Thailand's One Health Report

on Antimicrobial Consumption and Antimicrobial Resistance

in 2020

Thailand's One Health Report

on Antimicrobial Consumption and Antimicrobial Resistance in 2020

Thailand's One Health Report

on Antimicrobial Consumption and Antimicrobial Resistance in 2020

Produced by:
Health Policy and Systems Research on Antimicrobial Resistance (HPSR-AMR) Network

Published by:
International Health Policy Program, Ministry of Public Health, Thailand

Address:
Ministry of Public Health,
Tiwanon Rd. Nonthaburi 11000, Thailand
Phone: +66 (0) 2590-2366-7
Fax: +66 (0) 2590-2385

Suggested citations:

Thailand's One Health Report on Antimicrobial Consumption and Antimicrobial Resistance in 2020. Health Policy and Systems Research on Antimicrobial Resistance Network; 2022. Available from: https://www.thaiamrwatch.net.

This report is available at www.thaiamrwatch.net

ISBN: 978-616-11-4817-1

First published: 20 December 2022

Correspondence:
Any correspondence relating to this report should be sent by e-mail to hpsr_amr@ihpp.thaigov.net

Acknowledgements

A special thank to all partners for their continued support to the Health Policy and Systems Research on Antimicrobial Resistance Network.

This publication is supported by the World Health Organization Country Cooperation Strategy (WHO-CCS), which is a multi-funding platform contributed by the World Health Organization and the Royal Thai Government, and partner agencies including Ministry of Public Health, Thai Health Promotion Foundation, National Health Security Office, Health Systems Research Institute and National Health Commission Office, and Food and Agriculture Organization of the United Nation, and United States Agency for International Development.

Foreword

On behalf of the National Steering Committee on Antimicrobial Resistance, I welcome the publication of Thailand's One Health Report on Antimicrobial Consumption and Antimicrobial Resistance 2020. It has been produced to monitor antimicrobial consumption and antimicrobial resistance in humans and animals, and knowledge and public awareness on antimicrobial resistance since 2017 in response to the strategic goals of National Strategic Plan on Antimicrobial Resistance 2017-2021.

Regarding the strategic goals, by 2021, we need to reduce morbidity attributable to antimicrobial resistance by 50.0%; reduce antimicrobial consumption by 20.0% in the human sector and 30.0% in the animal sector; and increase the proportion of the population shown to have a predefined basic level of knowledge and awareness of antimicrobial resistance by 20.0%.

This year, the report provides data in 2020, and compares it with 2017 baseline data for the monitoring of NSP-AMR (2017-2021) strategic goals. The overall consumption of human antimicrobials was 46.3 Defined Daily Doses/1,000 inhabitants/day (-15.2% from 2017) and the overall consumption of veterinary antimicrobials was 421.5 mg/$PCU_{Thailand}$ (-36.0% from 2017). Percentage of *Escherichia coli* resistant to 3rd-generation cephalosporins was 41.4 in humans, 1.8 in chicken caeca and 13.6 in pig caeca.

We thank the members of the Health Policy and Systems Research on Antimicrobial Resistance (HPSR-AMR) Network, led by the International Health Policy Program, Ministry of Public Health, Thailand for their contribution to the development of this report. This report was produced through a collaborative process involving professionals working in the human and animal health sectors in Thailand.

We fully believe that cross-sectoral cooperation based on the One Health approach can effectively address antimicrobial resistance.

Dr. Paisarn Dunkum
Secretary-General
Food and Drug Administration
Ministry of Public Health

Dr. Supakit Sirilak
Director-General
Department of Medical Sciences
Ministry of Public Health

Dr. Opart Karnkawinpong
Director-General
Department of Disease Control
Ministry of Public Health

Dr. Somchuan Ratanamungklanon
Director-General
Department of Livestock Development
Ministry of Agriculture and Cooperatives

Mr.Chalermchai Suwannarak
Director-General
Department of Fisheries
Ministry of Agriculture and Cooperatives

Mr. Athapol Charoenchasa
Director-General
Pollution Control Department
Ministry of Natural Resources and Environment

Mrs. Piyanuch Wuttisorn
Director-General
National Statistical Office
Ministry of Digital Economy and Society

On behalf of the National Steering Committee on Antimicrobial Resistance

Contributor

Editor-in-Chief: Viroj Tangcharoensathien

Editorial team: Angkana Lekagul
Supapat Kirivan
Wanwisa Kaewkhankhaeng
Saowapa Khotchalai
Wimonrat Tanomsridachchai
Khanit Pisawong

	Data sources	Authors	Expert reviewers
SECTION A ANTIMICROBIAL CONSUMPTION			
A1. Antimicrobial Consumption in Humans	Food and Drug Administration, Ministry of Public Health	Supapat Kirivan Charunee Krisanaphan Kritsada Limpananont Chutamas Luangaroonchai Pongsathid Virungrojint	Khunjira Udomaksorn Inthira Kanchanaphibool Nussaraporn Kessomboon Rungpetch Sakulbumrungsil
A2. Antimicrobial Consumption in Food-Producing Animals			Nackanun Chitaroon Natthasit Tansakul
A3. Antimicrobial Consumption in Food-Producing Animals (Medicated Feed through Feed Mills)	Department of Livestock Development, Ministry of Agriculture and Cooperatives	Supapat Kirivan Julaporn Srinha Somsajee Sivilaikul Porjai Rattanapanadda Suchana Sukklad Passawee Pakpong	Boonyita Rujtikumporn Natthasit Tansakul
SECTION B ANTIMICROBIAL RESISTANCE			
B1. Antimicrobial Resistance in Humans	National Antimicrobial Resistance Surveillance Center Thailand (NARST), National Institute of Health, Department of Medical Sciences, Ministry of Public Health Division of AIDS and STIs, and Enhanced Gonococcal Antimicrobial Surveillance Programme (EGASP) in Thailand, Department of Disease Control, Ministry of Public Health	Sang Usayaporn Ratchanu Charoenpak Abhisit Prawang Noppavan Janejai Wantana Paveenkittiporn Aekkawat Unahalekhaka Pimrata Leethongdee Rossaphorn kittiyaowaman Pongsathorn Sangprasert Natnaree Girdthep	Chanwit Tribuddharat Lantharita Charoenpong
B2. Antimicrobial Resistance in Patients with Hospital-associated Infections	Bamrasnaradura Infectious Disease Institute, Department of Disease Control, Ministry of Public Health	Wanwisa Kaewkhankhaeng Anond Kulthanmanusorn Weerawat Manosuthi Visal Moolasart Lantharita Charoenpong	Kumthorn Malathum Suvaporn Anugulruengkitt
B3. Antimicrobial resistance in Food-Producing Animals	Department of Livestock Development, Ministry of Agriculture and Cooperatives	Saowapa Khotchalai Angkana Lekagul Julaporn Srinha Supaporn Wongsrichai Thanawan Na Thalang	Sanpech Angkititrakul Saharuetai Jeamsripong

Contents

Contents

ABBREVIATIONS AND ACRONYMS

ABC	Antibacterial consumption
AMC	Antimicrobial consumption
AMR	Antimicrobial resistance
API	Active pharmaceutical ingredient
AST	Antimicrobial Susceptibility Testing
ATC	Anatomical Therapeutic Chemical
ATCvet	Anatomical Therapeutic Chemical classification system for veterinary medicinal products
AWaRe	Access, Watch, Reserve classification of antibiotics
Aw	Average weight at the time of treatment
BLI	Beta-lactamase inhibitor
CAUTI	Catheter-associated urinary tract infections
CIA	Critically important antimicrobials
CLABSI	Central line-associated bloodstream infections
CLSI	Clinical and Laboratory Standards Institute
CRPA	Carbapenem-resistant *Pseudomonas aeruginosa*
CRE	Carbapenem-resistant *Enterobacteriaceae*
DDD	Defined Daily Dose
DID	Defined Daily Doses/1000 inhabitants/day
DLD	Department of Livestock Development, Ministry of Agriculture and Cooperatives
DOF	Department of Fisheries, Ministry of Agriculture and Cooperatives
EFSA	European Food Safety Authority
ESAC-Net	European Surveillance of Antimicrobial Consumption Network
ESVAC	European Surveillance of Veterinary Antimicrobial Consumption
EUCAST	European Committee on Antimicrobial Susceptibility Testing
FAO	Food and Agriculture Organization
FDA	Thailand Food and Drug Administration
HPSR-AMR	Health Policy and Systems Research on Antimicrobial Resistance
HAI	Hospital-Associated Infections
I	Intermediate
ICN	Infection control nurse
ICWN	Infection control ward nurse
ISO	International Organization for Standardization
IHPP	International Health Policy Program
MIC	Minimal Inhibitory Concentration
MOPH	Ministry of Public Health
MRCNS	Methicillin-resistant coagulase-negative Staphylococcus
MRSA	methicillin-resistant *Staphylococcus aureus*
NARST	National Surveillance System for Antimicrobial Resistance
NSP-AMR	National Strategic Plan on Antimicrobial Resistance
NIAH	National Institute of Animal Health
OIE	World Organisation for Animal Health
PCU	Population correction unit
PLO	Provincial Livestock Offices
R	Resistant
S	Susceptible
SAC	Surveillance of Antimicrobial Consumption
SD	Standard deviation
SDD	Strains susceptible-dose dependent
SSI	Surgical site infection
VAP	Ventilator-associated pneumonia
VRE	Vancomycin-resistant *Enterococcus*
WHO	World Health Organization

GLOSSARY

Antimicrobial consumption (AMC)

Antimicrobial consumption is the quantity of consumption of antimicrobial drugs, which is measured at the national level as the quantity of its production plus imports minus the quantity of its exports. AMC is expressed as the number of Defined Daily Doses (DDDs) per 1,000 inhabitants per day for human antimicrobials, and milligram per Population Correction Unit, modified by Thailand ($mg/PCU_{Thailand}$) for food-producing animals.

Antimicrobial resistance (AMR)

Antimicrobial resistance is the ability of microbes (e.g. bacteria, viruses and fungi) to grow or survive even after exposure to antimicrobial agents at concentrations that are normally sufficient to inhibit or kill that particular strain of microbe. In this report, AMR predominantly means AMR in bacteria.

Antituberculous drug

Antituberculous drugs in Thailand Surveillance of antimicrobial consumption (Thailand SAC) are drugs used solely for treatment of tuberculosis; however, this may or may not include certain groups of drugs such as macrolides, fluoroquinolones and ansamycins due to their other indications for non-mycobacterial infections.

Antimicrobial agent

Antimicrobial agents are substances with antimicrobial properties or the ability to inhibit growth or metabolic processes in microbes (e.g. bacteria, viruses and fungi). They are obtained from living organisms or through synthesis. In this report, antimicrobial agents predominantly refer to antibacterial agents; except for the human antimicrobial consumption chapters in which antimicrobial agents cover antimicrobials of all origins, antivirals, antifungals, antimycotics, antituberculous drugs, and antimalarials.

Antibiotics

Antibiotics are antimicrobial medicines with bactericidal properties, (including those with the ability to stop bacterial growth), obtained from living organisms or through synthesis. Examples include penicillin, amoxicillin, tetracycline, norfloxacin and azithromycin. The terms microbicide (microbe killer), antibacterial medicines and antibiotics are used interchangeably.

Bacteria

Bacteria are one of the major groups of microorganisms or microbes, some of which can infect and cause diseases in humans and animals. A range of descriptive terms are used. Bacteria cultivated in a laboratory are referred to as isolates, capable of causing disease are referred to as pathogens (pathogens that are transmissible between animals and humans are zoonotic), and those that are normally resident on or in humans or animals without causing disease are referred to as commensals or colonizers.

Critically Important Antimicrobials

In this report, the Critically Important Antimicrobials (CIA) refers to the lists of CIA for human medicine defined by the World Health Organization [1]. It ranks medically important antimicrobials for risk management of antimicrobial resistance due to non-human use. It was developed for cautious use in mitigating the human health risks associated with antimicrobial use (AMU) in both humans and food-producing animals.

One Health

A concept promoting a 'whole of society' approach to attain optimal health for people and animals, and a healthy environment.

Surveillance

Surveillance means a continuing process of collecting, collating and analysing data and communicating information to all relevant actors. It involves the generation and timely provision of information that can inform appropriate decision-making and action.

Susceptible

A category which implies that isolates are inhibited by the usually achievable concentrations of antimicrobial agent when the recommended dosage (dosage regimen) is used for achieving therapeutic effects at the site of infection (1).

Susceptible-dose dependent (SDD)

A category defined by a breakpoint that implies the susceptibility of an isolate is dependent on the dosing regimen that is used in the patient. In order to achieve levels that are likely to be clinically effective against isolates for which the susceptibility testing results are in the SDD category, it is necessary to use a dosing regimen (i.e., higher doses, more frequent doses, or both) that results in higher drug exposure than the dose that was used to establish the susceptible breakpoint.

Intermediate

A category which includes isolates with antimicrobial agent MICs that approach usually attainable blood and tissue levels and for which response rates may be lower than those for susceptible isolates, leading to less success rates of treatment (1).

Resistant

A category that implies that isolates are not inhibited by the usually achievable concentrations of the antimicrobial agent with normal dosage regimen and/or demonstrate MICs/zone diameters that fall in the range where specific microbial resistance mechanisms (e.g., β-lactamases) are likely to do and that clinical efficacy against the isolate has not been shown reliably in treatment studies (1).

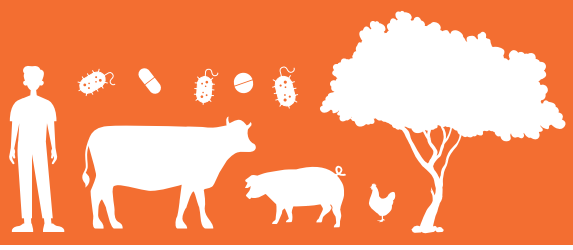
Non-susceptible

A category used for isolates for which only a susceptible breakpoint is designated because of the absence or rare occurrence of resistant strains. This includes isolates for which the antimicrobial agent minimum inhibitory concentrations (MICs) are above a susceptible breakpoint or their zone diameters fall below the value indicated for the susceptible.

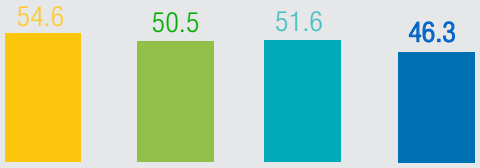
[1] World Health Organization. Critically important antimicrobials for human medicine, 6th revision. Geneva, 2019.

HIGHLIGHTS

HIGHLIGHTS

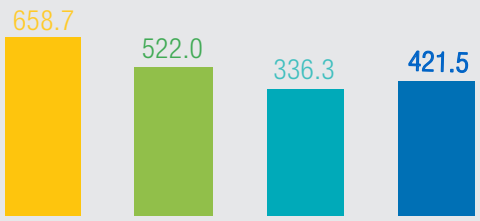


Antimicrobial consumption in humans (DID)*



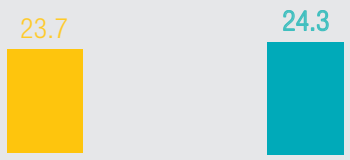
15.2%
2020 compared with 2017

Antimicrobial consumption in animals (mg/ $PCU_{Thailand}$)**



36.0%
2020 compared with 2017

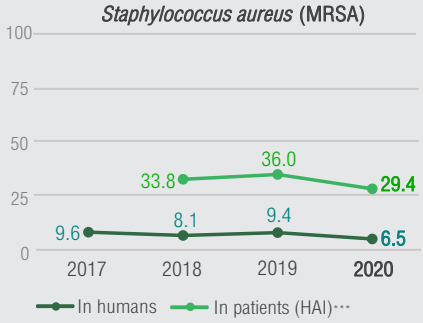
Knowledge and awareness on AMR (%)



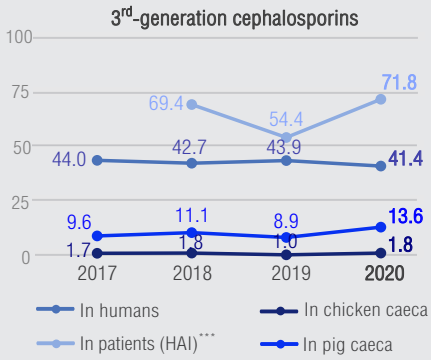
0.6% percentage point
2019 compared with 2017

Antimicrobial resistance in humans and animals (%)

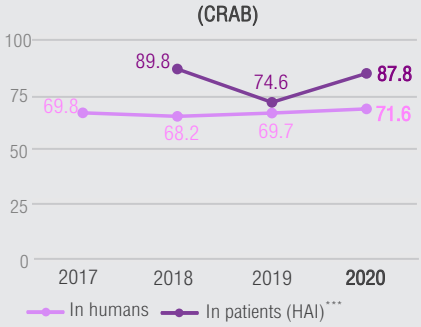
Methicillin-resistant *Staphylococcus aureus* (MRSA)



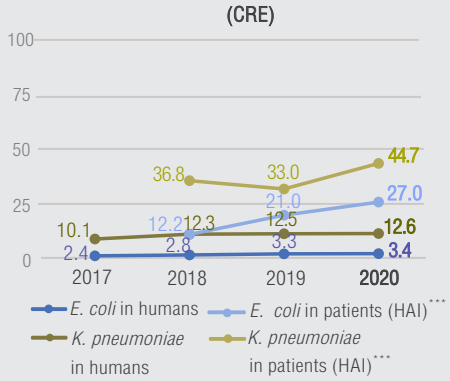
Escherichia coli resistant to 3rd-generation cephalosporins



Carbapenem-resistant *Acinetobacter baumannii* (CRAB)



Carbapenem-resistant *Enterobacteriaceae* (CRE)



* DID: Defined Daily Dose/1,000 inhabitants/day

** mg/$PCU_{Thailand}$: mg/ Population correction unit. $PCU_{Thailand}$ is modified from European Surveillance of Veterinary Antimicrobial Consumption (ESVAC) methodology by combining both PCU from terrestrial animals and biomass from aquatic animals.

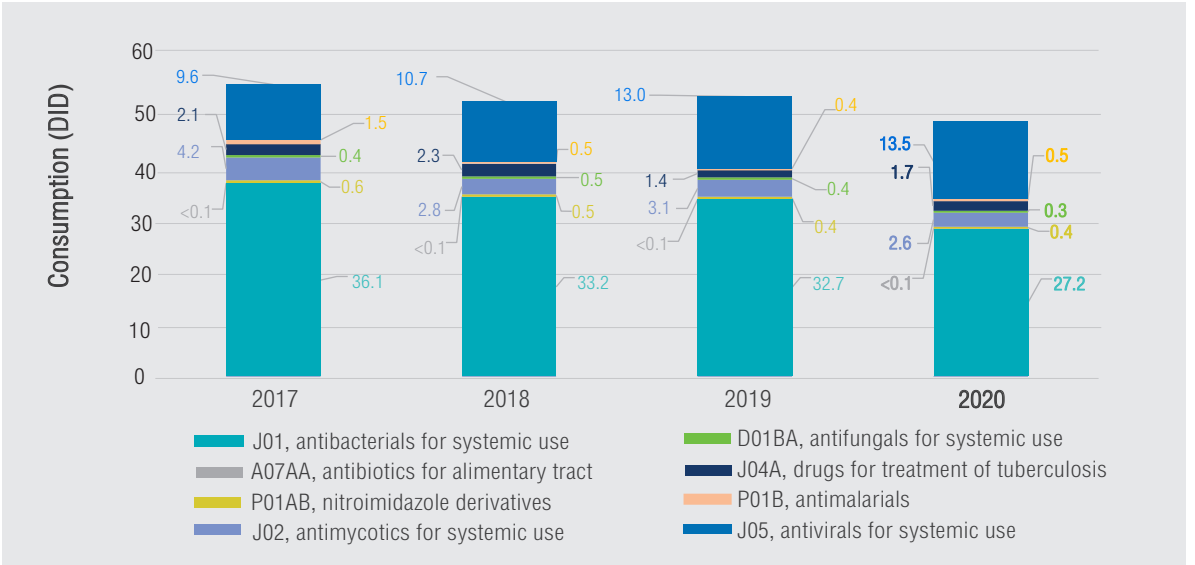
*** In patients (HAI): Patients with Hospital-Associated Infections

Data on monitoring and evaluation of the Goals of Thailand's National Strategic Plan on Antimicrobial Resistance 2017-2021

Indicator	Data			
	2017	2018	2019	2020
A. Antimicrobial consumption in humans and animals				
Antimicrobial consumption in humans (DID)	54.6 (baseline)	50.5 (⬇7.5%)	51.6 (⬇5.6%)	46.3 (⬇15.2%)
Antimicrobial consumption in food-producing animals (mg/ $PCU_{Thailand}$)	658.7 (baseline)	522.0 (⬇20.8%)	336.3 (⬇49.0%)	421.5 (⬇36.0%)
B. AMR in humans and animals				
Percentage of Methicillin-resistant *Staphylococcus aureus* (MRSA)				
- AMR in humans	9.6	8.1	9.4	6.5
- AMR in patients with hospital-associated Infections	-	33.8	36.0	29.4
Percentage of *Escherichia coli* resistant to 3rd-generation cephalosporins				
- AMR in humans	44.0	42.7	43.9	41.4
- AMR in patients with hospital-associated Infections	-	69.4	54.4	71.8
- AMR in chicken caeca	1.7	1.8	1.0	1.8
- AMR in pig caeca	9.6	11.1	8.9	13.6
Percentage of Carbapenem-resistant *Acinetobacter baumannii* (CRAB)				
- AMR in humans	69.8	68.2	69.7	71.6
- AMR in patients with hospital-associated Infections	-	89.8	74.6	87.8
Percentage of Carbapenem-resistant *Enterobacteriaceae* (CRE)				
- AMR in humans				
○ *Escherichia coli*	2.4	2.8	3.3	3.4
○ *Klebsiella pneumoniae*	10.1	12.3	12.5	12.6
- AMR in patients with hospital-associated Infections				
○ *Escherichia coli*	-	12.2	21.0	27.0
○ *Klebsiella pneumoniae*		36.8	33.0	44.7
C. Knowledge and awareness on AMR (percent)	23.7 (baseline)	-	24.3 (⬆ 0.6 percentage point)	-

I. Antimicrobial Consumption in Humans[1]

Antimicrobial consumption in humann in 2017-2020

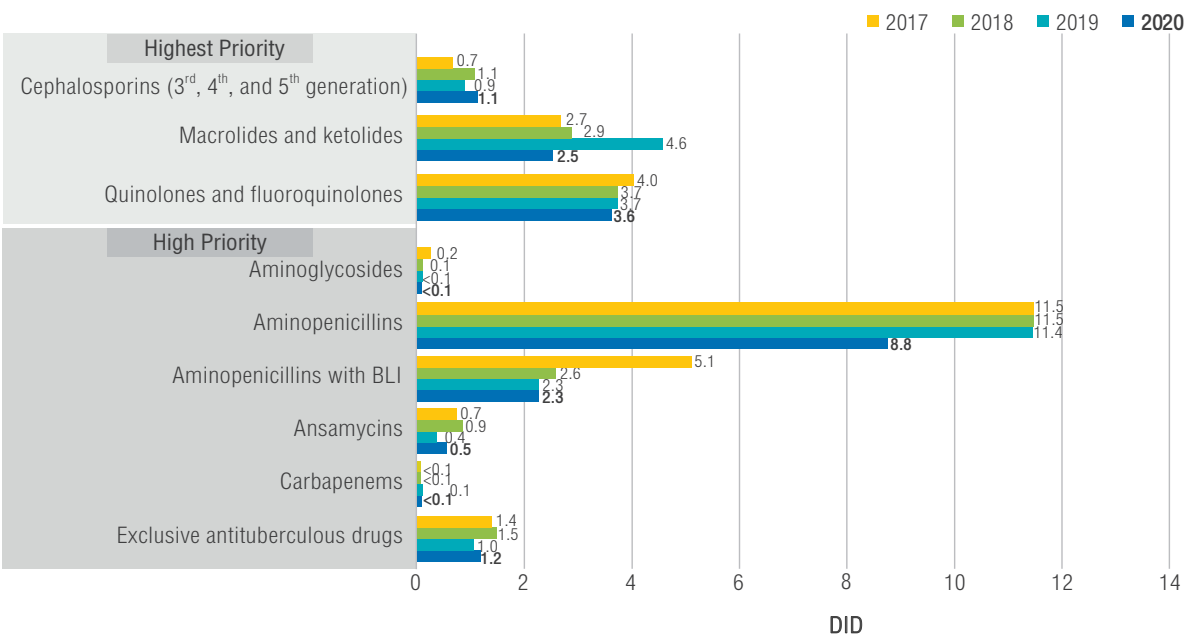


Top 10 antimicrobials consumption in humans in 2017-2020

Rank	Antimicrobial agent	Consumption (DID)			
		2017	2018	2019	2020
1	Amoxicillin	10.1	9.3	9.2	**6.6**
2	Emtricitabine, tenofovir disoproxil and efavirenz	1.3	1.8	2.5	**2.8**
3	Lamivudine	2.6	2.5	1.8	**2.5**
4	Tetracycline	3.4	3.7	2.3	**2.4**
5	Amoxicillin with beta-lactamase inhibitor	5.1	2.6	2.3	**2.3**
6	Ampicillin	1.4	2.2	2.2	**2.2**
7	Ketoconazole	3.7	2.1	2.4	**2.0**
8	Tenofovir disoproxil	0.1	0.2	1.6	**1.6**
9	Norfloxacin	2.0	1.4	1.4	**1.6**
10	Doxycycline	2.4	2.2	2.0	**1.6**

Note: Data ranked of top 10 from 2020.

Antimicrobial consumption in humans classified by WHO critically important antimicrobials[2] in 2017-2020

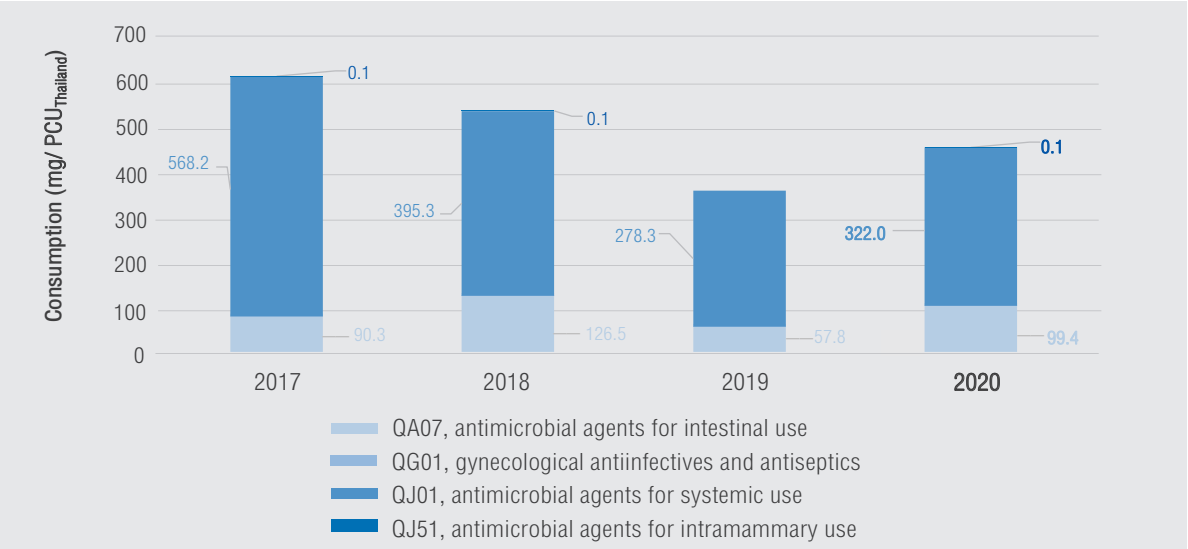


[1] Data source: Thailand Surveillance of Antimicrobial Consumption

[2] Source: WHO lists of Critically Important Antimicrobials for Human Medicine 6th edition

II. Antimicrobial Consumption in Food-Producing Animals[3]

Antimicrobial consumption in food-producing animals in 2017-2020



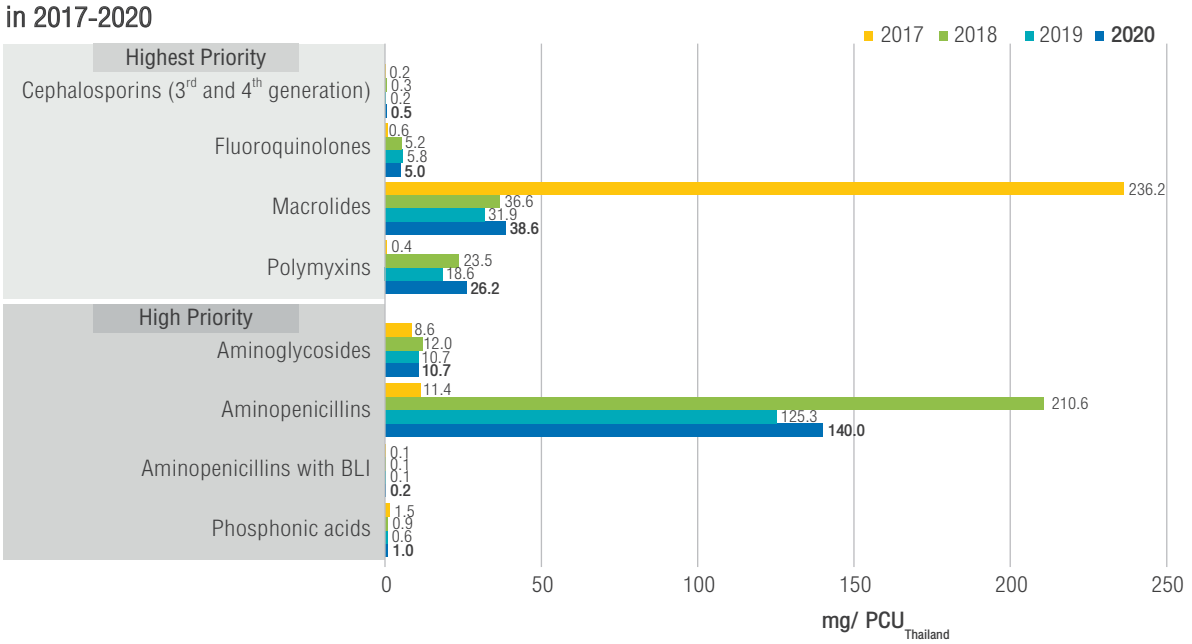
Note: The <0.1 tonnes of API not labeled (QG51, antiinfectives and antiseptics for intrauterine use).

Top 10 antimicrobials consumption for food-producing animals in 2017-2020

Rank	Antimicrobial agent	Consumption (mg/ PCU$_{Thailand}$)*			
		2017	2018	2019	2020
1	Amoxicillin	11.4	210.4	125.1	**139.8**
2	Emtricitabine, tenofovir disoproxil and efavirenz	52.9	42.8	44.8	**57.1**
3	Lamivudine	7.7	60.2	36.2	**45.6**
4	Tetracycline	10.5	14.6	18.4	**45.6**
5	Amoxicillin and beta-lactamase inhibitor	0.4	23.5	18.6	**26.2**
6	Ampicillin	8.9	16.7	16.3	**25.6**
7	Ketoconazole	73.3	80.5	14.8	**22.2**
8	Tenofovir disoproxil	19.1	14.6	13.0	**14.5**
9	Norfloxacin	223.7	14.3	8.8	**8.2**
10	Doxycycline	5.9	7.8	6.0	**5.5**

Note: Data ranked of top 10 from 2020.

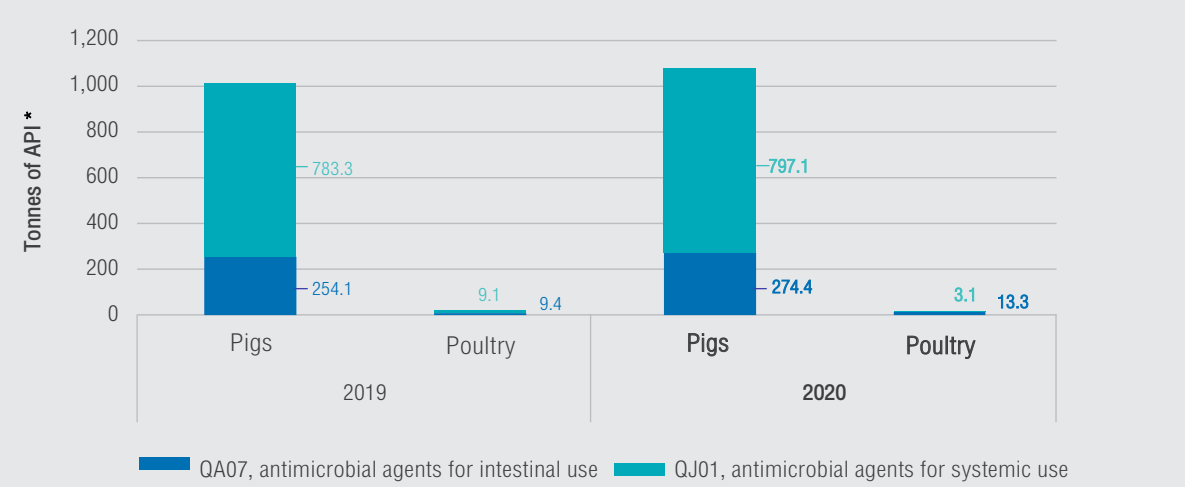
Antimicrobial consumption in food-producing animals classified by WHO citically important antimicrobials in 2017-2020



[3] Data source: Thailand Surveillance of Antimicrobial Consumption

III. Antibacterial Consumption in Food-Producing Animals (Medicated Feed Produced by Feedmills)[4]

Antibacterial consumption in medicated feed by species of food-producing animals in 2019-2020

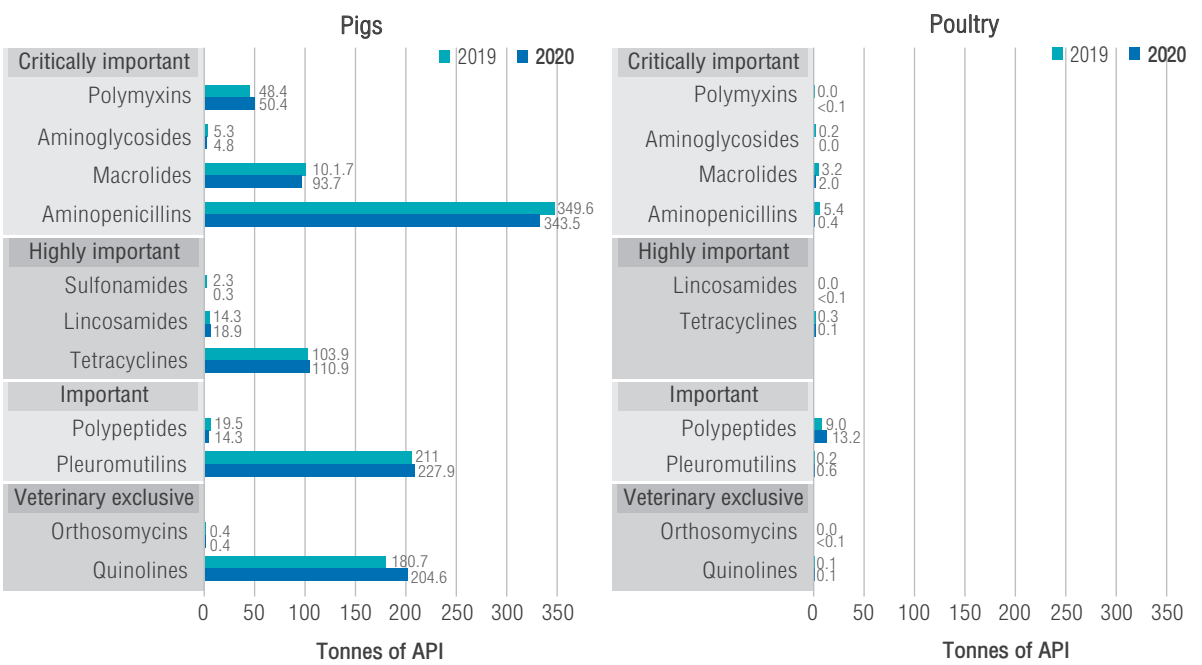


Top 10 antibacterials in medicated feed for pigs and poultry in 2019-2020

Rank	Pigs (Tonnes of API)			Poultry (Tonnes of API)		
	Antimicrobial agent	2019	2020	Antimicrobial agent	2019	2020
1	Amoxicillin	349.6	**343.5**	Bacitracin	9.0	**13.2**
2	Tiamulin	211.0	**227.9**	Tilmicosin	<0.1	**1.2**
3	Halquinol	180.7	**204.6**	Tylvalosin	0.3	**0.8**
4	Chlortetracycline	87.9	**84.7**	Tiamulin	0.2	**0.6**
5	Tilmicosin	54.8	**83.0**	Amoxicillin	5.4	**0.4**
6	Colistin	48.4	**50.4**	Doxycycline	0.1	**<0.1**
7	Doxycycline	12.9	**21.8**	Halquinol	<0.1	**<0.1**
8	Lincomycin	14.3	**18.9**	Kitasamycin	<0.1	**<0.1**
9	Bacitracin	19.5	**14.3**	Chlortetracycline	0.2	**<0.1**
10	Tylvalosin	3.4	**4.9**	Colistion	<0.1	**<0.1**

Note: Data ranked of top 10 from 2020

Antibacterial consumption in medicated feed for pigs and poultry by WHO critically important antimicrobials and chemical class in 2019-2020

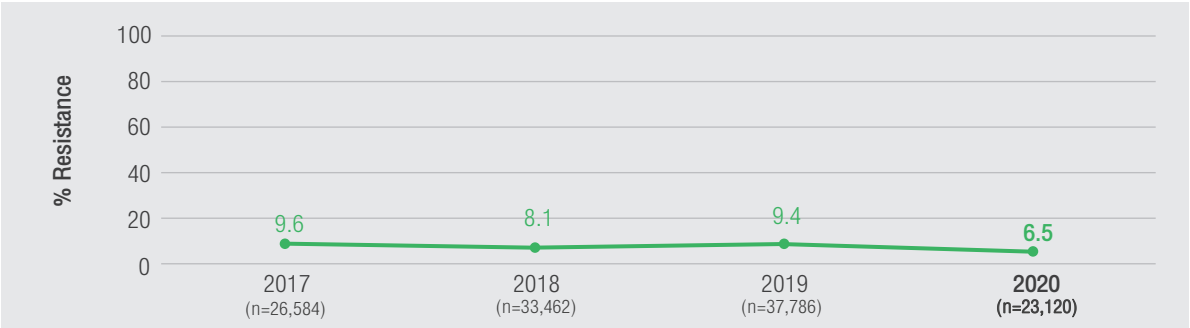


[4] Data source: Thailand Surveillance of Antimicrobial Consumption

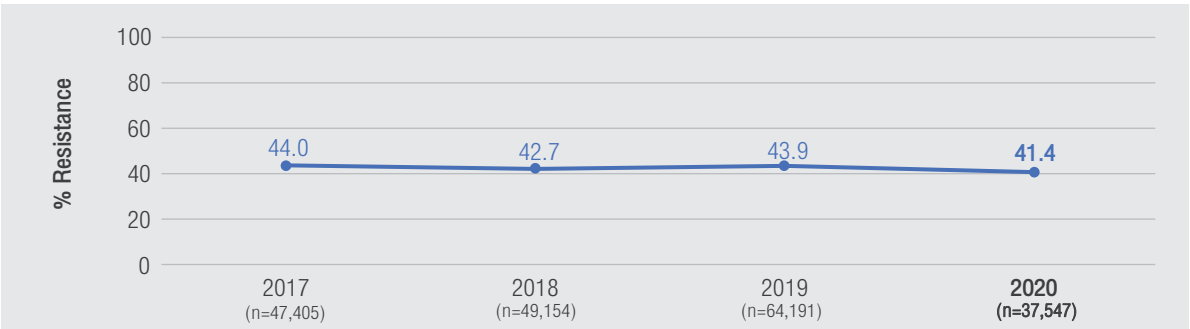
* API: Active Pharmaceutical Ingredient

IV. Antimicrobial Resistance in Humans[5]

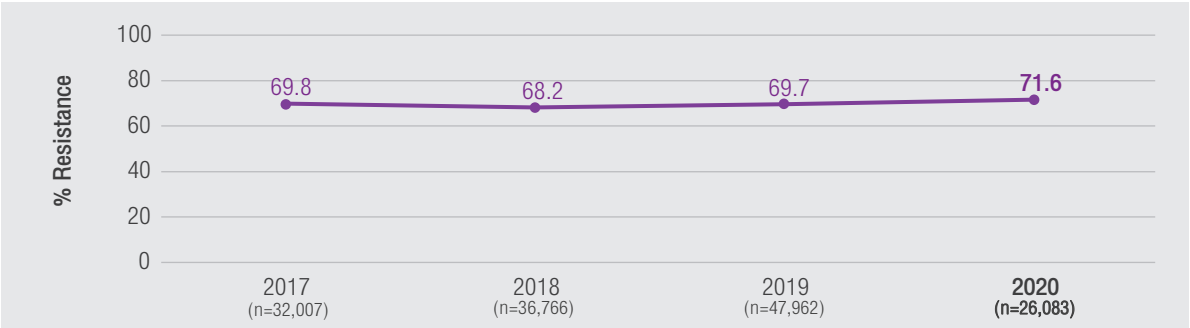
Percentage of Methicillin-resistant *Staphylococcus aureus* (MRSA) in 2017-2020



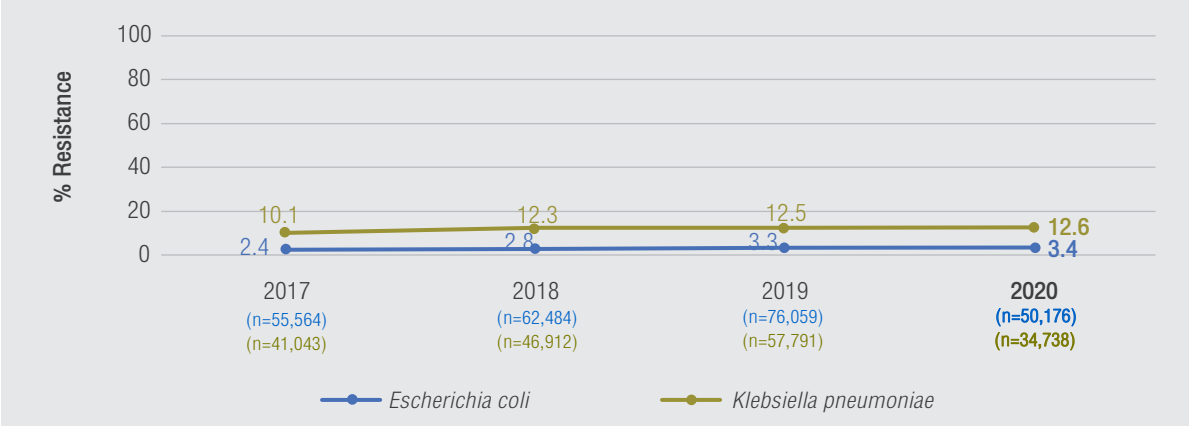
Percentage of *Escherichia coli* with 3rd-generation cephalosporins resistance in 2017-2020



Percentage of Carbapenem-resistant *Acinetobacter baumannii* (CRAB) in 2017-2020



Percentage of Carbapenem-resistant *Enterobacteriaceae* (CRE) in 2017-2020

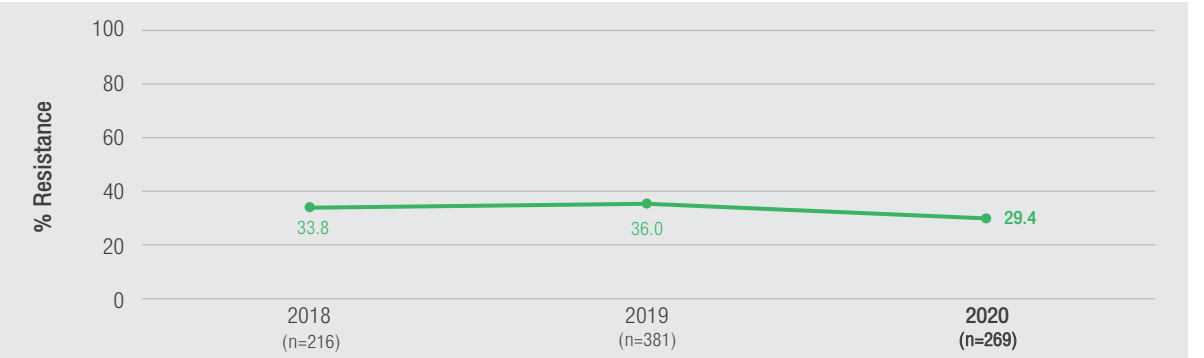


Note: Carbapenem-resistant *Enterobacteriaceae* (CRE) included *Klebsiella pneumoniae* and *Escherichia coli*.

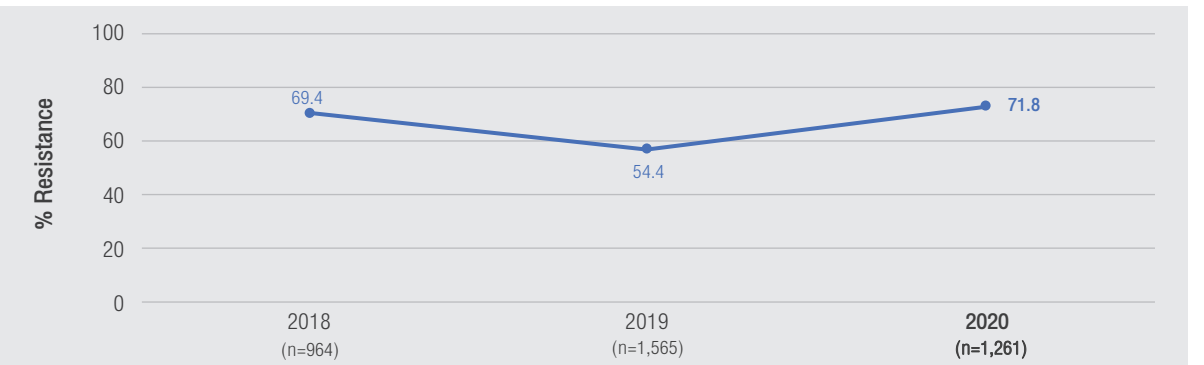
[5] Data source: National Antimicrobial Resistance Surveillance Center Thailand (NARST), National Institute of Health, Department of Medical Sciences, and Department of Disease Control

V. Antimicrobial Resistance in Patients with Hospital-Associated Infections[6]

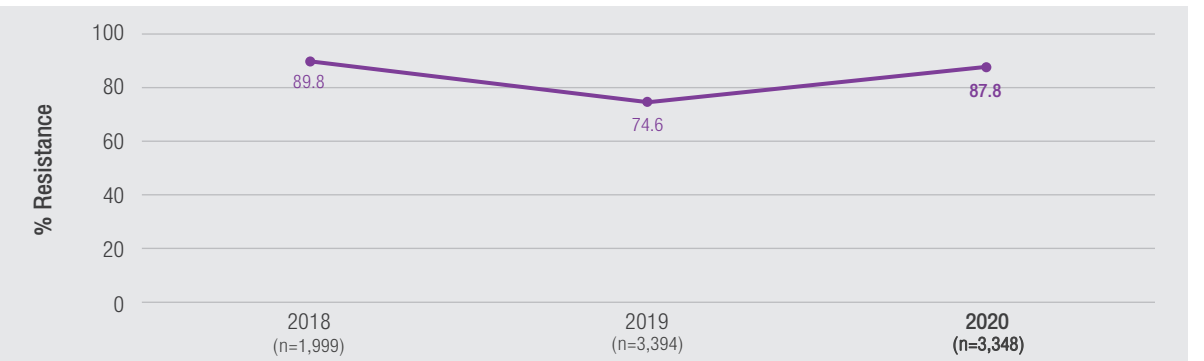
Percentage of Methicillin-resistant *Staphylococcus aureus* (MRSA) in patients with hospital-associated infections in 2018-2020



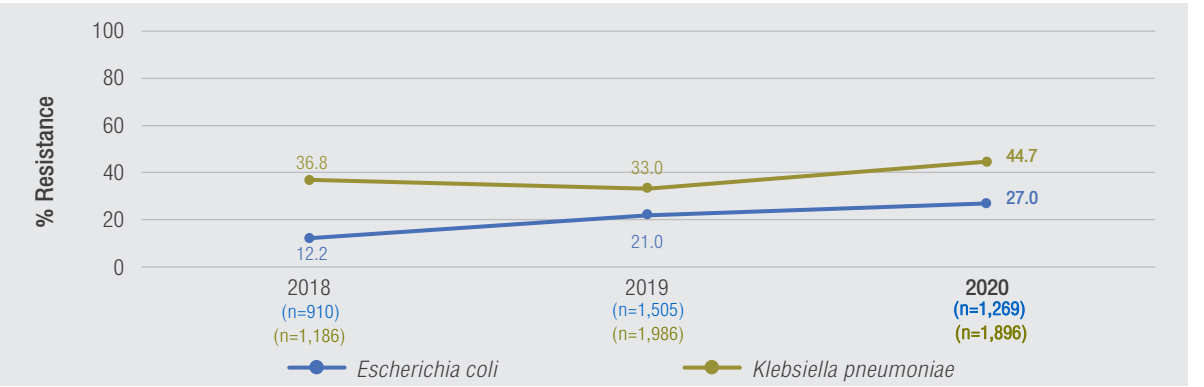
Percentage of *Escherichia coli* with 3rd-generation cephalosporins resistance in patients with hospital-associated infections in 2018-2020



Percentage of Carbapenem-resistant *Acinetobacter baumannii* (CRAB) in patients with hospital-associated infections in 2018-2020



Percentage of Carbapenem-resistant *Enterobacteriaceae* (CRE) in patients with hospital-associated infections in 2018-2020



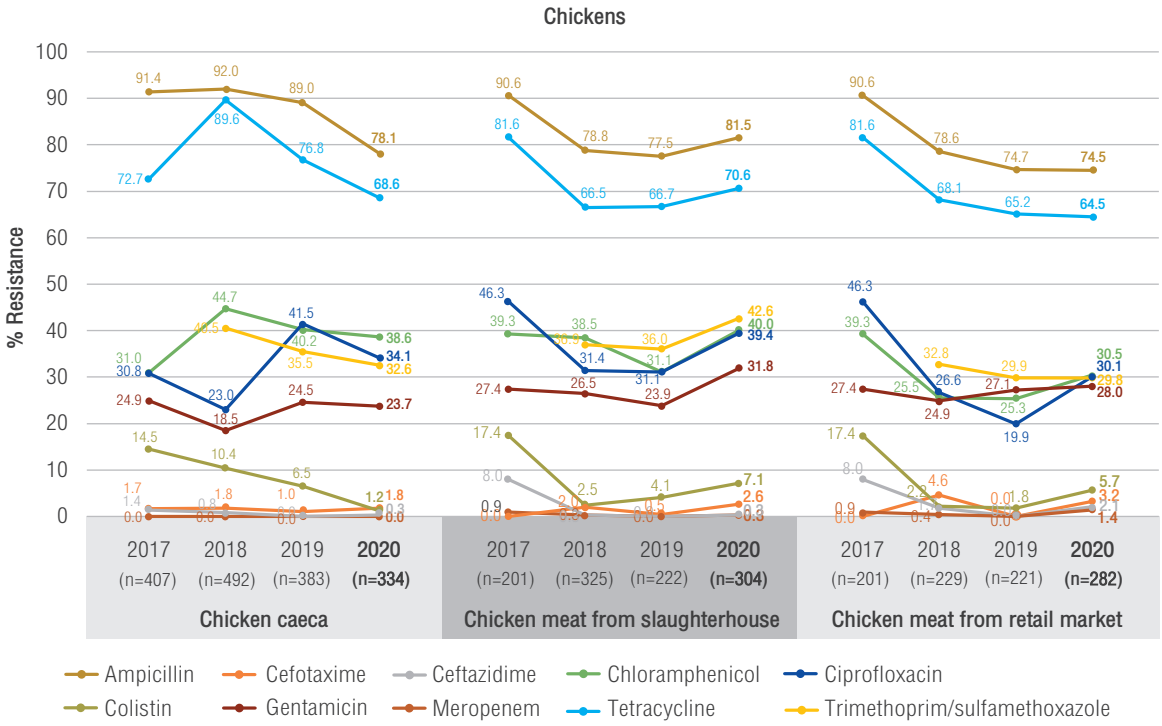
Note: Carbapenem-resistant *Enterobacteriaceae* (CRE) included *Klebsiella pneumoniae* and *Escherichia coli*.

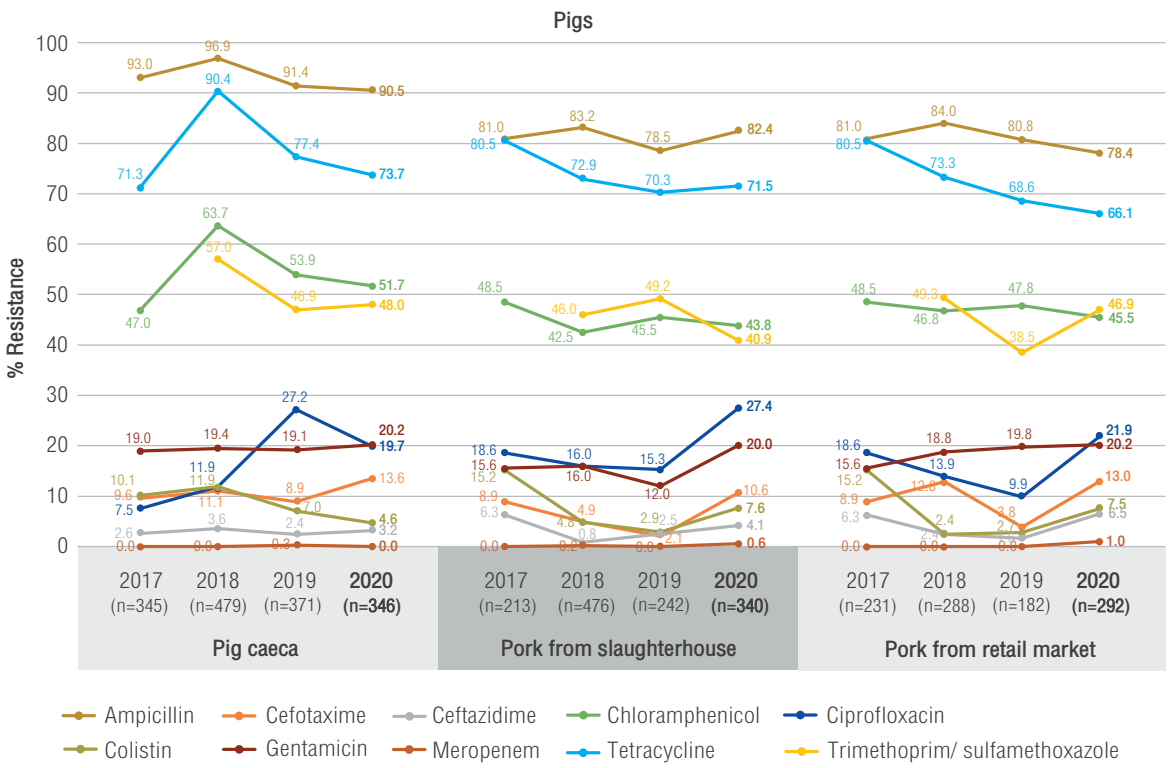
[6] Data source: Surveillance of Hospital-associated Infection, Bamrasnaradura Infectious Disease Institute

VI. Antimicrobial Resistance in Food-Producing Animals[7]

Escherichia coli

Percentage of antimicrobial resistance of *Escherichia coli* in 2017-2020

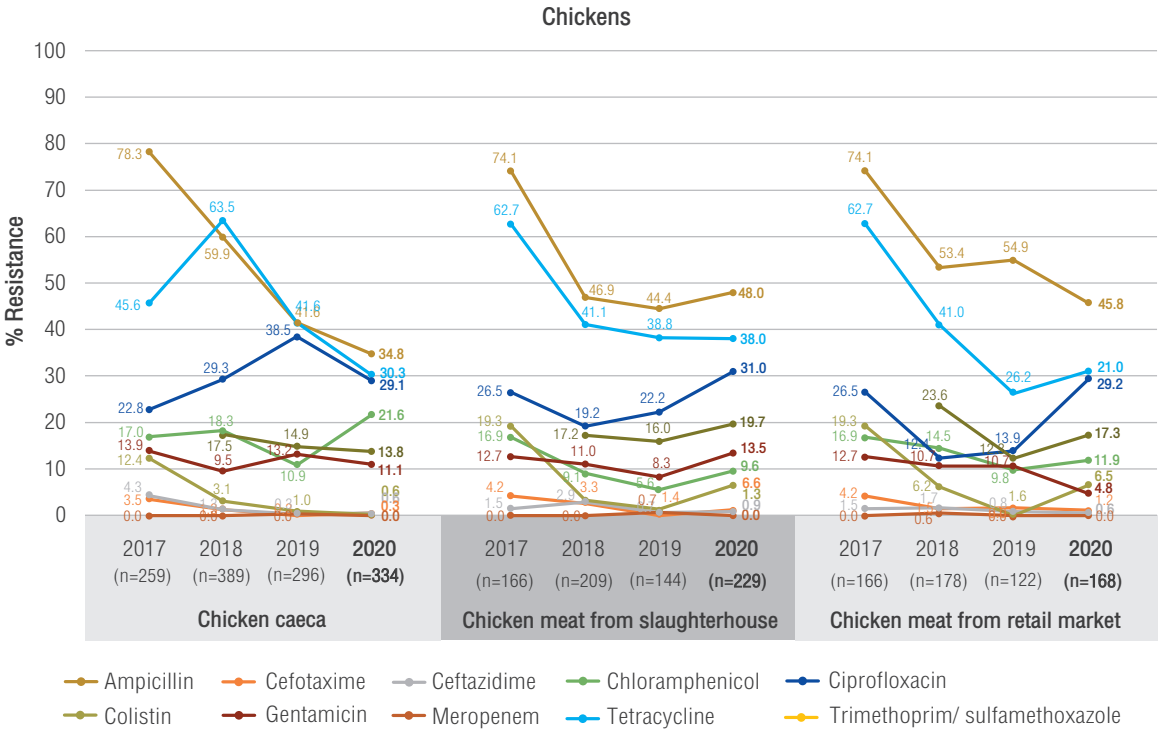


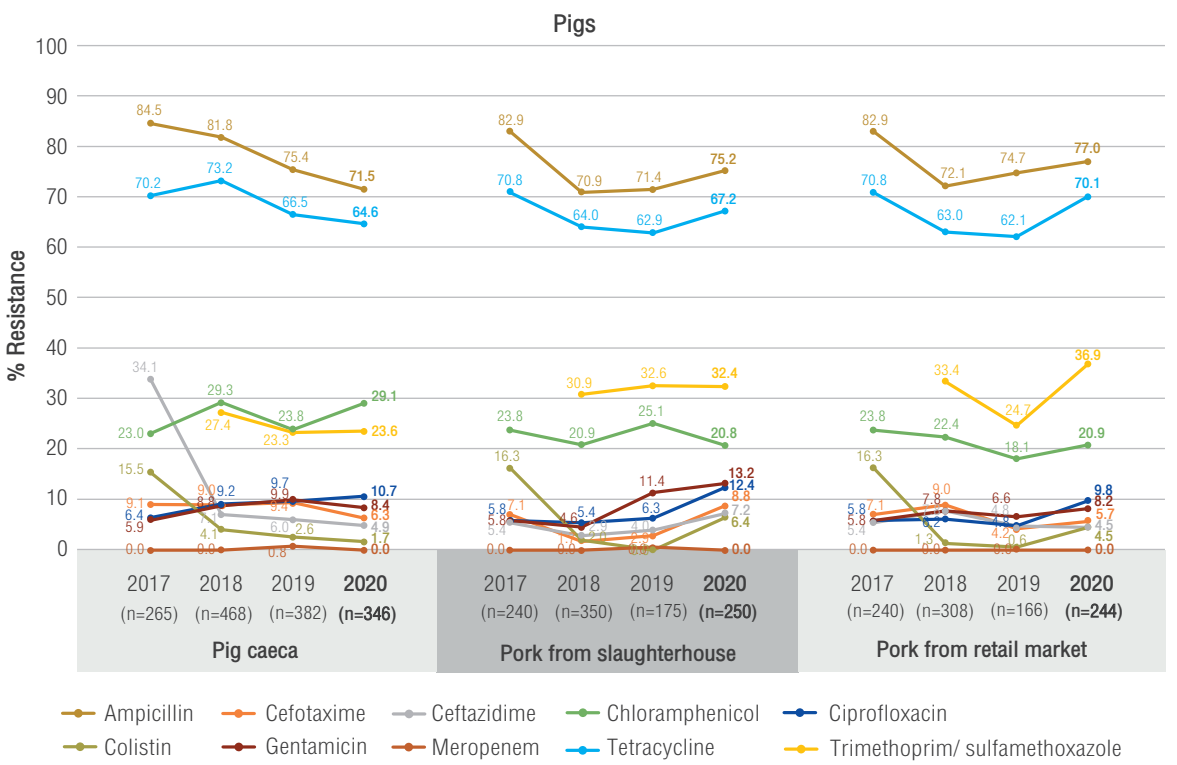


[7] Data source: Department of Livestock Development

Salmonella spp.

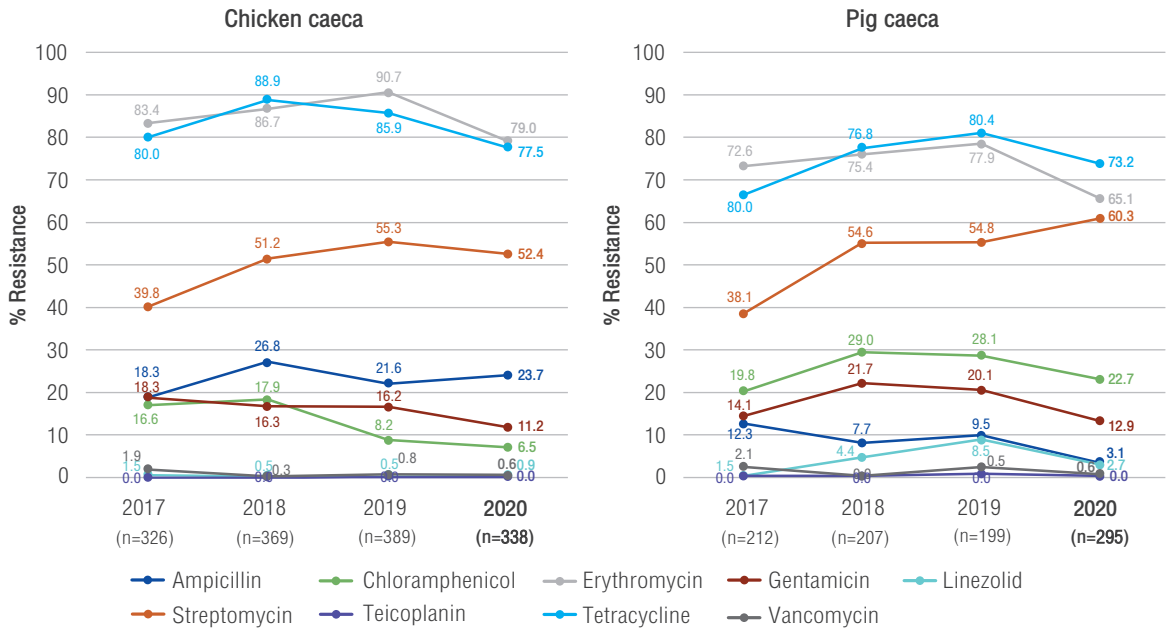
Percentage of antimicrobial resistance of *Salmonella* spp. in 2017-2020





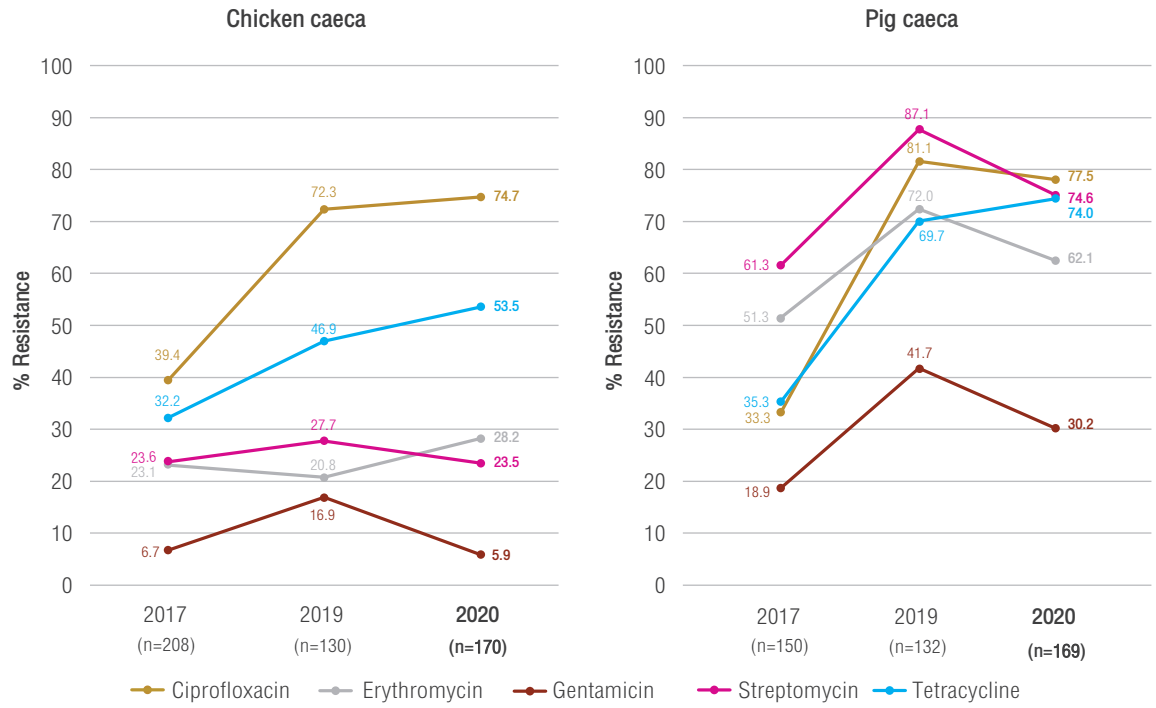
Enterococcus spp.

Percentage of antimicrobial resistance of *Enterococcus* spp. in 2017-2020



Campylobacter spp.

Percentage of antimicrobial resistance of *Campylobacter* spp. in 2017 and 2019-2020



SECTION A

ANTIMICROBIAL CONSUMPTION

SECTION A:
ANTIMICROBIAL CONSUMPTION

A1: Antimicrobial Consumption in Humans

A1.1 Overall consumption

- The overall consumption of human antimicrobials was 46.3 Defined Daily Doses/1,000 inhabitants/day (DID) in 2020 (-15.2% from 2017-20) (Figure A1.1).
- Overall, from 2017 to 2020, the majority of decrease in consumption came from antibacterial for systemic use (J01) (27.2, DID from 2017-2020), which was the main group of consumed antimicrobials in overall (58.7%), and from antimycotics for systemic infections (J02) (2.6 DID, from 2017-2020), the third contributor to the overall consumption (5.5%).
- On the contrary, the only group with increased consumption was antivirals for systemic use (J05) (+3.9 DID from 2017-2020), the second contributor to the overall consumption (13.5 DID).

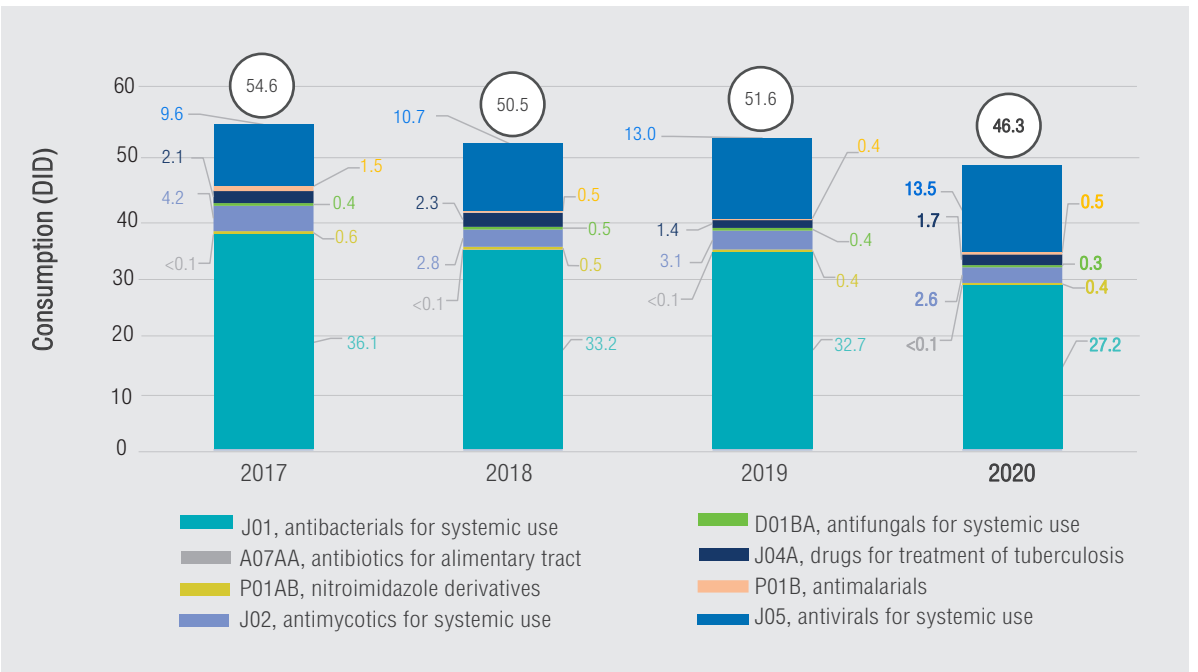


Figure A1.1 Consumption of target human antimicrobials (Defined Daily Doses/1,000 inhabitants/day, DID) classified by WHO Anatomical Therapeutic Chemical Classification (ATC) code from 2017 to 2020.

A1.2 Core and optional class breakdowns

Overall consumption of core class with highest proportion

As the major contributor to total human antimicrobial consumption (58.7% in 2020), the profile of antibacterials for systemic use (J01) still had penicillins (J01C) (48.4% of J01 in 2020) and tetracyclines (J01A) (14.9% of J01 in 2020), as the main consumption groups in J01 (Figure A1.2). The decrease of J01 (-9.0 DID from 2017-2020) mainly came from decrease in J01C and in J01A. In contrast to the decreased counterpart, only antimicrobial group in J01 was other antibacterials (J01X) (+0.2 DID from 2017-2020). Similar to the top-two J01 groups, the two most consumed antibacterial for systemic use in 2019 by ATC level 5 were amoxicillin (J01CA04) (6.6 DID, 24.2% of J01 consumption) and tetracycline (2.4 DID, 9.0% of J01 consumption) (Figure A1.3).

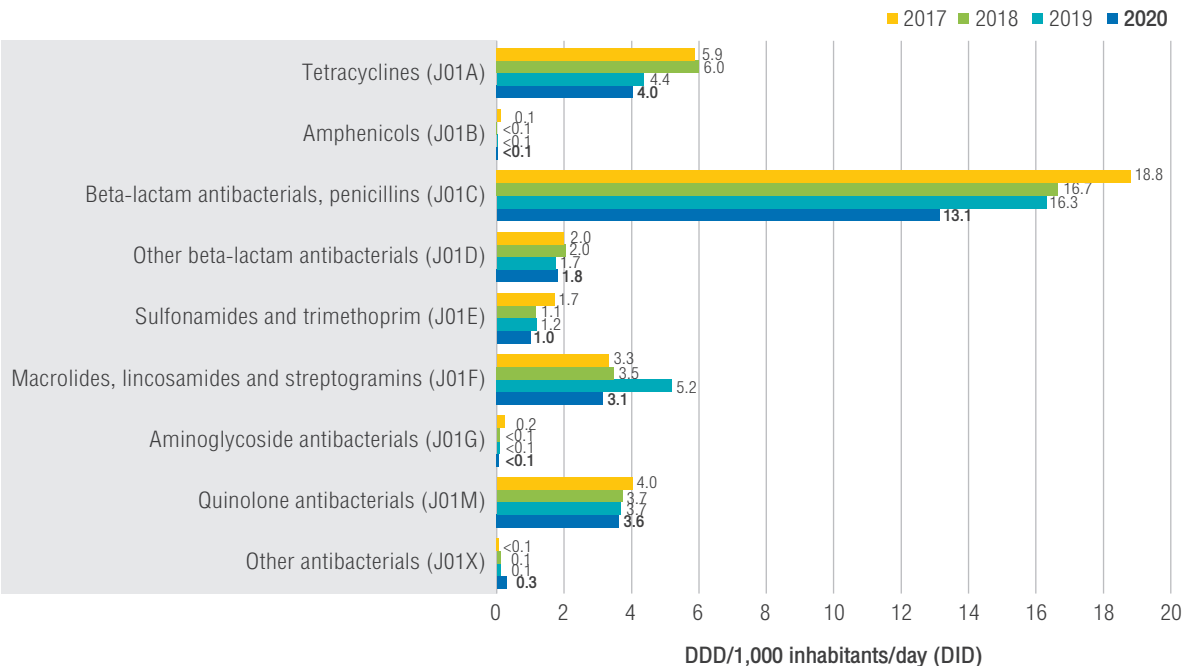


Figure A1.2 Consumption of human antimicrobials indicated for systemic use (J01) classified by ATC level 3, (DDD/1,000 inhabitants/day, DID) from 2017 to 2020.

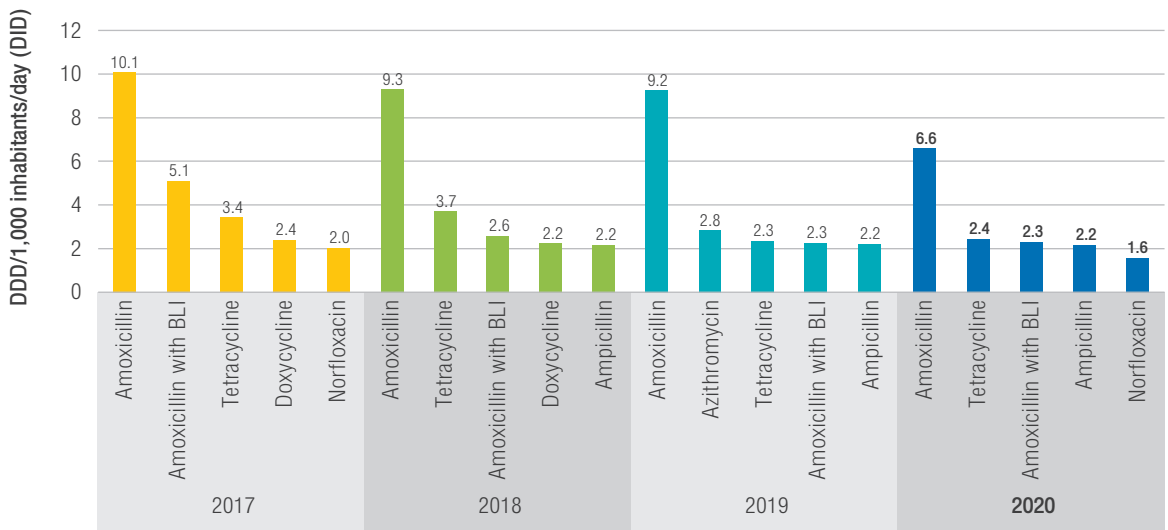


Figure A1.3 Consumption of the top-five antibacterials indicated for systemic use (J01) classified by ATC level 5 (DDD/1,000 inhabitants/day, DID) from 2017 to 2020.

Overall consumption of the other core classes

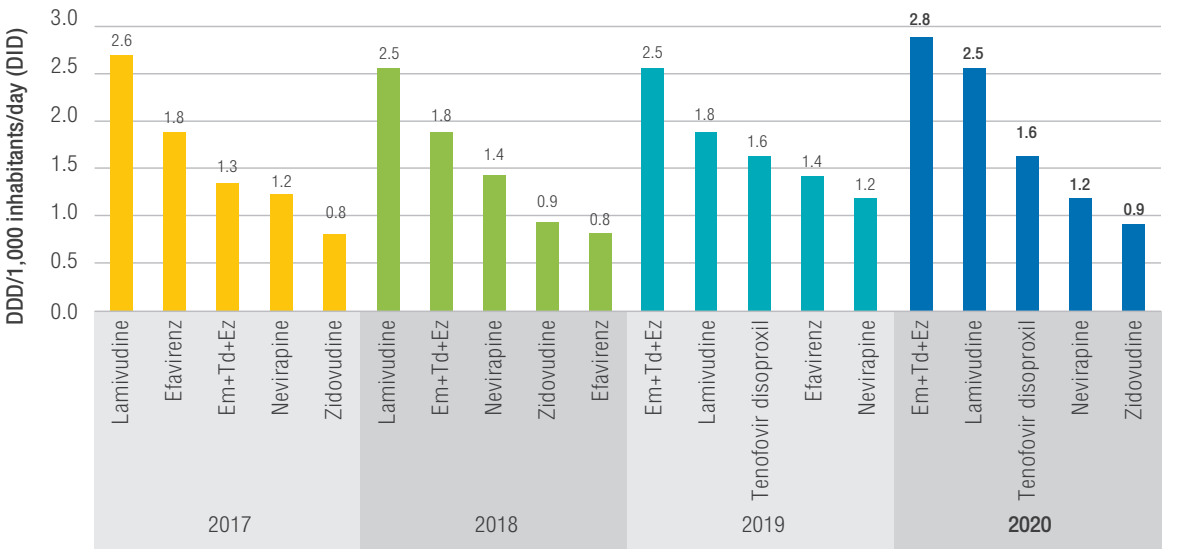
As the second rank in core class, nitroimidazole derivatives (P01AB) were decreased to 0.4 DID (-0.2 DID from 2017-2020) (Figure A1.1). The most consumed nitroimidazole in 2020 by ATC level 5 was metronidazole (P01AB01)(0.4 DID, 93.5% of P01AB consumption). The intestinal anti-infectives (A07AA) were consumed with annual fluctuations. The intestinal anti-infective most consumed in 2020 by ATC level 5 was nystatin (A07AA02) (<0.1 DID, 74.5 % of A07AA consumption).

Overall consumption of optional classes

Antivirals for systemic use (J05) have been increasingly consumed to 13.5 DID (+3.9 DID from 2017-2020). The consumptions of other optional classes, on the other hand, were decreased from 2017-2020 (J02, D01BA, J04A, and P01B) (Figure A1.1).

Consumption of the top-five antimicrobials in the optional classes classified by ATC level 5

- For antivirals for systemic use (J05), the most consumed antiviral in 2020 was still the combination of emtricitabine, tenofovir disoproxil and efavirenz (J05AR06) (2.8 DID, 20.5% of J05 consumption) (Figure A1.4). Lamivudine (J05AF05) still ranked second in 2020 (2.5 DID, 18.3% of J05 consumption). Tenofovir disoproxil (J05AF07) came as the third rank in J05 with an increase of 1.5 DID from 2017-2020.



Em, emtricitabine; Td, tenofovir disoproxil; Ez, efavirenz

Figure A1.4 Consumption of the top-five antivirals indicated for systemic use (J05) classified by ATC level 5 (DDD/1,000 inhabitants/day, DID) from 2017 to 2020 (the calculation method of tenofovir disoproxil in 2019 was different from that of 2020).

- For antimycotics (J02) and antifungals for systemic use (D01BA), ketoconazole (J02AB02), an antimycotic for systemic use, ranked first from 2017 to 2020 with annual fluctuations from 3.7 DID in 2017 to 2.0 DID in 2020 (Figure A1.5). Second rank for the three years, griseofulvin (D01BA01), an antifungal for systemic use, was consumed 0.4 DID in 2019 with fluctuations. The other two antimycotics, which remained top-five from 2017 to 2020, were fluconazole (J02AC01) and itraconazole (J02AC02).

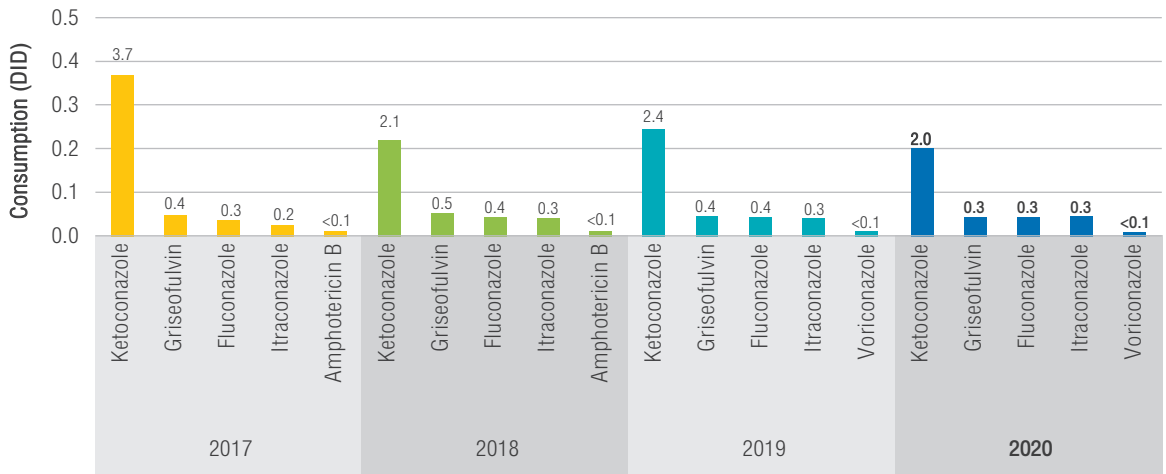


Figure A1.5 Consumption of the top-five antimycotics (J02) and antifungals for systemic use (D01BA) classified by ATC level 5 (DDD/1,000 inhabitants/day, DID) from 2017 to 2020.

- From 2017 to 2020, the top-two antituberculous drugs remained isoniazid (INH) (>35% of J04A consumption) and rifampicin (RIF) (>25% of J04A consumption) (Figure A1.6). Isoniazid was consumed 0.7 DID in 2020 with an increase from 2019 (+0.08 DID). Rifampicin was consumed 0.5 DID in 2020 with an increase from 2019 (+0.2 DID). Pyrazinamide (PZA) and ethambutol (EMB) still remained among the top-five antituberculous drugs from 2017 and 2020.

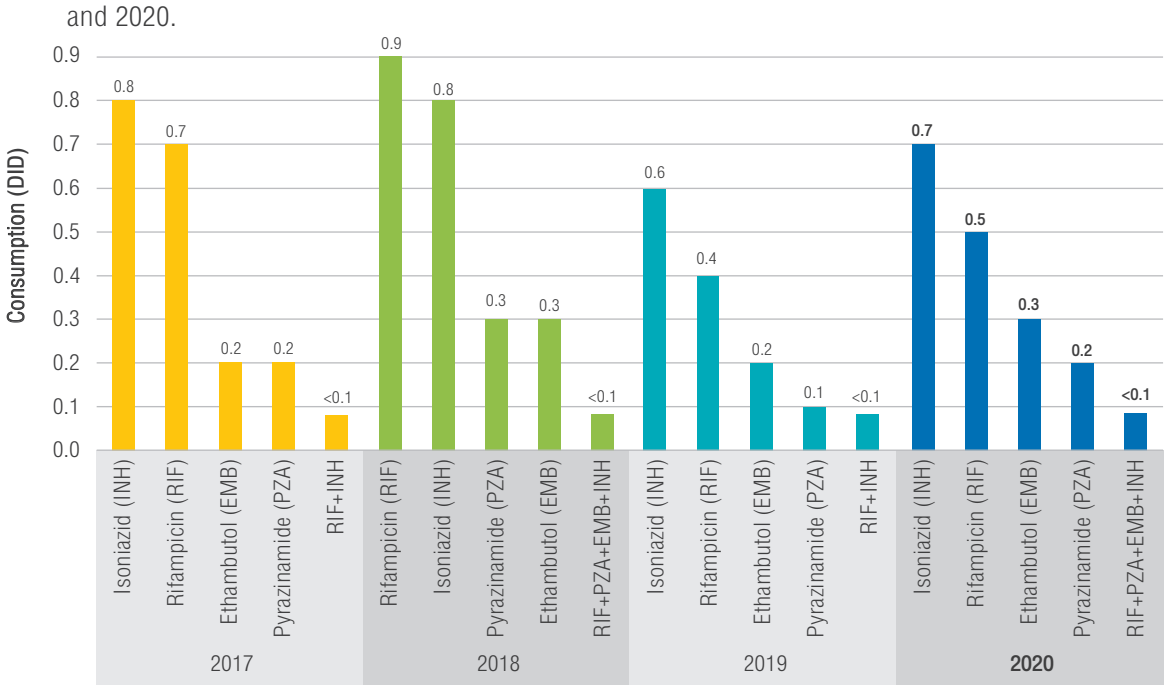


Figure A1.6 Consumption of the top-five antituberculous drugs for systemic use (J04A) classified by ATC level 5 (DDD/1,000 inhabitants/day, DID) from 2017 to 2020.

A1.3 Consumption of Critically Important Antimicrobials (CIA)

- Consumption profile of human antimicrobials remained Non-CIA-dominant from 2017 to 2020. However, by proportion of CIA consumption, the highest priority CIA increased from 13.5% in 2017 to 15.7% of total in 2020 (Figure A1.7).

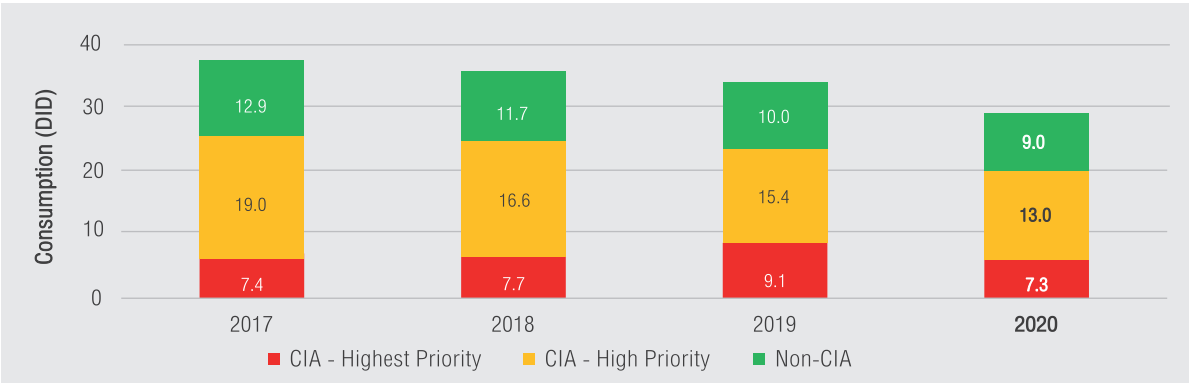


Figure A1.7 Comparative proportional consumption profile of Critically Important Antimicrobials (CIA) in humans from 2017 to 2019 (Non-CIA includes other antimicrobials in the scope of study, which are not categorized as CIA)

- In the highest-priority CIA, consumption has slightly decreased from 7.4 in 2017 to 7.3 DID in 2020 (Figure A1.7). The major contributor to this decrease was quinolones and fluoroquinolones (-0.4 DID from 2017-2020) and macrolides, including ketolides (-0.1 DID from 2017-2020) (Figure A1.8). The main decrease in quinolones came from norfloxacin (1.6 DID, -0.5 DID from 2017-2020) and ofloxacin (0.3 DID, -0.1 DID from 2017-2020).
- For macrolides and ketolides, the majority of the decrease came from roxithromycin (-0.2 DID from 2017-2020) and clarithromycin (-<0.1 DID from 2017-2020). In contrast to the highestpriority CIA, the consumption of the high priority CIA has decreased from 19.0 DID in 2017 to 13.0 DID in 2020 (Figure A1.7).
- The major contributors to this decrease were aminopenicillins (-2.7 DID from 2017-2020) and aminopenicillins with beta-lactamase inhibitor (BLI) (-2.8 DID from 2017-2020) (Figure A1.8). The top-two antimicrobials in the high-priority CIA with a large decrease in DID were amoxicillin (-3.5 DID from 2017-2020) and amoxicillin with a beta-lactamase inhibitor (-2.8 DID from 2017-2020).

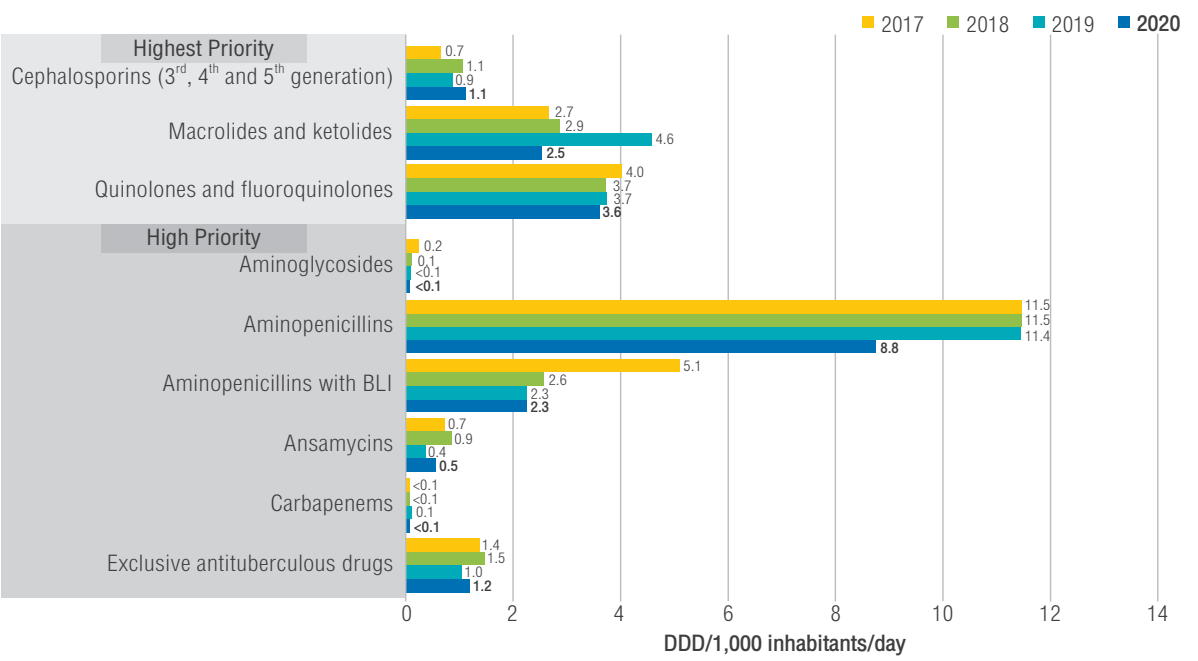


Figure A1.8 Consumption of Critically Important Antimicrobials classified by class of antimicrobials from 2017 to 2020 (DDDs/1,000 inhabitants/day, DID).

Note: Antimicrobial groups with less than 0.1 DID for 4 consecutive years (2017-2020) were not shown (highest priority-polymyxins, and glycopeptides and lipoglycopeptides; high priority-phosphonic acid derivatives, oxazolidinones, glycycyclines, and antipseudomonal penicillins).

A1.4 Consumption of Antimicrobials on AWaRe List

- Classified by WHO Access, Watch, Reserve classification of antibiotics (AWaRe), the overall trend has access (A) and watch (Wa) antibacterials as the main groups of consumption (Figure A1.9). The consumption of antimicrobials on the access list has decreased (-9.5 DID from 2017-2020). On the other hand, the consumption on the watch has fluctuated from 2017-2020 with a decrease -0.6 DID from 2017-2020.

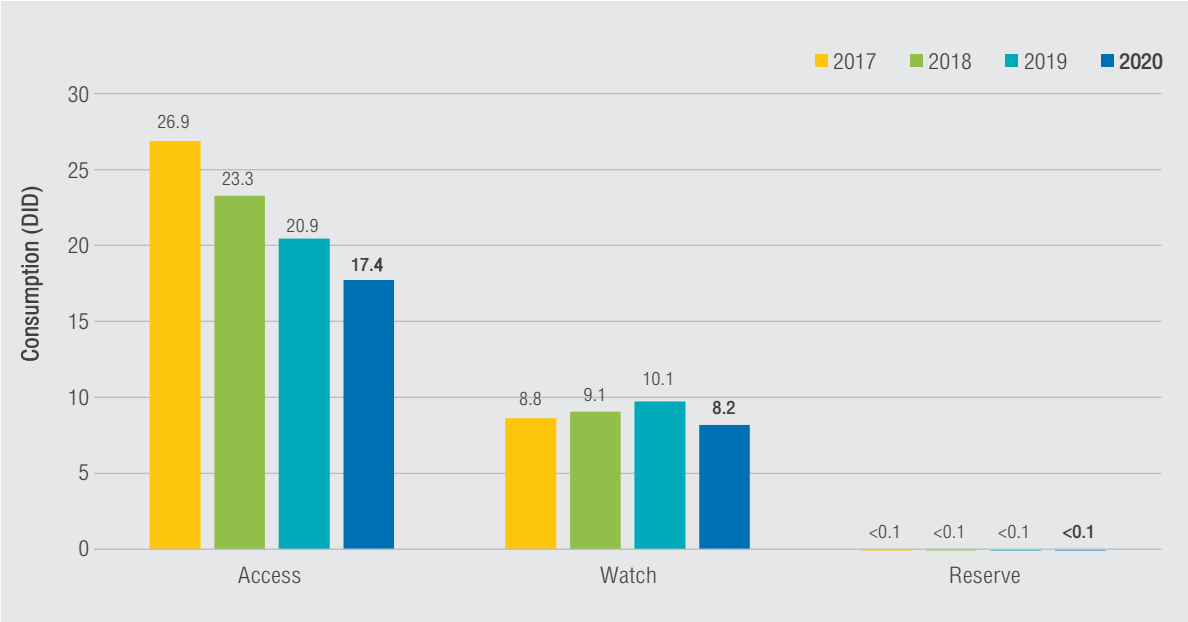


Figure A1.9 Consumption of antimicrobials by AWaRe classification from 2017 to 2020 (excluding antimicrobials by ATC level 5 not listed or recommended by AWaRe classification)

- On the watch list, the most antimicrobial consumed was norfloxacin despite a decrease (1.6 DID) (Figure A1.10). The other top-five antimicrobials on this list in 2020 were roxithromycin (1.4 DID), ciprofloxacin (1.3 DID), ceftriaxone (0.8 DID), and azithromycin (0.7 DID).

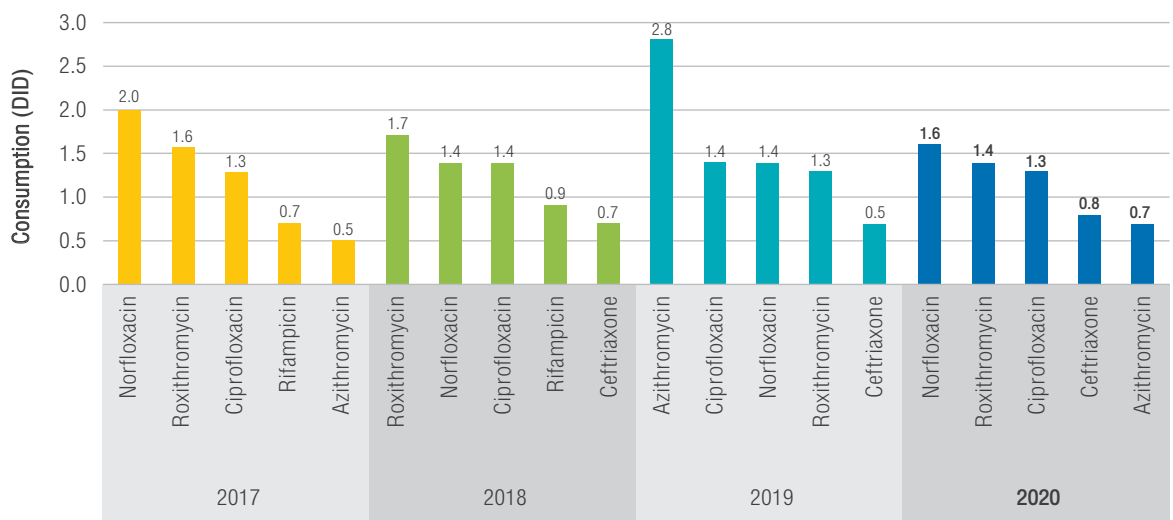
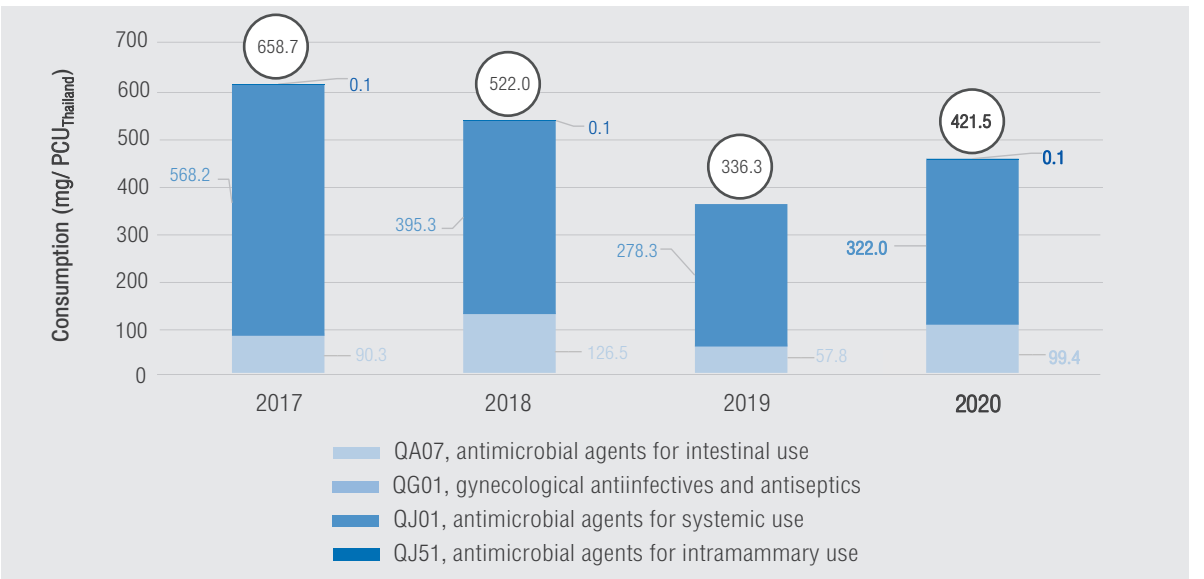


Figure A1.10 Consumption of top-five antimicrobials on the Watch list by AWaRe classification from 2017 to 2020

A2: Antimicrobial Consumption in Food-producing Animals

A2.1 Overall consumption

- The overall consumption of animal antimicrobials was 421.5 mg/ $PCU_{Thailand}$ in 2020 (36.0% from 2017) (Figure A2.1).
- The majority of consumption in 2020 still belonged to antibacterials for systemic use (QJ01; 76.4%), followed by intestinal anti-infectives (QA07; 23.6%) (Figure A2.1). Hence, the decrease in the national indicator was derived from decreases in both QA07 by 10.1% and QJ01 by 43.3% from 2017 to 2020. For the minority groups of consumption (QG01, QG51, and QJ51; <0.1% each), the same decreasing patterns were also found.



Note: The <0.1 tonnes of API not labeled (QG51, antiinfectives and antiseptics for intrauterine use).

Figure A2.1 Consumption of veterinary antimicrobials classified by Anatomical Therapeutic Chemical classification system for veterinary medicinal products (ATC vet) code from 2017 to 2020.

A2.2 Consumption breakdown by chemical class of antimicrobials and dosage form

Consumption by ATC vet code

- When comparing antibacterials for systemic use (QJ01) from 2017 to 2020, the most consumed QJ01 profile had shifted from dominance of macrolides (QJ01F) and sulfonamides (QJ01E) in 2017 to penicillins (QJ01C) and tetracyclines (QJ01A) in 2018, 2019 and 2020 (Figure A2.2).
- The majority of QJ01 consumption came from QJ01C (44.1%), followed by QJ01A (23.8%), and other antibacterials (QJ01X) (14.7%). However, the decrease in QJ01 came from decreases in QJ01E and QJ01F.
- The most consumed of antibacterials in QJ01C was amoxicillin (QJ01CA04) (139.8 mg/ $PCU_{Thailand}$, 98.4% of QJ01C consumption). The second rank was procaine benzylpenicillin (QJ01CE09) (1.0 mg/ $PCU_{Thailand}$, 0.7% QJ01C consumption).

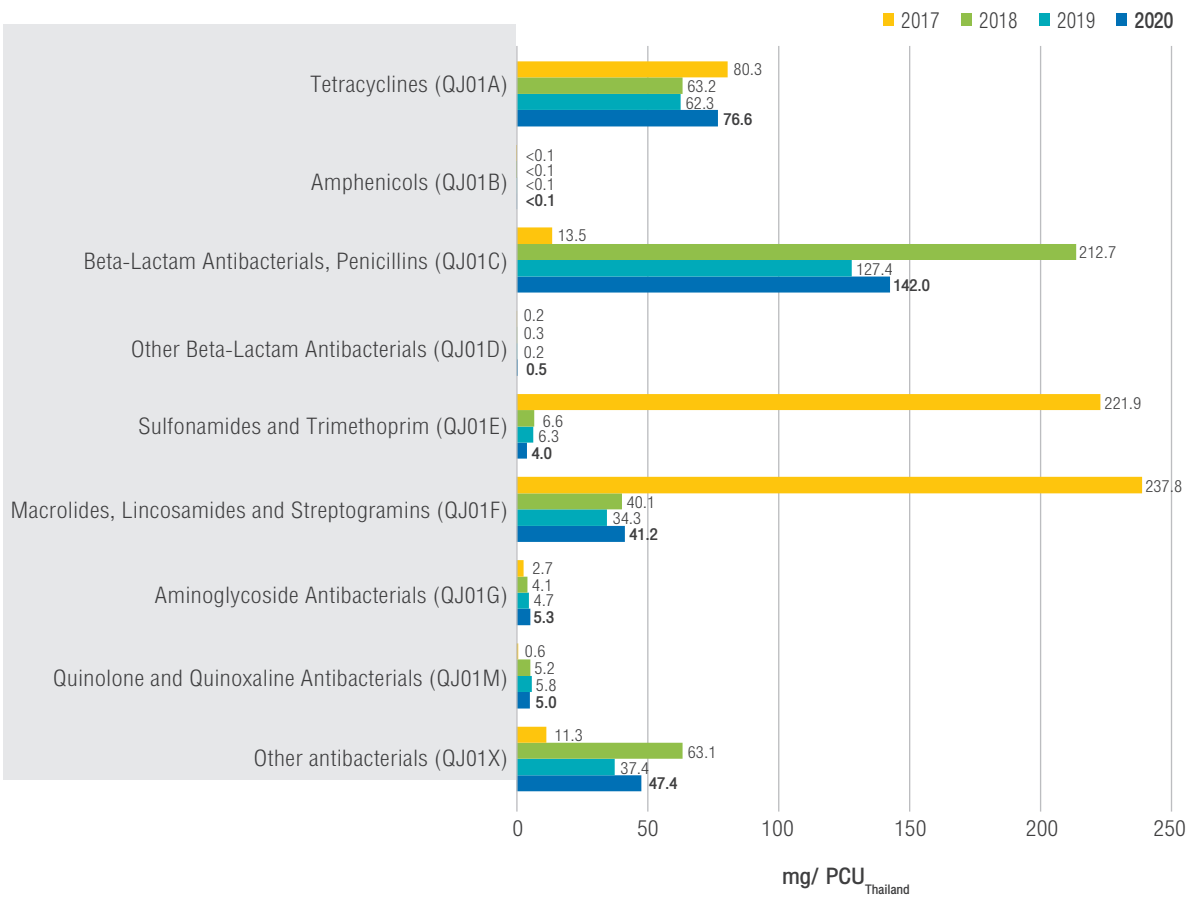


Figure A2.2 Consumption of veterinary antimicrobials indicated for systemic use classified by ATC level 3 from 2017 to 2020.

Consumption by chemical class

- Comparing consumption profiles by chemical class from 2017 to 2020, the profile was shifted from macrolides in 2017 to penicillins-dominant consumption in 2018-2020 (Figure A2.3).
- The three antimicrobial groups with most increase were penicillins (+128.5 mg/ $PCU_{Thailand}$ from 2017-2020), pleuromutilins (+37.9 mg/ $PCU_{Thailand}$ from 2017 to 2020), and polymyxins (+35.1 mg/ $PCU_{Thailand}$ from 2017 to 2020). However, when compared with 2017, the two antimicrobial classes with most decrease in consumption in 2020 were sulfonamides (-218.0 mg/ $PCU_{Thailand}$) and macrolides (-197.6 mg/ $PCU_{Thailand}$). Both of these antimicrobial classes were the top-two classes with highest consumption in 2017.
- Despite constantly ranked among top-three of overall consumption from 2017 to 2020, tetracyclines were consumed with a fluctuation from 80.3 mg/ $PCU_{Thailand}$ in 2017 to 76.6 mg/ $PCU_{Thailand}$ in 2020.

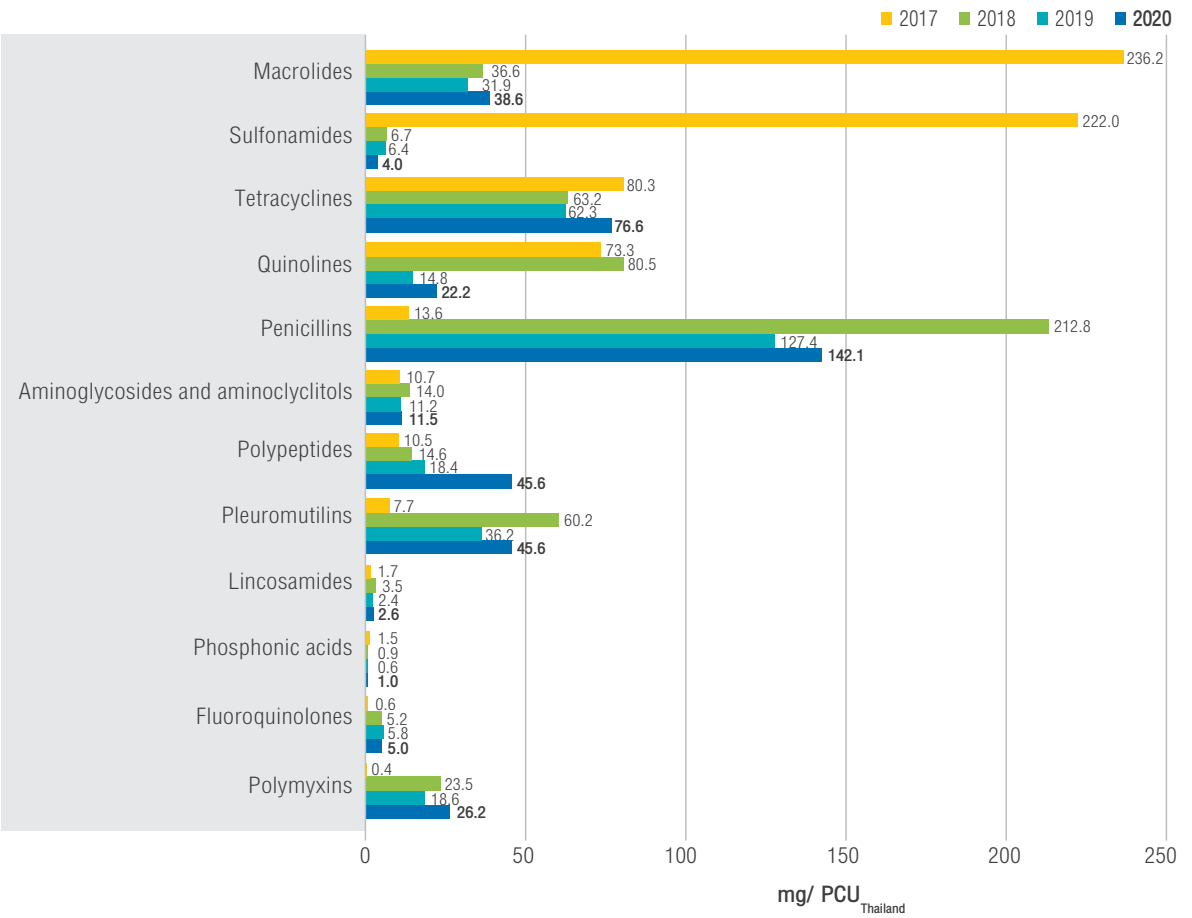


Figure A2.3 Consumption of veterinary antimicrobials by class of antimicrobials from 2017 to 2020 (Amphenicols and orthosomycins consumption less than 0.1 mg/ $PCU_{Thailand}$ from 2017 to 2020 are not shown.)

Consumption by route of administration and pharmaceutical dosage form

- Classified by route of administration and dosage form, the profiles of 2017-2020 were similar in that premix was the main dosage form (94.5%, 59.1%, 61.9%, and 58.1%, respectively) (Figure A2.4). The top-five antimicrobials used as a premix for medicated feeding stuff were changed in rank over time. Still, the list of top ten antimicrobials in 2020 almost remained the same as in 2019, except for switching between amoxicillin and chlortetracycline as the first and second ranks (Figure A2.5).
- As the second route and dosage form with an increasing trend in proportion (3.5%, oral powder) was consumed more than 80.0% in the form of powder for drinking water, mainly from amoxicillin from 2017-2020. One type of oral powder with an increase in proportion was powder for use in drinking water/milk, mainly from amoxicillin (>95.0% from 2017-2020).
- Injection dosage form was consistently ranked third in proportion from 2017 to 2020 (1.6%, 2.9%, 4.3%, and 3.7% of the total, respectively). From 2017 to 2020, the main pharmaceutical dosage forms in this group were suspensions (>50.0%) and solutions (>20.0%). The top-three main antimicrobials in injectable suspensions from 2017 to 2020 remained amoxicillin, dihydrostreptomycin, and procaine benzylpenicillin, respectively. For injectable solutions, oxytetracycline remained among the top five from 2017 to 2020, while gentamicin, kanamycin, and enrofloxacin consumptions in 2020 increased from baseline in 2017 (+1.2, +1.2, and +1.1 mg/ $PCU_{Thailand}$, respectively).

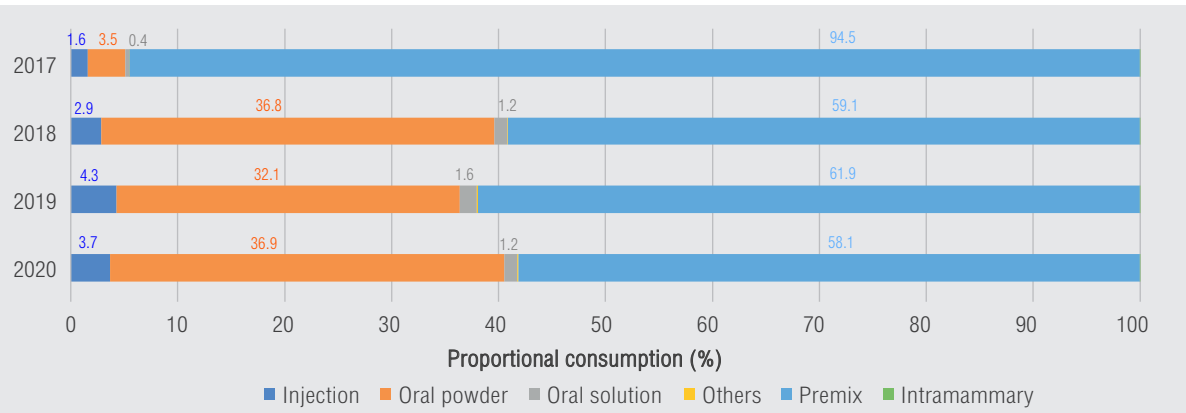


Figure A2.4 Proportional consumption of veterinary antimicrobials by route of administration and pharmaceutical dosage form from 2017 to 2020 (intramammary and others routes accounted for <0.1% each from 2017 to 2020.)

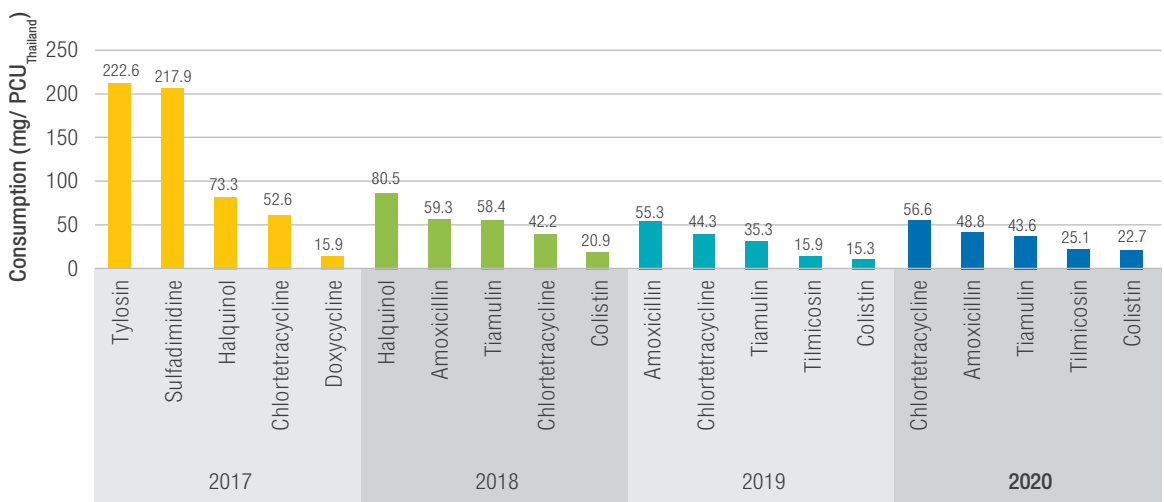


Figure A2.5 Consumption of top-five veterinary antimicrobials used as medicated premix from 2017 to 2020.

A2.3 Consumption of Critically Important Antimicrobials (CIA)

- Overall, the consumption profile was shifted from non-CIA (60.7% in 2017) to more proportion of CIA in 2018, 2019, and 2020 (55.4%, 57.5%, and 52.7%, respectively) (Figure A2.6). From 2017 to 2020, the consumption of CIA decreased by 36.7 mg/ $PCU_{Thailand}$ from 2017-2020, but highly important antimicrobials decreased by 220.8 mg/ $PCU_{Thailand}$, and important antimicrobials increased by 71.7 mg/ $PCU_{Thailand}$. Moreover, the proportion of CIA consumption shifted from the highest priority in 2017 (91.7% of CIA consumption) to high priority (68.4% of CIA consumption).
- For the highest-priority CIA, the consumption had decreased over the four years (Figure A2.6). The decreasing trend was derived from constant drops in macrolide consumption (197.6 mg/ $PCU_{Thailand}$ from 2017-2020), mainly from tylosin (-215.5 mg/ $PCU_{Thailand}$ from 2017-2020) (Figure A2.6). Ranked second in the proportion of highest priority CIA, polymyxins had a fluctuation (0.4 mg/ $PCU_{Thailand}$ in 2017 to 26.2 mg/ $PCU_{Thailand}$ in 2020), solely from colistin.
- For high-priority CIA, the consumption had increased overall (Figure A2.7). The main contributing class to this increase was aminopenicillins (+128.6 mg/ $PCU_{Thailand}$ from 2017-2020), mainly from amoxicillin (+128.4 mg/ $PCU_{Thailand}$ from 2017-2020) (Figure A2.6). The second rank in this priority with similar trend was aminoglycosides, mainly from gentamicin (+1.2 mg/ $PCU_{Thailand}$ from 2017-2020) and kanamycin (+1.2 mg/ $PCU_{Thailand}$ from 2017-2020).

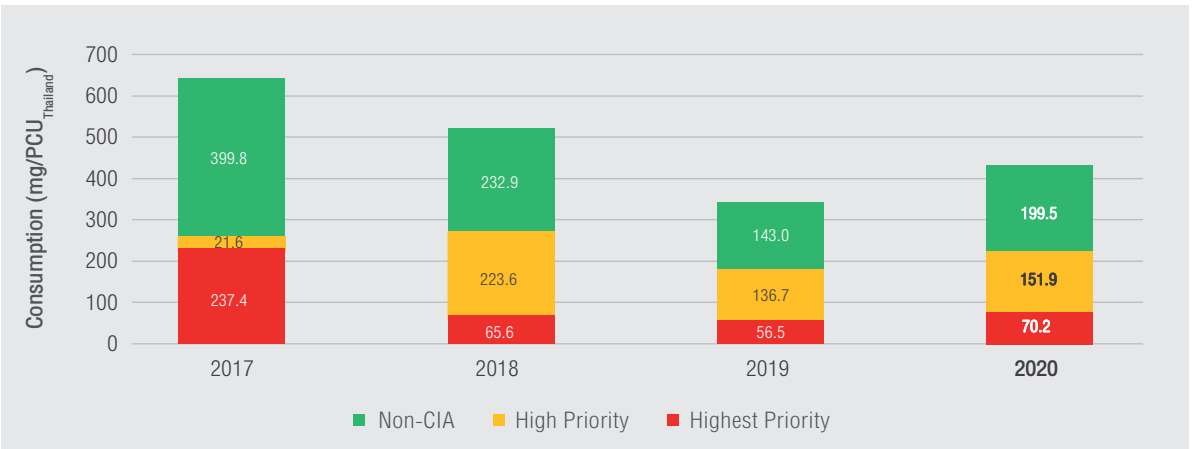


Figure A2.6 Comparative proportional consumption profile of CIA in food-producing animals from 2017 to 2020.

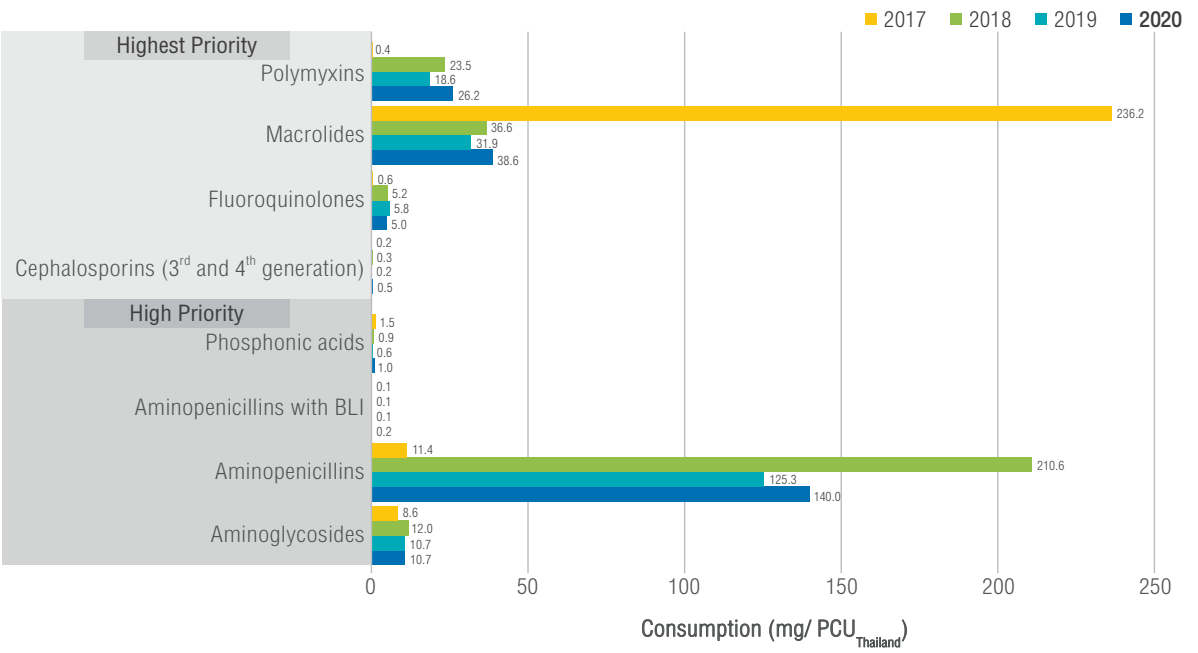


Figure A2.7 Consumption profile of CIA in food-producing animals from 2017 to 2020

- Comparing consumption profiles of CIA between humans and food-producing animals in 2020, food-producing animals consumed CIA overall more than humans, and both sectors consumed more high priority than highest priority CIA (Figure A2.8). For the highest-priority CIA, humans consumed cephalosporins (3rd, 4th, and 5th generation) and fluoroquinolones more than food-producing animals, while food-producing animals consumed polymyxins and macrolides more than humans. Regarding high priority CIA, humans consumed aminopenicillins with BLI more than food-producing animals while some food-producing animals consumed aminopenicillins and aminoglycosides more than humans. The antimicrobial class with least difference was phosphonic acid derivatives (6 tonnes), solely from fosfomycin in both humans and food-producing animals.

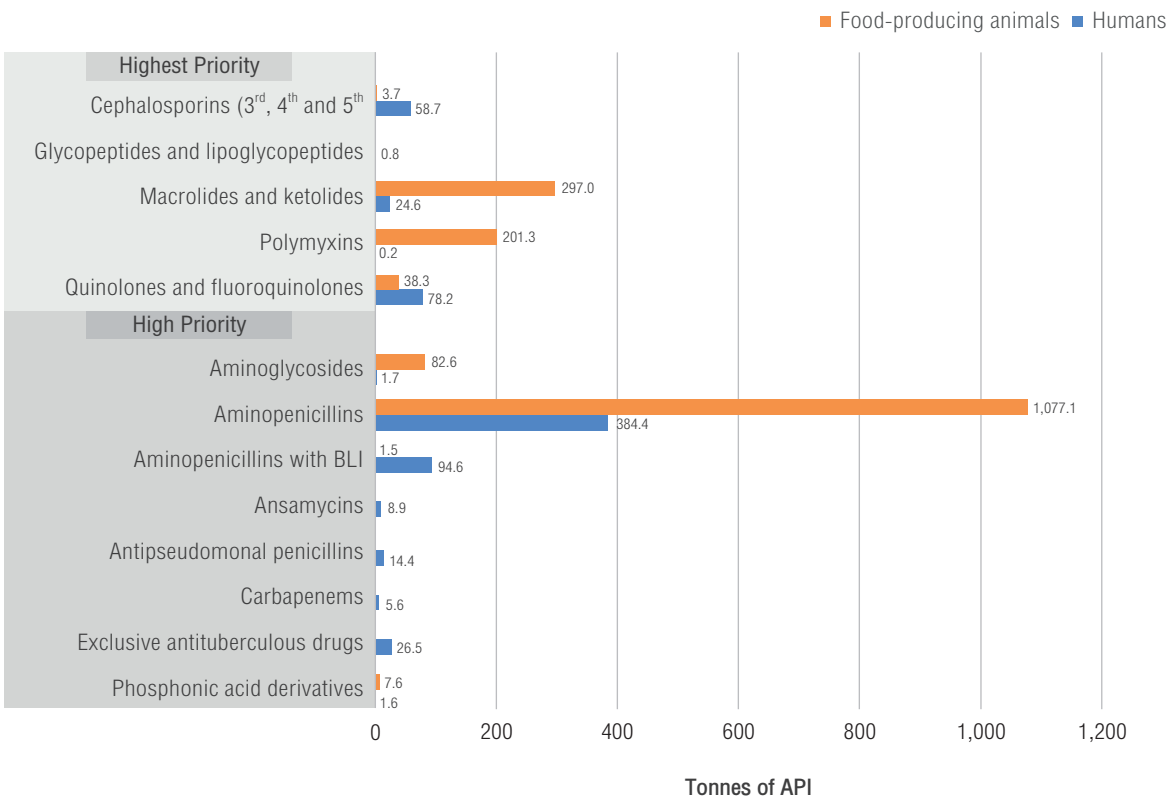


Figure A2.8 Comparative profile of CIA consumption between humans and food-producing animals in 2020 (Glycylcyclines and oxazolidinones are not shown due to their consumption less than 0.1 tonnes of API and only consumption in humans; 5th generation cephalosporins, glycopeptides and lipoglycopeptides, ketolides, ansamycins, antipseudomonal penicillins, carbapenems, and exclusive antituberculous drugs were not registered for animals in Thailand.)

A3: Antimicrobial Consumption in Food-Producing Animals (Medicated Feed through Feed mills)

A3.1 Overall consumption

- Overall, antibacterial consumption through medicated feed in pigs was significantly more than that of poultry (Figure A3.1).
- Classified by ATC vet code level 2 and animal species in 2020, pigs mostly consumed antibacterials for systematic (QJ01) (74.4% of pig antibacterial consumption) and for intestinal infections (QA07) (25.6% of pig antibacterial consumption).
- Poultry, on the other hand, mainly consumed QA07 (81.0% of poultry antibacterial consumption) and QJ01 (19.0% of poultry antibacterial consumption) (Figure A3.1).

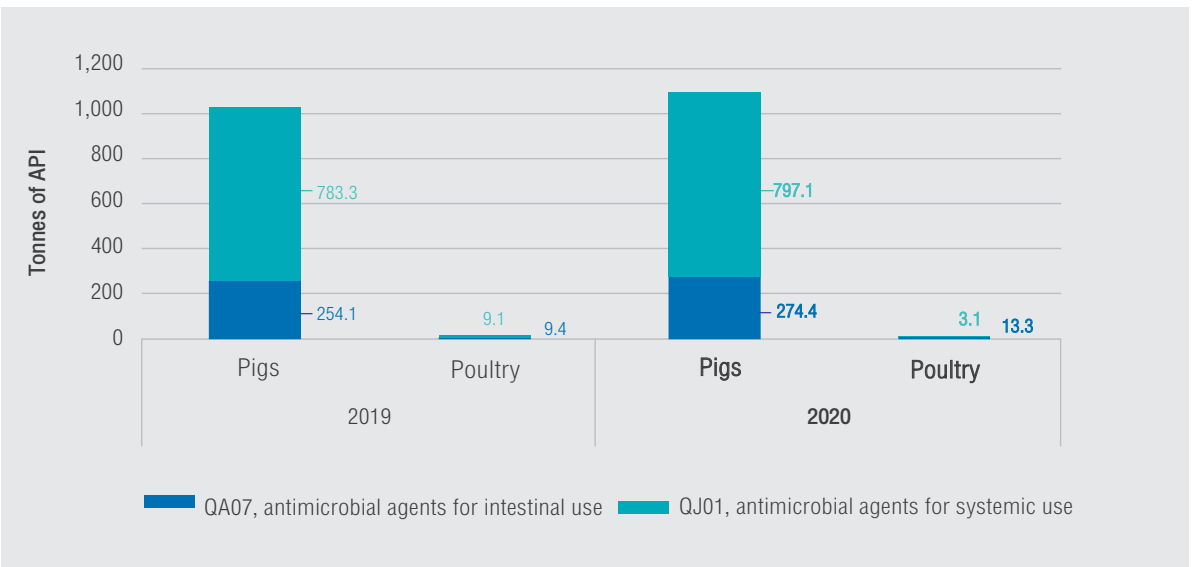


Figure A3.1 Antibacterial consumption through medicated feed by ATC vet code level 2 and animal species from 2019 to 2020.

A3.2 Consumption by chemical class of antibacterials and animal species

- Antibacterial consumption profiles in medicated feed of pigs and poultry were different in the profile of chemical class (Figure A3.2).
- Through more than 70.0% in medicated feed 2020, pigs consumed top-three antibacterial classes: penicillins (32.1% of pig antibacterial consumption), pleuromutilins (21.3%), and quinolines (19.1% of pig antibacterial consumption) (Figure A3.2). The top-three antibacterials came from top of each the three classes: amoxicillin (343.5 tonnes), tiamulin (227.9 tonnes), and halquinol (204.6 tonnes). Amoxicillin was the most consumed by piglets (167.2 tonnes), followed by pig breeders (101.9 tonnes).
- For poultry antibacterial consumption in medicated feed, the top-three antibacterials in 2020 were polypeptides (80.5% of poultry antibacterial consumption), macrolides (12.2% of poultry antibacterial consumption), and pleuromutilins (3.9% of poultry antibacterial consumption) (Figure A3.3). The top-three antibacterials most consumed by poultry were bacitracin (13.2 tonnes), tilmicosin (1.2 tonnes) and tylvalosin (0.8 tonnes). Bacitracin was the most consumed by laying hens (6.7 tonnes), followed by broiler (6.1 tonnes).

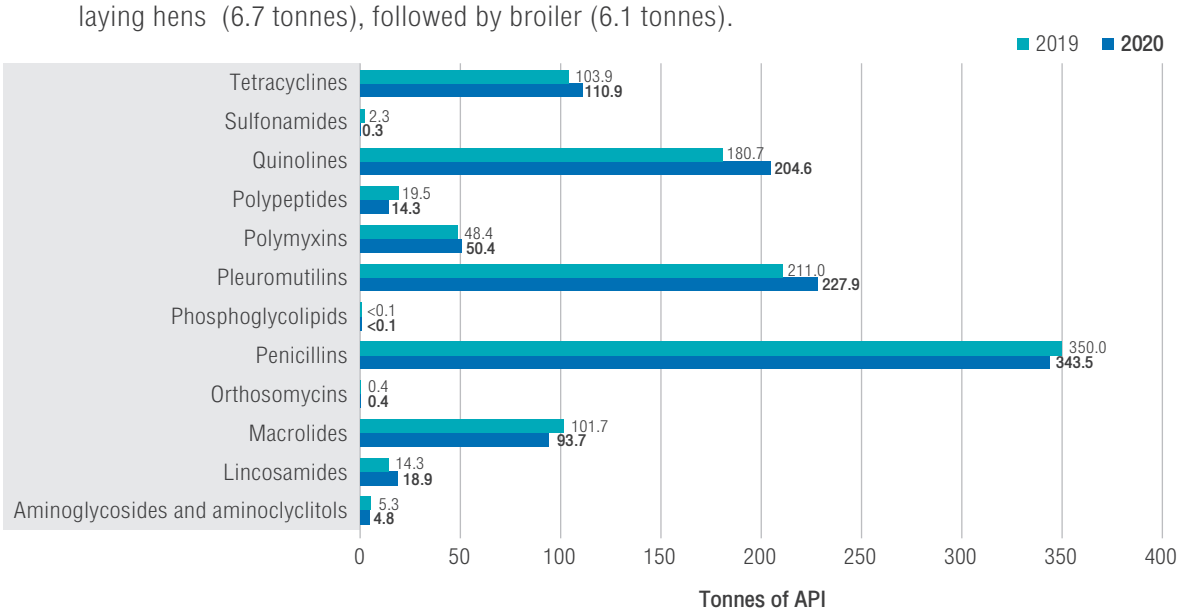


Figure A3.2 Antibacterial consumption through medicated feed in feed mills by chemical class in pigs from 2019 to 2020.*

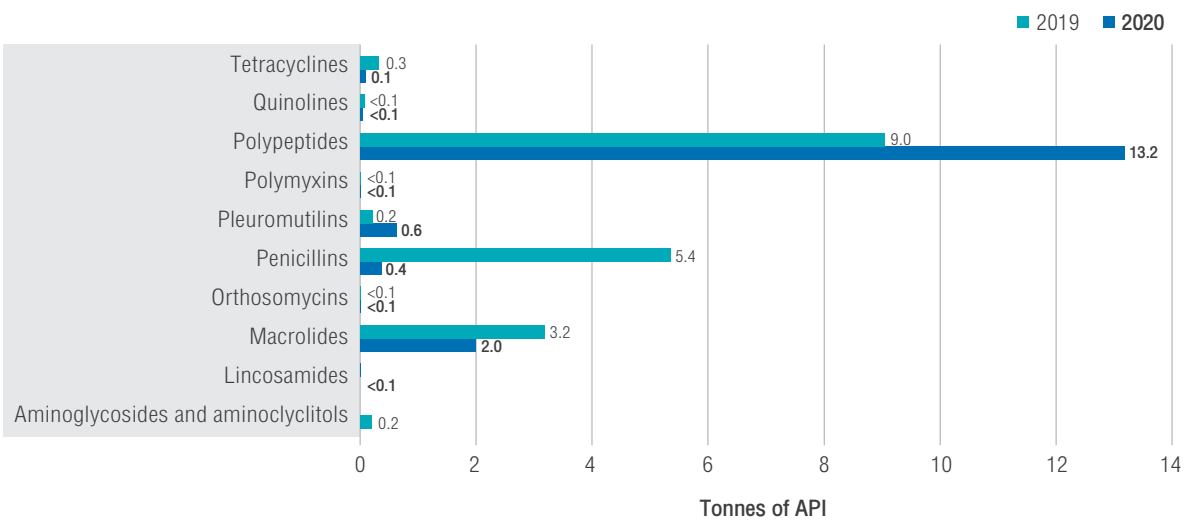


Figure A3.3 Antibacterial consumption through medicated feed in feed mills by chemical class in poultry from 2019 to 2020.*

* Sulfonamides includes sulfonamides and dihydrofolate reductase

A3.3 Consumption of Critically Important Antimicrobials (CIA) by animal species

- Classified by human CIA, the consumption profiles through medicated feed in feed mills between pigs and poultry were similar in 2020 (Figure A3.4). Pigs mainly consumed CIAs at 492.4 tonnes (46.0% of pig antibacterial consumption) and important antimicrobials at 242.3 tonnes (22.6% of pig antibacterial consumption) while poultry principally consumed important antimicrobials at 13.8 tonnes (84.4%) and CIAs at 2.4 tonnes (14.5% of poultry antibacterial consumption) (Figure A3.3).
- For CIA in 2020, pigs mainly consumed aminopenicillins (343.5 tonnes) and macrolides (93.7 tonnes) (Figure A3.5). The main CIA consumer in pigs were piglets (239.1 tonnes), followed by pig breeders (137.9 tonnes) and fattening pigs (115.5 tonnes). The two most consumed CIAs in pigs were amoxicillin (343.5 tonnes) and tilmicosin (83.0 tonnes).
- For poultry in 2020, they mainly consumed CIA in macrolides (2.0 tonnes) and aminopenicillins (0.4 tonnes) (Figure A3.5). The main CIA consumers in poultry were broiler breeder (1.9 tonnes) and layering hens (0.3 tonnes). The two most consumed CIAs were macrolides: tilmiconsin (1.2 tonnes) and tylvalosin (0.8 tonnes).

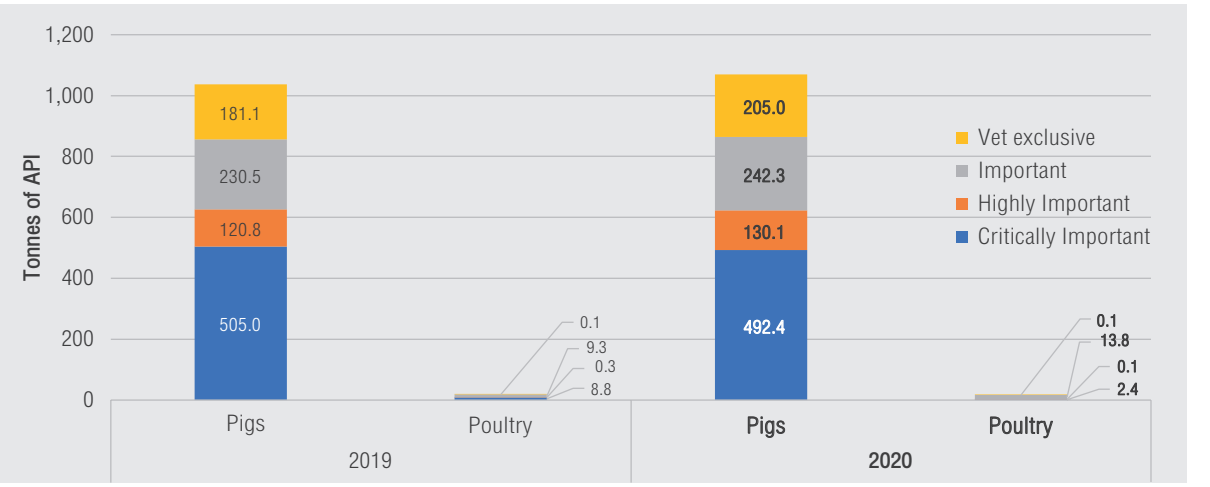


Figure A3.4 Antimicrobial consumption by type of WHO CIA through medicated feed in feed mills by chemical class and animal species from 2019 to 2020.*

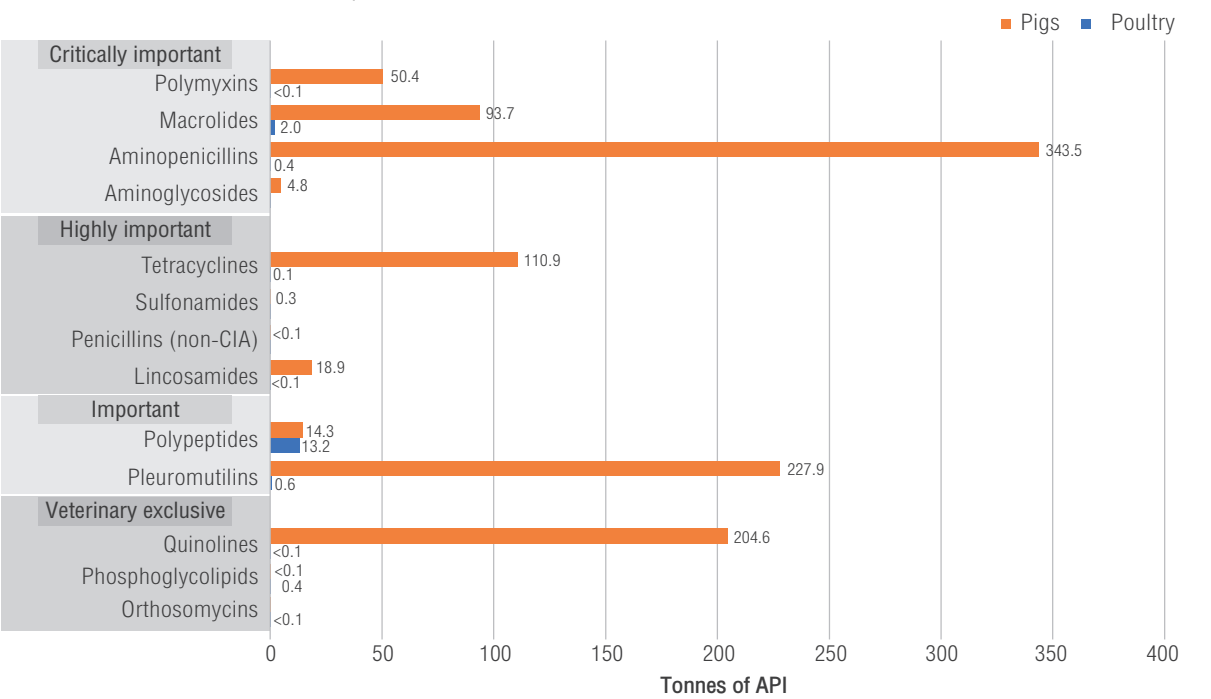


Figure A3.5 Antimicrobial consumption by type of WHO CIA through medicated feed in feed mills by chemical class

* Sulfonamides includes sulfonamides and dihydrofolate reductase; aminoglycosides does not include aminocyclitols

SECTION B

ANTIMICROBIAL RESISTANCE

SECTION B:
ANTIMICROBIAL RESISTANCE

B1. Antimicrobial Resistance in Humans

B1.1 Gram-negative bacteria

Acinetobacter calcoaceticus-baumannii* complex (*A. calcoaceticus-baumannii* complex)

- The trends in carbapenem-resistant *Acinetobacter baumannii* were steady at around 70.0%. Meanwhile, an increasing trend in resistance was observed for ampicillin/sulbactam from 62.2% in 2019 to 71.8% in 2020 (+9.6%).
- The proportion of colistin resistance in 2020 was 2.2%, decreasing from 2.7% in 2019 (-0.5%)(Figure B1.1). The minimum inhibitory concentration 90 (MIC90) of colistin in 2020 <1.0 mg/L, decreased from 2.0 mg/L in 2019.

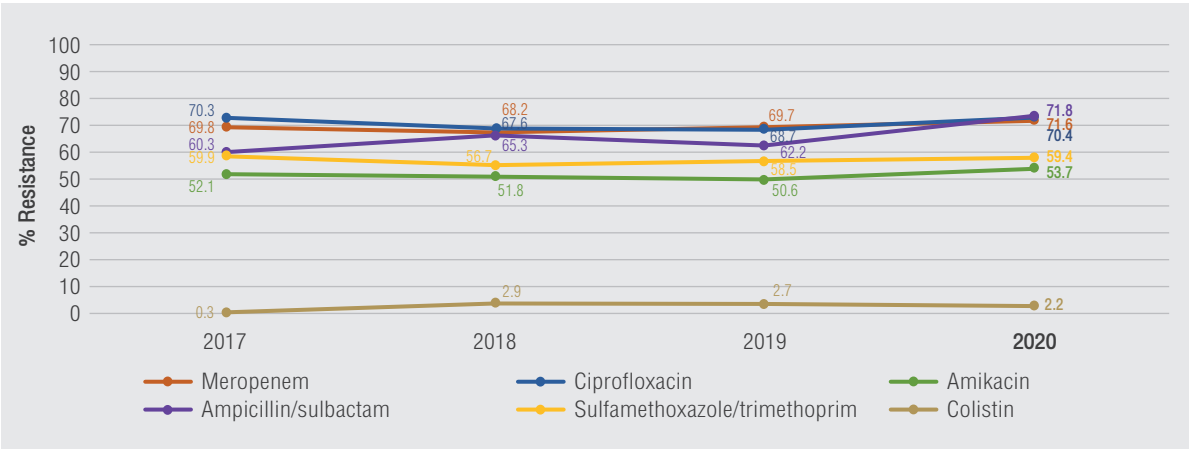
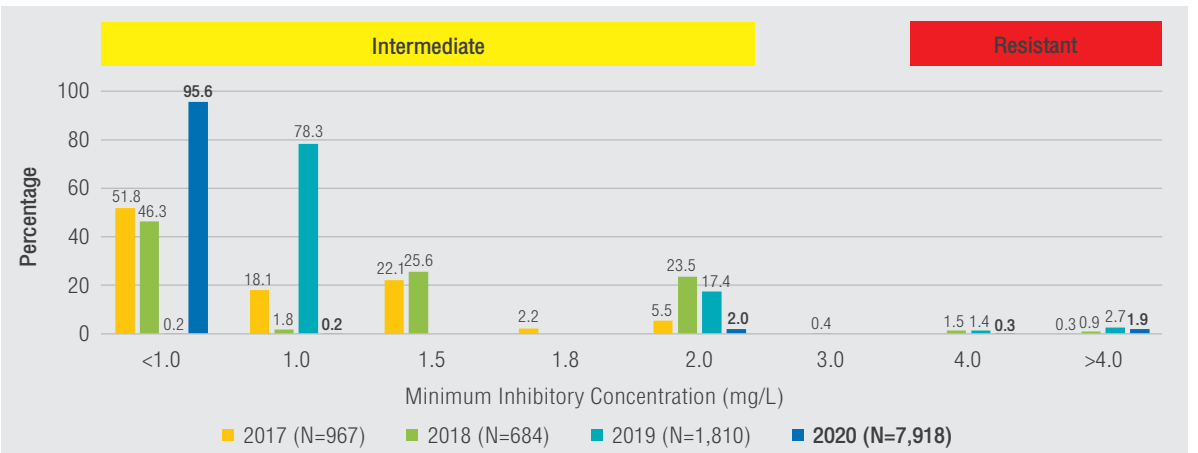


Figure B1.1 Percent resistance among *A. calcoaceticus-baumannii* complex in 2017 to 2020

Note: In 2020, A. calcoaceticus-baumannii complex resistance to colistin using MIC ≥ 4.0.



Colistin MIC by Sensititre® (number of hospitals)	2017 (7)	2018 (6)	2019 (5)	2020 (5)
MIC_{50} (mg/L)	<1.0	1.5	1.0	<1.0
MIC_{90} (mg/L)	1.5	2.0	2.0	<1.0

Figure B1.2 MIC distribution of colistin for *A. calcoaceticus-baumannii* complex in 2017 to 2020

* Given the highest prevalence of A. baummanii in clinical specimens tested in laboratories where accurate species can be performed and its virulence properties, the A. calcoaceticus-baumannii complex is considered as A. baumannii in this report.

Pseudomonas aeruginosa (P. aeruginosa)

- The recent trends in carbapenem-resistant *P. aeruginosa* (CRPA) remained steady in 2020 at 19.4% and 22% resistance for meropenem and imipenem, respectively.
- A considerably decreasing trend in colistin resistance was observed among isolates of *P. aeruginosa* from 2.2% in 2019 to 1.1% in 2020 (Figure B1.3). Additionally, the colistin MIC90 value over the three-year period were steady at 2.0 mg/L, which were intermediate range.

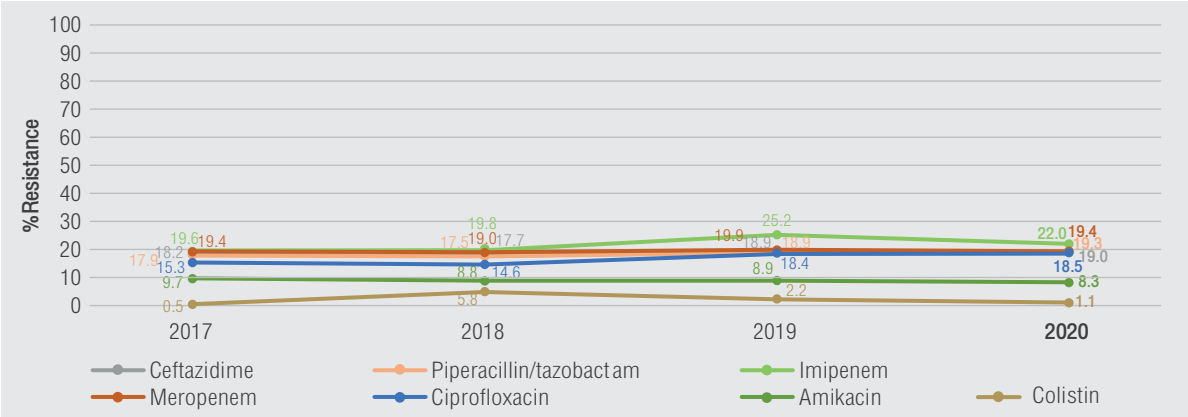


Figure B1.3 Percent resistance among *P. aeruginosa* in 2017 to 2020
Note: In 2020, *P. aeruginosa* resistance to colistin using MIC ≥ 4.0.

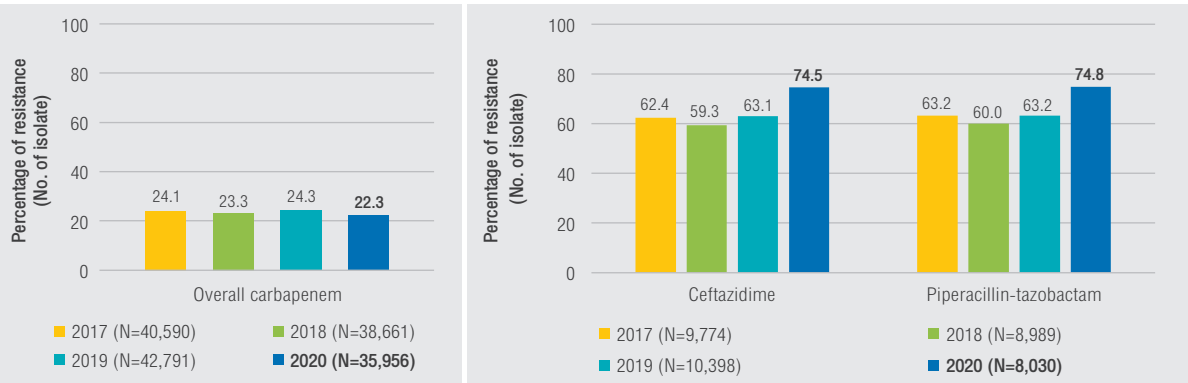
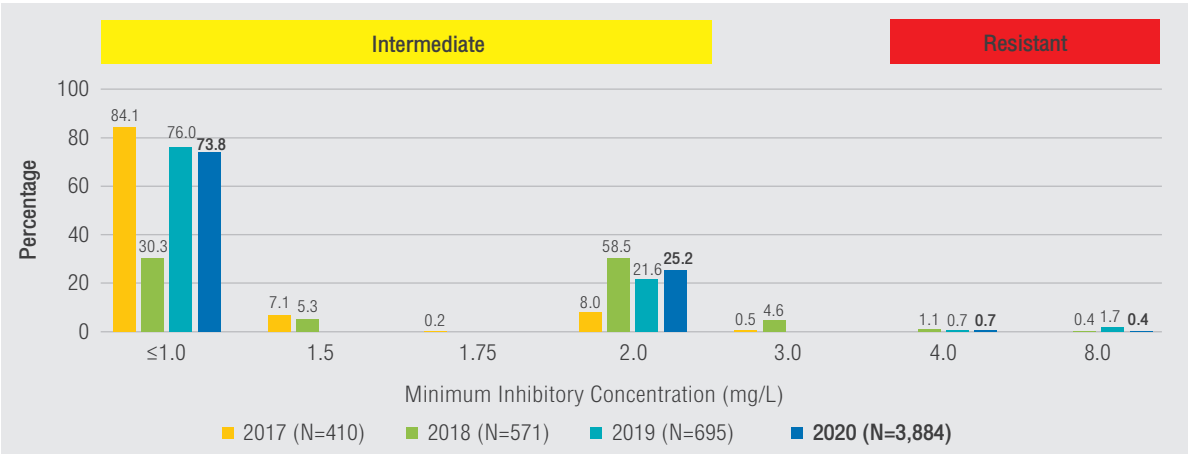


Figure B1.4 Percent resistance among carbapenem-resistant *P. aeruginosa* in 2017 to 2020



Colistin MIC by Sensititre® (number of hospitals)	2017 (7)	2018 (6)	2019 (5)	2020 (5)
MIC_{50} (mg/L)	≤1.0	2.0	≤1.0	≤1.0
MIC_{90} (mg/L)	1.5	2.0	2.0	2.0

Figure B1.5 MIC distribution of colistin for *P. aeruginosa* in 2017 to 2020

Escherichia coli (E. coli)

- The proportion of third-generation cephalosporins resistant *E. coli* has slightly changed from 43.9% in 2019 to 41.4% in 2020.
- The proportion of fluoroquinolone resistant *E. coli* accounted for 60.0% in 2019-2020, increased from 50.5% in 2018 (+10.0%).
- Regarding carbapenem-resistant *Enterobacteriaceae* (CRE), *E. coli* resistance rate for carbapenems in 2020 was 3.4%, which was not changed from 2019 (3.3%).
- In 2020, the majority of *E. coli* isolates (96.6%) were susceptible to colistin, the MIC90 was ≤1.0 mg/L.

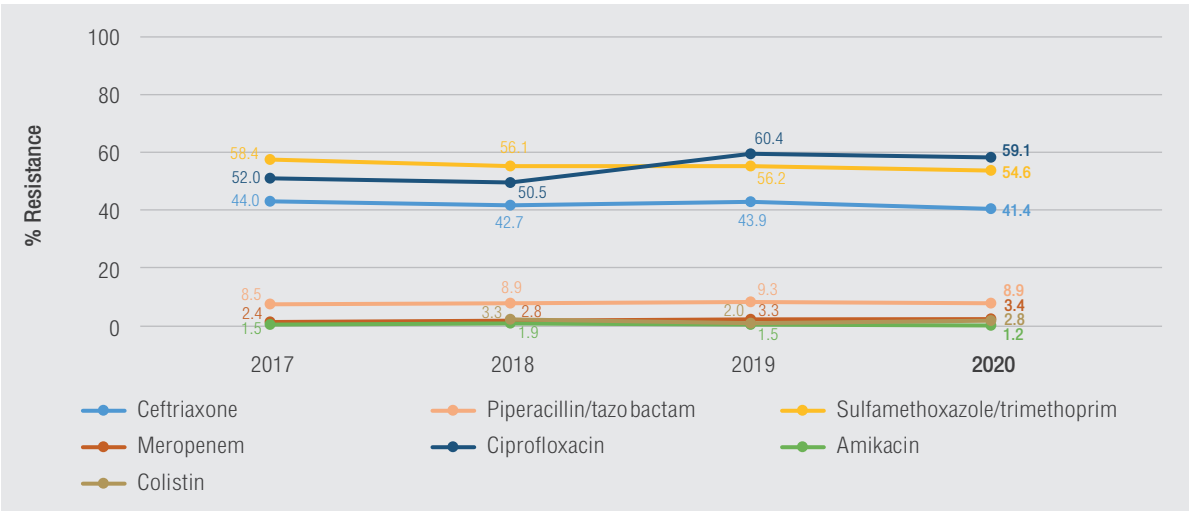
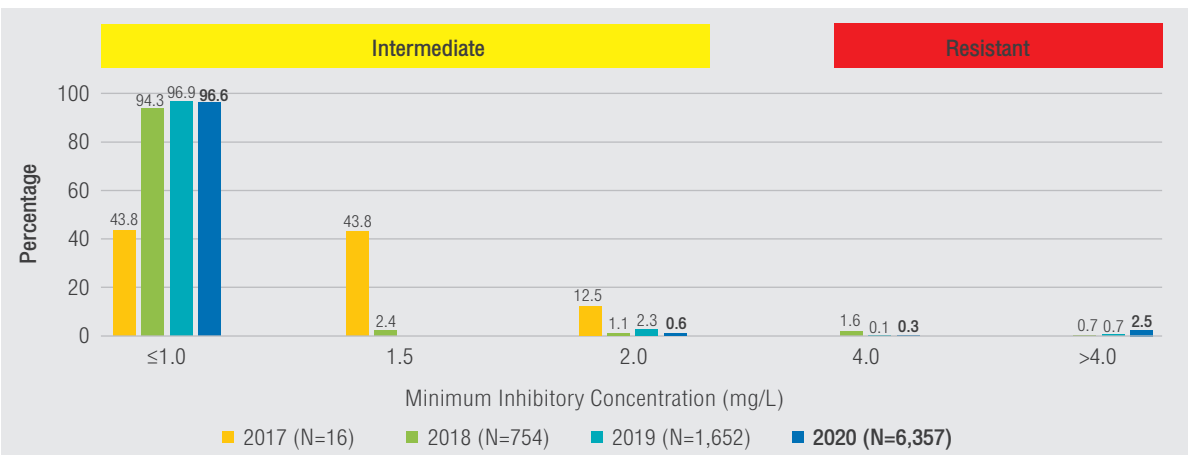


Figure B1.6 Percent resistance among *E. coli* in 2017 to 2020



Colistin MIC by Sensititre® (number of hospitals)	2017 (4)	2018 (4)	2019 (4)	2020 (5)
MIC_{50} (mg/L)	1.5	≤1.0	≤1.0	≤1.0
MIC_{90} (mg/L)	2.0	≤1.0	≤1.0	≤1.0

Figure B1.7 MIC distribution of colistin for *E. coli* in 2017 to 2020

Klebsiella pneumoniae (K. pneumoniae)

- The proportion of third- generation cephalosporins resistant *K. pneumoniae* in 2019 stayed at the same rate as 2019 at around 40.0%.
- The proportion of fluoroquinolone resistant *K. pneumoniae* was slightly decreased from 48.8% in 2019 to 45.8% in 2020 (-3.0%).
- The overall trend in carbapenem-resistant *K. pneumoniae* has remained steady at 12.6% in 2020.
- The proportion of colistin-resistant *K. pneumoniae* in 2020 slightly increased to 4.3%, MIC90 maintained at ≤1.0 mg/L.

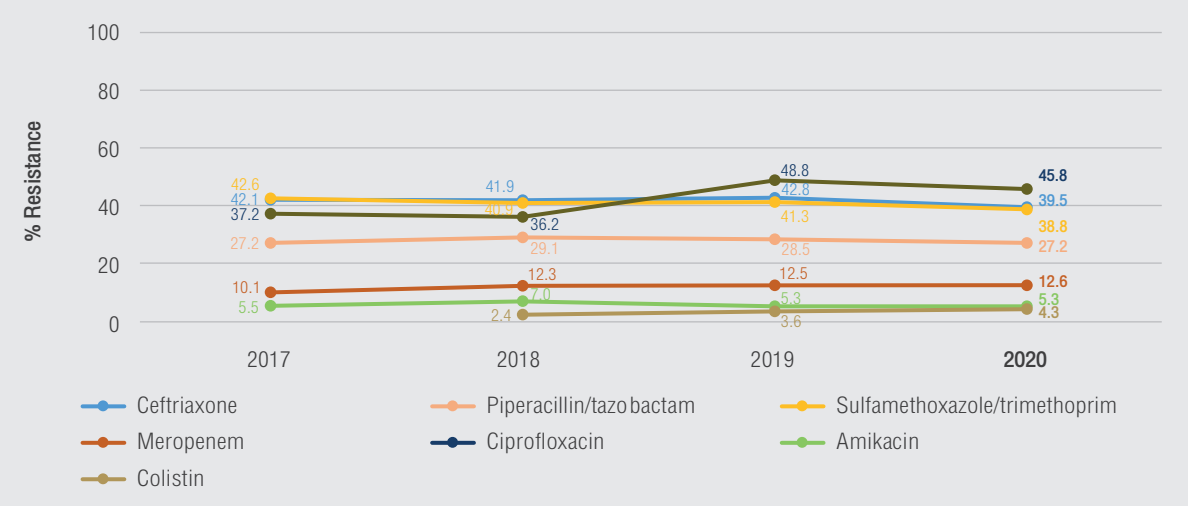
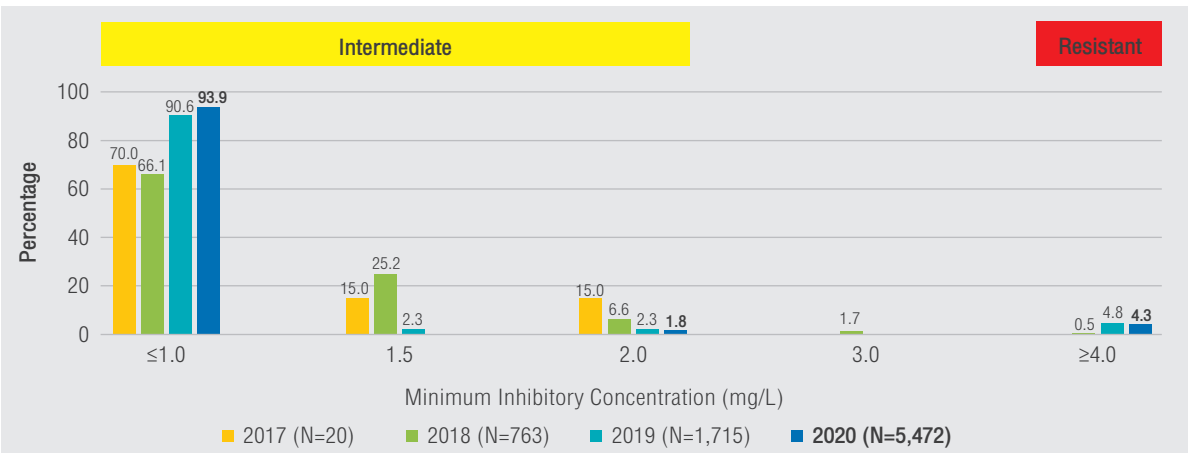


Figure B1.8 Percent resistance among *K. pneumoniae* in 2017 to 2020

Note: In 2020, K. pneumoniae resistance to colistin using MIC ≥ 4.0.



Colistin MIC by Sensititre® (number of hospitals)	2017 (4)	2018 (6)	2019 (5)	2020 (9)
MIC_{50} (mg/L)	≤1.0	≤1.0	≤1.0	≤1.0
MIC_{90} (mg/L)	2.0	1.5	≤1.0	≤1.0

Figure B1.9 MIC distribution of colistin for *K. pneumoniae* in 2017 to 2020

B1.2 Gram-positive bacteria

Staphylococcus aureus (S. aureus)

- The proportion of methicillin-resistant *Staphylococcus aureus* (MRSA) has been decreasing gradually from 9.6% in 2017 to 6.5% in 2020. On the other hand, the proportion of methicillin-resistant coagulase-negative *Staphylococcus* (MRCNS) increased from 53.2% in 2017 to 64.3% in 2020. None of the isolates in 2020 were resistant to vancomycin.

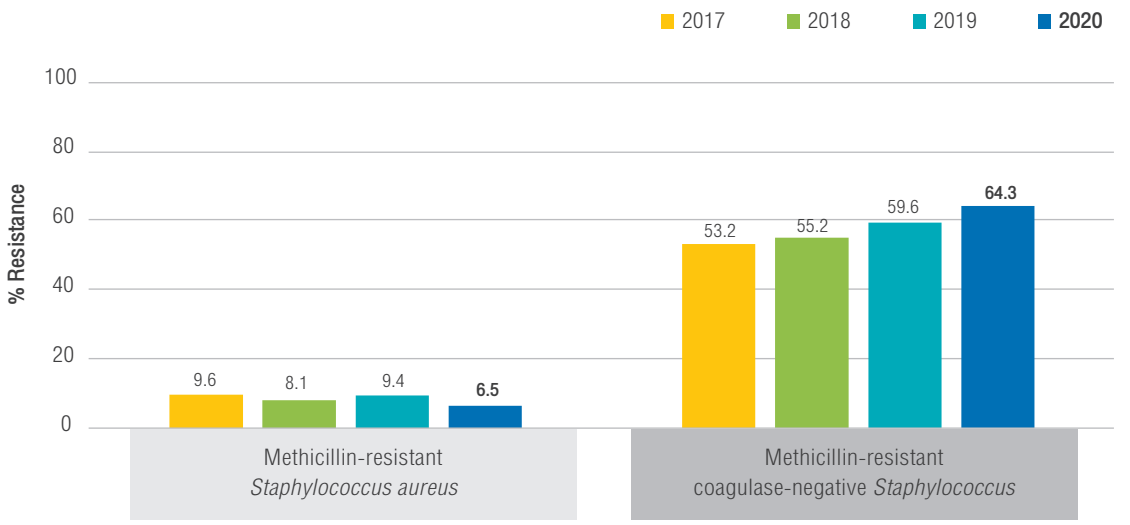


Figure B1.10 Percentage of methicillin resistance among *S. aureus* (MRSA) and coagulase-negative *Staphylococcus* (MRCNS) in 2017 to 2020

Streptococcus pneumoniae (S. pneumoniae)

- For non-cerebrospinal fluid (CSF) samples, the proportion of penicillin non-susceptible *S. pneumoniae* (PNSP) including *S. pneumoniae* with intermediate level of penicillin resistance was at 6.4% in 2020, which minimally decreased from 7.2% in 2019 (-0.5%). For cephalosporin resistance in 2020, approximately 3.4% and 8.9% were intermediate-resistant to ceftriaxone and cefotaxime, respectively.
- For CSF samples, approximately 33.3% were resistant to penicillin in 2020. None of the isolates were resistant to ceftriaxone and cefotaxime. This implies that penicillin should not be used for empirical treatment of acute bacterial meningitis in Thailand.

Table B1.1 The proportion (%) of antimicrobial resistance in *S. pneumoniae*

Drug	% resistant (number isolates)				E-test, (number isolates)							
					CSF samples				Non-CSF samples			
	2017	2018	2019	2020	2017	2018	2019	2020	2017	2018	2019	2020
Penicillin*	65.8 (371)	63.4 (366)	64.3 (1,276)	53.8 (788)	50.0 (2)	57.1 (7)	88.9 (9)	33.3 (6)	10.0 (369)	5.6 (359)	7.2 (1,267)	6.4 (956)
Cefotaxime*	-	-	-	-	0.0 (11)	0.0 (3)	-	0.0 (4)	0.0 (144)	1.0 (209)	6.9 (663)	8.9 (404)
Levofloxacin	0.9 (1,437)	1.0 (1,750)	1.2 (2,383)	1.4 (1,109)	-	-	-	-	-	-	-	-

*Interpretation by minimum inhibitory concentration test

***Enterococcus* spp.**

- In 2020, ampicillin-resistant *E. faecalis* was found in around 5.2% of all isolates tested. *E. faecium* was nonetheless, resistant to ampicillin more than 90.0%. In addition, the percentage of vancomycin-resistant *enterococcus* (VRE) isolates was found in approximately 0.9% of *E. faecalis* and 7.3% of *E. faecium*.
- About 7.1% of *Enterococcus* were resistant to vancomycin in 2020.
- In 2020, a large number of Enterococcus spp. isolates were tested by broth microdilution method. The susceptibility data of VRE in 2020 were somewhat similar to isolates that tested by disk diffusion method.

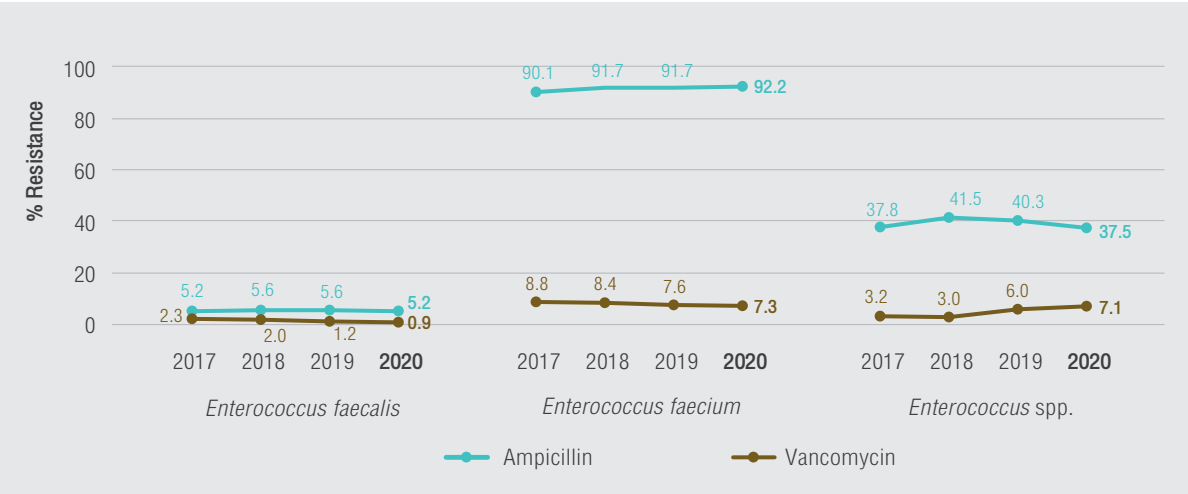


Figure B1.11 Percent resistance among *E. faecalis*, *E. faecium*, *Enterococcus* spp. in 2017 to 2020

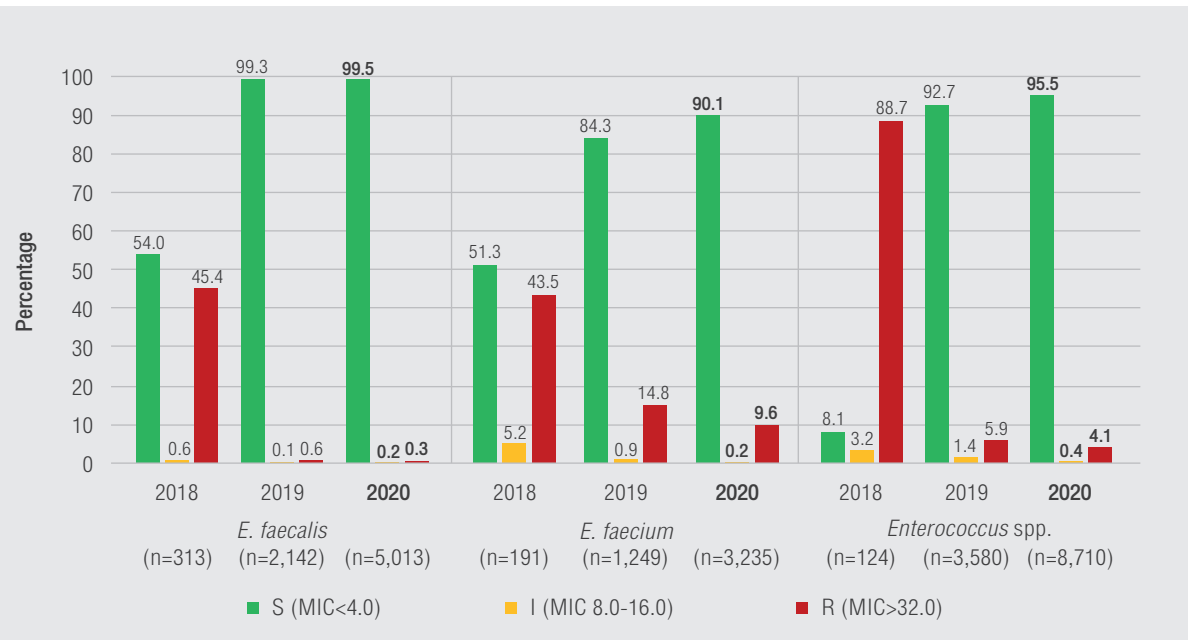


Figure B1.12 Percentage of susceptible, intermediate and resistance to vancomycin among *E. faecalis, E. faecium, Enterococcus* spp. in 2018 to 2020

B1.3 Other antimicrobial-resistant bacteria

Non-typhoidal *Salmonella* spp.

- Determination of ciprofloxacin susceptibility for non-typhoidal *Salmonella* from extraintestinal isolates showed that 5.9% was ciprofloxacin resistant in 2020, slightly decreased from 6.1% in 2019 (-0.2%).
- The overall trends of third-generation cephalosporins resistance in *Salmonella* spp. was 14% in 2020.

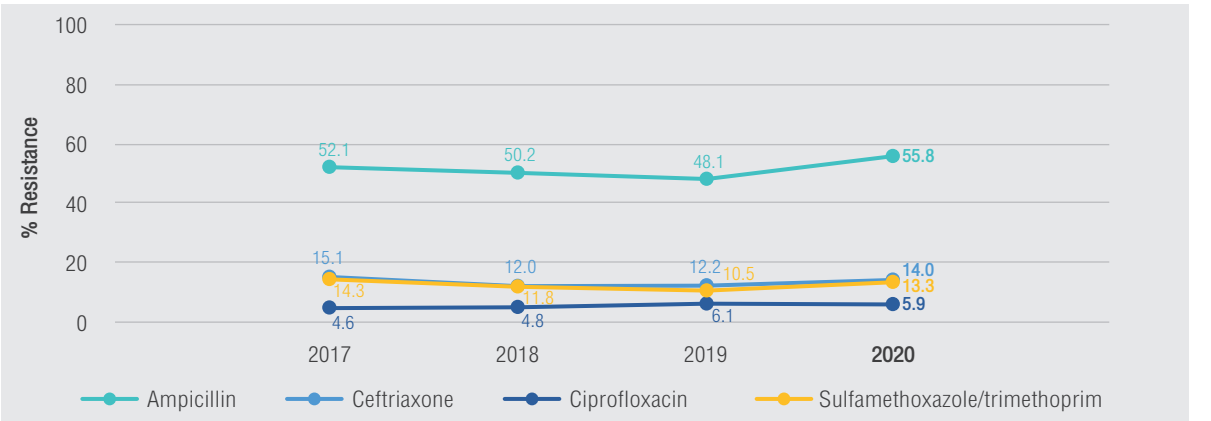


Figure B1.13 Percent resistance among Non-typhoidal *Salmonella* spp. from extraintestinal isolates in 2017 to 2020

Neisseria gonorrhoeae (N. gonorrhoeae)

- *N. gonorrhoeae* isolates showed a hundred percent of resistance to penicillin. In addition, 94.7% of *N. gonorrhoeae* isolates were non-susceptible to ciprofloxacin and 96.9% of those were non-susceptible to tetracycline in 2020.
- However, no resistance to cefixime or ceftriaxone were found during 2017-2020. All isolates have remained susceptible to azithromycin in 2020.

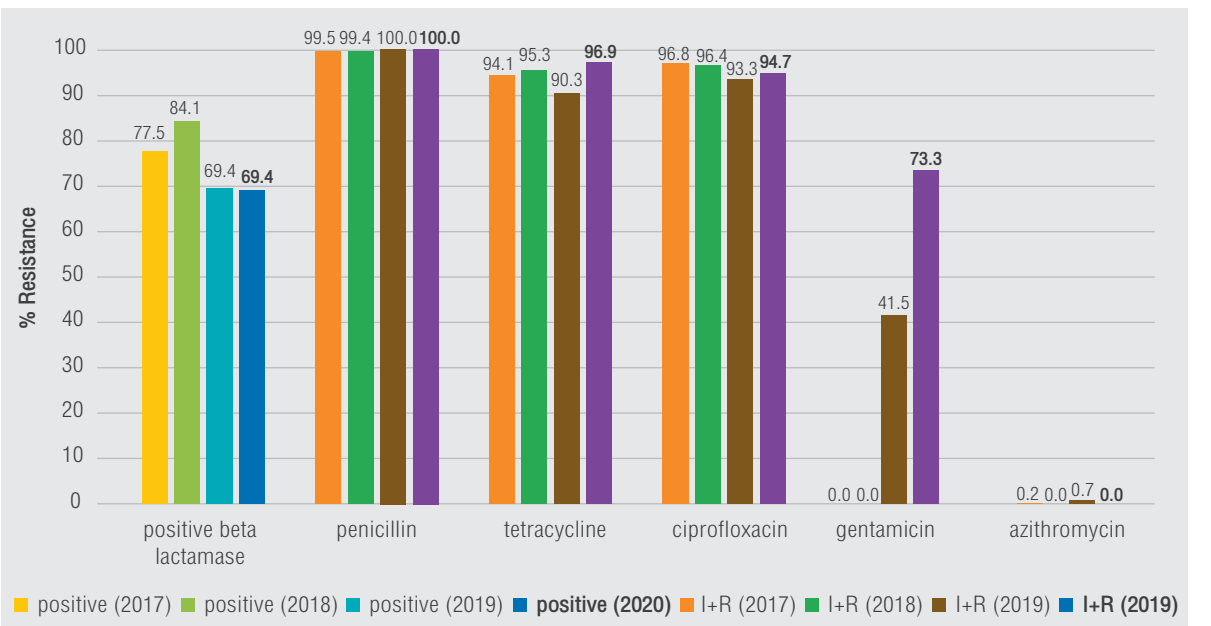


Figure B1.14 Percent resistance among *N. gonorrhoeae* in 2017 to 2020)

positive: enzyme β-lactamase was detected.

I+R: resistant or non-susceptible

B1.4 Empirical therapy combinations

- The data in table B1.2 and B1.3 showed the combination regimens for empirical therapy of *A. baummanii*, carbapenem-resistant *E. coli*, and carbapenem-resistant *K. pneumoniae* infection according to susceptibility pattern of antimicrobials in 2019-2020. These data were based on a criterion which was at least one antimicrobial of both antimicrobial combinations had been reported as susceptible, will be counted into susceptible regimens.
- The regimen of empirical therapy for infection should be considered when it shows more than 80.0% susceptible. The recommendation of appropriate combination regimens for empirical therapy in patient, who is suspected of *A. baummanii* or carbapenem-resistant *E. coli* or *K. pneumoniae* infection are colistin+co-trimoxazole, colistin +fosfomycin, and colistin+ amikacin, respectively. These tables only provided data on susceptibility aspect, therefore pharmacokinetic properties and adverse drug reactions should be taken into consideration.

Table B1.2 Susceptible levels (%) among diagnostic isolates of *A. baumannii*

Empiric therapy combinations	2019 (N)	2020 (N)
Colistin + Meropenem	98.6 (707)	**97.8 (8,832)**
Colistin + Imipenem	99.3 (675)	**97.8 (8,816)**
Colistin + Gentamicin	97.6 (484)	**94.9 (445)**
Colistin + Amikacin	98.9 (731)	**97.8 (7,128)**
Colistin + Sulbactam	99.9 (931)	**99.0 (1,859)**
Colistin + Co-trimoxazole	99.2 (499)	**99.5 (6,129)**

Table B1.3 Susceptible levels (%) among diagnostic isolates of carbapenem-resistant *Enterobacteriaceae* (CRE)

Antibiotic	*E. coli*		*K. pneumoniae*	
	2019 (N=3,514)	2020 (N=2,764)	2019 (N=9,570)	2020 (N=6,468)
Amikacin	91.3 (2,787)	**89.3 (2,309)**	77.8 (6,507)	**65.6 (4,033)**
Gentamicin	39.2 (1,005)	**37.7 (946)**	67.7 (4,641)	**65.3 (4,303)**
Fosfomycin	90.3 (495)	**93.1 (421)**	69.7 (796)	**71.5 (647)**
Empiric combination therapy				
Meropenem + Amikacin	91.7 (2,801)	**89.6 (2,318)**	78.3 (6,553)	**66.1 (4,062)**
Meropenem + Gentamicin	45.3 (1,161)	**43.5 (1,090)**	70.5 (4,831)	**68.5 (4,514)**
Meropenem + Colistin	97.6 (847)	**97.5 (588)**	90.2 (2,012)	**92.0 (1,859)**
Meropenem + Fosfomycin	91.2 (500)	**93.6 (423)**	73.0 (834)	**76.5 (692)**
Colistin + Amikacin	99.8 (838)	**99.7 (1,183)**	97.1 (2,107)	**99.3 (805)**
Colistin + Gentamicin	97.8 (668)	**98.4 (1,159)**	96.1 (1,682)	**98.9 (806)**
Colistin + Fosfomycin	99.8 (2,527)	**99.3 (148)**	96.5 (462)	**97.8 (305)**
Amikacin + Fosfomycin	98.8 (512)	**98.8 (402)**	89.3 (897)	**97.3 (778)**
Gentamicin+ Fosfomycin	92.9 (468)	**92.7 (497)**	84.8 (833)	**96.9 (1,670)**

B2. Antimicrobial Resistance in Patients with Hospital-Associated Infections

B2.1 Hospital-associated infection

Incidence of Hospital-Associated Infections (HAI)

- Overall, in 2020, total 11,030 HAI events were reported in 8,979 patients from 50 hospitals. The incidence rate (per 1,000 patient-days) and incidence proportion (%) of HAI by year and type of hospital are shown in Table B2.1.
- The incidence rate and incidence proportion of HAI increased form 1.5 per 1,000 patient-days and 0.5% of total inpatients in 2019 to 1.8 per 1,000 patient-days and 0.7% of total inpatients in 2020.
- In 2020, other public hospitals had the highest HAI incidence rate (3.5 per 1,000 patient-days) and incidence proportion 1.7% of total in patients. The lowest HAI incidence rate and incidence proportion were found in community hospitals at 0.3 per 1,000 patient-days and 0.1% of total inpatients.

Table B2.1 Incidence rate (per 1,000 patient-days) and incidence proportion (%) of HAI by types of hospital

Hospital type	2020						2019		2018	
	HAI patient	HAI events	Patient-days	Discharged patient	Weighted HAI incidence rate	Weighted HAI incidence proportion (%)	Weighted HAI incidence rate	Weighted HAI incidence proportion (%)	Weighted HAI incidence rate	Weighted HAI incidence proportion (%)
Regional hospital	5,843	7,270	3,135,154	593,194	2.3	1.0	2.4	1.0	3.4	1.2
General hospital	2,350	2,798	2,143,871	995,253	1.3	0.2	1.3	0.4	1.2	0.4
Community hospital	75	84	272,209	86,141	0.3	0.1	0.4	0.1	1.0	0.3
Other MOPH hospital	80	109	33,962	6,198	3.2	1.3	3.2	1.3	2.9	1.0
Other public hospital	607	740	208,452	34,957	3.5	1.7	3.9	2.3	3.3	1.7
Private hospital	24	29	81,669	30,63	0.4	0.1	0.5	0.1	0.7	0.2
Total	**8,979**	**11,030**	**5,875,317**	**1,746,356**	**1.5**	**0.4**	**1.5**	**0.5**	**2.5**	**0.8**

HAI by age groups

- HAI events were found in elderly patients (age >60 years old) (51.7%, 5,705 events) more than other age groups (Figure B2.1).
- In 2020, almost of pediatric patients (newborn, infant, 1-15 years) with HAI events were newborn 5.9% (652 events).

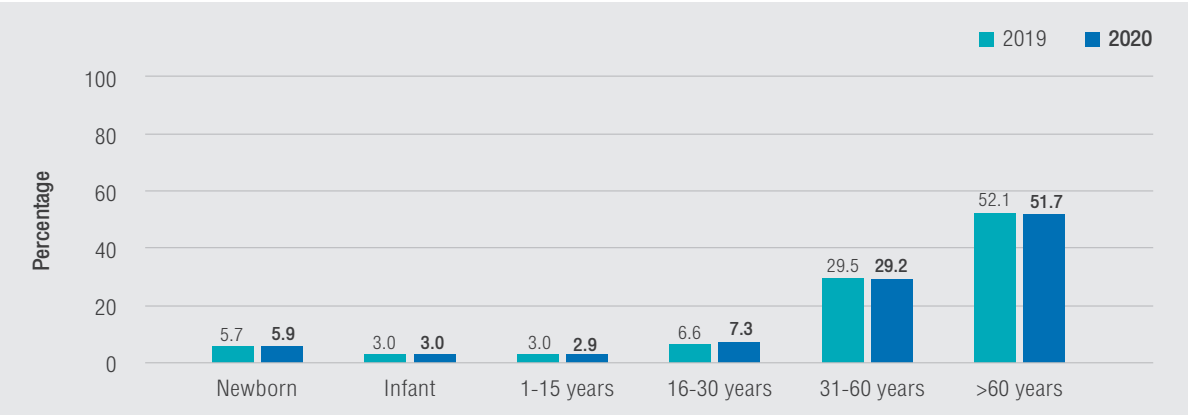


Figure B2.1 Percentage of HAI events by age group

Note: Data in 2018 was not available.

HAI by site of infection

- In 2020, the top-three sites of HAI infection were respiratory tract infection (49.5%), urinary tract infection (25.3%), and bloodstream infection (10.4%). The 2020 profile was similar to 2019 and 2018 (Figure B2.2).

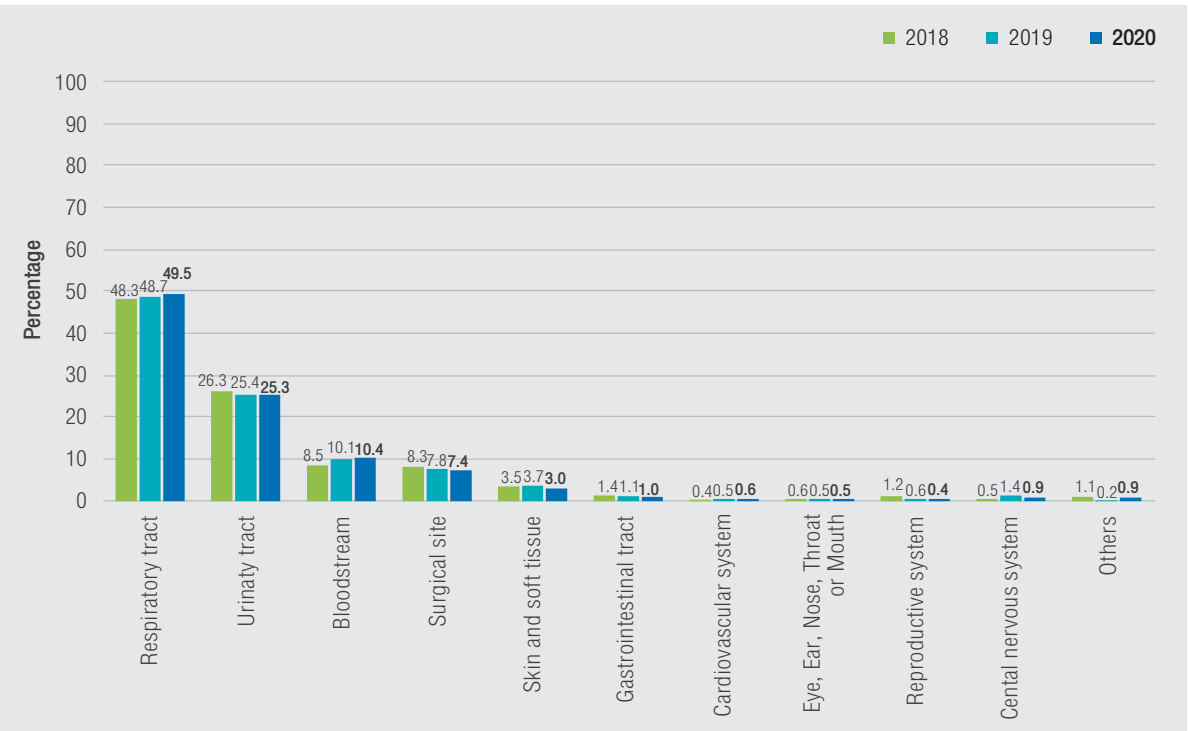


Figure B2.2 Hospital-associated infection by site of infection

- Overall, incidence rate of ventilator-associated pneumonia (VAP), central line-associated bloodstream infections (CLABSI), and catheter-associated urinary tract infections (CAUTI) was 3.7 per 1,000 ventilator-days, 1.5 per 1,000 catheter-days, and 1.3 per 1,000 catheter-days in 2020. The incidence rate of surgical site infection (SSI) decreased from 0.3 per 100 surgeries in 2019 to 0.2 per 100 surgeries in 2020 (Table B2.2).
- The VAP incidence rate in other MOPH hospitals had the highest rate accounting for 8.7 per 1,000 ventilator-days while community hospitals had the lowest VAP incidence at 1.2 per 1,000 ventilator-days in 2020.
- The CLABSI incidence rate in other MOPH hospitals had the highest rate at 8.9 per 1,000 catheter-days while there was no CLABSI incidence rate in community and private hospitals.
- The CAUTI incidence rate in other MOPH hospitals and other public hospitals were 3.3 per 1,000 catheter-days while community hospitals and private hospitals had lowest incidence rate at 0.2 per 1,000 catheter-days.
- Finally, the incidence rate of SSI was the highest in regional hospitals (0.5 per 100 surgeries) while there was no SSI incidence rate in community hospitals.

Table B2.2 Incidence of invasive device-related HAIs and surgical site infection (weighted incidence rate) by types of hospital

Hospital type	2020				2019				2018			
	VAP	CLABSI	CAUTI	SSI	VAP	CLABSI	CAUTI	SSI	VAP	CLABSI	CAUTI	SSI
Regional hospital	4.0	1.7	1.6	0.5	4.0	1.7	1.6	0.5	6.0	2.7	2.4	0.4
General hospital	3.4	0.9	1.2	0.2	3.7	0.9	1.3	0.2	4.2	0.7	1.3	0.2
Community hospital	1.2	0.0	0.2	0.0	2.4	3.3	0.5	0.1	6.8	1.2	1.6	0.2
Other MOPH hospital	8.7	8.9	3.3	0.1	6.5	3.6	3.4	0.1	3.3	3.0	5.1	0.1
Other public hospital	2.9	1.4	3.3	0.2	2.6	1.2	3.5	0.3	4.1	0.9	3.9	0.2
Private hospital	3.6	0.0	0.2	0.4	2.2	0.0	0.3	0.1	5.5	0.0	1.4	0.2
Total	**3.5**	**1.5**	**1.3**	**0.2**	**3.7**	**1.5**	**1.4**	**0.3**	**5.5**	**2.2**	**2.1**	**0.3**

Causative organisms of HAI

- The top-three causative pathogens of HAI in 2020 were *A. baumannii* (30.3%), *K. pneumoniae* (14.8%), and *E. coli* (11.8%). This profile was similar to the top-three in 2019 and 2018 (Figure B2.3).

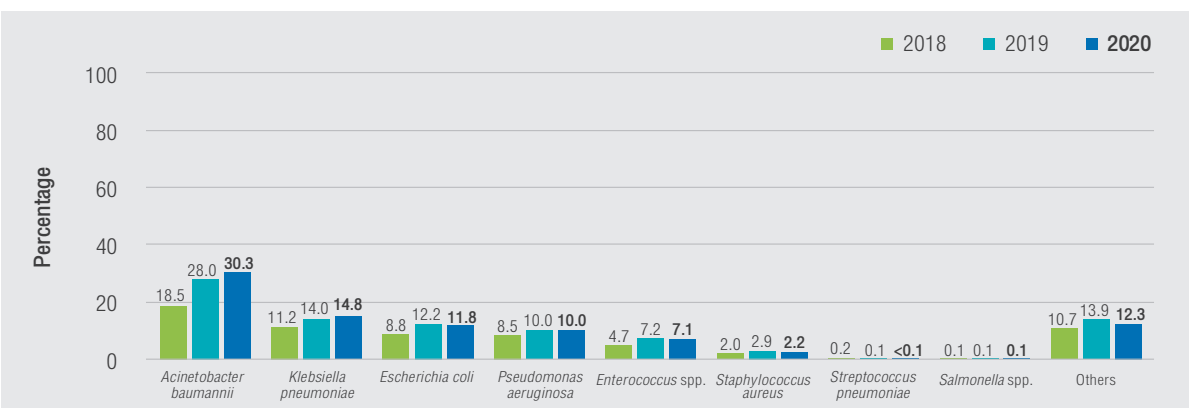


Figure B2.3 Causative organisms of HAI events by targeted pathogen
Note: Others are not targeted pathogen.

B2.2 Antimicrobial resistance[9]

Incidence of AMR in HAI patients

- In 2020, of the total 11,030 HAI events and 8,979 HAI patients, there were 5,854 AMR reported events (53.1% of total HAI events) in 4,721 AMR patients (52.6% of total HAI patients) (Table B2.3).
- The incidence rate and incidence proportion of AMR infection in 2020 were 0.7 per 1,000 patient-days and 0.2% of total inpatients, which slightly increased from 0.6 per 1,000 patient-days and 0.2% of total inpatients in 2019.
- Other MOPH hospitals had the highest AMR incidence rate (1.5 per 1,000 patient-days).
- The lowest AMR incidence rate was found in community hospitals and private hospitals at 0.1 per 1,000 patient-days while the lowest AMR incidence proportion was found in community hospitals at 0.02%.

Table B2.3 Incidence rate (per 1,000 patient-days) and incidence proportion (%) of AMR by types of hospital

Hospital type	2020						2019		2018	
	AMR patients	AMR events	Patient-days	Discharged patient	Weighted AMR incidence rate	Weighted AMR proportion	Weighted AMR incidence rate	Weighted AMR proportion	Weighted AMR incidence rate	Weighted AMR proportion
Regional hospital	3,185	3,935	3,135,154	593,194	1.3	0.5	1.1	0.5	1.8	0.7
General hospital	1,274	1,589	2,143,871	995,253	0.7	0.1	0.5	0.2	0.9	0.3
Community hospital	15	17	272,209	86,141	0.1	<0.1[+]	0.1	0.0	0.6	0.2
Other MOPH hospital	34	52	33,962	6,198	1.5	0.5	1.5	0.5	1.7	0.7
Other public hospital	203	249	208,452	34,957	1.2	0.6	1.6	0.9	1.4	0.8
Private hospital	10	12	81,669	30,613	0.1	<0.1[++]	<0.1[*]	<0.1[**]	0.5	0.1
Total	**4,721**	**5,854**	**5,875,317**	**1,746,356**	**0.7**	**0.2**	**0.6**	**0.2**	**1.4**	**0.5**

Note: [+]0.02, [++]0.03, [*]0.01, [**]0.002

AMR in HAI patients by age groups

- Half of AMR events in 2020 (55.5%, 3,248 of 5,856 events) occurred in elderly patients (age>60 years old).
- Almost half of paediatric patients infected (newborn, infant, and 1-15 years) with AMR pathogens were newborn 3.6% (208 events).

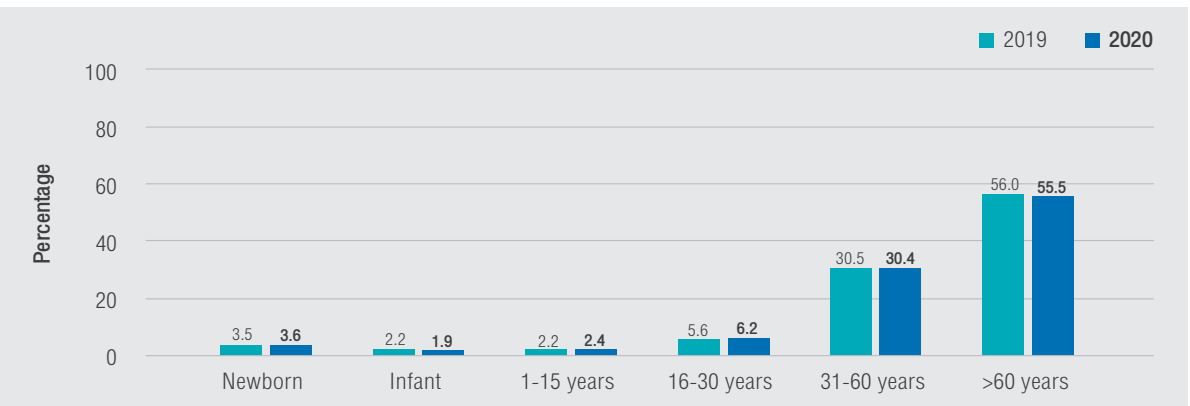


Figure B2.4 Number of AMR events by age group
Note: Data in 2018 was not available.

[9] In this chapter, AMR is defined as the resistance of target bacterial pathogens to at least one of the listed antimicrobials (*Acinetobacter baumannii, Klebsiella pneumoniae, Escherichia coli, Pseudomonas aeruginosa, Enterococcus* spp., *Staphylococcus aureus, Streptococcus pneumoniae, Salmonella* spp., and *Neisseria gonorrhoeae*) in accordance with the National Strategic Plan on AMR (2017-2020). In case a patient was reported with similar AMR pathogen infection within a 14-day period, a deduplication of AMR events was done.

AMR in HAI patients by sites of infection

- Among all AMR events, the top-three sites were respiratory tract infection (59.3%), urinary tract infection (23.1%), and bloodstream infection (7.5%), similar to the data in 2019 (Figure B2.5).

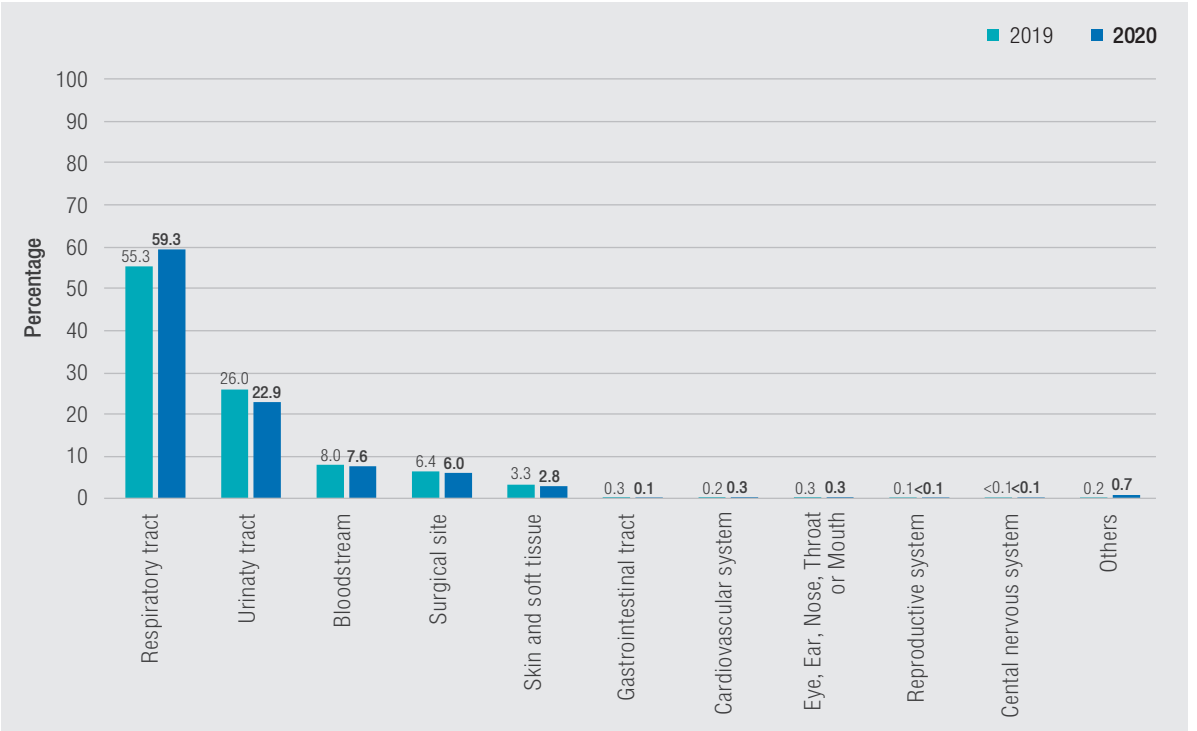


Figure B2.5 Antimicrobial infection by sites of infection

Note: Reproductive system was 0.04% in 2019. Central nervous system was 0.04% and 0.03% in 2019 and 2020, respectively.

Note: Data in 2018 was not available.

AMR in HAI patients by targeted pathogens

- In 2020, among the total 5,856 AMR events, *A. baumannii* was the most common pathogen (48.6%, 2,848 events), followed by *K. pneumoniae* (25.3%, 1,482 events), and *E. coli* (16.8%, 981 events).
- This result, *Salmonella* spp. was low of AMR event (<0.1%, 1 event) while there was no penicillin resistant *Streptococcus pneumoniae* in 2020 (Figure B2.6).

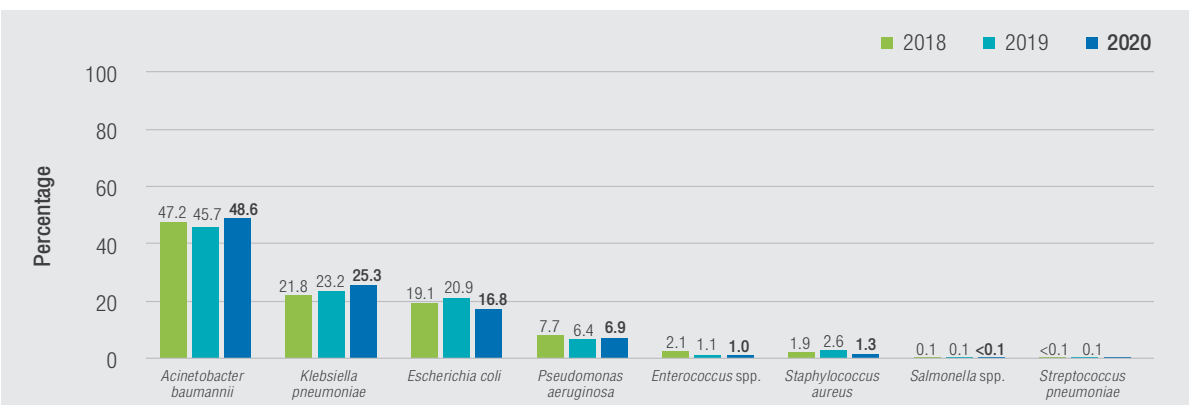


Figure B2.6 AMR events by targeted pathogens

Resistance percentage in HAI patients

- Trend of carbapenem resistance in *A. baumannii* (87.8%), *K. pneumoniae* (44.7%), *E. coli* (27.0%), and *P. aeruginosa* (31.2%), increased from the data in 2019.
- More than two-third of *K. pneumoniae* and *E. coli* isolates were resistant to third generation cephalosporins which were 79.3% and 71.8%, respectively. These resistance percentage were higher than the percentage in 2018 and 2019.
- In 2020, none of *S. aureus* isolates (n = 235) was resistant to vancomycin and none of *S. pneumoniae* (n = 1) was resistant to penicillin and third generation cephalosporins.
- Vancomycin-resistant *Enterococcus* increased from 6.6% in 2019 to 8.5% in 2020 (n = 717).

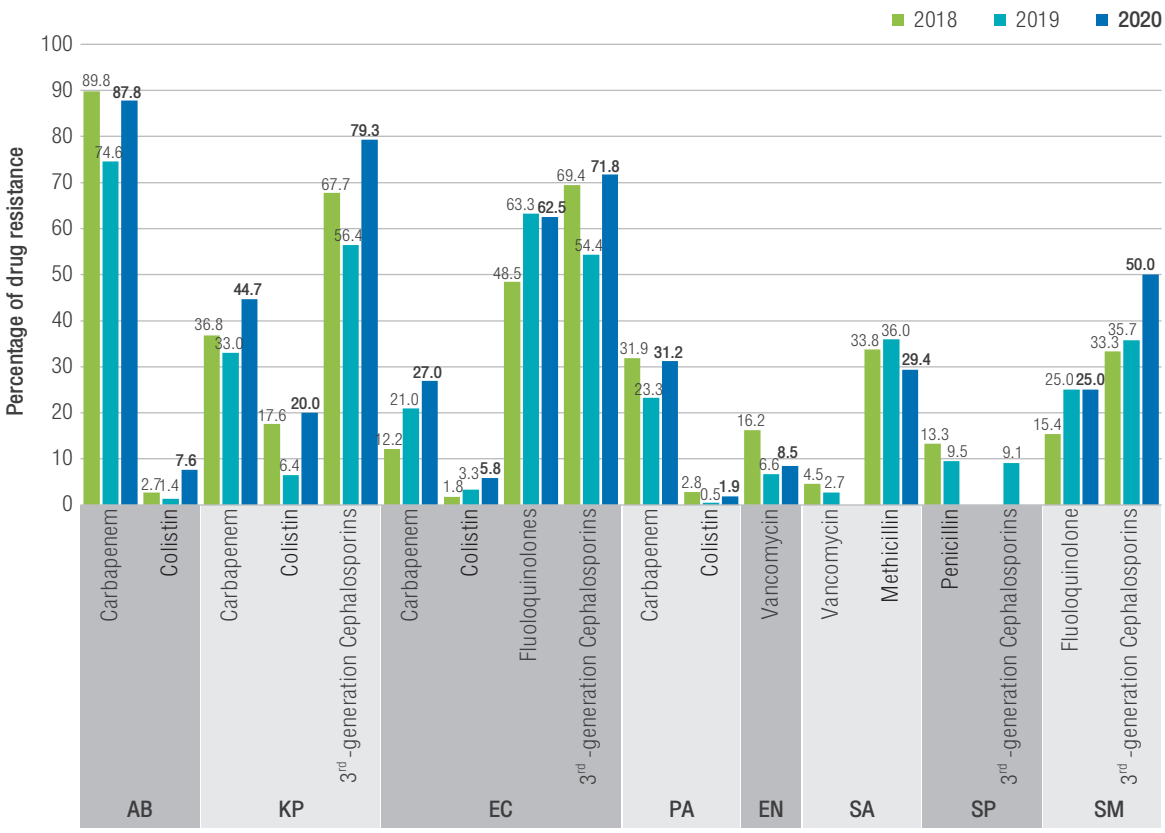


Figure B2.7 Percentage of drug resistance in targeted pathogens

Note: AB: *A. baumannii*, KP: *K. pneumoniae*, EC: *E. coli*, PA: *P. aeruginosa*, EN: *Enterococcus* spp., SA: *S. aureus*, SP: *S. pneumoniae*, SM: *Salmonella* spp.

Note: *Salmonella* spp. was not resistant to colistin in 2018, 2019, and 2020.

*Count only first isolate pathogen

B2.3 Incidence rate of HAI and AMR by ward types

HAI events and AMR events by ward type

- In 2020, the most incidence of HAI events and AMR events by specialty ward occurred in medicine wards (2.4 per 1,000 patient-days for HAI and 1.4 per 1,000 patient-days for AMR), followed by surgery wards (2.3 per 1,000 patient-days for HAI and 1.2 per 1,000 patient-days for AMR), and mixed wards (1.3 per 1,000 patient-days for HAI and 0.7 per 1,000 patient-days for AMR). These results were common top-three of incidence rate HAI and AMR events similar to 2019.
- In 2020, the incidence rates of HAI events and AMR events by ward type in ICU wards were higher than non-ICU wards at 6.3 per 1,000 patient-days for HAI and 3.5 per 1,000 patient-days for AMR, respectively (Figure B2.8).

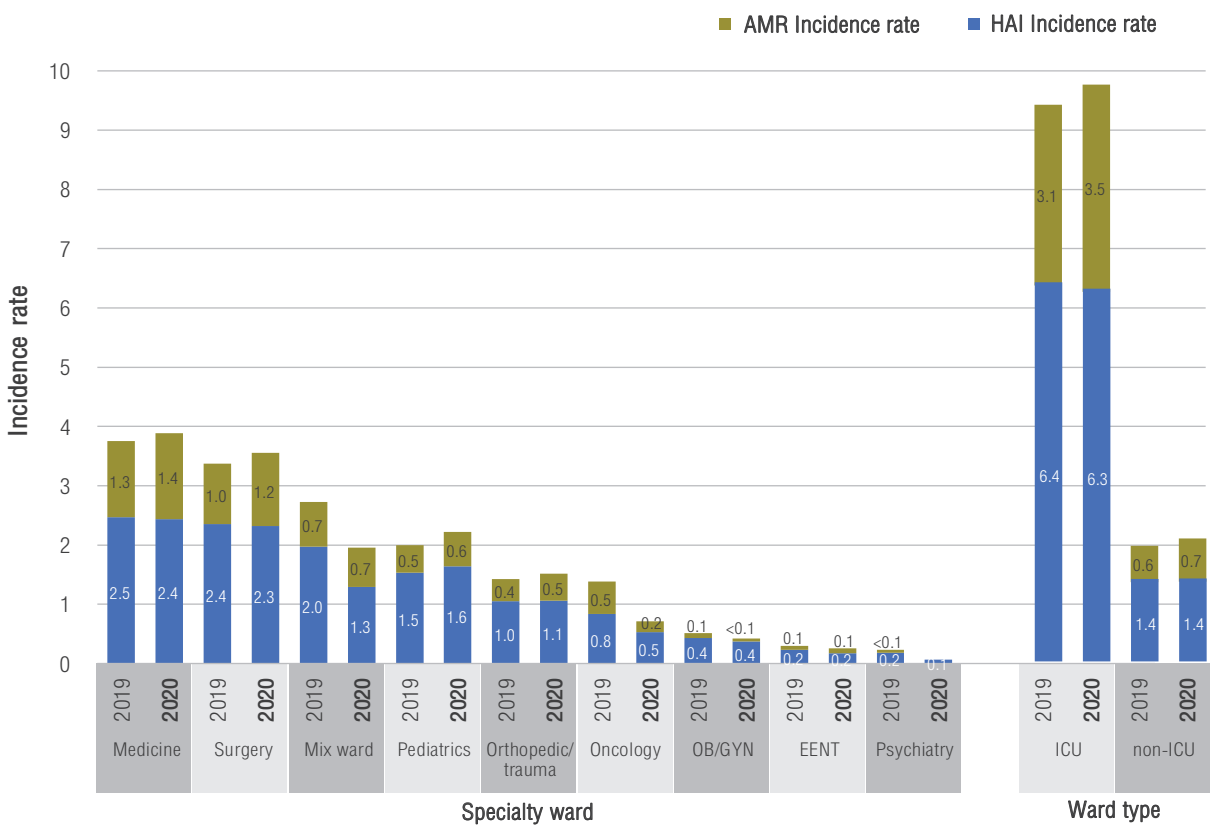


Figure B2.8 Incidence rate (per 1,000 patient-days) HAI and AMR events by ward types

Note: OB/GYN was 0.05 per 1,000 patient-days for AMR in 2020. Psychiatry was 0.05 per 1,000 patient-days for AMR in 2019 and none AMR events by ward type in 2020.

Note: Data in 2018 was not available.

B3. Antimicrobial Resistance in Food-Producing Animals

B3.1 *Escherichia coli*

E. coli isolates from chickens

- High levels of *E. coli* resistance against ampicillin and tetracycline in chicken caeca and chicken meat from slaughterhouses and retail markets were reported in 2020.
- None of the *E. coli* isolates in chicken caeca was resistant to meropenem in 2020, but low levels of meropenem resistance were detected in chicken meat from slaughterhouses (0.3%) and retail markets (1.4%).
- Low levels of resistance (<4.0%) against third generation cephalosporins (e.g. cefotaxime, ceftazidime) were detected in chicken caeca and chicken meat from slaughterhouses and retail markets.
- Between 2017-2020, the prevalence of AMR in *E. coli* isolates in all tested antimicrobials from chickens slightly decreased.
- *E. coli* from chicken caeca isolates resistant to colistin declined from 14.5% in 2017 to 1.2% in 2020.

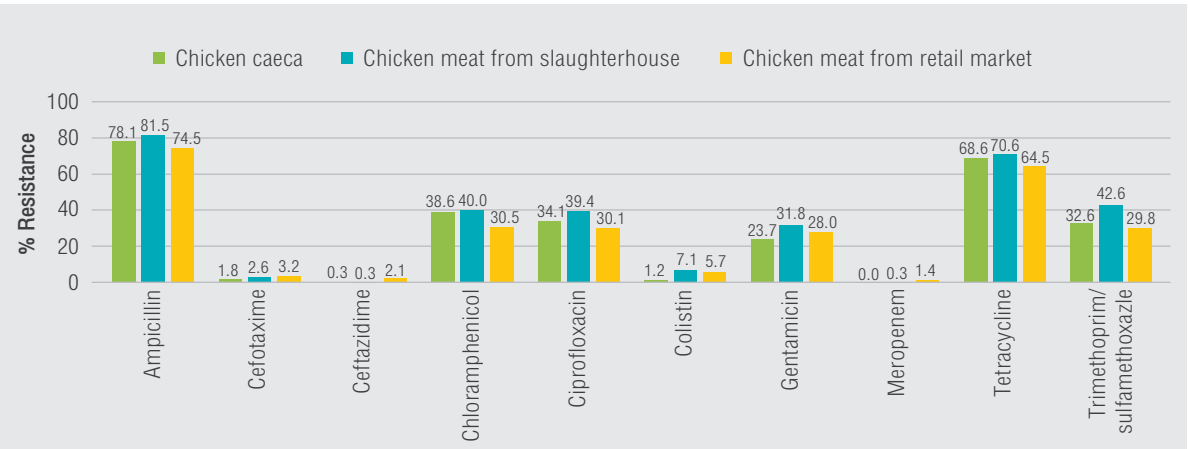


Figure B3.1 Percent resistance of *E. coli* isolates in chicken caeca, and chicken meat from slaughterhouses and retail markets in 2020

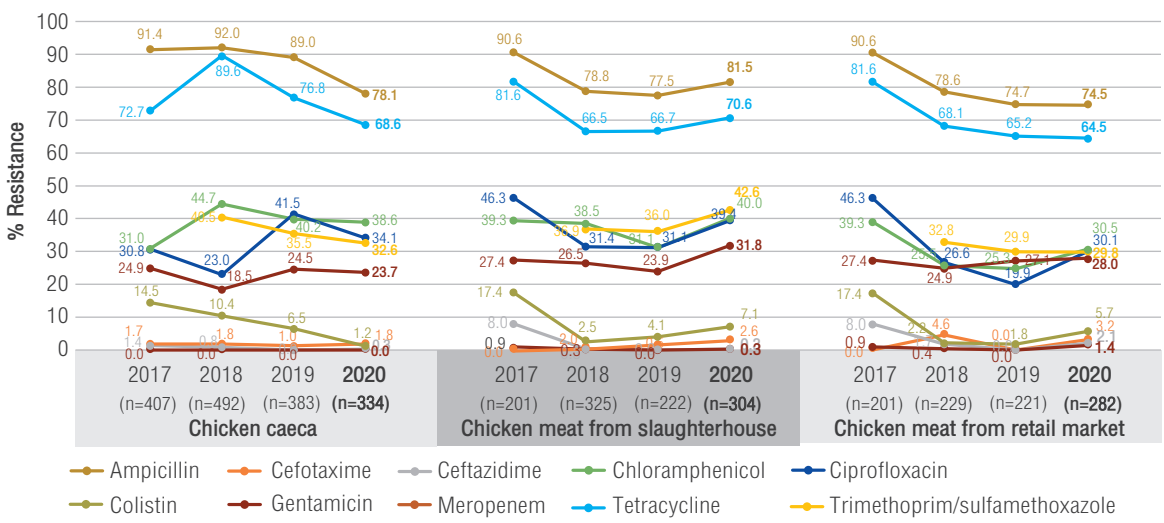


Figure B3.2 Percent resistance of *E. coli* in chicken caeca, and chicken meat from slaughterhouses and retail markets, Thailand in 2017 to 2020

E. coli isolates from pigs

- High levels of *E. coli* resistance against ampicillin, tetracycline, chloramphenicol, and trimethoprim/sulfamethoxazole in pig caeca and pork from slaughterhouses and retail markets were reported in 2020.
- None of the *E. coli* isolates in pig caeca was resistant to meropenem in 2020. However, low levels of meropenem resistance were detected in pork from slaughterhouses (0.6%) and retail markets (1.0%).
- The resistance level to third generation cephalosporins were detected in pig caeca and pork from slaughterhouses and retail markets are low (<15% of cefotaxime and <10% of ceftazidime).
- Between 2017-2020, the prevalence of AMR in *E. coli* isolates from pigs slightly declined. However, *E. coli* isolates in pork from slaughterhouses showed resistance to ciprofloxacin (from 18.6% in 2017 to 27.4% in 2020) and the isolates in pork from retail markets showed resistance to gentamicin (from 15.6% in 2017 to 20.2% in 2019).
- *E. coli* from pig caeca isolates resistant to colistin declined from 10.1% in 2017 to 4.6% in 2020.

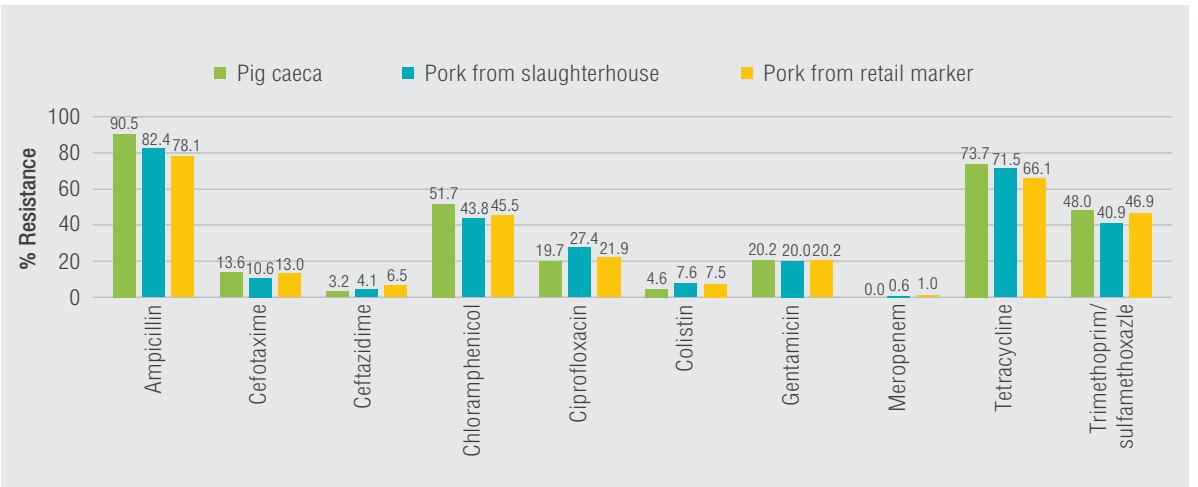


Figure B3.3 Percent resistance of *E. coli* isolates in pig caeca, and pork from slaughterhouses and retail markets in 2020

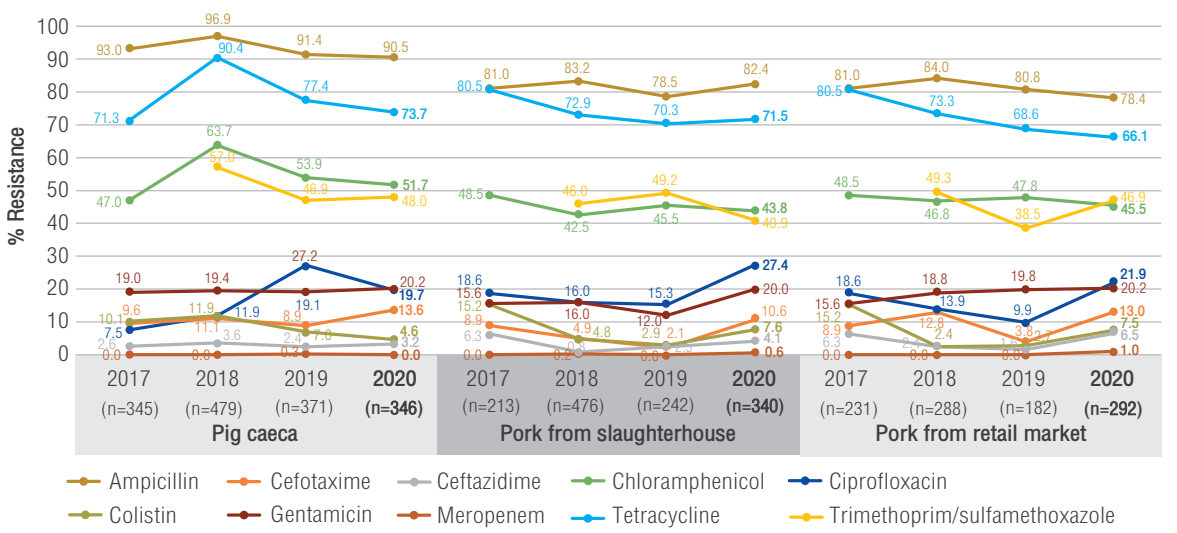


Figure B3.4 Percent resistance of *E. coli* in pig caeca, and pork from slaughterhouses and retail markets, Thailand in 2017 to 2020

B3.2 *Salmonella* spp.

Salmonella isolates from chickens

- High levels of *Salmonella* spp. resistance against ampicillin and tetracycline in chicken caeca and chicken meat from slaughterhouses and retail markets were reported in 2020.
- No meropenem resistance was found in *Salmonella* isolated from all source.
- In 2020, low levels of AMR (<2.0%) against third generation cephalosporins were detected in chicken caeca and chicken meat from slaughterhouses and retail markets.
- Between 2017-2020, the prevalence of *Salmonella* spp. resistant to ampicillin and tetracycline in chickens significantly declined, whereas the resistant to ciprofloxacin significantly increased.
- *Salmonella* isolates from all sources resistant to colistin significantly declined.

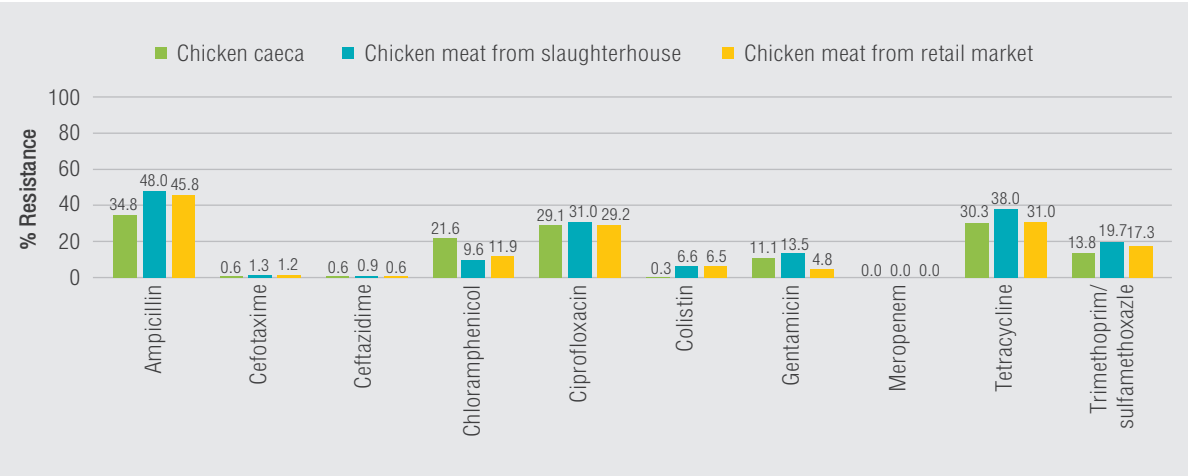


Figure B3.5 Percent resistance of *Salmonella* isolates in chicken caeca, and chicken meat from slaughterhouses and retail markets in 2020

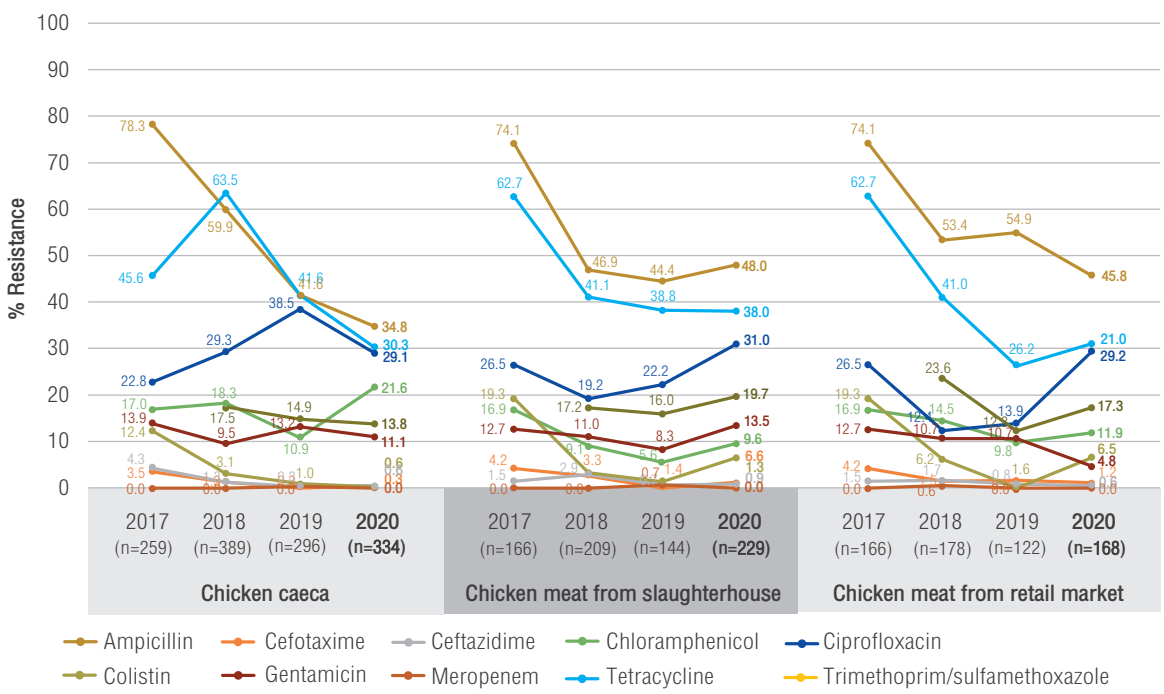


Figure B3.6 Percent resistance of *Salmonella* spp. in chicken caeca, and chicken meat from slaughterhouses and retail markets, Thailand in 2017 to 2020

Salmonella isolates from pigs

- High levels of *Salmonella* spp. resistance against ampicillin and tetracycline in pig caeca and pork from slaughterhouses and retail markets were reported in 2020.
- No meropenem resistance was found in *Salmonella* isolated from all sources.
- In 2020, low levels of resistance (<10.0%) against third generation cephalosporins were detected in pig caeca and pork from both slaughterhouses and retail markets.
- Between 2017-2020, the prevalence of *Salmonella* spp. resistant to ampicillin and tetracycline in pigs significantly declined, whereas the resistance to ciprofloxacin significantly increased.
- *Salmonella* isolates from all sources resistant to colistin significantly declined.

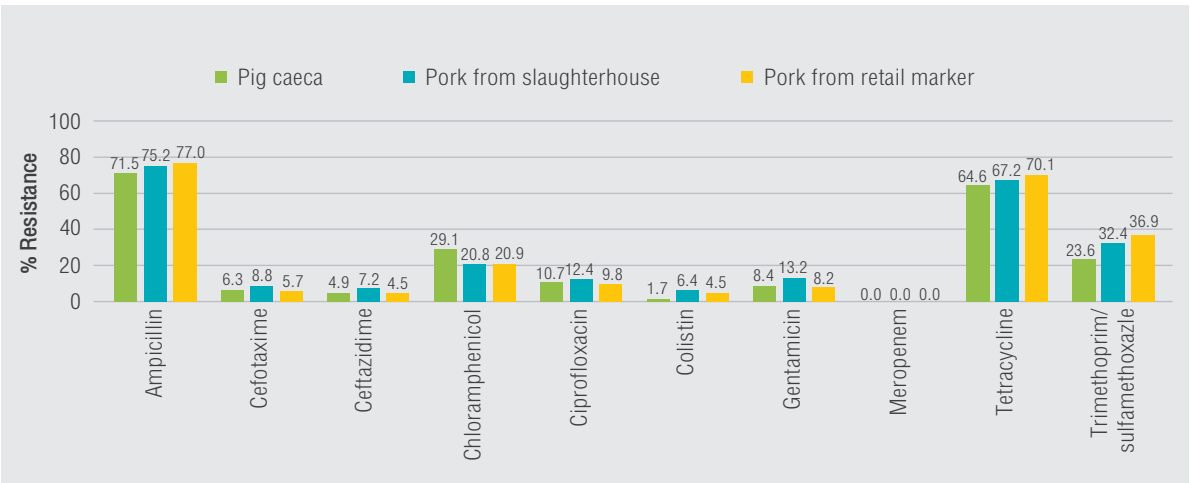


Figure B3.7 Percent resistance of *Salmonella* isolates in pig caeca, and pork from slaughterhouses and retail markets in 2020

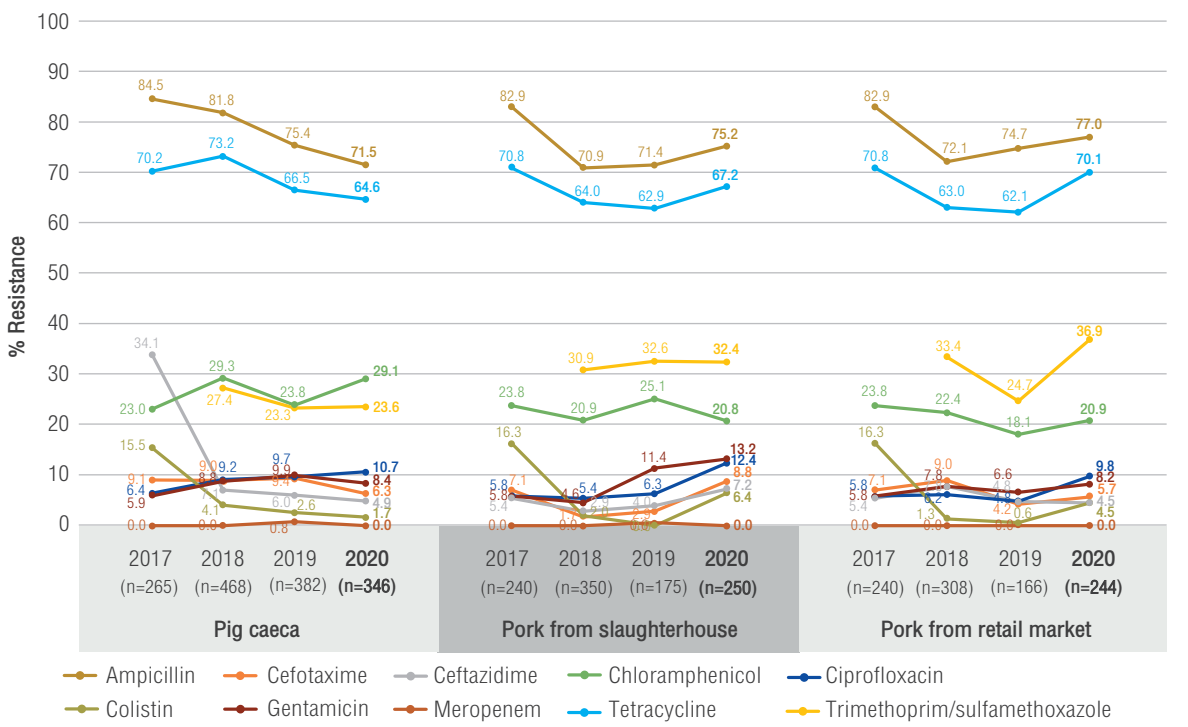


Figure B3.8 Percent resistance of *Salmonella* spp. in pig caeca, and pork from slaughterhouses and retail markets, Thailand in 2017 to 2020

B3.3 *Enterococcus* spp.

Enterococcus isolates from chickens

- High levels of *Enterococcus* spp. resistance against erythromycin (79.0%) and tetracycline (77.5%) in chicken caeca were reported in 2020. However, resistance to these antimicrobials declined in 2020 in comparison to 2019.
- Low levels of resistance (<2.0%) against vancomycin, linezolid, and teicoplanin were reported in chicken caeca in 2020.
- Between 2017 and 2020, the prevalence of resistant *Enterococcus* spp. to chloramphenicol significantly increased.

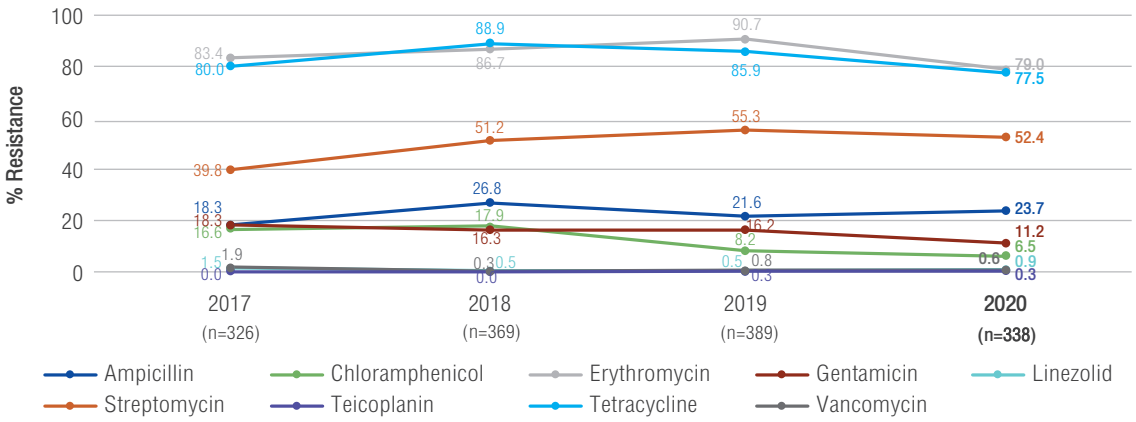


Figure B3.9 Percent resistance of *Enterococcus* spp. in chicken caeca, Thailand in 2017 to 2020

Enterococcus isolates from pigs

- High levels of *Enterococcus* spp. resistance against tetracycline (73.2%) and erythromycin (65.1%) were reported in pig caeca in 2020. However, the decrease resistance to those antimicrobials was examined in 2020 in comparison to 2019.
- Low levels of resistance to vancomycin (0.3%) and linezolid (2.7%) were detected in pig caeca. None teicoplanin resistance was found in *Enterococcus* isolates from pig caeca in 2020.
- Between 2017 and 2020, the prevalence of *Enterococcus* spp. resistant to streptomycin significantly increased.

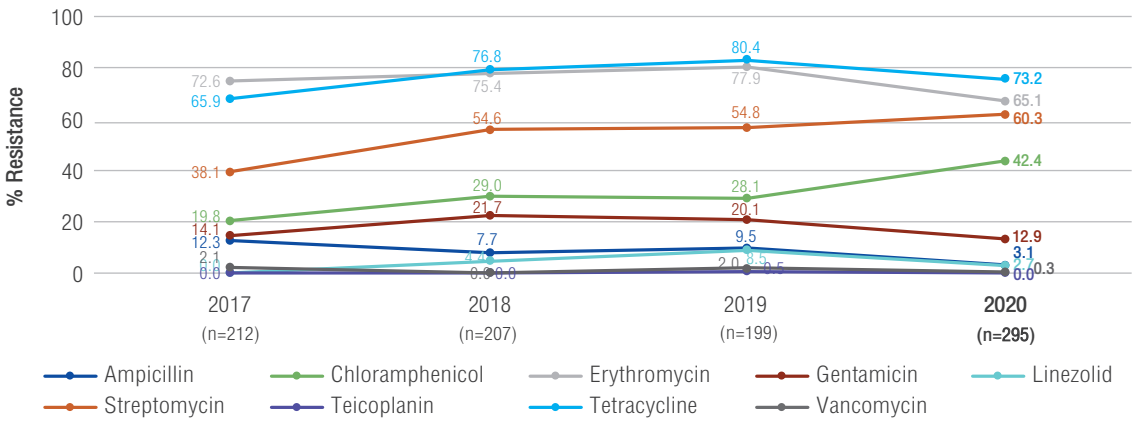


Figure B3.10 Percent resistance of *Enterococcus* spp. in pig caeca, Thailand in 2017 to 2020

B3.4 *Campylobacter* spp.

Campylobacter isolates from chickens

- High levels of *Campylobacter* spp. resistance against ciprofloxacin (74.7%) and tetracycline (53.5%) were reported in chicken caeca in 2020.
- The prevalence of resistant *Campylobacter* spp. in chicken caeca against ciprofloxacin, erythromycin, and tetracycline increased between 2017 and 2020.
- The reduction of resistance to streptomycin and gentamicin was observed in *Campylobacter* isolated from chicken caeca.

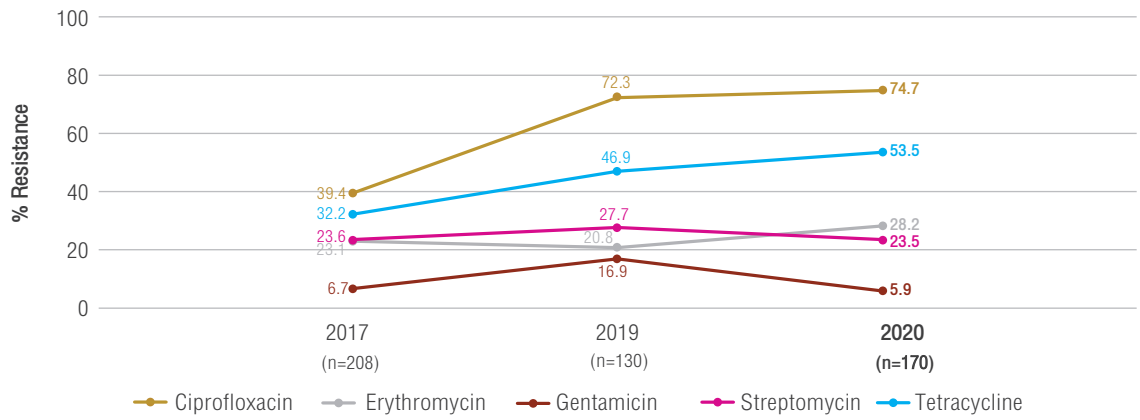


Figure B3.11 Percent resistance of *Campylobacter* spp. in chicken, Thailand in 2017, 2019 and 2020
Note: Data 2018 was not available.

Campylobacter isolates from pigs

- *Campylobacter* spp. were highly resistant to ciprofloxacin (77.5%), streptomycin (74.6%), and tetracycline (74.0%) in pig caeca in 2020.
- The prevalence of resistant Campylobacter spp. in all tested antimicrobials in pig caeca increased from 2017 to 2020. However, *Campylobacter* spp. resistance to ciprofloxacin, erythromycin, gentamycin, and streptomycin decreased from 2019 to 2020.

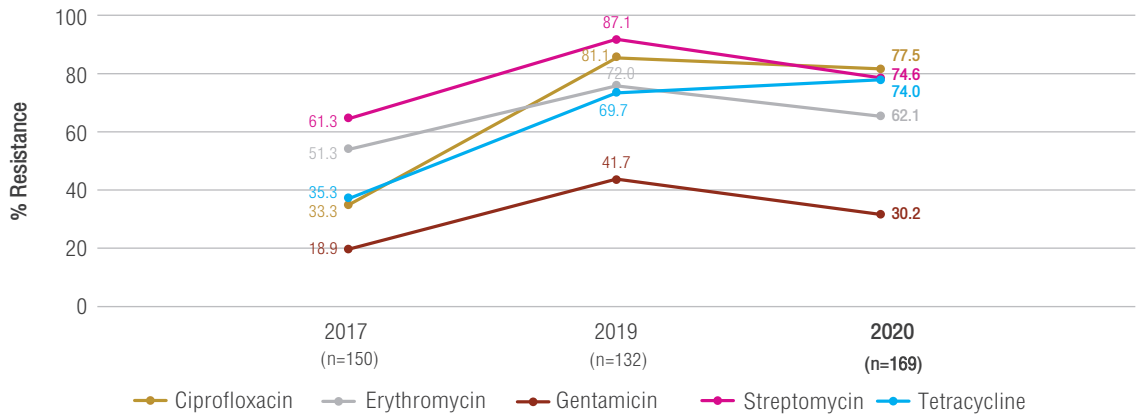


Figure B3.12 Percent resistance of *Campylobacter* spp. in pigs, Thailand in 2017, 2019 and 2020
Note: Data 2018 was not available.

ANNEX

ANNEX

1. ANTIMICROBIAL CONSUMPTION : METHODOLOGY

1.1 Human and Animal Populations

The number of human populations in 2020 was retrieved from World development indicator (2). The number of animal populations in 2020 was collected, retrieved and verified by various relevant stakeholders to ensure their accuracy. On the basis of populations potentially exposed to antimicrobials, the figure of each particular population was used as a denominator to calculate the amount of national antimicrobial consumption.

1.1.1 Human population

In 2020, the mid-year population in Thailand was calculated for the particular reporting year, while the number of migrants was estimated in the latest reporting year. (Table D1). Both data were from World development indicator (2).

Table D1. Human population (2020)

Population (reporting year)	Male	Female	Total
Citizen (2020)	33,966,060	35,833,918	69,799,978
Migrant (2015)	3,913,258		3,913,258
	Total		**73,713,236**

1.1.2 Animal population

The number of food-producing animals was collected and verified through cooperation between the Department of Livestock Development (DLD), Department of Fisheries (DOF), private sector and relevant stakeholders. For terrestrial food-producing animals, the data were collected and verified from three sources: 1) livestock surveys by district and provincial DLD offices, 2) data records from the E-movement system of DLD, and 3) large-scale livestock producers.

The weights for each animal category based on the European Surveillance of Veterinary Antimicrobial Consumption (ESVAC) were used in the calculation. It is the theoretical weight at the likely time for treatment. For farmed fish, the fish biomass live-weight slaughtered is used to calculate the total PCU. However, the weight of certain species was raised as food-producing animals in Thailand are not available or not relevant to the local context (3). Consequently, Aw were estimated based on standing weight of these animal species including broiler breeder, layer breeder, laying hen, pullet, broiler duck breeder, broiler duck, layer duck and dry cow (Table D2). Population Correction Unit (PCU) is used as a denominator for AMC in food-producing animals and calculated by applying ESVAC methodology. According to the ESVAC, PCU is assumed to be a surrogate for the animal population at risk of being exposed to antimicrobials (4).

For the aquatic animal population, data were collected from surveys and estimated by the Fisheries Development Policy and Strategy Division, Department of Fisheries. The estimation were done using estimated annual amount of fishes or shrimps raised in a particular area and the size of the area. The species included were major fishes and shrimps produced from coastal and fresh waters (Table D2). The figures of aquatic animals are shown in biomass. The PCU used as a denominator in this report was modified from ESVAC by combining both PCU from terrestrial animals and biomass from aquatic animals, so it is called $PCU_{Thailand}$.

Table D2. Food-producing animal population (2020)

Food-producing animal category			
Terrestrial animals (number of animals)	**Weight (kg)**	**Head count**	**PCU (kg)**
Pigs			
Pig breeders	240**	1,206,566	289,575,840
Fattening pigs	65**	22,050,733	1,433,297,645
Poultry			
Broiler breeders	4*	17,518,500	70,074,000
Broilers	1**	1,757,871,998	1,757,871,998
Layer breeders	2*	49,778,787	1,340,986
Laying hens	2*	49,533,033	99,557,574
Pullets	1.5*	41,749,950	62,624,925
Broiler duck breeders	3.5*	344,208	1,204,728
Integrated broiler ducks	3.3*	34,420,840	113,588,772
Free-market broiler ducks	3.3*	15,741,011	51,945,336
Integrated layer ducks	2.5*	9,114,559	22,786,398
Free-market layer ducks	2.5*	6,602,297	16,505,743
Cattle			
Dairy cows	425**	320,613	136,260,525
Dry cows	425*	386,623	164,314,775
Beef cows	425**	6,230,140	2,647,809,500
Aquatic animals		**1,000 tonnes of biomas**	**PCU (kg)**
Coastal aquatic animals		413,648	413,648,000
Fresh water aquatic animals		413,455	413,455,000
	Total $PCU_{Thailand}$		**7,695,861,744**

*Thailand SAC

**ESVAC

1.2 Antimicrobial Consumption in Humans and Food-producing Animals

1.2.1 Overview

In Thailand, oral human antimicrobials and their preparation for external use are classified as dangerous drugs, which must be dispensed only by a licensed pharmacist. In 2019, some oral antimicrobials such as oral antituberculous drugs and injectable antimicrobials were classified as special controlled drugs, which require a prescription from a licensed physician (5). Some veterinary antimicrobials are classified as dangerous drugs, which must be dispensed by a licensed pharmacist or veterinarian without a prescription requirement. In 2019, some veterinary antimicrobials (antibacterials in medicated premix, quinolones and derivatives, cephalosporins, macrolides, and polymyxins) are classified as specially controlled drugs, which require a prescription before being dispensed (6,7).

According to the NSP-AMR, one of the goals is to reduce human antimicrobial consumption by 20% and veterinary antimicrobial consumption by 30% by 2021 (8). In order to make the goals measurable, the methodology of monitoring antimicrobial consumption is of substantial importance and that is one of the reasons that Thailand SAC has been developed. Aside from monitoring the national goals, the data from Thailand SAC are useful for both health professionals and policymakers because consumption data can help assess the effects of policy implementation, particularly improving the Antimicrobial Stewardship Program and law enforcement such as the re-classification of antimicrobials. With some improvements in methodology and data granularity, such useful information can be utilised not only at national, but also at local and regional levels to tackle antimicrobial resistance problems in an efficiently practical way.

1.2.2 Data sources

According to Drug Act B.E. 2510 (1967) Section 85 including its amendments, all pharmaceutical manufacturers and importers are required by FDA to submit an annual report, which consists of their total produced, imported, and/or exported volumes of registered products, by 31 March of the following year (9,10) . The data were then electronically retrieved on 31 March 2021 for analysis. The assumption that domestic consumption equals the amount of manufactures and imports subtracted by that of exports (11).

For human target antimicrobials, it covers the core and optional classes of antimicrobials recommended by the World Health Organization (12) (Table D3). The unit of measurement was DDD/1,000 inhabitants/day (DID), computed from Defined Daily Dose (DDD) as a numerator and the mid-year human population as a denominator. The standard of DDDs in this report applies the latest version of Anatomical Therapeutic Chemical (ATC)/DDD alterations, which is produced by the WHO Collaborating Centre for Drug Statistics Methodology (13).

For the scope of veterinary target antimicrobials, Thailand SAC covered a list of target antimicrobials in alignment with the World Organisation for Animal Health and ESVAC (3,14) (Table D4).

Table D3. The core and optional classes of target human antimicrobials by WHO

Target human antimicrobials	ATC code
1. Core class	
• Antibacterials for systemic use	J01
• Antibiotics for alimentary tract	A07AA
• Nitroimidazole derivatives	P01AB
2. Optional class	
• Antimycotics for systemic use	J02
• Antifungals for systemic use	D01BA
• Antivirals for systemic use	J05
• Drugs for treatment of tuberculosis	J04A
• Antimalarials	P01B

Table D4. The scope of target antimicrobials intended for use in food-producing animals

Target veterinary antimicrobials	ATC vet codes
1. Antimicrobial agents for intestinal use	
• Antibiotics	QA07AA
• Sulfonamides	QA07AB
• Other intestinal anti-infectives	QA07AX
2. Antimicrobial agents for intrauterine use	
• Antibiotics	QG01AA, QG01BA
• Sulfonamides	QG01AE, QG01BE
• Antibacterials	QG51AA
• Anti-infectives for intrauterine use	QG51AG
3. Antimicrobial agents for systemic use	QJ01
4. Antimicrobial agents for intramammary use	QJ51

1.2.3 Limitations

A few limitations are addressed. Thailand SAC relies on the concept that domestic consumption equals to manufacture and importation data minus the export volume. This concept has an inevitable disadvantage that the accuracy of the data could be disturbed by the amount of stock finished products not consumed. As a result, some efforts have been made to pass a new regulation requiring the pharmaceutical operators to submit the distribution amounts based on sale data in 2020. This requirement will come into effect in the annual report of 2022. Besides, awareness and compliance of pharmaceutical operators with the new requirement is needed. Moreover, annual reports to FDA capture only all legal import and manufacture medicines.

With effort to achieve the actual national consumption Figures, Thai FDA have received cooperation from pharmaceutical operators in reporting and advances methodology to capture all antimicrobials, resulting in not only more accurate amounts of reported registered products but also improvements in data quality. Along with verification of the registration database from 2017-19, especially related to drug strengths and ATC codes, the differences in annual consumption data may be derived not only from policies in relation to antimicrobial distribution but from these methodological improvements as well as systematic verification, which requires pharmaceutical operators of any registered antimicrobials with a change of more than 150% compared to the previous year will be asked to verify whether the amount of finished products reported was accurate or not.

1.2.4 Prospect

In order to fully capture antimicrobial consumption, all export values need to be reported and verified with other sources such as port of entry for air, land and sea borders. In doing so, it increases not only the accuracy of the data, but also prevents illegal importation and smuggling along borders. As an unavoidable disadvantage of estimating domestic consumption in this report, the consumption data cannot provide information on how many antimicrobials have been annually used at primary healthcare, retail and inpatient hospital care sectors, resulting in lack of data granularity at user level such as age, gender and ward. Therefore, sales data would be more accurate than import, local production and export data, but mandatory reporting for the sales data requires legislative amendments. An amendment of Ministerial regulations was endorsed and mandatorily requires pharmaceutical operators to electronically submit annual reporting of distribution channels and export volumes of all medicines including antimicrobials (10). For the ultimate goal, antimicrobial consumption at user level should be considered because it reflects antimicrobial use at point of service, the real selective pressure on AMR, and policy consequences. However, the acquisition of the data requires a good drug-dispensing system aligned with reliable seamless information systems from upstream to downstream of the pharmaceutical supply chains.

1.3 Antimicrobial Consumption in Food-Producing Animals (Medicated Feed through Feed Mills)

1.3.1 Overview

Given the limitations of Thailand SAC, data are not available to disaggregate by animal species. In 2017, the working group decided to collect data of antimicrobial used in medicated feed (medicated premix) which can divided the amount of antimicrobial use by animal species. More than half of veterinary antimicrobials in Thailand was consumed through medicated feed, which can be produced by either feed mills or farm mixers (15,16). By law, medicated premixes containing antibacterial(s) have been classified as specially controlled medicine, which must be dispensed by a licensed pharmacist and requires a prescription from a veterinarian (17,18). Therefore, veterinary prescription is needed for feed mills before medicated feed production, and for farmers who produce farm-mixed medicated feed on farms (19).

According to the NSP-AMR, one of the goals is to reduce veterinary antimicrobial consumption by 30% in 2021 (8). In order to achieve the goal and close the gaps of pharmaceutical supply chains, feed mills are a potential platform for monitoring and evaluation in Thailand SAC. Aside from monitoring the national goal to pragmatic utility, the data from Thailand SAC may be useful for both health professionals and policymakers. This is because that they can help assess the effects of policy implementation, law enforcement, antimicrobial stewardship program, and other relevant interventions imposed at national level.

1.3.2 Data sources

According to Animal Feed Quality Control Act B.E. 2558 (2015), all feed mills and feed importers are required by DLD to submit an annual report, which consists of their total production and/or importation volumes of feed and medicated feed by animal species, before 31 March of the following year (20, 21). The data were electronically retrieved on 31 March 2021 for analysis. “Other” type of animal including any other species than poultry and pigs was excluded in the analysis and the past data suggested that it represented only a small proportion. Data were derived from 73 feed mills, of which 72 were large-scale and the other one was small-to-medium-scale justified by production capacity, by which a feed mill with total feed production of more than 10 tonnes per hour is considered a large-scale feed mill (22).

1.3.3 Limitations

Data on medicated feed reported by licensed farm mixers were firstly collected in 2020 as the first-year implementation with mandatory report. Antibacterial agents, which had been mixed with feed at the farm mixer, were reported using a paper-based survey. DLD has visited representative farms to verify reliability and accuracy of data inputs. Because of some disadvantages of the paper-based surveys, DLD is now developing an internet-based survey. The data of all antimicrobial use in feeds through feed mills and farm mixers is expected to be captured legally in 2020.

1.3.4 Prospect

To fully capture veterinary consumption through the whole system, the reporting system should be linked and shared between all stakeholders such as the Thai FDA and DLD using registration ID of products to be used in medicated feed. The next step will be much easier to achieve in terms of tracking the illegal veterinary medicinal products to their source, directly solving the problems on the spot.

2. ANTIMICROBIAL RESISTANCE

2.1 Antimicrobial Resistance in Humans: lab-based surveillance

2.1.1 Overview

Antimicrobial resistance (AMR) in bacterial isolates from human in Thailand has been increasing, especially in Gram-negative bacteria. To date, the data regarding systematic antimicrobial susceptibility is limited. For the surveillance report, we aimed to observe and implement the antimicrobial data into clinical practice.

2.1.2 Method and data sources

Antimicrobial resistance data were collected from 74, 85, 92 and 83 hospitals in Thailand during 2017, 2018, 2019 and 2020, respectively, with support from NARST, National Institute of Health, Department of Medical Sciences, The Ministry of Public Health, Thailand. The 2017, 2018, 2019 and 2020 gonococcal antimicrobial resistance data were provided by Division of AIDS and STIs, and Enhanced Gonococcal Antimicrobial Surveillance Programme (EGASP) in Thailand, Department of Disease Control, Ministry of Public Health, respectively. Data on antimicrobial resistance and MIC values in 2017, 2018, 2019 and 2020 were interpreted according to the Clinical and Laboratory Standards Institute (CLSI) susceptibility breakpoints 2017, 2018, 2019 and 2020, respectively.

Note: nearly all antimicrobial resistance data in this chapter, intermediate category was classified as resistance, unless otherwise specified.

2.1.3 Limitations

- This report did not identify risk factors linked with baseline characteristics of patients and did not show the distribution of isolates from different hospital levels (primary, secondary or tertiary care).
- For most data in this report, all types of specimen were selected for calculation of resistance rate.
- This report did not divide isolates into those from outpatient or inpatient hospital departments including intensive care units.
- Due to the cost of the MIC test, most of the *Staphylococcus aureus* and coagulase-negative *Staphylococcus* spp. isolates were tested by disk diffusion method, instead of the MIC test for vancomycin that is recommended by the CLSI guidelines.
- Because the colistin MIC breakpoints was modified in CLSI 2020 that MIC value of ≤2 and ≥ 4 mg/L were defined as intermediate and resistant, respectively with no susceptible breakpoint, the percentage of colistin resistance in 2020 was demonstrated from only MIC value ≥ 4 mg/L. As the resistance data in the previous years were demonstrated from MIC value >2 mg/L which intermediate category were included. Therefore, interpretation for antimicrobial susceptibility should be noted between 2018-2019 and 2020.

2.1.4 Recommendations

- Covid-19 situation has impacted on working conditions and might impact on antimicrobial resistance data in 2020.
- The data regarding trends towards antimicrobial resistance should be observed for several years in order to assess the evolution and overall situation of antimicrobial resistance problems in Thailand. Findings will contribute substantially to addressing the problem of AMU and AMR and support implementation of effective antimicrobial stewardship policies and infection control programs.
- Time trends analysis using logistic regression models over a longer period is needed in order to understand how significant changes in the past several years have evolved.

- Systematically combining data on antimicrobial consumption and antimicrobial resistance at patient, hospital, and community levels should be done to allow further analyses of the association between antimicrobial use and the development of resistance.
- Antimicrobial resistance data should be separately analyzed into specimen types (blood, sputum, urine, etc.) or at least sterile and non-sterile sites, and should be stratified by healthcare service sectors, for instance, the proportion of isolates from outpatient departments and inpatient departments including intensive care units.
- Regional antimicrobial resistance rates should be further analyzed and compared.
- Laboratory consideration of MIC testing is very crucial in dose optimization to tackle the antimicrobial resistance problem; thus, MICs of antimicrobial agents against certain bacterial species as suggested by international guidelines should be performed and reported in settings with available resources, for example, in vancomycin for *Staphylococcus aureus*.
- Antimicrobial resistance genes in highly antimicrobial-resistant organisms, (e.g. carbapenem-resistant Enterobacterales, CRE) the carbapenemase genes should be identified and reported. This information may be of value in developing treatment guidelines to suggest reasonable therapeutic options on the essential medicines list.
- Because of the alarming trend of CRE and steady high prevalence of carbapenem-resistant *A. baumannii*, a specific plan at the national level should be constructed and implemented in a systematic manner to alleviate the healthcare burdens caused by these organisms, especially improving health services with tightened infection prevention and control.
- Data on antiviral resistance and antimicrobial resistance in fungi and *Mycobacterium tuberculosis* should be reported in the future.
- The greater number of isolates, the more accurate data will be seen. Efforts should be made to empower laboratories to be capable of carrying out the tests for both epidemiologic and clinical purposes around the country.

2.2 Antimicrobial Resistance in Patients with Hospital-Associated Infections: case-based surveillance

2.2.1 Overview

Antimicrobial Resistance Surveillance System is one of the six strategies of the National Strategic Plan on Antimicrobial Resistance 2017-2021 (NSP-AMR 2017-2021). One of five goals in the NSP-AMR 2017-2021 is to reduce AMR morbidity by 50% by 2021. However, various departments of the Ministry of Public Health host fragmented AMR monitoring platforms. Currently, there are two potential platforms to monitor AMR morbidity: 1) the Global Antimicrobial Resistance Surveillance System, Thailand (GLASS-Thailand) hosted by the National Institute of Health; and 2) Hospital Associated Infection Surveillance hosted by the Bamrasnaradura Infectious Diseases Institute (BIDI's HAI surveillance).

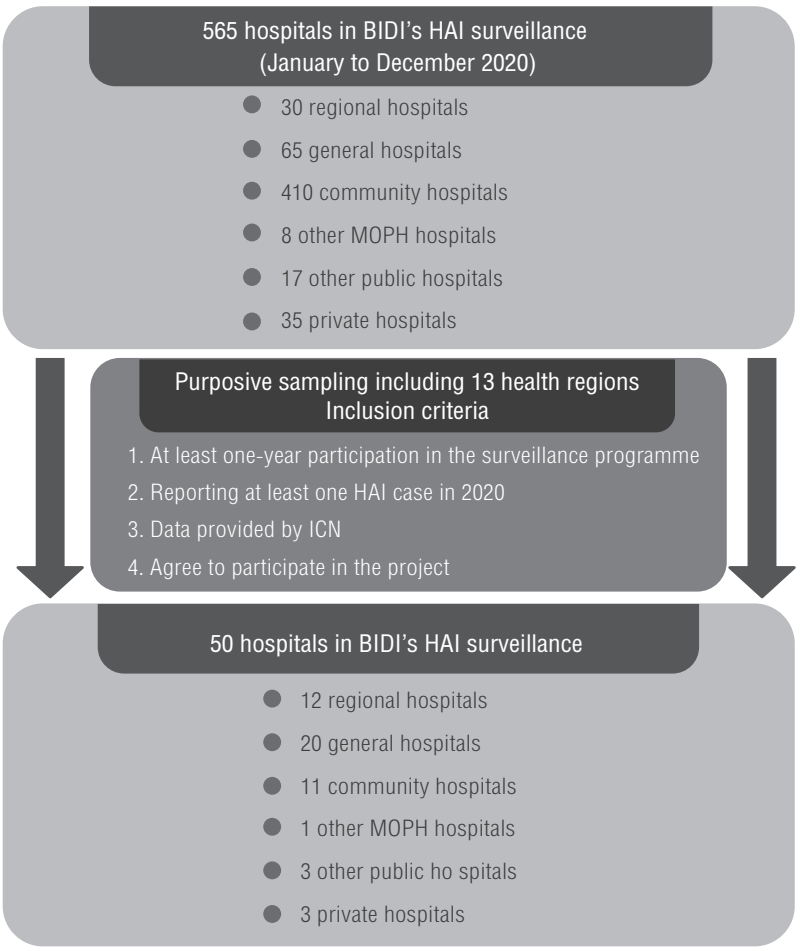
Since 2018, BIDI's HAI surveillance have undertaken HAI and AMR case-based surveillance in Thailand involving public and private hospitals; 50 hospitals were included in this study in 2020. In this report, the main objective of the analysis was to estimate 2020 AMR morbidity and compare with the 2018 and 2019 results.

2.2.2 Method and data sources

Data from BIDI's hospital-wide surveillance were analysed including all HAI cases entered in the surveillance system during January and December 2020. All HAI cases occurring in the hospitals were detected by infection control ward nurses (ICWNs) and confirmed by infection control nurses (ICNs) in each hospital using the definition in the Thai Manual of HAI Diagnosis 2018[10]. Data of patients with HAI were manually submitted to the surveillance web portal on a monthly basis. Antimicrobial susceptibility data (susceptible, intermediate or resistant) of HAI patients reported in laboratory results was collected. In addition, hospital service profiles such as the number of patient-days, the number of discharged patients and the number of ventilator-days were used as a denominator.

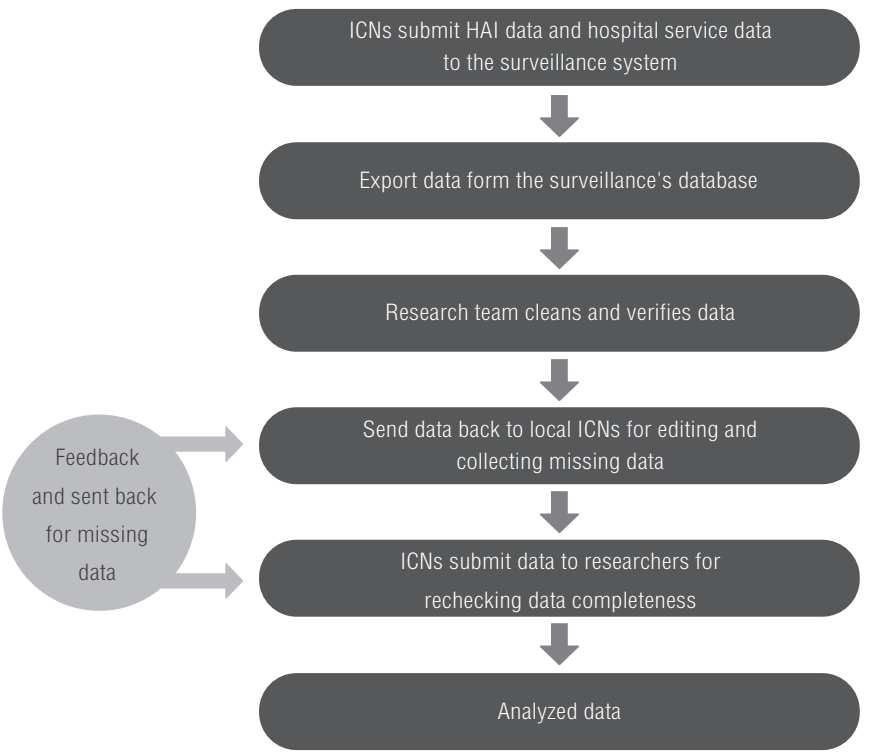
In 2020, 565 hospitals participated in the surveillance system. Of 565 hospitals, data from 50 hospitals were included in the analysis. ICNs in these hospitals were requested to retrospectively review and complete any missing data using their hospital database. Data was verified by researchers.

[10] Bamrasnaradura Infectious Diseases Institute. manual of HAI diagnosis (คู่มือวินิจฉัยการติดเชื้อในโรงพยาบาล), 2018.



Data collection

Data from 50 sampled hospitals including both patient records and hospital service profiles, were exported from the database. Then, all patient records were verified with local ICNs to fulfill the missing data from their own hospital database. After ICNs completed the missing data, data were rechecked, and the complete data set was analysed by the research team.



2.2.3 Limitations and Prospect

- The data from the BIDI's surveillance cover only HAI data. There are still lack of community associated infection (CAI) data, that demonstrated cover about the data of incidence rate of infection and data antimicrobial infection in Thailand. By definition, the BIDI system will not have data of community-acquired infection. It has to be a separate system for community AMR surveillance. Furthermore, type of organisms and patterns of resistance among community-acquired infection are different from those causing HAI. Therefore, target pathogens will be different and route causes of MDR are also different.
- Purposive sampling of 50 hospitals may limit the interpretation of the HAI and AMR in Thailand. We do not know whether hospitals with a strong surveillance system that are capable of providing AMR-HAI data are also have strong preventive efforts in parallel. If so, we could expect that the actual AMR-HAI might be much higher since all other hospitals would be unable to recognize AMR problem in their hospitals and response appropriately.
- AMR pathogens (9 pathogens) in this study are the pathogens that are defined in the AMR strategic plan. Therefore, may not cover all of the pathogens isolated and identified from patients in hospitals.
- Antimicrobials agents for drug sensitivity testing in this study were cover both class of antibiotic (ATC level 4) and type of antibiotic (ATC level 5), that were the limitation to interpreting results. Next study may be assigned only type of antibiotic to interpret result.
- Pandemic of coronavirus (COVID-19) affected to quantity and quality of data submission and verification data onsite of the surveillance program.
- In this year, the quantity and quality of data from the BIDI's surveillance program were verified and validated at only hospital level, lack of verified and validated of data by program owners or researchers.
- In some hospitals, clinical microbiology laboratories are still lack capacity to colistin susceptibility testing. Due to limitations on equipment and laboratory standards determination of colistin resistance requiring broth/ microbroth dilution cannot be performed.

2.3 AMR in Food-Producing Animals

2.3.1 Overview

In response to the global agenda and Thailand's national strategic plan on AMR 2017-2021, the Department of Livestock Development has played a key role in controlling and regulating antimicrobial use in animal sector, and initiated the surveillance system on AMR in food-producing animals since 2017. The AMR surveillance system aimed to monitor the trend of AMR for promoting the prudent use of antimicrobials in food-producing animals and food safety in Thailand. The AMR surveillance has been conducted in nine laboratories under the National Institute of Animal Health, Bureau of Quality Control of Livestock Product, and Regional Veterinary Research and Development Center.

2.3.2 Data sources

The specimens for AMR monitoring were collected from broiler chickens and pigs based on the main food-producing animals in Thailand. The sample collection was performed across the food production chain from slaughterhouses (cecum and meat samples) to retails (meat samples). In compliance with the OIE guideline, the sample size was calculated, and a total of 4,608 samples were obtained from 77 provinces. All the samples were collected by Provincial Livestock Offices and transported to the laboratories for further analysis.

The target bacteria of national AMR surveillance included

1) Zoonotic bacteria: *Salmonella* spp., *Campylobacter* spp.
2) Indicator bacteria: *Enterococcus* spp., and *E. coli*

Antimicrobial susceptibility testing (AST) was performed based on the Clinical and Laboratory Standards Institute (CLSI), International Organization for Standardization (ISO) 20776-1, and the European Committee on Antimicrobial Susceptibility Testing (EUCAST).

The tested antimicrobials included:

- Critically important antimicrobials (CIA): polymyxins (colistin), fluoroquinolones (ciprofloxacin), and third generation cephalosporins (cefotaxime and ceftazidime),
- Some antimicrobials, which have been banned or do not used in livestock, were included in this study for surveillance purposes, including carbapenems (meropenem), amphenicols (chloramphenicol), glycopeptides and lipoglycopeptide (vancomycin and teicoplanin), and oxazolidinones (linezolid)
- Other antimicrobial groups used in livestock including sulfonamides, dihydrofolate reductase inhibitors and combinations (sulfamethoxazole and trimethoprim), and aminoglycosides (gentamicin and streptomycin).

Table D5. Responsible organisation, sampling details, and antimicrobial susceptibility testing

The responsible agency	1. National Institute of Animal Health 2. Bureau of Quality Control of Livestock Product 3. Regional Veterinary Research and Development Center 4. Division of Animal Feed and Veterinary Products Control	
Target animal	Broiler chicken and pigs	
Target specimen/sample and responsible organisation	- Cecum of chicken and pigs - National Institute of Animal Health, and Regional Veterinary Research and Development Center	- Chicken meat and pork - Bureau of Quality Control of Livestock Product, and Regional Veterinary Research and Development Center
Sampling location	Slaughterhouses	Slaughterhouses and retail markets
Target bacterial isolates	*E. coli* *Salmonella* spp. *Enterococcus* spp. *Campylobacter* spp.	*E. coli* *Salmonella* spp.
Antibiotics Susceptibility testing	MIC determination: Broth microdilution, Conventional method and automated MIC device	
Reference	WHO, OIE, FAO, CLSI, EUCAST and ISO 20776-1	
Drug panel for AST	All class of antibiotics for testing pathogen reference from CLSI, EUCAST and European Food Safety Authority (EFSA)	

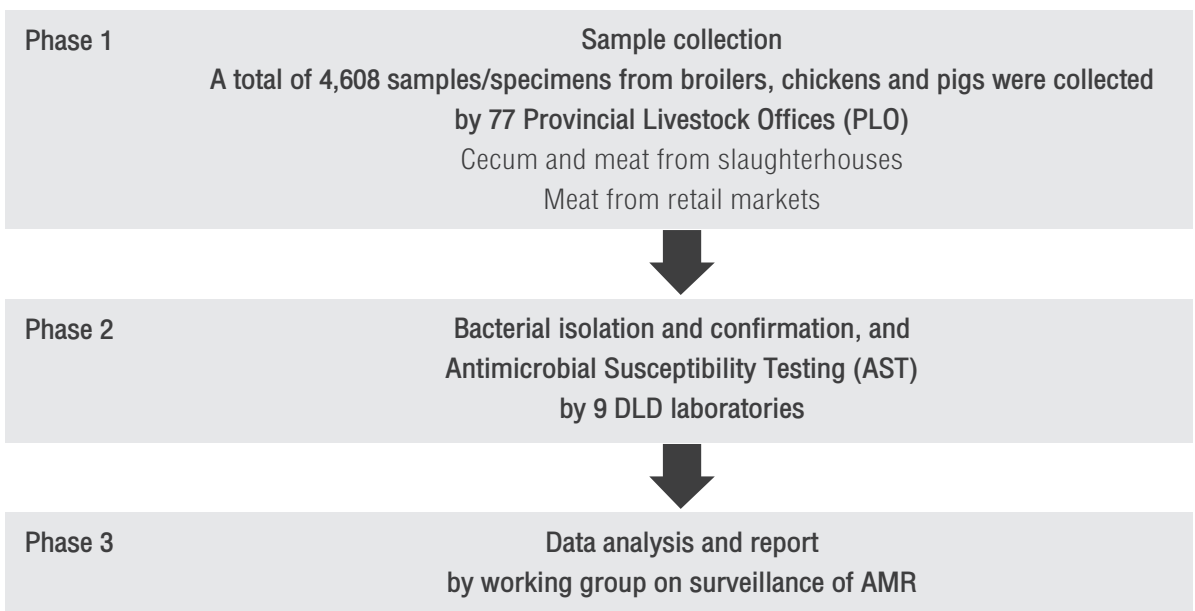


Figure D1. Process of sample collection, microbiological testing, and data analysis

2.3.3 Limitations and Prospect

Some antimicrobials included in this antibiotic panel were resistant in different rates, even though they have been banned in livestock for a long time (vancomycin and chloramphenicol), unavailable for animals (teicoplanin) or used as a representative drug of antimicrobial class (ciprofloxacin for fluoroquinolones). Consequently, careful interpretation on these AMR results should be advised. The AMR surveillance in food-producing animals were mainly focused on phenotypic characterization of AMR. Genetic characterization of AMR and their resistant determinants should be further performed on AMR surveillance to support efficient control and prevention of AMR. In the next phase, the DLD has been planned to include Extended Spectrum Beta- Lactamase (ESBL) phenotypic screening test in the surveillance panel.

The surveillance of AMR indicated the current situation of AMR in the animal sector. For Critically Important Antimicrobials, the use of cephalosporins (3rd and 4th generation), polymyxins, and macrolides should be restricted in food-producing animals. Despite a low resistance rate of antimicrobials from the CIA list, the routine surveillance of AMR in chickens and pigs should be implemented to monitor AMR bacteria in food-producing animals throughout the food production chain. Moreover, further studies of resistance determinants are needed to strengthen AMR capacity in Thailand.

3. Health Policy and Systems Research on Antimicrobial Resistance (HPSR-AMR) Network members

MINISTRY OF PUBLIC HEALTH

International Health Policy Program

Viroj Tangcharoensathien
Angkana Lekagul
Supapat Kirivan
Wimonrat Tanomsridachchai
Wanwisa Kaewkhankhaeng
Saowapa Khotchalai
Oranat Rueangna
Anond Kulthanmanusorn
Hathairat Kosiyaporn
Khanit Pisawong

Food and Drug Administration

Charunee Krisanaphan
Varavoot Sermsinsiri
Nithima Sumpradit
Kritsada Limpananont
Chutamas Luangaroonchai
Pischa Lusanandana
Chaiporn Pumkam
Sitanan Poonpolsub
Pongsathid Virungrojint

Bamrasnaradura Infectious Diseases Institute, Department of Disease Control

Weerawat Manosuthi
Visal Moolasart
Lantharita Charoenpong
Varaporn Thienthong
Winnada Kongdejsakda
Ratchanu Charoenpak

National Institute of Health of Thailand, Department of Medical Sciences

Noppavan Janejai
Wantana PaveenkIttIporn
Aekkawat Unahalekhaka
Pimrata Leethongdee

Division of AIDS and STIs, Department of Disease Control

Rossaphorn kittiyaowaman
Pongsathorn Sangprasert
Natnaree Girdthep

MINISTRY OF AGRICULTURE AND COOPERATIVES

Department of Livestock Development

Rakthai Ngampak
Pacharee Thongkamkoon
Lertchai Jintapitaksakul
Thanida Harintharanon
Sasi Jareonpoj
Watcharachai Narongsak
Julaporn Srinha
Thammarath Sujit
Supaporn Wongsrichai
Suchana Sukklad
Somsajee Sivilaikul
Passawee Pakpong
Thanawan Na Thalang
Porjai Rattanapanadda
Premwadee Yod-ei

Department of Fisheries

Janejit Kongkumnerd
Thitiporn Laoprasert
Chanotit Nakmanoch
Jutamas Auewongaree
Siriwimon thamgandee

MINISTRY OF DIGITAL ECONOMY AND SOCIETY

National Statistical Office of Thailand

Apichart Thunyahan
Waree Maneepiphatkamol

MINISTRY OF NATURAI RESOURCES AND ENVIRONMENT

Water Quality Management Division, Pollution Control Department

Chaiyut Sanghaisuk
Wimolporn Wainipee
Chaowalit Jangaksorn

ACADEMIA

Faculty of Pharmaceutical Sciences, Chulalongkorn University

Rungpetch Sakulbumrungsil
Sang Usayaporn

Faculty of Pharmacy, Silpakorn University

Inthira Kanchanaphibool

Faculty of Pharmaceutical Sciences, Khon Kaen University

Supon Limwattananon
Nussaraporn Kessomboon

Faculty of Pharmaceutical Sciences, Prince of Songkla University
Khunjira Udomaksorn

Faculty of Veterinary Science, Mahidol University
Walasinee Sakcamduang
Boonrat Chantong
Sarin Suwanpakdee
Anuwat Wiratsudakul

Faculty of Public Health, Mahidol University
Fuangfa Utrarachkij
Chayaporn Saranpuetti
Peeraya Ekchariyawat
Neunghatai Supa
Yuwanda Thongpanich
Pramualchai Ketkhao

Faculty of Veterinary Science, Chulalongkorn University
Saharuetai Jeamsripong

Faculty of Veterinary Medicine,Kasetsart University
Natthasit Tansakul

Faculty of Veterinary Medicine, Khon Kaen University
Sunpetch Angkititrakul

Faculty of Medicine Ramathibodi Hospital, Mahidol University
Kumthorn Malathum

Faculty of Medicine Siriraj Hospital
Chanwit Tribuddharat

Faculty of Science, Mahidol University
Parinda Thayanukul

PRIVATE SECTOR

Thai Feed Mill Association
Boonyita Rujtikumporn
Wichai Thermphonboon
Chaiwat Suvanatad
Sompong Harnuthaikij
Krisada Rithichaidumrongkul
Yamuna Patthong
Sureemas Nitikanchana
Pranee Pirompud

Animal Health Products Association

Nackanun Chitaroon
Panitan Suwannapetch
Eagaluk Theerakornsakul
Varisara Jirathitivong

INTERNATIONAL PARTNERS

World Health Organization Country Office, Thailand

Richard Brown
Phiangjai Boonsuk

Food and Agriculture Organization of the United Nations

Kachen Wongsathapornchai
Mary Joy Gordoncillo
Katinka de Balogh
Yin Myo Aye

USAID/Regional Development Mission for Asia

Daniel Schar
Karoon Chanachai

REFERENCE

REFERENCE

1. Performance standards for antimicrobial susceptibility testing. Clinical and Laboratory Standards Institute (CLSI). CLSI supplement M100. [cited 2021 Mar 16]. Available from: https://clsi.org/media/3481/m100ed30_sample.pdf.
2. World development indicator 2020. World Bank. [cited 2021 Oct 25]. Available from: https://data.worldbank.org/country/TH.
3. Sales of veterinary antimicrobial agents in 30 European countries in 2016. European Medicines Agency ESVAC. 2018. Available from: https://www.ema.europa.eu/en/documents/report/sales-veterinary-antimicrobial-agents-30-european-countries-2016-trends-2010-2016-eighth-esvac_en.pdf.
4. Radke BR. Towards an improved estimate of antimicrobial use in animals: Adjusting the "population correction unit" calculation. Can J Vet Res. 2017;81(3):235.
5. Government official document. Ministerial Notification on Specially-controlled drug. 2019 [cited 2021 Mar 10];(53). Available from: https://www.fda.moph.go.th/sites/drug/Shared Documents/Law03-TheMinistryOfHealth/SPC(53).pdf.
6. Government official document. Ministerial Notification on Specially-controlled drug. 2019 [cited 2021 Oct 26];(50). Available from: https://www.fda.moph.go.th/sites/drug/Shared Documents/Law03-TheMinistryOfHealth/SPC(50).pdf.
7. Government official document. Ministerial Notification on Specially-controlled drug. 2019 [cited 2021 Oct 26];(54). Available from: https://www.fda.moph.go.th/sites/drug/Shared Documents/Law03-TheMinistryOfHealth/SPC(54).pdf.
8. Government official document. Thailand's National Strategic Plan on Antimicrobial Resistance 2017-2021. 2017 [cited 2021 Oct 26]; Available from: https://www.who.int/publications /m/item/thailand-national-strategic-plan-on-antimicrobial-resistance-2017-2021.
9. Government official document. Drugs Act. B.E. 1967. [cited 2021 Oct 26]. Available from: http://www.fda.moph.go.th/sites/logistics/ Thelaws_Document/Drugs Act, B.E. 2510 (1967)/ DRUGSB.E.2510.pdf.
10. Government official document. Ministerial Regulations. Amendments to Drug Act. 2020 [cited 2021 Oct 26]. Available from: https://www.fda.moph.go.th/sites/drug/Shared Documents/Law02-Ministerial-regulations/ministerial-30.PDF
11. Sommanustweechai A, Chanvatik S, Sermsinsiri V, Sivilaikul S, Patcharanarumol W, Yeung S, et al. Antibiotic distribution channels in Thailand: results of key-informant interviews, reviews of drug regulations and database searches. Bull World Health Organ. 2018;96(2):101.
12. World Health Organization. WHO report on surveillance of antibiotic consumption: 2016-2018 early implementation. Geneva. 2018.
13. World Health Organization. Purpose of the ATC/DDD system. [cited 2021 Oct 26]. Available from: https://www.whocc.no/atc_ddd_methodology/purpose_of_the_atc_ddd_system/.
14. World Organisation for Animal Health (OIE). OIE annual report on the use of antimicrobial agents intended for use in animals. The fifth report. Paris France.. 2021 [cited 2021 Oct 26]. Available from: https://www.oie.int/app/uploads/2021/05/a-fifth-annual-report-amr.pdf.
15. Thai working group on health policy and systems research on antimicrobial resistance (HPSR-AMR). Consumption of antimicrobial agents in Thailand in 2017. 2018 [cited 2021 Oct 26]. Available from: http://ihppthaigov.net/DB/publication/attachresearch/421/chapter2.pdf.
16. Thai working group on health policy and systems research on antimicrobial resistance (HPSR-AMR). Thailand's One Health Report on antimicrobial consumption and antimicrobial resistance in 2018. 2018 [cited 2021 Mar 16]. Available from: http://ihppthaigov.net/DB/publication/attachresearch/432/chapter1.pdf.

17. Government official document. Special drug control (ประกาศยาควบคุมพิเศษ ฉบับที่ 50). [cited 2021 Oct 26].Available from: https://www.fda.moph.go.th/sites/drug/SharedDocuments/Law03-The MinistryOfHealth/SPC(50).pdf.
18. Government official document. Special drug control (ประกาศยาควบคุมพิเศษ ฉบับที่ 54). [cited 2021 Oct 26]. Available from: https://www.fda.moph.go.th/sites/drug/SharedDocuments/Law03-The Ministry OfHealth/SPC(54).pdf.
19. Government official document. Notification of Department of Livestock Development on Specifications of Prescription. 2018 [cited 2021 Oct 26]; Available from: http://www.ratchakitcha.soc.go.th/DATA/PDF/2561/E/251/T_0009.pdf.
20. Government official document. Notification of Department of Livestock Development on Specifications and Conditions of Medicated Feed Manufactured, Imported, Sold, and Used. 2018 [cited 2021 Oct 26]; Available from: http://www.ratchakitcha.soc.go.th/DATA/PDF/2561/E/073/ 12.pdf.
21. Government official document. Animal feed quality control act B.E. 2558. Available from: https://bit.ly/2Im581C.
22. Government official document. Ministerial regulation on fee in accordance with animal feed quality control act B.E. 2558. 2017 [cited 2021 Oct 26]. Available from: https://bit.ly/2VXKAj3.

International Health Policy Program, Ministry of Public Health, Thailand