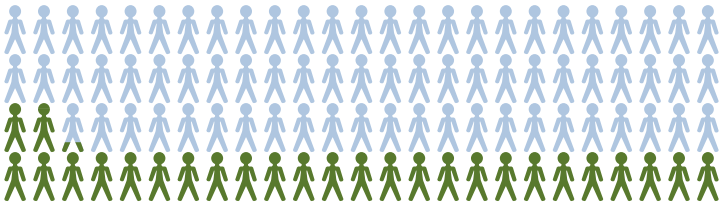


There has been a **1.4%** year-on-year **decrease** over the **last five years**.

When expressed using DDDs, antibiotic use in **2022** was **16.7 DDDs** per 1,000 population per day compared to **15.1** in **2021**.

There has been a **2.6%** year-on-year **decrease** over the **last five years**.

In **2022**, **27.3%** of the Scottish population received **at least one course of antibiotics** in primary care, excluding dental.

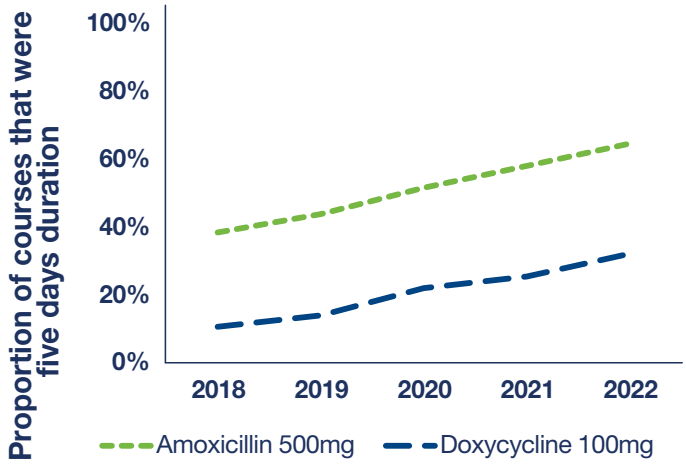


In **2022**, **79.6%** of antibiotic items were from the **Access category**, compared to **77.6%** in **2021**.

Duration of treatment

When antibiotics are clinically appropriate, unnecessary exposure can be avoided by using the recommended evidence based duration specified within prescribing guidelines. Respiratory infections are commonly encountered in primary care and prescribing guidelines reflect the evidence that for treatment of respiratory infection, when antibiotics are clinically indicated, a five-day course is recommended.

In **2022**, **64.7%** of courses of **amoxicillin 500mg capsule** prescriptions were for **five days duration**, compared to **58.1%** in **2021**.



In **2022**, **32.2%** of courses of **doxycycline 100mg capsule** prescriptions were for **five days** duration, compared to **25.5%** in **2021**.

This may suggest improving compliance with antibiotic prescribing policies, however there is room for further optimisation.

Of the total number of antibiotic items prescribed in primary care in 2022

73.3% of **all antibiotic items** were written by **GPs**

14.3% of items were written by **nurse prescribers**

8.6% were written by **dentists**

3.7% were written by **pharmacists**

This multi-professional approach to antibiotic prescribing in primary care in Scotland reflects changes in how individuals present for care and treatment in the community. This must be considered in communications and education to optimise antibiotic use through local and national antimicrobial stewardship initiatives.

For detailed information on antibiotic use in primary care see **Supplementary Data**.

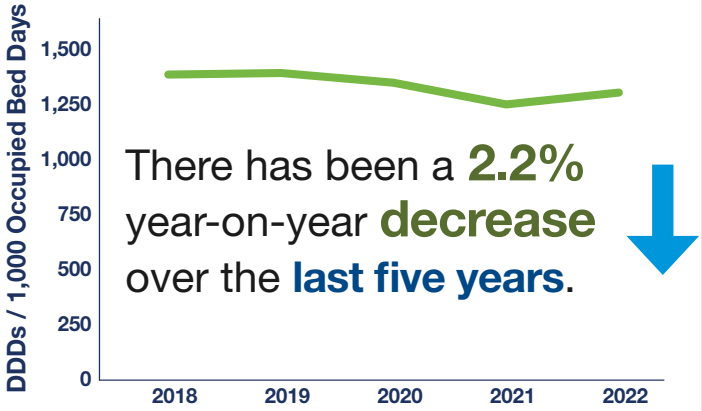
Antibiotic use in acute hospitals

Most suspected bacterial infections in patients in acute hospitals will be managed empirically. The choice of initial empirical antibiotic treatment will be based on evidence based antibiotic guidelines. These guidelines are intended to support clinicians through promoting use of narrow spectrum antibiotics where appropriate and minimising inappropriate use of broader spectrum treatments.

Antibiotic use in acute hospitals

In **2022**, antibiotic use was **1,311.8 DDDs** per 1,000 occupied bed days.

There has been a **4.3% increase** in the rate between **2021** and **2022**.



There has been a **2.2%** year-on-year **decrease** over the **last five years**.

Choice of antibiotic

Access antibiotics accounted for **63.6%** of total antibiotic use in **2022**, compared to **64.3%** in **2021**.

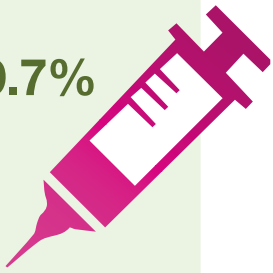
In **2019**, a **national indicator** was developed by Scottish Government with support from ARHAI Scotland and Scottish Antimicrobial Prescribing Group (SAPG), to encourage **compliance with local antibiotic prescribing policies** and minimise inappropriate use of broad spectrum antibiotics.

National indicator: at least 60% of total antibiotic use in acute hospitals to be Access antibiotics by 2023.

Indicator currently achieved

Route of administration

Regular clinician review of hospital patients receiving antibiotics by intravenous (IV) injection to prompt switching to oral therapy or discontinuing antibiotics remains an important element of antimicrobial stewardship in Scotland.



In **2022**, **antibiotics given intravenously** accounted for **29.7%** of total antibiotic use (DDDs) in acute hospitals compared to **31.6%** in **2021**.

A **national indicator** was developed to measure progress with achieving reliable and timely review of IV antibiotic therapy: **IV antibiotic use in secondary care to be no higher in 2023 than in 2018.**

In **2022**, the rate of **IV antibiotic use** in all secondary care was **0.9 DDDs** per 1,000 population per day compared to **0.8** in **2021** and **0.9** in **2018**.

For detailed information on antibiotic use in acute hospitals see **Supplementary Data**.

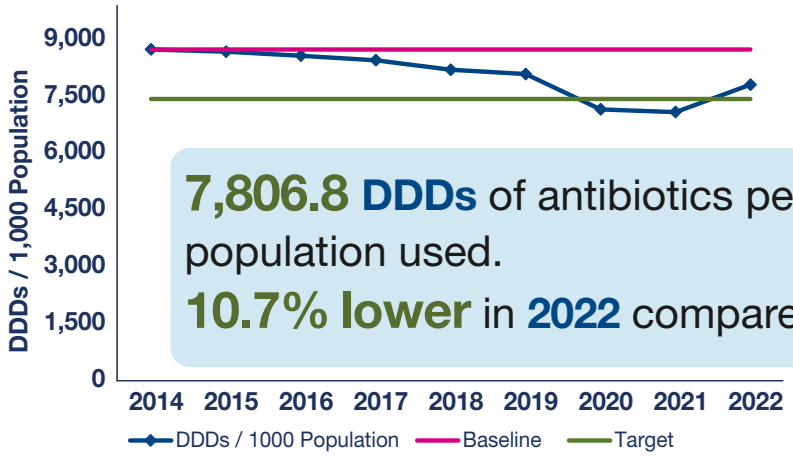
UK Antimicrobial Use National Action Plan Targets

The UK antimicrobial resistance national action plan '**Tackling antimicrobial resistance 2019–2024**' sets out measures of success to ensure progress, including targets on antimicrobial use.

In 2022...

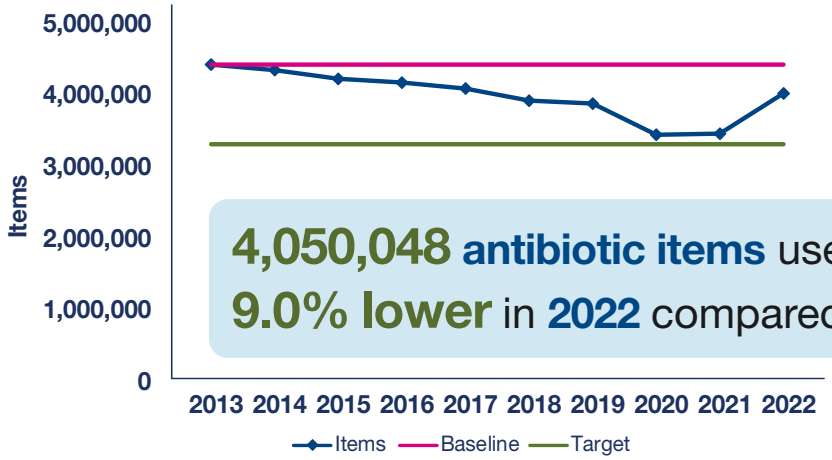
Currently not meeting target

Ambition to reduce antimicrobial use in humans by 15% by 2024 (2014 baseline)



7,806.8 DDDs of antibiotics per 1,000 population used.
10.7% lower in **2022** compared with **2014**.

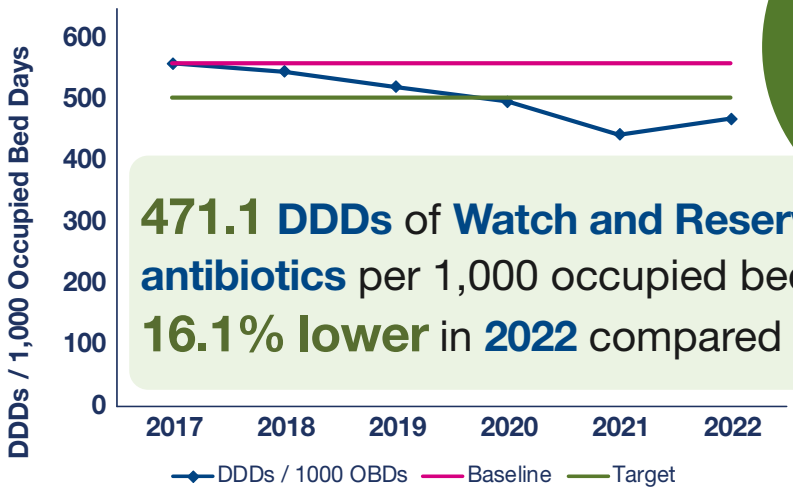
Ambition to reduce primary care antimicrobial use by 25% by 2024 (2013 baseline)



4,050,048 antibiotic items used.
9.0% lower in **2022** compared to **2013**.

Currently meeting target

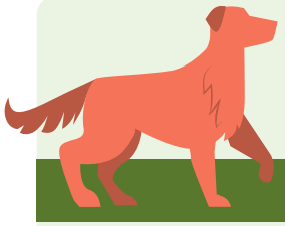
Ambition to reduce use of Watch and Reserve antibiotics by 10% by 2024 (2017 baseline)



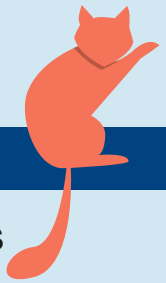
471.1 DDDs of **Watch and Reserve antibiotics** per 1,000 occupied bed days used.
16.1% lower in **2022** compared to **2017**.

Antimicrobial use in companion animals

Data on antimicrobial use (AMU) in dogs and cats were obtained from a small number of veterinary practices in Scotland contributing voluntarily to the **Small Animal Veterinary Surveillance Network (SAVSNET)** and therefore cannot be assumed to be representative of all companion animal practices in Scotland.



In 2022, **13** veterinary practices in Scotland contributed data from **52,513** individual consultations and **30,945** individual animals.



Dogs

15.6% of consultations resulted in prescription of **antimicrobials**.

There has been a **14.2%** **decrease** between **2021** and **2022**.

There has been a **2.6%** year-on-year **decrease** over the **last five years.**

The proportion of prescriptions that were **HP-CIAs*** **remained stable** over the **last five years**.

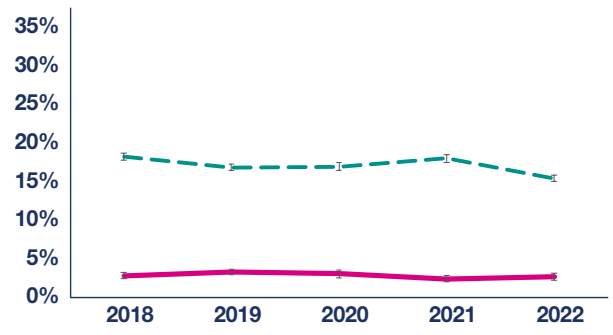
Cats

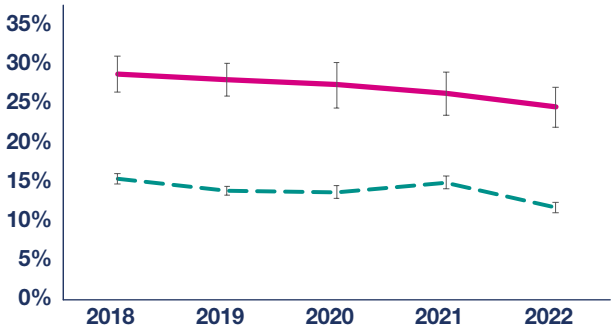
11.9% of consultations resulted in prescription of **antimicrobials**.

There has been a **21.1%** **decrease** between **2021** and **2022**.

There has been a **4.7%** year-on-year **decrease** over the **last five years**.

There was a **3.6%** year-on-year **decrease** in the proportion of prescriptions that were **HP-CIAs*** over the **last five years**.





Consultations resulting in prescription of at least one antimicrobial (%)

Total antimicrobials prescribed that were HP-CIAs* (%)

*Highest priority critically important antimicrobials (HP-CIAs) for human health are: cefovecin, ciprofloxacin, enrofloxacin, marbofloxacin, ofloxacin, orbifloxacin and pradofloxacin

For detailed information on AMU in companion animals see **Supplementary Data**.

Antimicrobial resistance in humans

Important changes to the way antimicrobial resistance is reported in this year's report

Antimicrobial resistance (AMR) susceptibility categories: AMR results included in this report are 'percentage resistant' as opposed to 'percentage non-susceptible' i.e., results reported are for resistant isolates only as opposed to 'intermediate and resistant'.

This aligns with the approach adopted by the **English Surveillance Programme for Antimicrobial Utilisation and Resistance annual report** enabling meaningful comparisons to be made and provides consistent metrics for the ambitions of the 2019 to 2024 UK five-year AMR national action plan (NAP).

European Committee on Antimicrobial Susceptibility Testing (EUCAST) Breakpoint Changes: Throughout 2022, the majority of Scottish NHS microbiology diagnostic laboratories, on a phased basis, changed to the EUCAST breakpoint table version 12.0. Breakpoints were generally lower in version 12.0 with some exceptions where the breakpoint increased. This must be considered when interpreting results for this report.

Further details on changes to definitions of susceptibility testing categories and breakpoints are available on the **EUCAST website**.

Antimicrobial resistance in humans

Drug resistant infections are harder to treat and result in prolonged hospital stay, use of more complex antimicrobial therapy and can lead to worse outcomes for patients. Reducing the burden of drug resistant infections is critical to controlling AMR by reducing the further spread of drug resistant micro-organisms and the need for antimicrobials. Robust intelligence and metrics are required to plan, prioritise, and evaluate interventions to reduce the burden.

Antimicrobial Resistance Burden

In **2022**, the most common cause of drug resistant bacteraemia was ***Escherichia coli (E. coli)***, followed by ***Klebsiella pneumoniae (K. pneumoniae)*** and ***Enterococcus faecium (E. faecium)***.

16.7% of bacteraemia were resistant to **at least one** key antibiotic, an estimated **1,372** resistant bacteraemia.

Of those, **87.5%** were caused by drug resistant **Gram-negative bacteria.**

24.1% of ***E. coli* bacteraemia** in Scotland were resistant to **at least one** key antibiotic.

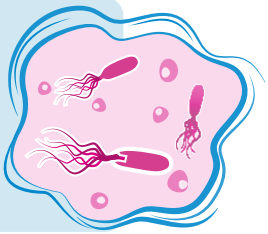
ARHAI Scotland share these data alongside Gram-negative bacteraemia data to allow the UK Government to monitor progress against the ambitions laid out in the UK five-year AMR NAP.

For more information on the burden of drug resistant bacteraemia see **Supplementary Data**.

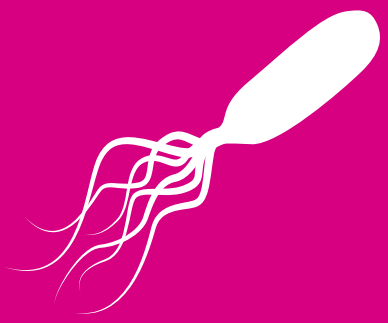
Antimicrobial resistance in Gram-negative organisms

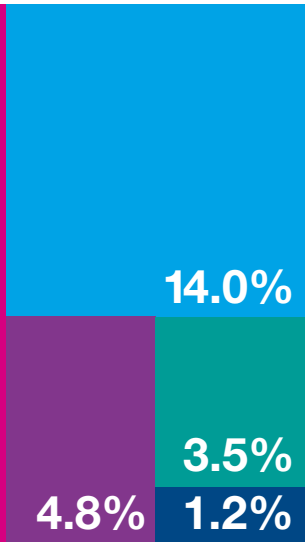
Gram-negative bacteria are a common cause of serious infection in both healthcare and community settings. AMR in Gram-negative bacteria, particularly *E. coli*, significantly contributes to the overall burden of AMR.

In **2022**, there were **5,506 Gram-negative bacteraemia** in Scotland caused by the **five Gram-negative pathogens** which are routinely monitored by ARHAI Scotland.



***E. coli* was the most common cause of Gram-negative bacteraemia with an incidence of 77.0 per 100,000 population.**

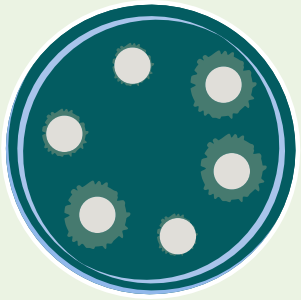




- *Escherichia coli*
- *Klebsiella pneumoniae*
- *Pseudomonas aeruginosa*
- *Klebsiella oxytoca*
- *Acinetobacter* species

Resistance to key antibiotics in **Gram-negative bacteraemia** has **remained stable** between **2021** and **2022**.

With the exception of ***E. coli* bacteraemia** where resistance to **temocillin decreased**.



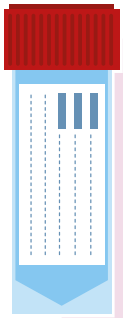
AMR in Gram-negative bacteraemia data:

- Are shared via **Discovery Dashboards** enabling board comparisons.
- Inform quality improvement initiatives.
- Guide empirical antibiotic use to improve patient outcomes.

For information on AMR in Gram-negative organisms see **Supplementary Data**.
For further information on Discovery Dashboards see **Public Health Scotland.**

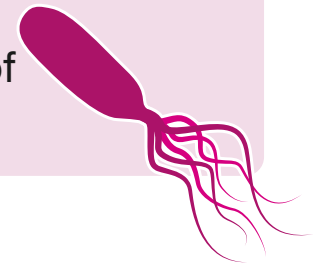
Urinary tract infections caused by *Escherichia coli*

Urinary tract infections (UTIs) are commonly diagnosed in community and healthcare settings and AMR in urinary isolates significantly adds to the burden of AMR. Monitoring AMR in urinary isolates provides intelligence that underpins decision making and local prescribing policies.



E. coli was the most commonly reported organism in urinary isolates.

In **2022**, there were **142,615** episodes of ***E. coli*** isolated from urine.



Resistance to key antibiotics in ***E. coli* urinary isolates remained stable** between **2021** and **2022**.

With the exception of resistance to **co-amoxiclav**, **nitrofurantoin** and **piperacillin-tazobactam** which **decreased**.

ARHAI Scotland use these data to support the Scottish Antimicrobial Prescribing Group (SAPG) and NHS boards' antimicrobial management teams to optimise antibiotic prescribing and stewardship ensuring empiric guidelines are based on current trends in AMR.

For further information on AMR in *E. coli* urinary isolates see **Supplementary Data**.

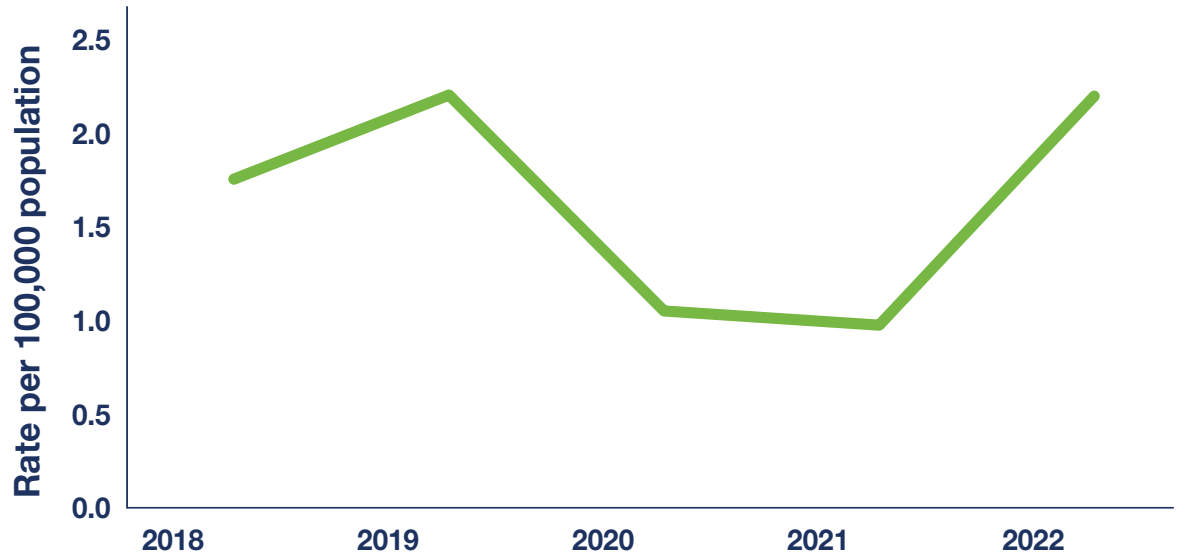
Carbapenemase-producing organisms

Carbapenems are beta-lactam antibiotics with a very broad spectrum of activity, often reserved as last-line agents for the treatment of bacterial infections. The primary mechanism of carbapenem resistance is the production of acquired carbapenemases, enzymes which inactivate carbapenem antibiotics rendering many beta-lactams ineffective. Bacteria that have the ability to do this are referred to as carbapenemase-producing organisms (CPOs).

In **2022**, there were **121** cases of **CPO** reported in Scotland, compared to **54** in **2021**.

The annual **CPO incidence** rate was **2.2** per 100,000 population.

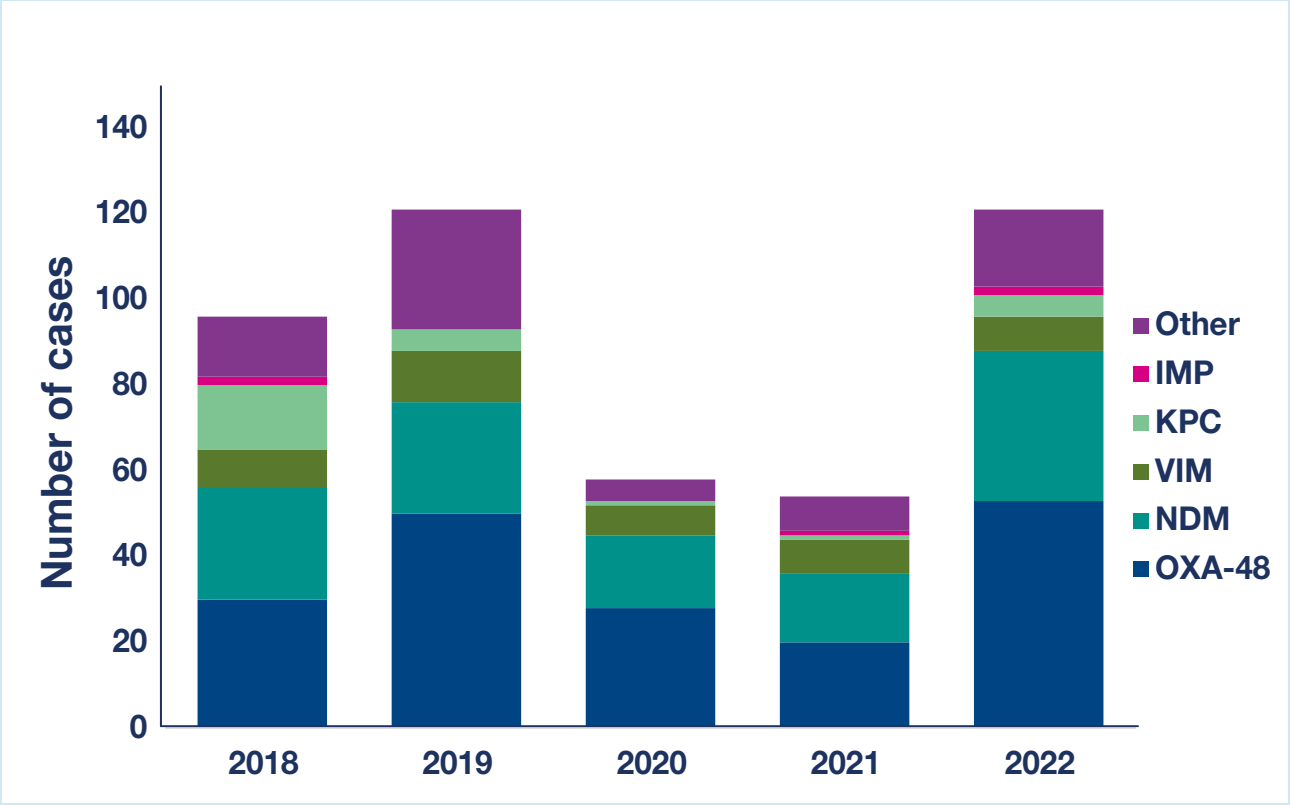
The incidence of CPO reduced during the COVID-19 pandemic in line with fewer hospital admissions and restrictions on international travel. CPO incidence has returned to pre-pandemic levels in 2022.



84.3% of CPOs identified in **2022** were **carbapenemase-producing Enterobacterales**.

The remaining were **non-fermenters** such as *Acinetobacter* species and *Pseudomonas aeruginosa*.

In **2022**, the most frequently identified enzyme genes were **Oxacillinase (OXA)-48** and **New Delhi Metallo-beta-lactamase (NDM)**.



In 2023, ARHAI Scotland will continue to develop further intelligence relating to CPO epidemiology in Scotland. The findings will be used to support SAPG and the Scottish Microbiology and Virology Network, driving forward the antibiotic stewardship agenda.

For further information on CPOs see **Supplementary Data**.

Antimicrobial resistance in Gram-positive organisms

Enterococcal bacteraemia

Enterococci are distributed widely in nature and are found in humans, animals, soil, food and plants. They are a commensal of the gastrointestinal tract of most species, including humans. *Enterococcus* species survive in harsh environments and can cause infections in humans such as UTI, infective endocarditis and bacteraemia.

In **2022**, the annual **incidence** of ***Enterococcus faecalis (E. faecalis)*** and ***E. faecium*** **bacteraemia** was **8.5** and **5.3** per 100,000 population, respectively.

The annual **incidence** of ***E. faecalis*** and ***E. faecium*** **bacteraemia** has **remained stable** over the **last five years**. 

AMR in ***E. faecium*** and ***E. faecalis*** blood isolates has **remained stable** between **2021** and **2022**. 

Vancomycin resistance was reported in **40.0%** of ***E. faecium*** blood isolates and **0.5%** of ***E. faecalis*** blood isolates.

Scotland has one of the highest reported proportions of vancomycin resistance in *E. faecium* blood isolates in Europe. Infections caused by vancomycin resistant enterococci (VRE) are associated with higher mortality rates compared with those caused by vancomycin sensitive enterococci. During 2023, work will commence, adopting a One Health approach, to better understand the population at risk and to inform future work, policies, and interventions with respect to VRE.

For more information on AMR in enterococcal bacteraemia see **Supplementary Data**.

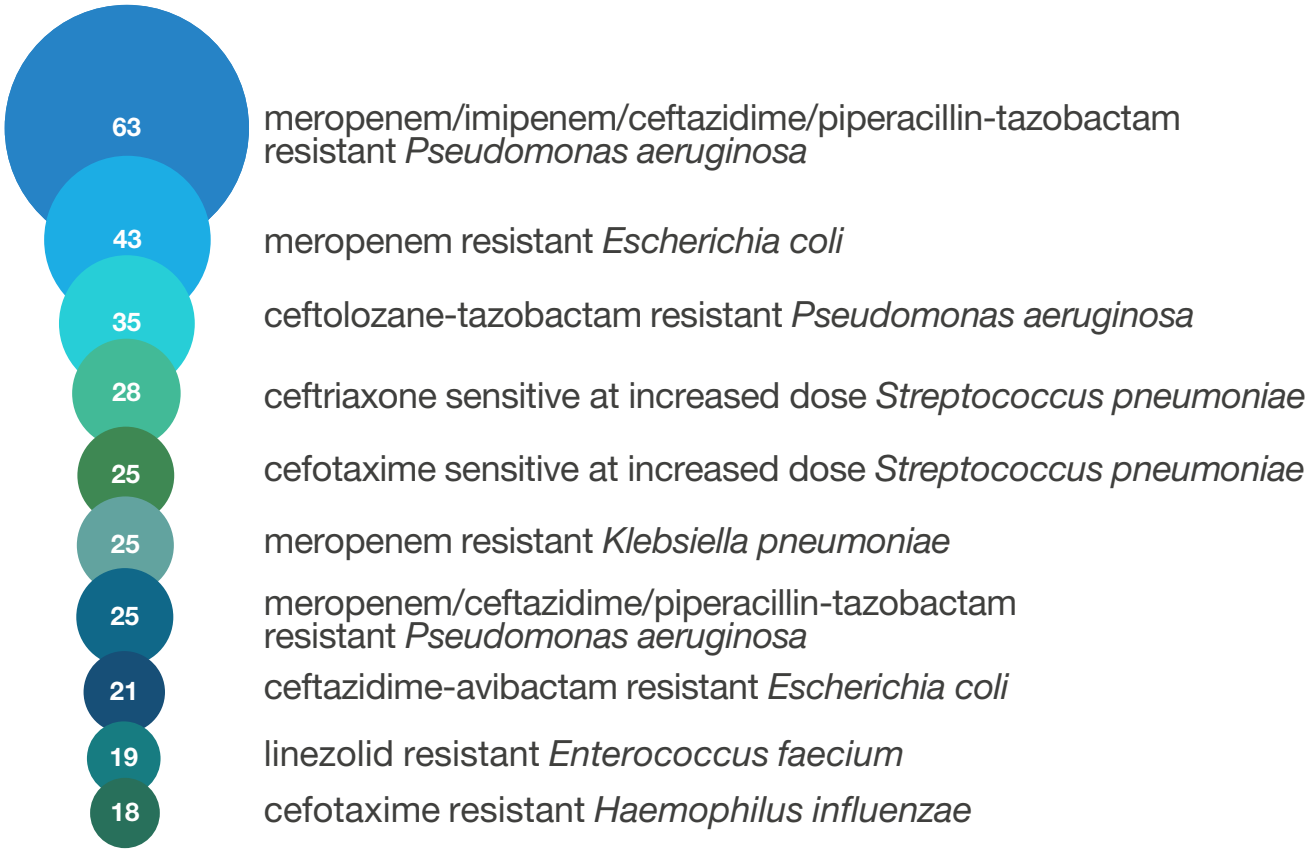
Unusual phenotypes

An unusual phenotype is an instance of unexpected resistance in an organism. ARHAI Scotland monitor unusual phenotypes, as per **Appendix 13** of the **National Infection Prevention and Control Manual**, to enable a timely scientific and public health response to potential emerging AMR issues. This informs infection control practices and appropriate therapy, and is critical to contain the development and spread of resistance. Additionally, ARHAI Scotland communicate any identified issues with other public health bodies as necessary.

Local monitoring ensures that microbiology clinicians, infection prevention and control teams, and health protection teams, as appropriate, are aware of each identified case as per local protocols.

In **2022**, **547** instances of unusual phenotypes were reported through the **AMR Early Warning System**.

The **ten most frequently reported** unusual phenotypes were:



ARHAI Scotland will continue to monitor unusual AMR incidents throughout 2023.

For further information on unusual phenotypes, including those that are less frequently reported, see **Supplementary Data**.

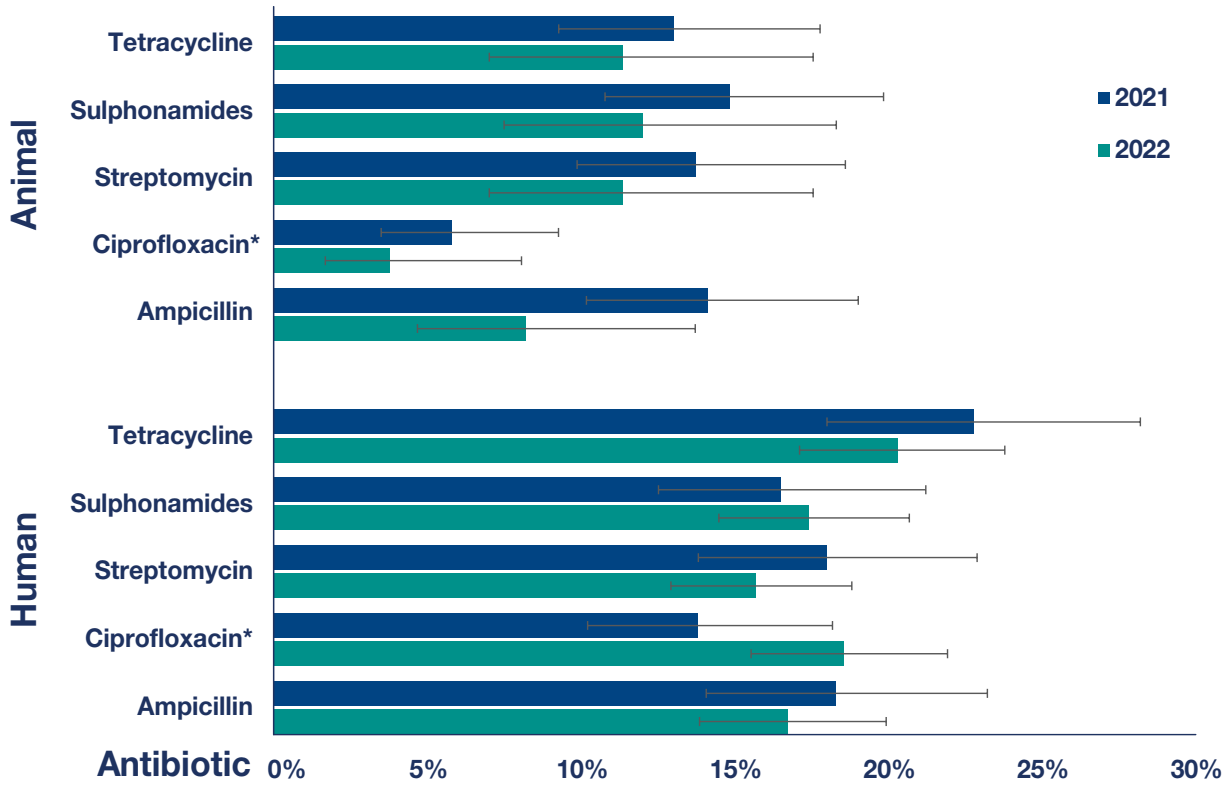
Antimicrobial resistance in *Salmonella*

Salmonella is a Gram-negative bacterium, ubiquitous in nature. *Salmonella* is notifiable in humans and a reportable animal pathogen in the UK. The availability of data from isolates from different source populations (humans and animals) which have undergone the same processing by the same laboratory offers an opportunity to monitor the trends in resistance and identify epidemiological links in these populations.

In humans, *Salmonella* is a common cause of gastrointestinal illness which is usually self-limiting and for which treatment with antibiotics is not routinely recommended. However, in some cases antibiotics may be required, particularly for severe or extraintestinal infections.

Salmonella is a zoonosis – a wide range of domestic and wild animals can act as a reservoir, including cattle, sheep, pigs, poultry, reptiles and household pets. Infected animals are often asymptomatic.

Resistance to key antibiotics **remained stable** between **2021** and **2022** for animals and humans.



*includes mutations and acquired genes associated with reduced susceptibility (minimum inhibitory concentration > 0.06mg/L as recommended by the European Committee on Antimicrobial Susceptibility Testing Jan 2021)

For information on antimicrobial resistance in *Salmonella* from humans and animals see **Supplementary Data**.

Antimicrobial resistance in animals

Antimicrobial resistance in veterinary clinical isolates from livestock

For 2022, detailed information on antimicrobial resistance (AMR) in veterinary clinical isolates from livestock species are presented in **Supplementary Data**. These data derive from clinical specimens submitted to the farm animal diagnostic services offered by Scotland's Rural College (SRUC) Veterinary Services. These samples are tested on a 'charged for' basis to inform private veterinary treatment of diseased animals. There is a cost to the animal keeper that affects the submission of samples to these services.

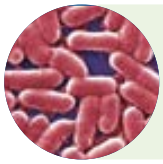
The primary purpose of screening for AMR is to inform veterinary treatment and isolates from animals are tested against a panel of antimicrobials relevant for that purpose at, where they exist, species-relevant clinical breakpoints.

The micro-organisms included are selected based both on their prevalence among all submissions, i.e. their importance as causes of animal morbidity, as well as, in some cases, their similarity to micro-organisms that cause morbidity in humans.

Staphylococcus species are common commensal organisms that can act as important opportunistic pathogens of humans and other animals.

Streptococcus species can be important pathogens or opportunistic colonisers of livestock species, with the potential to cause severe disease of the skin, respiratory tract, body cavities, wounds and urinary tract. Some species, including *Streptococcus agalactiae*, *Streptococcus dysgalactiae*, and *Streptococcus suis*, are also recognised in human infections.

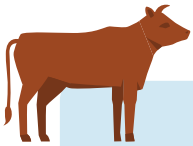
Pasteurellaceae are important causes of potentially severe respiratory and soft tissue infections in livestock animals. In livestock animals, high levels of morbidity and mortality can result with consequential significant economic losses.



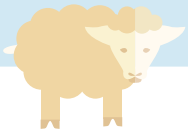
Escherichia coli (E. coli) are a major constituent of the normal faecal flora of humans and warm-blooded animals. However, some strains can cause intestinal and extraintestinal disease.

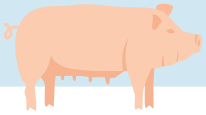
Antimicrobial resistance in *Escherichia coli* isolates from healthy livestock

In addition to diagnostic isolates, *E. coli* collected from enteric samples of healthy animals are tested as a measure of the background resistance in livestock entering the food chain. This is undertaken in collaboration with Food Standards Scotland monitoring AMR in *E. coli* from cattle, sheep, pigs and poultry presenting at abattoirs in Scotland for slaughter for human consumption. The antibiotics tested for resistance were selected for their relevance for human treatment, rather than veterinary practice.



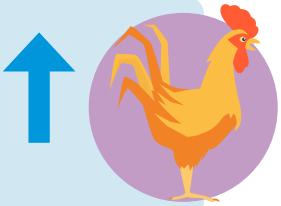
Proportions of antimicrobial resistance to key antibiotics in *E. coli* isolates from pigs, poultry, sheep and cattle over the last five years are presented in the **Supplementary Data**.

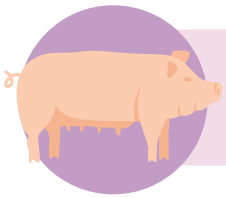




Amongst highest priority critically important antimicrobials for human health and carbapenems, in 2022:

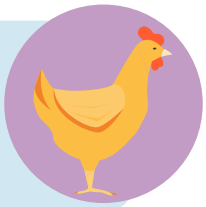
Ciprofloxacin (fluoroquinolone) **resistance increased** in **poultry** and was detected from **14.3%** (62 of 435 tested) of isolates compared to **6.7%** (29 of 435 tested) in **2021**.





Resistance to **ciprofloxacin** was detected in **a single** isolate from **pigs** (0.2% of 476 tested).

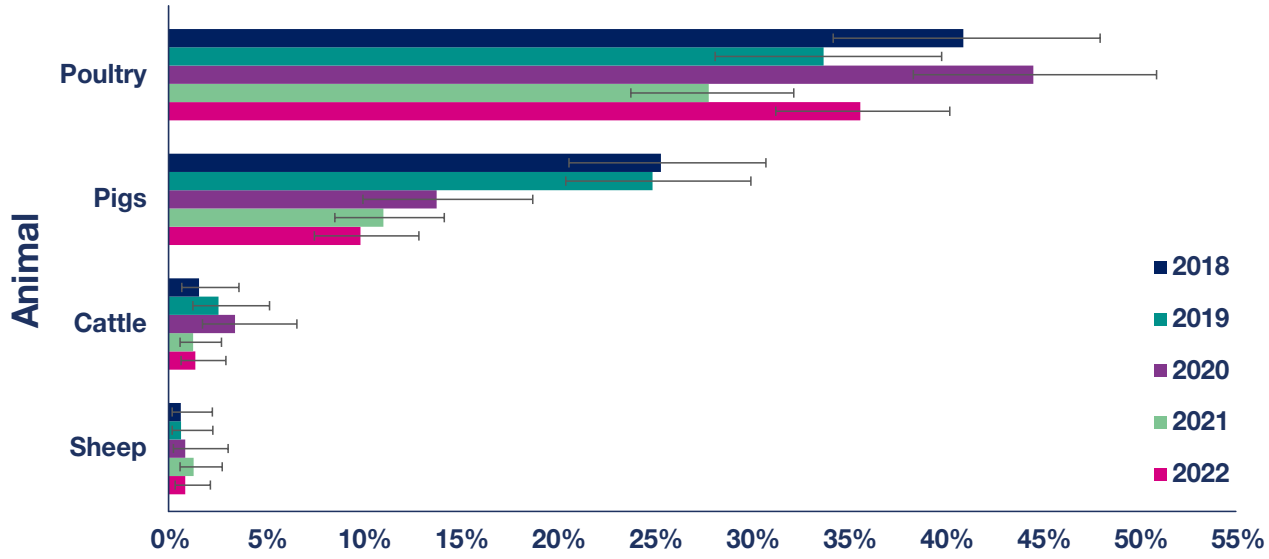
Resistance to **third generation cephalosporins** was detected in **a single** isolate from **poultry** (0.2% of 435 tested).



There was **no resistance** to **ertapenem** detected across all isolates.

Multi Drug Resistance in *E. coli* isolates from healthy livestock

The percentage of multi drug resistant (MDR) *E. coli* isolates reported was **higher** in **poultry and pigs** than in **cattle and sheep**, where MDR was **low and stable**.

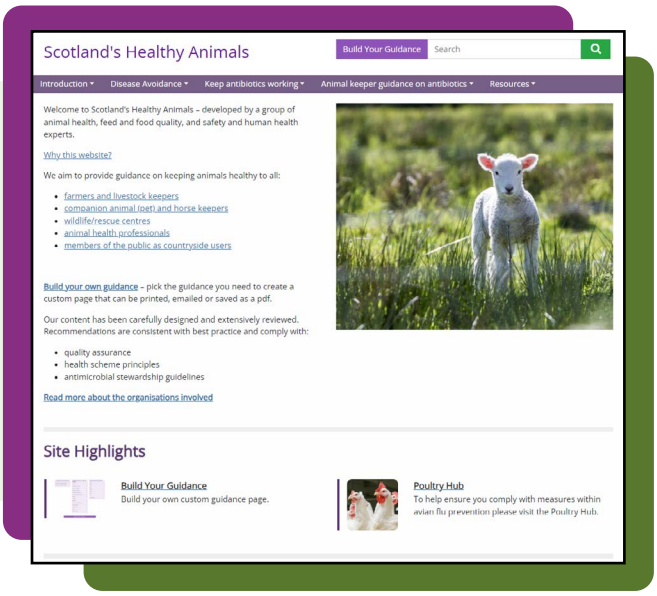


For information on AMR in *E. coli* from healthy animals see **Supplementary Data**.

Scotland's Healthy Animals website

Guidance on keeping animals healthy and antimicrobial stewardship for all animal sectors can be found on the extensively revised **Scotland's Healthy Animals website**.

www.scotlandshealthyanimals.scot



Antimicrobial resistance in the environment

Minimising the spread of antimicrobial resistance (AMR) through the environment remains a UK priority and the UK's five-year national action plan (NAP) sets out the ambitions in this area. The environment has long been recognised as a dispersal route and reservoir of resistant pathogens, and as an arena for the evolution of resistance. Additionally, environmental AMR monitoring can serve as an early warning system for the presence of AMR pathogenic bacteria of public health importance. ARHAI Scotland have worked closely with the Scottish Environment Protection Agency (SEPA) to gather more intelligence to support the environmental AMR ambition.

SEPA analyse water samples for the presence of *Escherichia coli (E. coli)* and intestinal enterococci throughout Scotland's designated bathing water sites during the bathing water season (June to mid-September). In 2018, SEPA started testing and reporting on cefotaxime resistance in *E. coli* (results can be accessed on the **SEPA infographics website**) and recently expanded the repertoire of AMR monitoring to vancomycin resistance in enterococci.

AMR is a global problem affecting humans, the environment and animals and adopting a One Health approach is essential to containing and controlling AMR. In 2023, ARHAI Scotland will continue to work with stakeholders in the environment and animal sectors, in a joint effort, to progress the AMR One Health agenda. Additionally, ARHAI Scotland, in partnership with Public Health Scotland, SEPA, Scotland's Rural College, and others, will support the development of the Scottish Government Waste Water Monitoring Programme.

List of Abbreviations and Acronyms

AMR	Antimicrobial Resistance
AMU	Antimicrobial Use
ARHAI Scotland	Antimicrobial Resistance and Healthcare Associated Infection Scotland
AST	Antimicrobial Susceptibility Testing
AWaRe	Access, Watch, Reserve
CI	Confidence Interval
CHI	Community Health Index
CLSI	Clinical and Laboratory Standards Institute
COVID-19	Coronavirus disease 2019
CPO	Carbapenemase-producing Organism
DDDs	Defined Daily Doses
E. coli	*Escherichia coli*
EDRIP	ECOSS Roll-out Implementation Programme
E. faecalis	*Enterococcus faecalis*
E. faecium	*Enterococcus faecium*
ECDC	European Centre for Disease Prevention and Control
ECOSS	Electronic Communication of Surveillance in Scotland
ESPAUR	English Surveillance Programme for Antimicrobial Utilisation and Resistance
EUCAST	European Committee on Antimicrobial Susceptibility Testing
GP	General Practitioner
HMUD	Hospital Medicines Utilisation Database
HP-CIA	Highest Priority Critically Important Antibiotics
IMP	Imipenemase
ISD(S)1	Information Services Division
IV	Intravenous
K. oxytoca	*Klebsiella oxytoca*
KPC	*Klebsiella pneumoniae* Carbapenemase
K. pneumoniae	*Klebsiella pneumoniae*
MDR	Multi Drug Resistant
NAP	National Action Plan
NDM	New Delhi Metallo-beta-lactamases
NHS	National Health Service
NRS	National Records of Scotland

NSS	NHS National Services Scotland
OBD	Occupied Bed Days
OXA	Oxacillinase
P. aeruginosa	*Pseudomonas aeruginosa*
PHS	Public Health Scotland
PIS	Prescribing Information System
S. aureus	*Staphylococcus aureus*
SAPG	Scottish Antimicrobial Prescribing Group
SAVSNET	Small Animal Veterinary Surveillance Network
SEPA	Scottish Environmental Protection Agency
SMiRL	Scottish Microbiology Reference Laboratory
SONAAR	Scottish One Health Antimicrobial Use and Antimicrobial Resistance
S. pneumoniae	*Streptococcus pneumoniae*
SRUC	Scotland's Rural College
UK	United Kingdom
UKAS	United Kingdom Accreditation Service
UTI	Urinary Tract Infection
VIM	Verona integrin-encoded metallo-beta-lactamase
VRE	Vancomycin-resistant enterococci
WGS	Whole Genome Sequencing
WHO	World Health Organization

Appendix 1 - Background Information

Revisions to the surveillance

Description of Revision	First report revision applied	Report section(s) revision applies to	Rationale for revision
Colistin results	2016	Antimicrobial resistance in humans	A joint European Committee on Antimicrobial Susceptibility Testing (EUCAST) and Clinical and Laboratory Standards Institute (CLSI) subcommittee issued a warning on methodological issues with regard to the antimicrobial susceptibility testing of colistin, and, as such, results have not been included within this report.
Implementation of new Biomerieux® VITEK antimicrobial susceptibility testing (AST) cards within laboratories	2020	Antimicrobial resistance in humans	Implementation of new Biomerieux® VITEK AST cards in late 2018 that test amoxicillin in combination with a fixed clavulanic acid concentration of 2 mg/L as per the EUCAST recommendations. Roll out across NHS boards was variable due to laboratories depleting existing stock of older cards. This change was associated with an increase in co-amoxiclav non-susceptibility in 2019.

Temocillin breakpoints (Enterobacterales)	2020	Antimicrobial resistance in humans	No EUCAST breakpoint available. Initially all Biomerieux® VITEKs used the British Society for Antimicrobial Chemotherapy (BSAC) legacy urinary tract infection breakpoint of 16. NHS Greater Glasgow and Clyde moved to systemic breakpoint of 8 in ~2015. Other NHS boards moved variably up until end 2017. NHS Greater Glasgow and Clyde and some others retained an 'I' category (minimum inhibitory concentration 16) up until Oct 2019 when all moved to S<8 and R>8.
Change to episode based reporting for antimicrobial susceptibility data	2020	Antimicrobial resistance in humans	Data processing antimicrobial susceptibility data: For bacteraemias and bacteriurias, only the first isolate (of one specific organism per rolling 14-day period for blood and per rolling 30-day period for urine) is reported as a case. This is equivalent to one episode of infection. The most complete or most resistant AST result during each episode is reported for each case. Where more than one organism was present in a sample de-duplication was carried out separately for each organism.

Implementation of v_11.0 EUCAST breakpoints	2021	Antimicrobial resistance in humans	Changes can be accessed **here**.
Change to ceftazidime resistance and non-susceptibility figures	2021	Antimicrobial resistance in humans	Due to an incorrect mapping of antibiotic code in Electronic Communication of Surveillance in Scotland (ECOSS), ceftazidime was being incorrectly reported as cefradine. This was limited to one NHS board but accounted for a significant number of results since 2007. This has been corrected and amended retrospectively for data included in this report.
Implementation of v_12.0 EUCAST breakpoints	2022	Antimicrobial resistance in humans and Antimicrobial resistance in *Escherichia coli* isolates from healthy livestock	Changes can be accessed **here**. Breakpoints are generally lower in the EUCAST breakpoint table version 12.0. Exceptions to this are trimethoprim for both Enterobacterales and *Staphylococcus aureus (S. aureus)* and azithromycin for *S. aureus* only, where the breakpoint has increased. A reduction in a breakpoint will result in an increase in the number of isolates falling into the resistant category. Conversely, an increased breakpoint will result in a reduction in the numbers in the resistant category.

New definitions of Sensitive, Intermediate and Resistant antimicrobial resistance categories	2022	Antimicrobial resistance in humans and Antimicrobial resistance in animals	Previously, intermediate and resistant isolates were grouped and reported as one category: non-susceptible isolates. Antimicrobial resistance results included in this report are percentage resistant as opposed to percentage non-susceptible.
Carbapenemase-producing organisms	2022	Antimicrobial resistance in humans	Mixed cultures with a positive enzyme are now excluded from analysis. This has been corrected and amended retrospectively for data included in this report.
Change to de-duplication method for AST data	2022	Antimicrobial resistance in humans	Changes were made to the data processing to improve the de-duplication method and better identify isolates with the most complete and most resistant AST results. This has been corrected and amended retrospectively for data included in this report.
Fosfomycin results	2022	Antimicrobial resistance in humans	EUCAST have noted that testing for fosfomycin susceptibility in *Escherichia coli* urinary isolates using VITEK 2 may lead to errors, and recommend that this method of testing is not used (see **here** for further details). The majority of laboratories in NHS Scotland use VITEK 2 and therefore AST results for fosfomycin may be unreliable. Consequently, fosfomycin resistance is not included in this report.

Appendix 2 – Metadata

Publication title

Scottish One Health Antimicrobial Use and Antimicrobial Resistance in 2022 (SONAAR report, 2022)

Description

This annual report provides data relating to antimicrobial use and antimicrobial resistance in Scotland during 2022.

Theme

Health and Care (ARHAI Scotland, NHS National Services Scotland (NSS) and Public Health Scotland (PHS)).

Topic

Antimicrobial use and resistance in humans and animals.

Format

Online resource (PDF).

Data source(s)

Antimicrobial use in humans

Antibiotic use in primary care: Prescribing Information System (PIS), PHS and NSS.

Population denominator data: Mid-year population projections for Scotland: National Records of Scotland (NRS) population estimates.

Antibiotic use in secondary care: Hospital Medicines Utilisation Database (HMUD), PHS and NSS.

Healthcare associated denominator: Total occupied bed days (OBD), Sum of OBDs for all hospitals in numerator: Information Services Division (ISD(S)1), PHS.

Antimicrobial use in companion animals: Small Animal Veterinary Surveillance Network (SAVSNET).

Antimicrobial resistance in humans

Bacteraemia:
Case data: Electronic Communication of Surveillance in Scotland (ECOSS).

Population denominator data: Mid-year population projections for Scotland, NRS population estimates.

Urinary tract infections caused by *Escherichia coli*: ECOSS.

Carbapenemase-producing organisms:
Case data: ECOSS and the Scottish Microbiology Reference Laboratory (SMiRL), Glasgow.

Population denominator data: Mid-year population projections for Scotland, NRS population estimates.

Unusual phenotypes: ECOSS.

Antimicrobial resistance in *Salmonella*: SMiRL via PHS.

Antimicrobial resistance in animals: Scotland's Rural College (SRUC) Veterinary Services.

Antimicrobial resistance in the environment: N/A

Date that data are acquired

Antimicrobial use in humans

Antibiotic use in primary care:

Patient-based analysis: 30/06/2023

Urinary tract infections (UTI) analysis: 30/06/2023

Primary care trend data: 14/06/2023

Primary care duration of course analysis: 15/06/2023

Primary care variation analysis: 15/06/2023

Primary care antifungal analysis: 14/06/2023

Population denominator data: Mid-year population projections for Scotland: 07/06/2023

Antibiotic use in secondary care:

Secondary care trend analysis: 03/07/2023

Secondary care antifungal analysis: 03/07/2023

Healthcare denominator data: Total OBD, Sum of OBDs for all hospitals in numerator: 12/06/2023

Antimicrobial use in companion animals: 25/08/2023

Antimicrobial resistance in humans

Bacteraemia:

Case data: 12/07/2023

Population denominator data: Mid-year population projections for Scotland: 07/06/2023

Urinary tract infections caused by *Escherichia coli*: 12/07/2023

Carbapenemase-producing organisms:

Case data: 22/09/2023

Population denominator data: Mid-year population projections for Scotland: 07/06/2023

Unusual Phenotypes: 07/09/2023

Antimicrobial resistance in *Salmonella:* 07/08/2023

Antimicrobial resistance in animals

Antimicrobial resistance in veterinary clinical isolates from livestock: 18/07/2023

Antimicrobial resistance in *Escherichia coli* isolates from healthy livestock: 06/06/2023

Antimicrobial resistance in the environment: N/A

Release date

21 November 2023

Frequency

Annual

Timeframe of data and timeliness

The latest iteration of data are to 31 December 2022, therefore 11 months in arrears.

Antimicrobial use in humans: Data are for 2018 to 2022 and are timely for this report.

Antibiotic use in companion animals: Data are for 2018 to 2022 and are timely for this report.

Antimicrobial resistance in humans

Bacteraemia: Data are for 2018 to 2022 and are timely for this report.

Urinary tract infections caused by *Escherichia coli*: Data are for 2018 to 2022 and are timely for this report.

Carbapenemase-producing organisms: Data are for 2018 to 2022 and are timely for this report.

Unusual Phenotypes: Data are for 2022 and are timely for this report.

Antimicrobial resistance in *Salmonella*: Data are for 2021 and 2022 and timely for this report.

Antimicrobial resistance in animals: Data are for 2018 to 2022 and are timely for this report.

Antimicrobial resistance in the environment: N/A

Continuity of data

Antimicrobial use in humans: Changes in healthcare activity during the COVID-19 pandemic may have affected antimicrobial use (AMU) and comparison of results should be interpreted with caution.

Antimicrobial use in companion animals: The COVID-19 pandemic may have affected the level of contact between companion animals and their vets, and the number of consultations reported between 2020 and 2022. Comparison of results should be interpreted with caution.

Antimicrobial resistance in humans:
Throughout 2022, the majority of Scottish NHS diagnostic laboratories, on a phased basis, changed from version 9.0 of the European Committee on Antimicrobial Susceptibility Testing (EUCAST) breakpoint table to version 12.0. Breakpoints are generally lower in the EUCAST breakpoint table version 12.0. Exceptions to this are trimethoprim for both Enterobacterales and *Staphylococcus aureus (S. aureus)* and azithromycin for *S. aureus* only, where the breakpoint has increased. A reduction in a breakpoint will result in an increase in the number of isolates falling into the resistant category. Conversely, an increased breakpoint will result in a reduction in the numbers in the resistant category. This must be considered when interpreting results for this report.

Previously, intermediate and resistant isolates were grouped and reported as one category: non-susceptible isolates. Antimicrobial resistance (AMR) results included in this report are percentage resistant as opposed to percentage non-susceptible, and therefore not comparable with previously published SONAAR reports.

Changes in healthcare activity and patient populations during the COVID-19 pandemic may have affected the epidemiology of infections included in this report and comparison of results should be interpreted with caution.

Antimicrobial resistance in *Salmonella*:

Previously, intermediate and resistant isolates were grouped and reported as one category: non-susceptible isolates. AMR results included in this report are percentage resistant as opposed to percentage non-susceptible, and therefore not comparable with previously published SONAAR reports.

Changes in healthcare activity, patient populations and contact between animals and their vets during the COVID-19 pandemic may have affected the epidemiology of *Salmonella* and comparison of results should be interpreted with caution.

Antimicrobial resistance in animals:

Previously, intermediate and resistant isolates were grouped and reported as one category: non-susceptible isolates. AMR results included in this report are percentage resistant as opposed to percentage non-susceptible, and therefore not comparable with previously published SONAAR reports.

The COVID-19 pandemic may have affected the level of contact between animals and their vets between 2020 and 2022. Comparison of results should be interpreted with caution.

Antimicrobial resistance in the environment: N/A

Revisions statement

These data are not subject to planned major revisions. However, ARHAI Scotland aims to continually improve the interpretation of the data and therefore analysis methods are regularly reviewed and may be updated in the future.

Revisions relevant to this publication

Antimicrobial use in humans: None

Antimicrobial use in companion animals: There has been a change in the analytical process for companion animal antimicrobial use figures. Previously the data was processed and analysed by ARHAI Scotland. For this report, it was undertaken by SAVSNET.

Antimicrobial resistance in humans

Previously, intermediate and resistant isolates, as defined by EUCAST, were grouped and reported as one category: non-susceptible isolates. Following a definition update from EUCAST, and to align with **English Surveillance Programme for Antimicrobial Utilisation and Resistance (ESPAUR) annual report**, AMR results included in this report are percentage resistant as opposed to percentage non-susceptible. The new methods have been applied to historic data to allow year-on-year trend analyses using the same definitions.

When applying these new definitions, temocillin resistance in *Escherichia coli (E. coli)* bacteraemia increased from 2020 to 2021, as opposed to non-susceptibility remaining stable, as was reported in the SONAAR Report, 2021.

Bacteraemia: Changes were made to the data processing to improve the de-duplication method and better identify isolates with the most complete and most resistant antimicrobial susceptibility testing (AST) results. This change has been applied to historic data to allow year-on-year trend analyses using the same definitions.

Urinary tract infections caused by *Escherichia coli*: Changes were made to the data processing to improve the de-duplication method and better identify isolates with the most complete and most resistant AST results. This change has been applied to historic data to allow year-on-year trend analyses using the same definitions.

Carbapenemase-producing organisms: Mixed cultures with a positive enzyme are now excluded from analysis. This has been corrected and amended retrospectively for data included in this report.

Antimicrobial resistance in *Salmonella*:

Retrospective amendments have been applied to the proportion of human *Salmonella* isolates resistant to tetracycline and ciprofloxacin in 2021 in supplementary appendix data table 41.3.

Antimicrobial resistance in animals:

Previously, intermediate and resistant isolates were grouped and reported as one category: non-susceptible isolates. Following a definition update from EUCAST, and to align animal AMR reporting with human AMR reporting, AMR results included in this report are percentage resistant as opposed to percentage non-susceptible. The new methods have been applied to historic data to allow year-on-year trend analyses using the same definitions.

Antimicrobial resistance in the environment: N/A

Concepts and definitions

Statistical significance: Please note where an increase or decrease is stated in this report this refers to a statistical change. Where a trend is referred to as stable, there has been no statistically significant increase or decrease. Statistical significance has been determined by a p-value of less than (<) 0.05. Due to the number of tests being done at the same time a Bonferroni correction has been applied and the p-values adjusted to reflect the number of tests undertaken for each organism. In order to keep the number of multiple testing to a minimum, only organism and drug combinations with enough numbers each year have been tested.

Confidence Intervals: Confidence intervals (95% CI) for proportions were calculated to indicate robustness of the proportions presented. Where a 95% CI has been quoted or displayed in a figure as an error bar around a percentage, the method used is the Wilson Score.

Rounding: Please note that due to rounding to 1 decimal place, values may not add to 100%.

Year to Year Comparisons: The current calendar year 2022 is compared to the previous calendar year 2021 using two-sided z-tests for proportions and rate ratio tests (using Poisson counts) for rates. A resulting p-value of less than 0.05 was deemed statistically significant to determine an increase or decrease relative to the previous year.

Five Year Trends: Rates and proportions over the past five years are modelled using Poisson regression and negative binomial regression respectively. This is performed to determine the presence of a significant upwards or downwards linear trend in the changing rate or proportion, and the corresponding rate of change of the best-fit gradient over the past five years from 2018 to 2022.

Antimicrobial use in humans

Prescribing data: **https://www.isdscotland.org/Health-Topics/Prescribing-and-Medicines/**

Population estimates: **https://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/population/population-estimates/mid-year-population-estimates**

Occupied bed days (OBD): **https://www.isdscotland.org/Health-Topics/Hospital-Care/Beds/**

Defined Daily Dose (DDDs,) World Health Organisation (WHO): **https://www.whocc.no/atc_ddd_index/**

Adapted Access, Watch, Reserve (AWaRe) classification of antibiotics: Budd, E., et al. (2019) Adaptation of the WHO Essential Medicines List for national antibiotic stewardship policy in England: being AWaRe. Journal of Antimicrobial Chemotherapy, 74(11), pp. 3384-3389. **https://doi.org/10.1093/jac/dkz321**

Unless otherwise stated Primary Care figures exclude Dental (GP14) Prescription Forms.

Primary care prescribing information sourced from PIS is linked to patient Community Health Index (CHI) numbers. Using patient CHI numbers, it is possible to analyse demographic information on patients prescribed antibiotics such as age and gender. Patients resident in Scotland have a unique CHI number meaning it is also possible to count numbers of distinct patients receiving a particular treatment or investigate prescribing patterns for particular individuals over time. From 2009 onwards, the majority of prescriptions can be linked to a valid CHI number, however CHI capture rates can vary by drug, geographical area or prescriber type, with GPs having better capture rates than other prescriber types. When interpreting trends in patient counts over time, the underlying CHI capture rate must also be considered. In the supplementary data for this report, where patient level data is used, the relevant CHI capture rates are also presented. It is difficult to identify with certainty how much impact increasing CHI completeness has on the number of patients identified, but the evidence available suggests that the impact is small when considering the scale of change in CHI completeness presented in this report and this should not generally be significantly affecting trends in patient counts.

Parenteral antibiotic DDDs are used to monitor use of intravenous antibiotics.

UK National Action Plan Targets for antimicrobial use:
The UK AMR National Action Plan (NAP) 2019-2024 includes targets on antibiotic use to act as a focus for improvement activity to preserve the effectiveness of the currently available antibiotics. The targets are to:

- Reduce UK antibiotic use in humans by 15% by 2024;
- Reduce UK antibiotic use in the community by 25% by 2024
- Reduce use of Watch and Reserve antibiotics in acute hospitals by 10% by 2024

Further information on the UK NAP: **https://www.gov.uk/government/publications/uk-5-year-action-plan-for-antimicrobial-resistance-2019-to-2024**

Antimicrobial use in companion animals

The SAVSNET data were collected via electronic health records within the practice management systems of first opinion veterinary practices (these record species, breed, date or year of birth, sex, nature of condition being treated and antibiotic treatments supplied, and postcode). These data are submitted voluntarily by participating veterinary practices and therefore cannot be interpreted as being representative of all of Scotland. Practices submitting data are not necessarily the same from year to year. Nevertheless, they provide additional important intelligence relating to another aspect of antibiotic use in the One Health ecosystem.

This important data stream allows a continuing impression of antibiotic use in companion animals in Scotland and will enable practitioners to evaluate their own data compared to these preliminary national data.

SAVSNET website: **https://www.liverpool.ac.uk/savsnet/**

Description of the methods used by SAVSNET to capture electronic health records: Sánchez-Vizcaíno, F., et al. (2015) Small animal disease surveillance. Veterinary Record 177, 591-594.
https://doi.org/10.1136/vr.h6174

D.A. Singleton, et al. (2017) Patterns of antimicrobial agent prescription in a sentinel population of canine and feline veterinary practices in the United Kingdom. The Veterinary Journal, Volume 224, Pages 18-24.
https://www.sciencedirect.com/science/article/pii/S1090023317300722#bib0090

Description of methods used by SAVSNET for syndromic analysis of antibiotic prescribing: D.A. Singleton, et al. (2019) Small animal disease surveillance: gastrointestinal disease, antibacterial prescription and Tritrichomonas foetus. Veterinary Record 10.1136/vr1722 (14th Feb p211-216)

D.A. Singleton, et al. (2019) Small animal disease surveillance 2019: pruritus, pharmacosurveillance, skin tumours and flea infestations. Veterinary Record 10.1136/vr16074 (19th Oct p470-475)

D.A. Singleton, et al. (2019) Small animal disease surveillance 2019: respiratory disease, antibiotic prescription, and canine infectious respiratory disease complex. Veterinary Record (25th May p640-645)

Antimicrobial resistance in humans

Case definitions: Total numbers, incidence rates and AST results for bacteraemia and bacteriuria were calculated using the following case definitions:

A new case of bacteraemia is a patient from whom an organism has been isolated from the patient's blood, and who has not previously had the same organism isolated from blood within a 14-day period (i.e. 14 days from date last positive sample obtained). The most complete then most resistant AST result during each episode is reported for each case.

A new case of bacteriuria (referred to in this report as 'episodes isolated from urine') is a patient from whom an organism has been isolated from the patient's urine, and who has not previously had the same organism isolated from urine within a 30-day period (i.e. 30 days from date last positive sample obtained). The most complete then most resistant AST result during each episode is reported for each case.

Isolate(s) refers to the organism isolated from each case of bacteraemia or bacteriuria.

With the exception of *E. coli* bacteraemia and *S. aureus* bacteraemia, all human bacteraemia data are based only on positive blood results extracted from ECOSS and are not validated cases. *E. coli* bacteraemia and *S. aureus* bacteraemia data use validated data collected as part of mandatory surveillance programme as detailed in the **Protocol for National Enhanced Surveillance of Bacteraemia**.

Please note that bacteriuria (bacteria present in urine) is used as a proxy for UTI and not all cases reported will be validated cases of UTI. As part of the **NHS Pharmacy First Scotland** service, community pharmacists have the ability to supply via patient group direction trimethoprim or nitrofurantoin for uncomplicated UTIs in females aged 16 years and over. This service has been available in all community pharmacies since August 2020 and is likely to have

had an impact on the number of urine samples being referred to laboratories since females with uncomplicated UTIs can be treated by pharmacists without attending their GP.

For carbapenamase-producing organisms (CPOs), a case was considered as the first isolate of one specific organism and enzyme combination per patient per calendar year. Where more than one organism was present in a sample, de-duplication was carried out separately for each organism and enzyme combination.

Incidence rates were calculated as follows: Bacteraemia rate per 100,000 population = (Number of cases per year / mid-year Scottish population) x 100,000.

Population estimates: **https://www.nrscotland.gov.uk/statistics-and-data/statistics/statistics-by-theme/population/population-estimates/mid-year-population-estimates**

Percentage resistance: Resistance is defined as isolates reported as resistant (R).

Percentage resistant = resistant isolates divided by the total number of isolates tested multiplied by 100.

Burden of drug resistant infection: The burden of drug resistant infections is estimated for *E. coli, Klebsiella pneumoniae (K. pneumoniae)* and *Klebsiella oxytoca (K. oxytoca), Acinetobacter* species*, Pseudomonas aeruginosa (P. aeruginosa), Enterococcus faecium (E. faecium), Enterococcus faecalis (E. faecalis), S. aureus* and *Streptococcus pneumoniae (S. pneumoniae)* bacteraemia cases based on the percentage of organisms resistant (R) to at least one key antibiotic (see Table of Key antibiotics by organisms).

Antimicrobial susceptibility results are not available for all bacteraemia cases, therefore the % resistance from available results is applied to the total number of bacteraemia cases to provide the estimated number of antibiotic resistant bacteraemias.

Table: Key antibiotics by organisms

E. coli, K. pneumoniae and *K. oxytoca*	Carbapenems (imipenem, meropenem or ertapenem) Third generation cephalosporins (one of ceftazidime, cefotaxime or ceftriaxone and not carbapenems) Gentamicin (and not carbapenems or third generation cephalosporins) Ciprofloxacin (and not carbapenems or third generation cephalosporins or gentamicin)
Acinetobacter species	Carbapenems (imipenem or meropenem) Aminoglycosides (amikacin or gentamicin) AND ciprofloxacin (and not carbapenems)
P. aeruginosa	Carbapenems (imipenem or meropenem) Three or more antimicrobial groups (but not carbapenems)
E. faecium and *E. faecalis*	Vancomycin
S. aureus	Meticillin
S. pneumoniae	Penicillin and macrolides Penicillin (and not macrolides)

Urinary tract infections caused by *Escherichia coli*: EUCAST have noted that testing for fosfomycin susceptibility in *E. coli* urinary isolates using VITEK 2 may lead to errors, and recommend that this method of testing is not used (see **here** for further details). The majority of laboratories in NHS Scotland use VITEK 2 and therefore AST results for fosfomycin may be unreliable. Consequently, fosfomycin resistance is not included in this report.

Carbapenemase-producing organisms: The term CPO encompasses all acquired carbapenemase-producing Gram-negative bacteria and is not limited to carbapenemase-producing Enterobacterales.

Case definitions can be accessed here: **https://www.nss.nhs.scot/publications/toolkit-for-the-early-detection-management-and-control-of-carbapenemase-producing-enterobacteriaceae-in-scottish-acute-settings/**

Unusual phenotypes: In 2018, the SONAAR team at ARHAI Scotland introduced an electronic process to run a twice weekly interrogation of ECOSS to identify unusual resistance phenotypes and contact the submitting laboratory requesting confirmation of reported resistance. All alerts are assessed by ARHAI Scotland and if of potential public health concern are drawn to the attention of the wider public health community for appropriate action.

Definitions of an unusual phenotype can be accessed here: **http://www.eucast.org/expert_rules_and_intrinsic_resistance/**

Appendix 13 of the National Infection Prevention & Control Manual contains a mandatory alert micro-organism/condition list. Local monitoring ensures that microbiology clinicians, infection prevention and control teams, health protection teams and antimicrobial management teams, as appropriate, are aware of each identified case as per local protocols.

The identification of an alert is dependent on laboratories actively performing AST and submitting results to ECOSS. This may result in underreporting, or no reporting, of a particular micro-organism/antibiotic resistance combination if there is limited or no testing performed.

An instance of an unusual phenotype was considered as the first isolate of one specific organism per patient per calendar year. Where more than one organism was present in a sample, de-duplication was carried out separately for each organism.

Antimicrobial resistance in *Salmonella*

Interpretation of *Salmonella* resistance to individual antibiotics is complicated by the fact that in some subtypes there are well-recognised genetic elements encoding resistance to multiple agents. Thus, the occurrence of resistance to individual antibiotics is not always independent and the apparent

prevalence of resistances to different agents can be strongly influenced by the abundance of *Salmonella* sub-types in the sample set for each reporting period.

Salmonella is notifiable in humans and a reportable animal pathogen in the UK. All medical diagnostic laboratories are required to forward suspect isolates from humans to the SMiRL which is responsible for testing antimicrobial susceptibility in *Salmonella*. All veterinary diagnostic laboratories isolating *Salmonella* from livestock species and dogs are also required to send suspect isolates for confirmation and typing to the SMiRL. The submission of animal samples is affected by the willingness of an animal keeper to pay the costs of laboratory testing to inform treatment, in addition to the clinical presentation in the affected animal(s). Whole genome sequencing (WGS) was introduced into routine use in the SMiRL in late 2017 for the identification and characterisation of *Salmonella* isolates. Following a review of published reports and an extensive validation confirming the high degree of correlation observed between the two approaches, the in silico prediction of AMR phenotype from WGS was introduced in January 2020. The predictive tools in use allow the identification of many individual AMR genes. The availability of data from isolates from different source populations (humans and animals) which have undergone the same processing by the same laboratory offers an opportunity to monitor the trends in resistance and identify epidemiological links in these populations.

Antimicrobial resistance in animals

Antimicrobial resistance in veterinary clinical isolates from livestock: Data presented here represent the percentage of resistant isolates over all tested isolates. The percentage of multi drug resistant (MDR) isolates, defined as isolates resistant to three or more antimicrobial classes, is also presented. These data represent a non-random sample of veterinary practices and veterinary isolates, based on voluntary submission of data to SRUC.

The data from veterinary clinical isolates are subject to a number of important biases. Unlike the clinical samples in humans in Scotland, the samples are tested on a ‘charged for’ basis to inform private veterinary treatment of diseased animals. There is a cost to the animal keeper that

affects the submission of samples to these services. In addition, the primary purpose of screening for AMR is to inform veterinary treatment and they are tested against a panel of antimicrobials relevant for that purpose at, where they exist, species-relevant clinical breakpoints, based on British Society for Antimicrobial Chemotherapy (BSAC) breakpoints. Interpretation of these data in terms of their relevance to public health is challenging beyond the notion of evidence of impact of a selection pressure existing in another compartment of the ecosystem that humans share closely with animals.

Antimicrobial resistance in *Escherichia coli* isolates from healthy livestock:
Data presented here represent the percentage of resistant isolates over all tested isolates. These isolates are from healthy livestock animals and are tested against a panel of antimicrobials, and at breakpoints, relevant to human clinical isolates. The percentage of MDR isolates, defined as isolates resistant to three or more antimicrobial classes, is also presented.

Breakpoints for AST in *E. coli* isolates from healthy livestock are provided by SRUC and are aligned with EUCAST breakpoints, except tetracycline which uses the Clinical and Laboratory Standards Institute (CLSI) breakpoint value. EUCAST breakpoints are applied to healthy livestock isolates to enable relevant comparisons of resistance with isolates from humans, to human relevant antibiotics. Changes to breakpoints over time have been applied retrospectively to healthy livestock isolates to allow year-on-year comparisons.

Antimicrobial resistance in the environment: N/A

Relevance and key uses of the statistics

Making information publicly available. The report is intended to support planning, prioritisation and evaluation of initiatives to optimise AMU and to minimise AMR.

Accuracy

Antimicrobial use in humans

Antibiotic use in primary care: A subset of these data are routinely validated by Practitioner Services on a monthly basis.

Healthcare associated denominator, total occupied bed days: Sum of OBDs for all hospitals in numerator, standardised methodology used.

Antimicrobial use in companion animals: Data and analyses provided by SAVSNET from a non-random sample of veterinary practices.

Antimicrobial resistance in humans

Bacteraemia: Data supplied by United Kingdom Accreditation Service (UKAS) accredited laboratories using standardised testing methodologies.

Urinary tract infections caused by *Escherichia coli*: Data supplied by UKAS accredited laboratories using standardised testing methodologies. However, it should be noted that Public Health Scotland are undertaking an ECOSS quality improvement project (ECOSS Roll-out Implementation Programme (EDRIP)) which has highlighted some inconsistent mapping and reporting of urine sample results in ECOSS. EDRIP is currently paused due to the roll out of a new laboratory information management system. Due to these data inconsistencies, it is not currently possible to report and compare incidence over time, however we do not expect this to impact the national antimicrobial resistance.

Carbapenemase-producing organisms: Data supplied by UKAS accredited laboratories using standardised testing methodologies.

Unusual phenotypes: Data supplied by UKAS accredited laboratories using standardised testing methodologies. Unusual phenotypes are confirmed with the sending laboratory.

Antimicrobial resistance in *Salmonella:* Data supplied by UKAS accredited laboratories using standardised testing methodologies. SMiRL.

Antimicrobial resistance in animals: Data supplied by UKAS accredited laboratories using standardised testing methodologies. SRUC (ISO:17025), SMiRL, Glasgow (ISO:15189).

Antimicrobial resistance in the environment: N/A

Completeness

Antimicrobial use in humans: All data for the reporting period have been included in the analysis.

Antibiotic use in companion animals: Database represents a non-random sample of veterinary practices based on voluntary submission of data to SAVSNET.

Antimicrobial resistance in humans

Bacteraemia: All data for the reporting period have been included in the analysis.

Urinary tract infections caused by *Escherichia coli*: All available data within ECOSS have been included in the analysis. However, it should be noted that Public Health Scotland are undertaking an ECOSS quality improvement project (EDRIP) which has highlighted some inconsistent mapping and reporting of urine sample results in ECOSS. In 2022, it was identified that urine isolates from one NHS board had not been reported in ECOSS. Following investigation, isolates were reported from September 2022 onwards. EDRIP is currently paused due to the roll out of a new laboratory information management system. Due to these data inconsistencies, it is not currently possible to report and compare incidence over time, however we do not expect this to impact the national AMR.

Carbapenemase-producing organisms: All data for the reporting period have been included in the analysis.

Unusual phenotypes: All laboratory confirmed isolates have been included in the analysis.

Antimicrobial resistance in *Salmonella*: All laboratory confirmed isolates have been included in the analysis.

Antimicrobial resistance in animals

Antimicrobial resistance in veterinary clinical isolates from livestock: These data represent a non-random sample of veterinary practices and veterinary isolates, based on voluntary submission of data to SRUC. Isolates are derived from samples and animal carcases submitted throughout the year to Disease Surveillance Centres operated by SRUC across Scotland.

Antimicrobial resistance in *Escherichia coli* isolates from healthy livestock: Samples are collected on a monthly basis from livestock animals presenting at abattoirs in Scotland and submitted to SRUC.

Antimicrobial resistance in the environment: N/A

Comparability

Antimicrobial use in humans

The numerator for antibiotic use includes the number of WHO DDDs and is comparable to other antibiotic use surveillance programmes using this method. These data are extracted from live databases (PIS and HMUD) where historic data may be subject to slight variation.

OBDs are derived using a standardised methodology allowing comparability across years.

Antimicrobial use in companion animals: N/A

Antimicrobial resistance in humans

Throughout 2022, the majority of Scottish NHS Diagnostic Laboratories, on a phased basis, changed to the EUCAST breakpoint table version 12.0. Breakpoints were generally lower in version 12.0 with some exceptions where the breakpoint increased. Exceptions to this were trimethoprim for both Enterobacterales and *S. aureus* and azithromycin for *S. aureus* only, where the breakpoint has increased. A reduction in a breakpoint will result in an increase in the number of isolates falling into the resistant category.

Conversely, an increased breakpoint will result in a reduction in the numbers in the resistant category. This must be considered when interpreting results for this report.

Previously, intermediate and resistant isolates were grouped and reported as one category: non-susceptible isolates. AMR results included in this report are percentage resistant as opposed to percentage non-susceptible. This aligns with the approach adopted by the **ESPAUR annual report** enabling meaningful comparisons to be made and informs metrics against the ambitions of the 2019 to 2024 UK five-year AMR NAP. However, data in this report are not comparable to previously published SONAAR reports.

Bacteraemia:
UK Health Security Agency report on national data on antibiotic resistance: **https://www.gov.uk/government/publications/english-surveillance-programme-antimicrobial-utilisation-and-resistance-espaur-report**

European Centre for Disease Prevention and Control (ECDC) report on Antimicrobial resistance surveillance in Europe: **https://www.ecdc.europa.eu/en/antimicrobial-resistance/surveillance-and-disease-data/report**

E. coli and *S. aureus* bacteraemia: **ARHAI Scotland Quarterly epidemiological data on *Clostridioides difficile* infection, *Escherichia coli* bacteraemia, *Staphylococcus aureus* bacteraemia and Surgical Site Infection in Scotland.**

ARHAI Scotland Annual report: **https://www.nss.nhs.scot/publications/arhai-scotland-2022-annual-report/**

Urinary tract infection caused by *Escherichia coli*:
UK Health Security Agency report on national data on antibiotic resistance: **https://www.gov.uk/government/publications/english-surveillance-programme-antimicrobial-utilisation-and-resistance-espaur-report**

Carbapenemase-producing organisms:
UK Health Security Agency report on Carbapenem resistance **https://www.gov.uk/government/collections/carbapenem-resistance-guidance-data-and-analysis**

ECDC report on Carbapenem resistance **https://ecdc.europa.eu/en/surveillance-atlas-infectious-diseases**

Unusual phenotypes: N/A

Antimicrobial resistance in *Salmonella:* N/A

Antimicrobial resistance in animals

Antimicrobial resistance in veterinary clinical isolates from livestock: The primary purpose of screening for AMR is to inform veterinary treatment and isolates from animals are tested against a panel of antimicrobials relevant for that purpose at, where they exist, species-relevant clinical breakpoints. Interpretation of these data in terms of their relevance to public health is challenging beyond the notion of evidence of impact of a selection pressure existing in another compartment of the ecosystem that humans share closely with animals.

Antimicrobial resistance in *Escherichia coli* isolates from healthy livestock: Breakpoints for AST in *E. coli* isolates from healthy livestock are provided by SRUC and are aligned with EUCAST breakpoints, except tetracycline which uses the CLSI breakpoint value. EUCAST breakpoints are applied to healthy livestock isolates to enable relevant comparisons of resistance with isolates from humans, to human relevant antibiotics. Changes to breakpoints over time have been applied retrospectively to healthy livestock isolates to allow year-on-year comparisons.

Antimicrobial resistance in the environment: N/A

Accessibility

It is the policy of NSS to make its web sites and products accessible according to published guidelines.

Coherence and clarity

Tables are accessible via our website at: **https://www.nss.nhs.scot/publications/scottish-one-health-antimicrobial-use-and-antimicrobial-resistance-in-2022/**

Value type and unit of measurement

Antimicrobial use in humans:

DDDs per 1,000 population per day (DDDs/1,000/day).

Percentage of DDDs by prescriber type (%) = count of DDDs by prescriber type / total count of DDDs.

Percentage of antibiotics use belonging to Access group (%) = count of antibiotic items belonging to Access group / total count of antibiotic items.

Count of items and number of items per 1,000 population per day (items/1,000/day).

Percentage of the Scottish population receiving at least one course of antibiotics (%) = count of individuals receiving at least one course of antibiotics / total population.

Percentage of antibiotic courses of five-day duration (%) = count of antibiotic items of five-day duration / total count of antibiotic items.

Percentage of primary care items by prescriber type (%) = count of antibiotic items by prescriber type in primary care / total count of antibiotic items in primary care.

DDDs per 1,000 occupied bed days (DDDs/1,000 occupied bed days).

Percentage of antibiotics given intravenously (%) = count of DDDs for IV antibiotics / total count of antibiotic DDDs.

Antimicrobial use in companion animals:

Count of consultations and individual animals.

Percentage of consultations resulting in prescription of antimicrobials (%) = count of consultations resulting in prescription of at least one antimicrobial / total count of consultations.

Percentage of antimicrobial prescriptions that were high priority critically important antimicrobials (%) = count of antimicrobial prescriptions that were high priority critically important antimicrobials / total count of antimicrobial prescriptions.

Antimicrobial resistance in humans

Bacteraemia:
Count of cases and incidence rates (per 100,000 population).

Percentage of resistant blood isolates (%) = count of blood isolates resistant for antibiotic/organism combination / total count of blood isolates tested for antibiotic/organism combination.

Urinary tract infections caused by *Escherichia coli*:
Count of cases.

Percentage of resistant urine isolates (%) = count of urine isolates resistant for antibiotic/organism combination / total count of urine isolates tested for antibiotic/organism combination.

Carbapenemase-producing organisms:
Count of cases and incidence rate (per 100,000 population).

Count of cases by enzyme type and organism.

Percentage of cases by organism (%) = count of cases by organism / total count of cases.

Unusual phenotypes:
Count of confirmed unusual phenotype instances, and count of confirmed unusual phenotype instances per organism/antibiotic combination.

Antimicrobial resistance in *Salmonella:*

Percentage of inferred phenotypic resistance from WGS by antimicrobial (%) = count of isolates with inferred phenotypic resistance / total count of tested isolates.

Antimicrobial resistance in animals

Antimicrobial resistance in veterinary clinical isolates from livestock:
Count of resistant isolates and count of all isolates tested.

Percentage of resistant isolates (%) = count of resistant isolates / total count of all isolates tested.

Antimicrobial resistance in *Escherichia coli* isolates from healthy livestock:
Count of resistant isolates and count of all isolates tested.

Percentage of resistant isolates (%) = count of resistant isolates / total count of all isolates tested.

Antimicrobial resistance in the environment: N/A

Disclosure

The PHS protocol on **Statistical Disclosure Protocol** is followed.

Official Statistics designation

Official Statistics

UK Statistics Authority Assessment

Not Assessed

Last published

15 November 2022

Next published

November 2024

Date of first publication

14 November 2017

Help email

NSS.ARHAIsonaar@nhs.scot

Date form completed

21 November 2023

Appendix 3 – Early Access Details

Pre-Release Access

Under terms of the 'Pre-Release Access to Official Statistics (Scotland) Order 2008', NSS is obliged to publish information on those receiving Pre-Release Access ('Pre-Release Access' refers to statistics in their final form prior to publication). The standard maximum Pre-Release Access is five working days. Shown below are details of those receiving standard Pre-Release Access.

Standard Pre-Release Access

- Scottish Government Health Department
- NHS Board Chief Executives
- NHS Board Communication leads

Appendix 4 – NSS and Official Statistics

Official Statistics

Our statistics comply with the **Code of Practice for Statistics** in terms of trustworthiness, high quality and public value. This also means that we keep data secure at all stages, through collection, processing, analysis and output production, and adhere to the '**five safes**'.