Antimicrobial Resistance Surveillance Program

2017 DATA SUMMARY REPORT

30th Pearl : **P**ush on and **E**ngage in the fight against **A**ntimicrobial **R**esistance our Legacy

Antimicrobial Resistance Surveillance Reference Laboratory

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ACRONYMS AND ABBREVIATIONS

Acronym	Description
AMR	Antimicrobial Resistance
ANSORP	Asian Network for Surveillance of Resistant Pathogens
ARSP	Antimicrobial Resistance Surveillance Program
ARSRL	Antimicrobial Resistance Surveillance Reference Laboratory
AST	Antimicrobial Susceptibility Testing
BGH	Baguio General Hospital and Medical Center
BRH	Batangas Medical Center
BRT	Bicol Regional Training and Teaching Hospital
CALABARZON	Cavite, Laguna, Batangas, Rizal and Quezon
CAR	Cordillera Administrative Region
CRH	Caraga Regional Hospital
CLSI	Clinical and Laboratory Standards Institute
CMC	Cotabato Regional Hospital and Medical Center
CVM	Cagayan Valley Medical Center
DMC	Southern Philippines Medical Center
DMU	Data Management Unit
DNA	Deoxyribonucleic acid
DOH	Department of Health
EQA	External Quality Assessment
ESBL	Extended-spectrum beta-lactamase
EVR	Eastern Visayas Regional Medical Center
FEU	Far Eastern University Hospital
GLASS	Global Antimicrobial Resistance Surveillance System
GMH	Governor Celestino Gallares Memorial Hospital
HFEP	Health Facilities Enhancement Program
JLM	Jose B. Lingad Memorial Regional Hospital
LCP	Lung Center of the Philippines
MAR	Mariano Marcos Memorial Hospital and Medical Center
MIC	Minimum Inhibitory Concentration
MIMAROPA	Mindoro, Marinduque, Romblon & Palawan
MMH	Corazon Locsin Montelibano Memorial Regional Hospital
MRSA	Methicillin-resistant *Staphylococcus aureus*
NCR	National Capital Region
NIHR	National Institute for Health Research
NKI	National Kidney and Transplant Institute
NMC	Northern Mindanao Medical Center
ONP	Ospital ng Palawan
PCHRD	Philippine Council for Health Research and Development
PCR	Polymerase Chain Reaction
PGH	Philippine General Hospital
PhilHealth	Philippine Health Insurance Corporation
PNDF	Philippine National Drug Formulary

Acronym	Description
RMC	Rizal Medical Center
RMT	Registered Medical Technologist
RTH	Dr. Rafael S. Tumbokon Memorial Hospital
RTM	Research Institute for Tropical Medicine
SLH	San Lazaro Hospital
SOCCSKSARGEN	South Cotabato, Cotabato, Sultan Kudarat, Sarangani & General Santos City
STU	University of Sto. Tomas Hospital
VSM	Vicente Sotto Memorial Medical Center
WHO	World Health Organization
ZMC	Zamboanga City Medical Center
ZPH	Zamboanga del Norte Medical Center

SURVEILLANCE, TESTING METHODS, DATA ANALYSIS & LIMITATIONS

The Surveillance

The DOH-ARSP implements an antimicrobial resistance surveillance on aerobic bacteria from clinical specimens. The surveillance collects culture and antimicrobial susceptibility data from its ***24 sentinel sites and 2 gonorrhoeae surveillance sites***. These sentinel sites participate in an external quality assessment scheme (EQAS) conducted by the reference laboratory to ensure quality of laboratory results. Periodic monitoring visits to sentinel sites are likewise done. All sentinel sites implement standard methods for culture and susceptibility testing based on the WHO Manual for the Laboratory Identification and Antimicrobial Susceptibility Testing of Bacterial Pathogens of Public Health Importance in the Developing World [1] and updated Clinical Laboratory Standards Institute (CLSI) references for antibiotic susceptibility testing and quality control [2] [3] [4] [5]. Using a standard format, routine culture and antimicrobial susceptibility test results are sent monthly by the sentinel sites to the coordinating laboratory of the program – the ***Antimicrobial Resistance Surveillance Reference Laboratory (ARSRL) at the Research Institute for Tropical Medicine***. Sentinel sites likewise send isolates with unusual antimicrobial susceptibility patterns to ARSRL for phenotypic and genotypic confirmatory testing.

The culture and antimicrobial susceptibility test results are encoded using a database software called ***WHONET***. WHONET is a Windows-based database software developed by the WHO Collaborating Centre for Surveillance of Antimicrobial Resistance based at the Brigham and Women's Hospital in Boston for the management and analysis of microbiology laboratory data with a special focus on the analysis of antimicrobial susceptibility test results. The ARSRL's Data Management Unit manages the cleaning, analysis, storage and security of the program's surveillance data.

Testing Methods

At the reference laboratory, all referred isolates with unusual susceptibility patterns are re-identified using both automated (Vitek) and conventional methods. Both minimum inhibitor concentration (MIC) via automated method (Vitek) and disk diffusion are employed in antimicrobial susceptibility testing. Further confirmatory tests are done such as: serotyping for *S. pneumoniae, H. influenzae*, Salmonellae and *Vibrio cholerae;* and identification of genes conferring antimicrobial resistance by multiplex PCR.

Panel of antibiotics for testing are based on the latest CLSI recommendations, [6] the World Health Organization Global Antimicrobial Resistance Surveillance System (GLASS) Report Early Implementation [7] and the latest Philippine National Formulary [8]. In the analysis of antimicrobial susceptibility testing, an isolate is considered resistant to an antimicrobial agent when tested and interpreted as resistant (R) in accordance with the clinical breakpoint criteria based on the most recent Clinical Laboratory Standards Institute (CLSI) references for antibiotic susceptibility testing.

Data Analysis

Analysis is restricted to the first isolate received (per genus under surveillance) per patient in the calendar year. Data are expressed as a cumulative resistance percentage, i.e. the percentage of resistant isolates out of all isolates with antimicrobial susceptibility testing (AST) information on that specific organism–antimicrobial agent combination. For selected analyses, a 95% confidence interval is determined for the resistance percentage. Cumulative percentages of resistance are compared as proportions using the Fisher's test, using a p value of <0.05 as statistically significant. Only species with testing data for 30 or more isolates are included in the analysis.

An annual report with a summary of the surveillance data focusing on aerobic bacterial pathogens of public health importance causing common infectious diseases with significant morbidity and mortality locally are disseminated to the program's stakeholders.

Limitations

Interpretation of data in this annual report should be undertaken with caution taking into consideration that there may be several factors that could influence and introduce bias to the data resulting in over- or underestimation of resistance percentages. Potential sources of bias include population coverage, sampling, and laboratory capacity.

1) Most of the resistance data in the program come from regional hospitals which typically cater to patients from towns and cities within the vicinity of the hospital. Resistance variations in local areas not covered by regional hospitals are not represented in the program data.
2) Data for the National Capital Region come from 8 sentinel sites while data for other regions come from 1 or 2 sentinel sites.
3) Given that the program data are from routine clinical samples, differences in factors indicating need for microbiological cultures may introduce variations in the resistance data.
4) Performance of culture and susceptibility tests in the sentinel sites is dependent on the diagnostic habits of the clinicians as well as the financial capability of patients for such test. Differential sampling can occur if cultures are typically only performed after empirical treatment shows no adequate therapeutic response. Predictably, this will lead to a serious overestimation of the percentage resistance by not including susceptible isolates in the denominator.
5) Lastly, the ability of the laboratory to identify the microorganism and its associated antimicrobial susceptibility pattern may differ.

EXECUTIVE SUMMARY

Resistance data for **76,892 bacterial isolates** coming from 24 sentinel sites hospital bacteriology laboratories located in 16 regions of the Philippines and 2 gonorrhoeae surveillance sites were analyzed for 2017. The most common isolate for 2017 was *Klebsiella pneumoniae*.

Streptococcus pneumoniae

Cumulative resistance rate of *S. pneumoniae* isolates from all specimen types reported for 2017 against penicillin, using meningitis breakpoints, was at 10% (n=421) and 0.5% using nonmeningitis breakpoints (n=421 isolates). When the pneumococcal isolates were analyzed by specimen type, penicillin resistance was at 7% for invasive (blood and CSF) isolates when analyzed using meningitis breakpoints but only 0.7% penicillin resistance rate for non-invasive isolates (non-CSF and non-blood) when analyzed using non-meningitis breakpoints. The most common invasive *S. pneumoniae* serogroups/serotypes identified for 2017 were 3,18, 1 and 23.

Haemophilus influenzae

Resistance rates against panel of antibiotics for 2017 isolates of *H. influenzae* are highest for co-trimoxazole at 37% (n= 399); and ampicillin at 14% (n=418). There were no reports of levofloxacin or azithromycin resistant *H. influenzae* for 2017.

Salmonella enterica serotype Typhi

S. enterica ser. Typhi isolates have remained susceptible to first line antibiotics with reported resistant isolates at 4% or less for ampicillin, co-trimoxazole and chloramphenicol for 2017. Although there was no reported ciprofloxacin resistant isolate for 2017, 23% tested as intermediate to the antibiotic.

Nontyphoidal Salmonella

Resistance rate of nontyphoid salmonella is at 9% for ciprofloxacin (n=165) and 12% for ceftriaxone (n=192). The commonest nontyphoidal Salmonella species serovar identified for 2017 are S. enterica serotype Enteritidis and S. enterica serotype Typhimurium.

Shigella species

Combined 2014-2017 data reveals emerging resistance of Shigella species against the fluoroquinolones as seen with cumulative rate of resistance at 11% against ciprofloxacin (n=51) and 18% against nalidixic acid (n=44).

Vibrio cholerae

Vibrio cholerae isolates remain susceptible to first line agents: chloramphenicol, co-trimoxazole and tetracycline with 2% or less reported resistance rates for 2017.

Neisseria gonorrhoeae

The 201 *N. gonorrhoeae* isolates have high rates of resistance against penicillin at 85% (n= 125); ciprofloxacin at 67% (n=156); and tetracycline at 55% (n=153). There were 3 reported but unconfirmed ceftriaxone resistant isolates for 2017.

Staphylococcus aureus

MRSA rate for 2017 is at 57% (n= 5,267). This is a statistically significant decrease from the reported MRSA rate of 62% in 2016. Resistance rates for 2017 against antibiotics used for treatment of *S. aureus* infections are as follows: 26% for co-trimoxazole (n=5,031); 13% for clindamycin (n=5,569); 6% for rifampicin (n=4,087); 1% for linezolid (n=4,964); and 2% for vancomycin (n=4,250). None of these linezolid and vancomycin resistant isolates were confirmed as resistant at the reference laboratory.

Enterococcus species

Rates of *E. faecalis* resistance is reported at 1% (n=1,342) for linezolid and 2% (n=1,447) for vancomycin. Rates of *E. faecium* resistance is reported at 1% (n=8046) for linezolid and 5% for vancomycin (n=791).

Escherichia coli

E. coli rates of resistance against the fluoroquinolones and third generation cephalosporins are at 41% for ciprofloxacin (n=7,601) and 39% for ceftriaxone (n=7,802). Resistance to carbapenems continue to rise with rates against ertapenem at 3% (n=4,775); imipenem at 5% (n=7,539) and meropenem at 5% (n=8,194). *E. coli* extended-spectrum β –lactamase suspect rates for 2017 is at 41% (n=3,488).

Klebsiella pneumoniae

Resistance to the carbapenems continue to rise with 2017 *K. pneumoniae* resistance rates as high as 8% for ertapenem (n=6,637); 11% for imipenem (n=10,496) and 11% for meropenem (n=11,409). *K. pneumoniae* extended-spectrum β –lactamase suspect rates for 2016 is at 41% (n=6,239). When the subset of invasive blood culture *K. pneumoniae* isolates were analyzed, even higher carbapenem resistance rates are noted, with meropenem resistance rate as high at 17% (n=1,116).

Pseudomonas aeruginosa

For 2017, carbapenem resistance is reported at 17% for imipenem (n=5,780) and 14% for meropenem (n=6,279). As much as 58% of *P. aeruginosa* isolates exhibited a pan-susceptible profile (n=2,406) for 2017. Commonest resistant profiles include- mono-resistance to aztreonam (9%), combined resistance to cephalosporins, piperacillin-tazobactam and aztreonam (5%); and strains with combined resistance to cephalosporins, piperacillin-tazobactam, aztreonam, amikacin, ciprofloxacin and meropenem (5%).

Acinetobacter baumannii

For the 2017 data, more than 50% of all reported *A. baumannii* isolates were already resistant to the following antibiotics: cefepime at 59% (n=4,378); imipenem at 57% (n=4,266); meropenem at 56% (n=4,643); ciprofloxacin at 55% (n=4,273); and co-trimoxazole at 52% (n=4,231). Among the isolates with complete panel of antibiotics tested, the most common resistant phenotype had a multi-drug resistant profile with combined resistance to aminoglycosides, fluoroquinolones, carbapenems and sulbactam at 42% of the isolates (n= 1,682 isolates).

Multidrug-resistant *Pseudomonas aeruginosa* & *Acinetobacter baumannii*

P. aeruginosa MDR and possible XDR rates for all isolates were at 21% and 16%, respectively. *A. baumannii* MDR and possible XDR rates for all isolates were at 63% and 52%, respectively.

HIGHLIGHTS OF THE 2017 ARSP DATA

The 2017 Isolates

Resistance data for **76,892 isolates** were reported and analyzed for the year 2017. This was a 6% increase when compared to the reported **72,347** isolates for 2016.

Sentinel Sites Data Contribution

The 2017 ARSP data came from the **24 sentinel and 2 gonorrhoeae surveillance sites** of the program which represents **16 regions of the Philippines**. Of the total number of isolates for 2017, 60% were from Luzon, 21% were from Visayas and 19% were from Mindanao. The 8 Metro Manila sentinel sites contributed 34% of the total 2017 annual data (Figure 1 and Table 1).

Specimen Types

The most common specimen types comprising the 2017 ARSP data were respiratory (31%), blood (23%), wound (17%) and urine (17%) specimens. Other specimen types contributing to the 2017 data were: tissues, cerebrospinal fluid, other fluids, genital specimens and stool (Figure 2).

Most Common Isolates

For 2017, *Klebsiella pneumoniae*, followed by *Escherichia coli* and *Pseudomonas aeruginosa* were the most commonly isolated bacterial organisms from all specimen types reported. The most commonly isolated bacteria by specimen type is seen at Table 2.

Figure 1. Percent isolate distribution by sentinel site, DOH ARSP, 2017 (N=76,892)

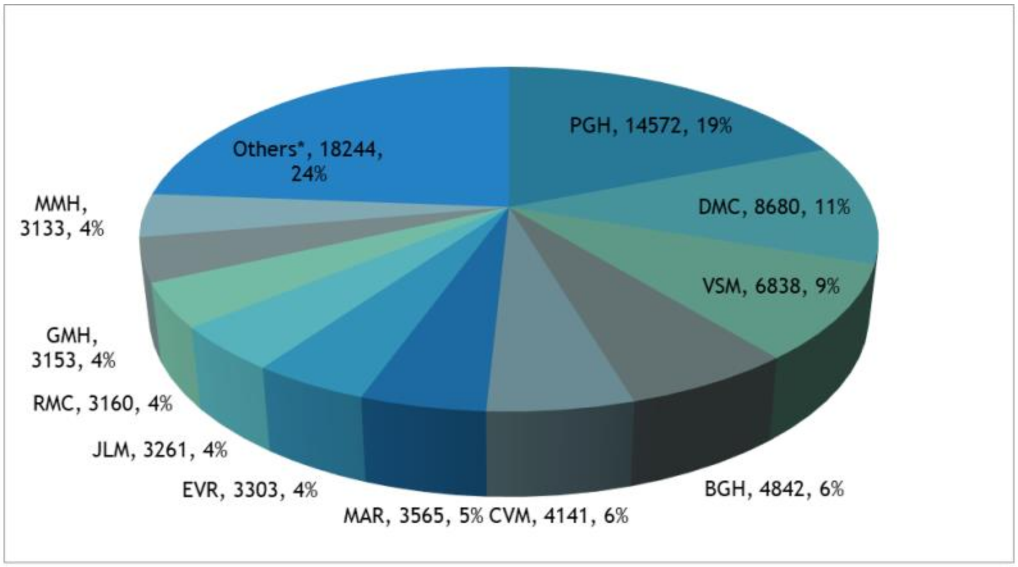


Figure 2. Percent distribution of isolates by specimen type, DOH ARSP, 2017 (N=76,892)

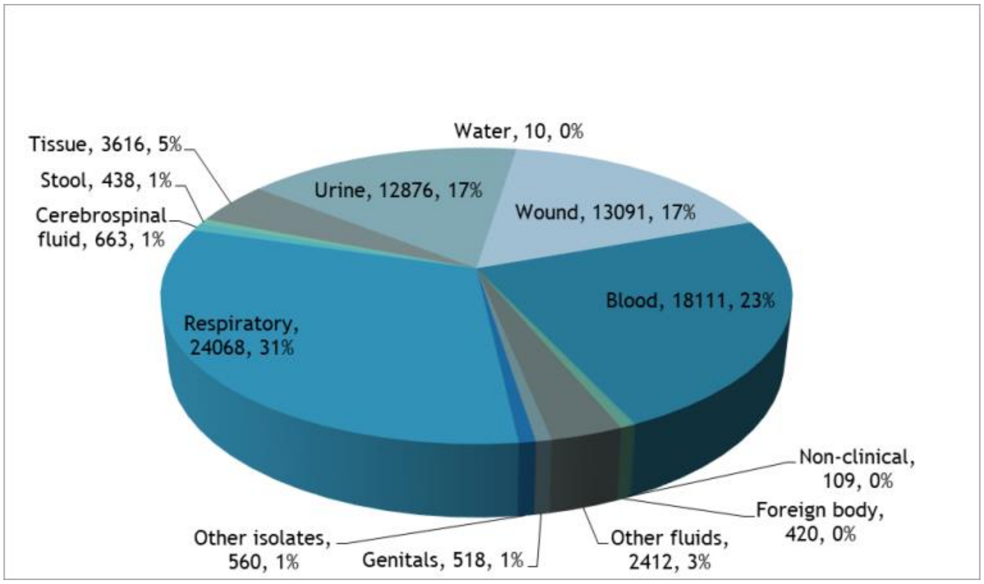


Table 1. Sentinel site isolate contribution ARSP 2008-2017

SENTINEL SITES	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	Change %
PGH	-	-	-	-	-	7093	12471	11710	12860	14572	12
RMC	757	878	962	845	942	1207	320	1054	3252	3160	-3
NKI	3112	3345	3681	2726	2403	2179	2918	1455	5894	627	-840
LCP	2701	2694	2	1233	2083	2253	2921	2905	3115	1367	-128
RTM	335	280	348	328	383	303	303	336	410	513	20
SLH	662	468	615	409	318	1132	575	824	1410	2460	43
GMH	826	1151	936	1119	1521	1307	1351	1807	1669	3153	47
ZMC	440	599	1060	686	721	822	819	841	1142	1222	7
FEU	690	699	864	1064	931	1050	956	712	810	1201	33
STU	1180	1722	1470	752	1788	2050	2002	1923	2275	2088	-9
EVR	466	340	530	744	507	697	823	1514	1731	3303	48
MMH	525	562	590	855	1153	1413	2289	2940	2886	3133	8
DMC	2374	2523	2870	2439	3332	3456	4062	5109	8058	8680	7
VSM	1241	1447	1931	2142	2450	3171	3951	3834	4803	6838	30
BGH	1329	2129	2199	1916	1972	2583	2625	3214	4628	4842	4
CMC	541	459	600	595	639	796	833	1300	1599	1704	6
BRT	401	618	486	537	677	611	1047	1251	1584	1640	3
RTH	19	-	-	-	-	-	-	-	25	69	64
ZPH	53	38	11	-	-	-	9	8	4	7	43
MAR		2275	1898	1851	1928	1773	1706	1849	2759	3565	23
BRH		1008	791	304	38	-	1022	1294	2075	2472	16
CVM		248	907	790	944	1100	1223	1512	3473	4141	16
JLM		387	1024	643	655	502	638	1266	2768	3261	15
NMC		814	1817	1776	1684	2131	2416	2237	3105	2245	-38
ONP									2	5	60
CRH									10	624	98
TOTAL	**17652**	**24684**	**25592**	**23754**	**27069**	**37629**	**47280**	**50895**	**72347**	**76892**	

Table 2. Most common isolates by specimen type, DOH ARSP, 2017

Respiratory specimens		Blood	
1	*Klebsiella pneumoniae*	1	*Staphylococcus,* coagulase negative
2	*Pseudomonas aeruginosa*	2	*Klebsiella pneumoniae*
3	*Acinetobacter baumannii*	3	*Staphylococcus aureus*
Cutaneous or Wound		**Stool**	
1	*Staphylococcus aureus*	1	*Vibrio cholerae*
2	*Escherichia coli*	2	*Salmonella* sp.
3	*Klebsiella pneumoniae*	3	*Aeromonas* sp.
Cerebrospinal Fluid		**Urine**	
1	*Staphylococcus*, coagulase negative	1	*Escherichia coli*
2	*Acinetobacter baumannii*	2	*Klebsiella pneumoniae*
3	*Pseudomonas sp.*	3	*Enterobacter sp.*

Streptococcus pneumoniae

Isolates

There were 485 reported *S. pneumoniae* isolates for 2017. This was 4% less than the 507 *S. pneumoniae* isolates reported for 2016. Major contributors together comprising 51% of the 2017 *S. pneumoniae* data were VSM (110 isolates), BGH (71 isolates) and DMC (68 isolates) (Figure 3). Majority of the *S. pneumoniae* reported were respiratory (66%) and invasive isolates (29%) from blood and cerebrospinal fluid cultures. The rest of the isolates were from wound, urine, tissue and other body fluids (Figure 4).

Antimicrobial Resistance

Since 2008, the Clinical and Laboratory Standards Institute (CLSI) recommends the use of different breakpoints for meningitis (MIC ≥ 0.12 ug/ml) and non-meningitis (MIC ≥ 8 ug/ml) pneumococcal infections when testing for penicillin. The recommended meningitis breakpoints are more stringent due to the poor penetration of penicillin thru the blood brain barrier. For 2017, penicillin resistance confirmed with MIC testing is at 10% (n=421 isolates) when all *S. pneumoniae* isolates were analyzed using meningitis breakpoints; and 0.5% (n=421 isolates) using non-meningitis breakpoints. When analyzed by specimen type, none of the CSF isolates tested (n=5) were penicillin-resistant using meningitis breakpoints; of the 115 blood isolates 7% were resistant using meningitis breakpoints while none were identified as resistant using nonmeningitis breakpoints. For the 302 respiratory and other isolates tested against penicillin, 11% were MIC-confirmed penicillin-resistant using meningitis breakpoints and only 0.7% (only 2 isolates) tested as resistant using nonmeningitis breakpoints.

Resistance rates of *S. pneumoniae* isolates for 2017 were highest against co-trimoxazole at 15% (n=423; 95% CI: 11.9-19); and erythromycin at 10% (n=457; 95% CI: 7.3-13). Resistance rates were lowest for levofloxacin at 1% (n=391; 95% CI: 0.2-3.8); and ceftriaxone at 1% (n=249; 95% CI: 0.3-3.8). From the reported levofloxacin and ceftriaxone resistant isolates, only 1 levofloxacin resistant respiratory isolate was sent to the referral laboratory and was confirmed as levofloxacin-resistant. These rates of resistance did not differ significantly from that reported for 2016 (p value > 0.5). The 2017 resistance rates and 10 year trends of resistance are seen in Figure 5 and Figure 6.

Serotyping

Serotyping of *S. pneumoniae* isolates referred to the reference laboratory was done to identify local prevailing serotype distribution. The method employed in the reference laboratory for pneumococci serotyping is the slide agglutination test (Denka Seiken). For 2017, there were 70 invasive (blood and CSF) pneumococci isolates sent to the national reference laboratory for confirmatory testing and serotyping. There were 23 different serotypes/groups identified, with commonest being 3,18, 23 and 1. Table 3 (Invasive *S. pneumoniae* serotypes, DOH ARSP, 2017) summarizes identified serotypes/groups for the 2017 invasive *S. pneumoniae* isolates by age group.

Figure 3. Percent sentinel site contribution for *S. pneumoniae* ARSP 2017 data (n=485)

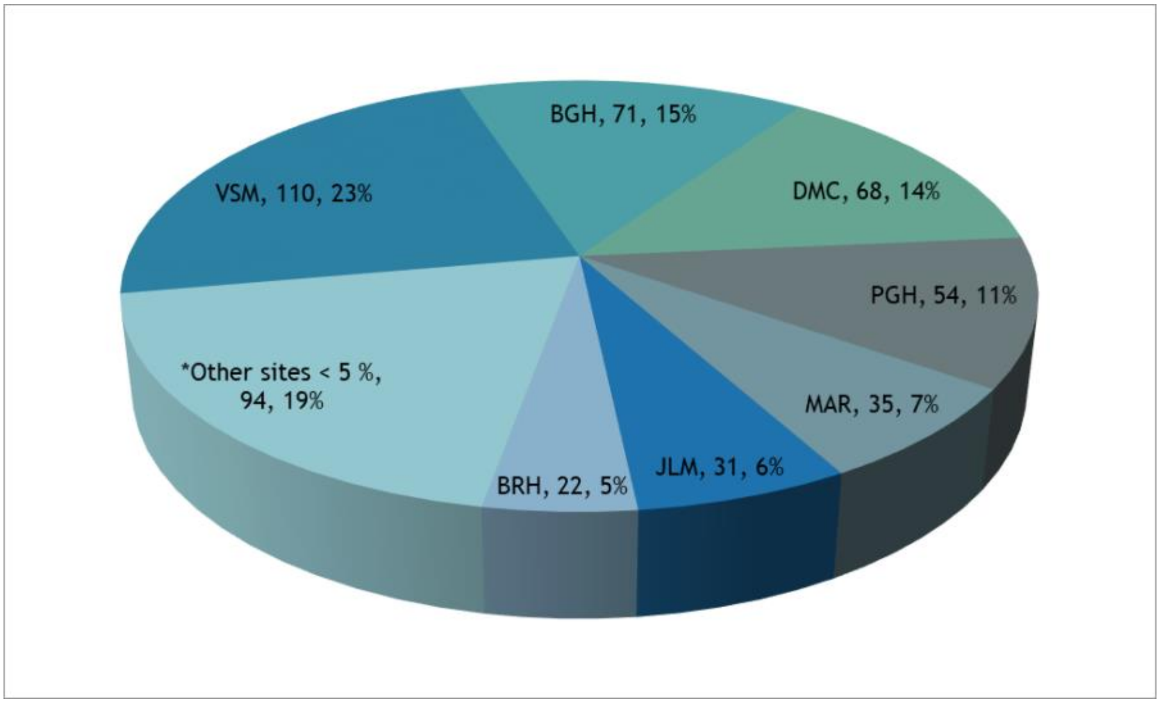


Figure 4. Distribution of *S. pneumoniae* by specimen type, DOH ARSP, 2017 (n=485)

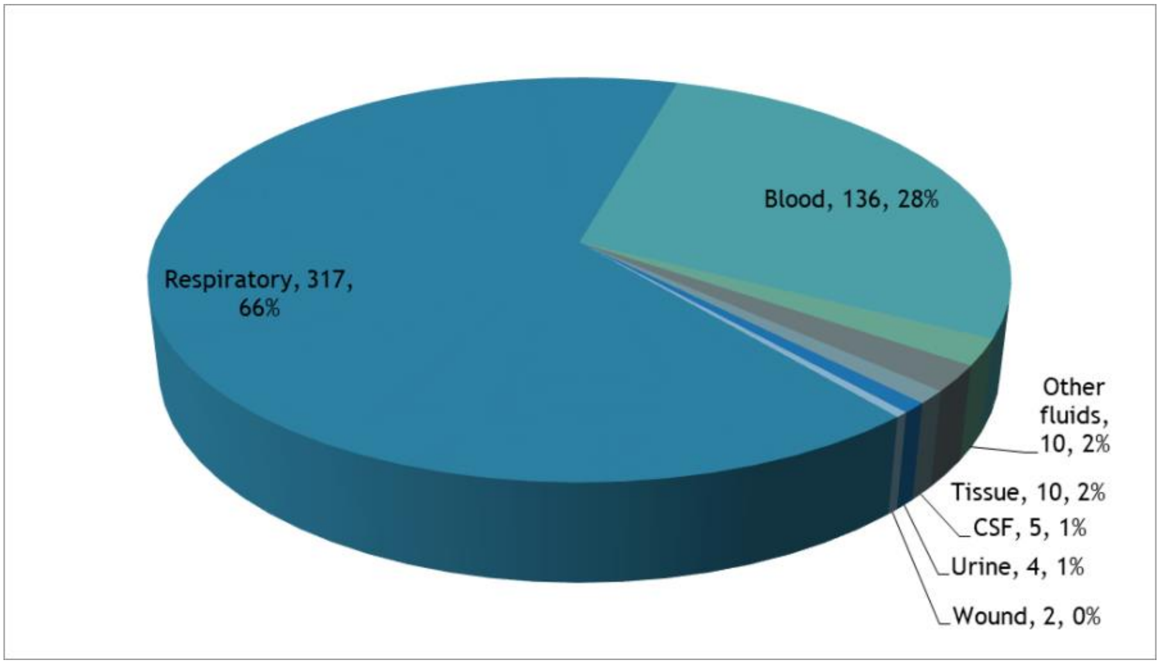


Figure 5. Percent resistance of *S. pneumoniae*, DOH ARSP, 2017

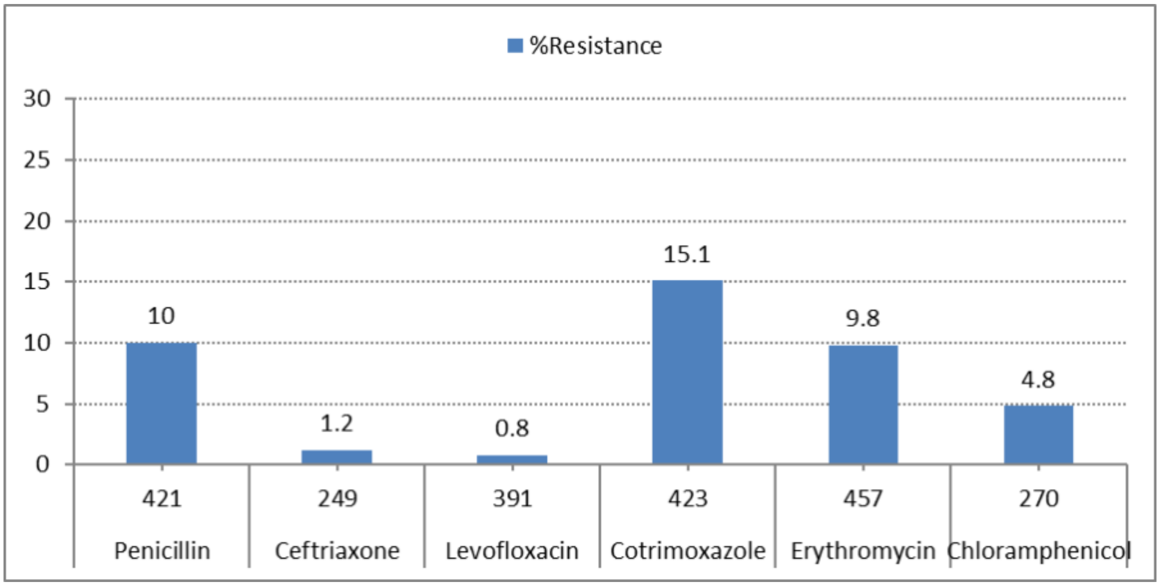


Figure 6. Yearly resistance rates of *S. pneumoniae*, DOH ARSP, 2008-2017

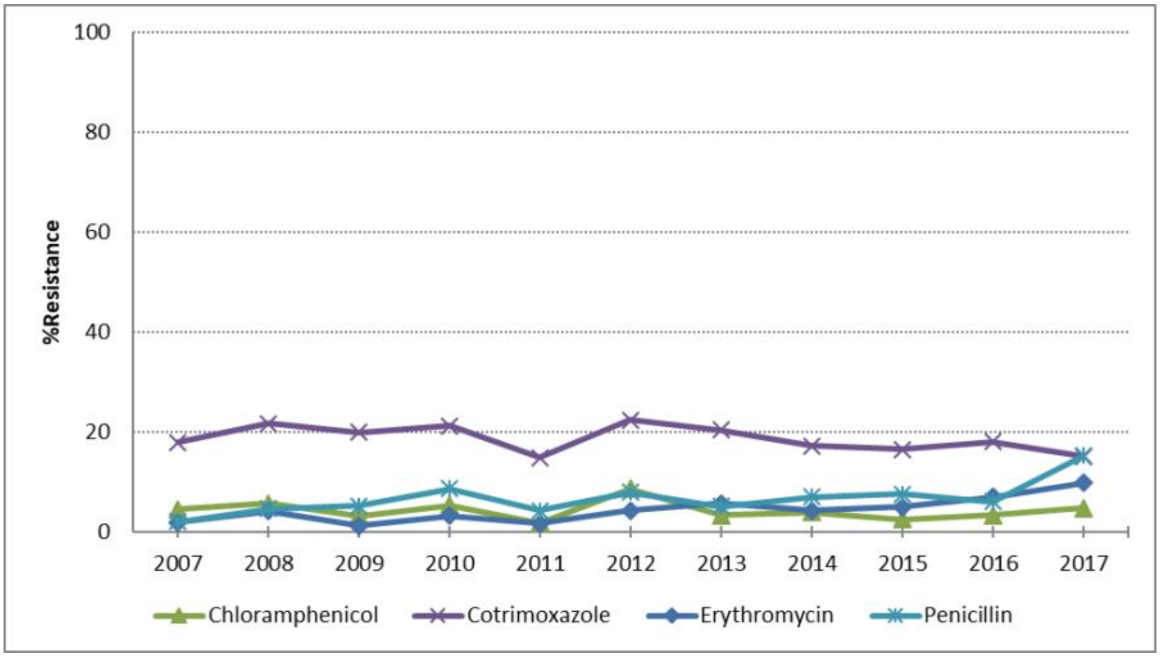


Table 3. Invasive S. pneumoniae serotypes, DOH ARSP, 2017

Serotype	0-4 years	5-19 years	20-64 years	65+ years	Grand Total
(non-serotypable)	4		4	2	10
Serotype 1	1	4	1		6
Serotype 2		1			1
Serotype 3	2		5	2	9
Serotype 4	2	1			3
Serotype 5	1				1
Serotype 6	2		1		3
Serotype 7			1		1
Serotype 10	1				1
Serotype 12			1		1
Serotype 14	3			2	5
Serotype 15	1		1		2
Serotype 16			1	1	2
Serotype 18	6	1		1	8
Serotype 20	1				1
Serotype 21	1				1
Serotype 22				1	1
Serotype 23	1		5		6
Serotype 25			1		1
Serotype 28	2				2
Serotype 29	2				2
Serotype 39		1			1
Serotype 40	1				1
Serotype 46	1				1
Grand Total	**32**	**8**	**21**	**9**	**70**

Haemophilus influenzae

Isolates

There were 498 reported *H. influenzae* isolates for 2017. This was 29% more than the 489 isolates reported for 2016. Biggest contributors for the 2017 *H. influenzae* data were VSM (98 isolates) BGH (89 isolates), and DMC (85 isolates). Percentage contribution of each sentinel site is illustrated in Figure 7. Percent sentinel site contribution to *H. influenzae*, DOH ARSP, 2017 (n=498). Majority of the 2017 *H. influenzae* isolates were from respiratory specimens (95%) while there were 19 blood isolates. Percentage specimen type distribution is illustrated in Figure 8.

Antimicrobial Resistance

Resistance rates of *H. influenzae* for 2017 were highest for: co-trimoxazole at 37% (n=399; 95% CI: 32.1-41.8) followed by ampicillin at 14% (n=418; 95% CI: 11.3-18.2) as seen Figure 25**.** When 2017 rates were compared to that reported for 2016, there were significant increase in resistance rates against ampicillin from 7.8% in 2016 to 14% in 2017 (*p* value 0.0018); chloramphenicol from 5.3% in 2016 to 9% in 2017 (*p* value 0.0361); and co-trimoxazole from 31.2% in 2016 to 37% in 2018 (*p* value 0.0935); while significant decrease in rates of resistance against ampicillin-sulbactam was noted from 7.7% in 2016 to 5% in 2018 (*p* value 0.0935). There were no reported levofloxacin-resistant or azithromycin-resistant *H. influenzae* isolate for 2017 as in the past decade. Trends of resistance for *H. influenzae* is illustrated in Figure 10.

Figure 7. Percent sentinel site contribution to *H. influenzae*, DOH ARSP, 2017 (n=498)

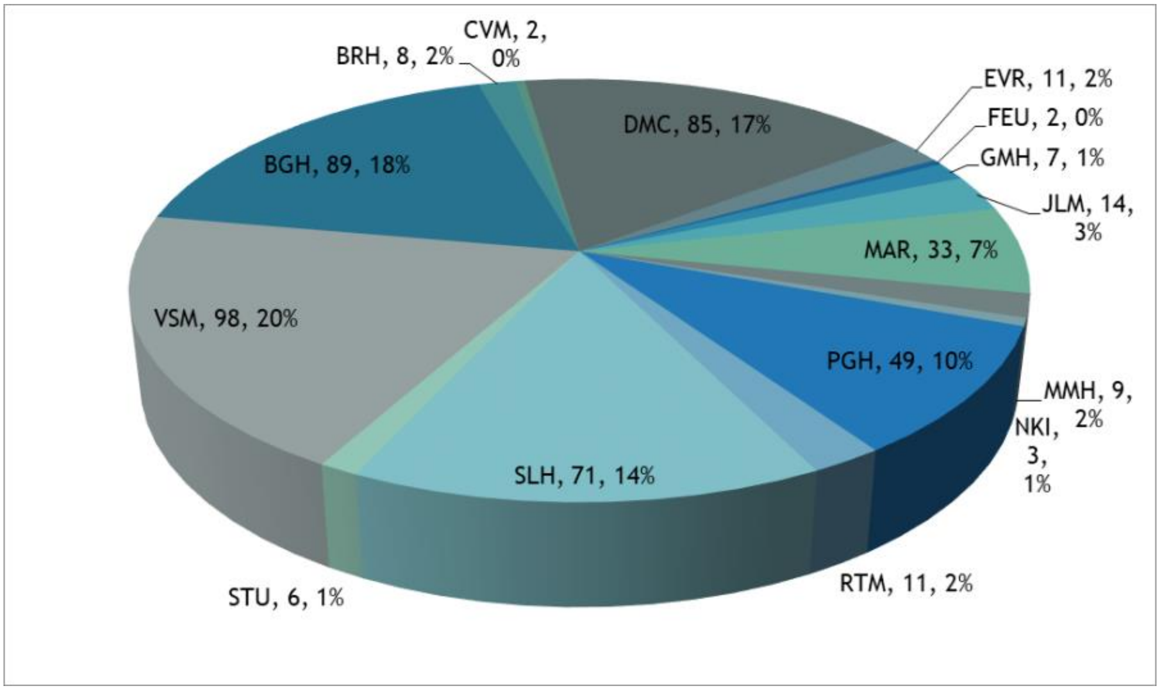


Figure 8. Distribution of *H. influenzae* by specimen type, DOH ARSP, 2017 (n=498)

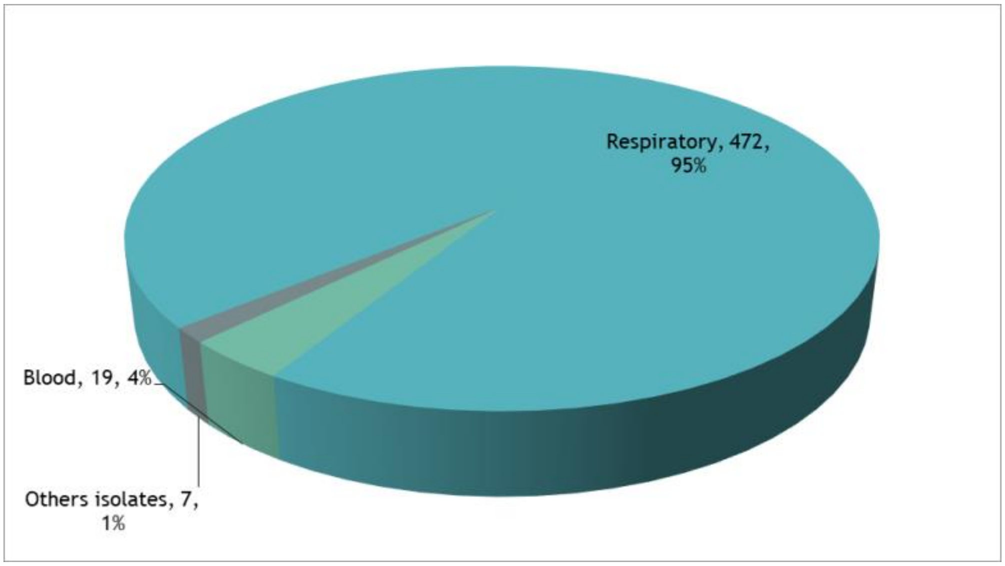


Figure 9. Percent resistance of *H. influenzae*, DOH ARSP, 2017

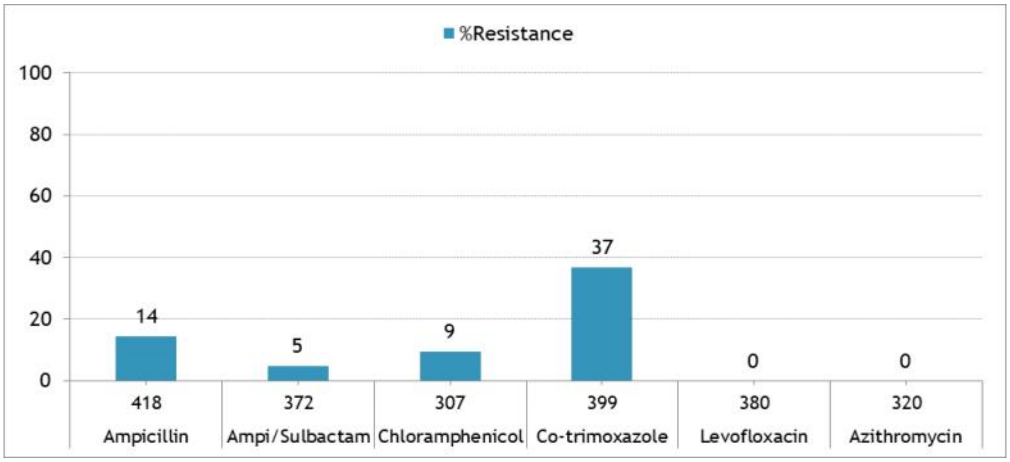
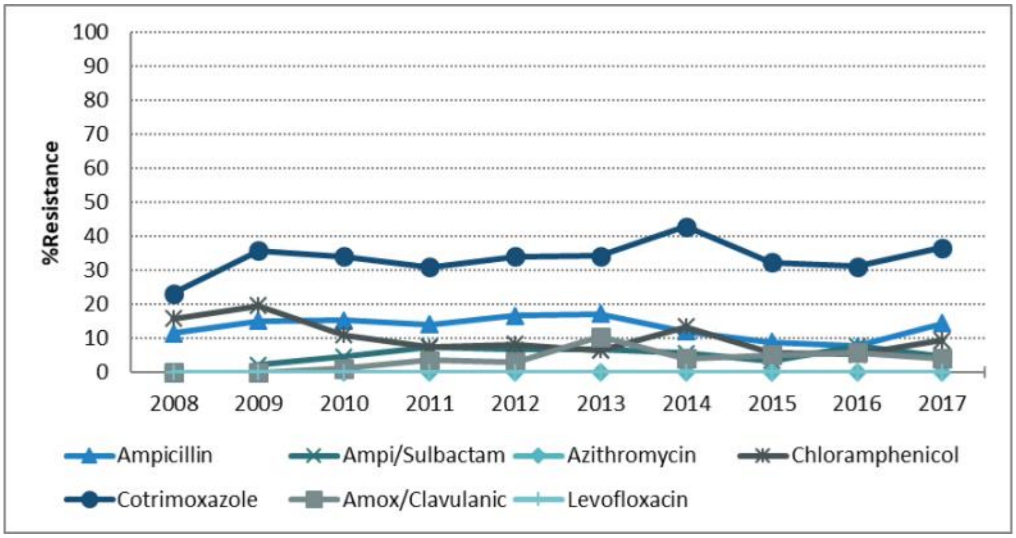


Figure 10. Yearly resistance rates of *H. influenzae*, DOH ARSP, 2008-2017



Salmonella enterica serotype Typhi

Isolates

There were 163 *S.* Typhi isolates reported and analyzed for 2017. This is 8% more than the 150 isolates reported for 2016. The largest sentinel site contributors making up 41% of the 2017 *S.* Typhi data were: VSM (33 isolates), BRT (17 isolates) and CVM (17 isolates) as seen in Figure 11. Most of the 2017 *S.* Typhi isolates were from blood specimens (93%). Others were isolated from stool, tissue, urine, wound and other body fluids Figure 12.

Antimicrobial Resistance

S. Typhi reported rates of resistance for the panel of antibiotics tested remained at less than 5% for 2017 (Figure 13). These reported 2017 rates did not significantly differ statistically from reported rates for 2016 (p value > 0.05).

Although there were no reported ciprofloxacin resistant isolates for 2017, resistance rates for nalidixic acid was at 4% (n=68; 95% CI: 1.1-13.2). Of these 3 nalidixic acid resistant isolates, all tested as intermediate to ciprofloxacin. Nalidixic acid-resistance in extra-intestinal Salmonella isolates predicts reduced susceptibility to fluoroquinolone and may signify poor fluoroquinolone treatment outcomes. *A* subset of *S.* Typhi isolates also may test susceptible against nalidixic acid but tests in vitro as intermediate or resistant to ciprofloxacin (decreased susceptibility to ciprofloxacin or DSC with MICs (≥0.12 µg/ml) for ciprofloxacin) often indicative of the presence of plasmid-related quinolone resistance. For 2017, of the 153 *S.* Typhi isolates tested against ciprofloxacin, 23% tested intermediate. Only 3 of the 7 ciprofloxacin-intermediate *S.* Typhi isolates tested against nalidixic acid were resistant. The 2017 percentage resistance and 10 year trends of resistance for *S.* Typhi are seen in Figure 14.

Figure 11. Percent sentinel site contribution for *S.* Typhi, DOH ARSP, 2017 (n=163)

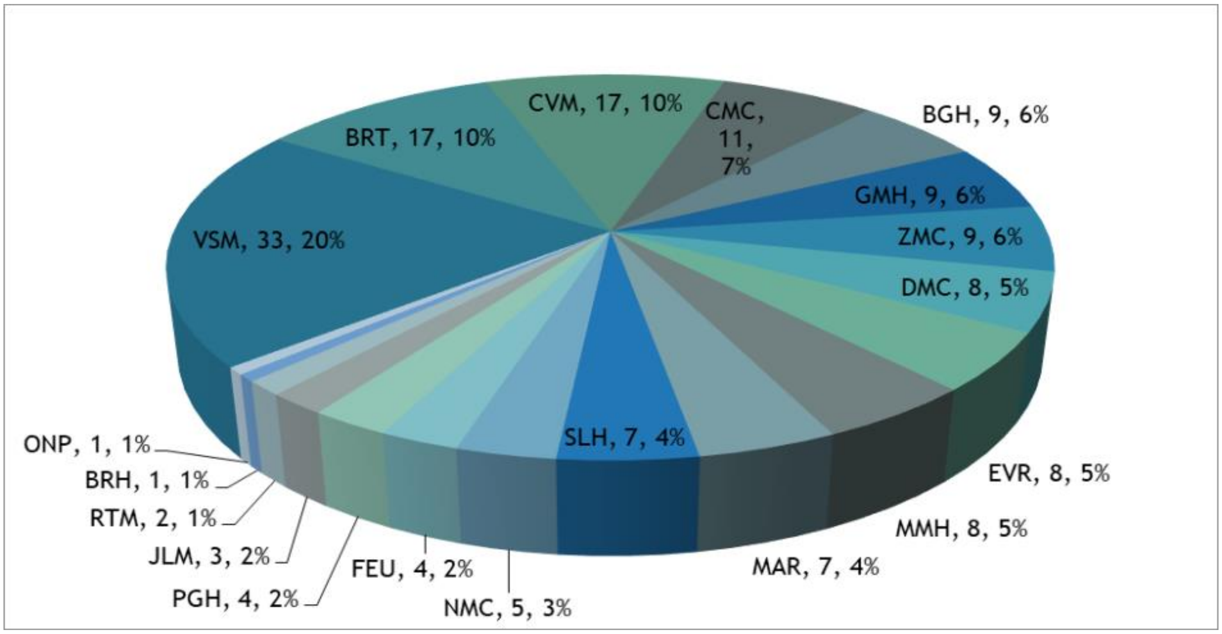


Figure 12. Distribution of *S.* Typhi by specimen type, DOH ARSP, 2017 (n=163)

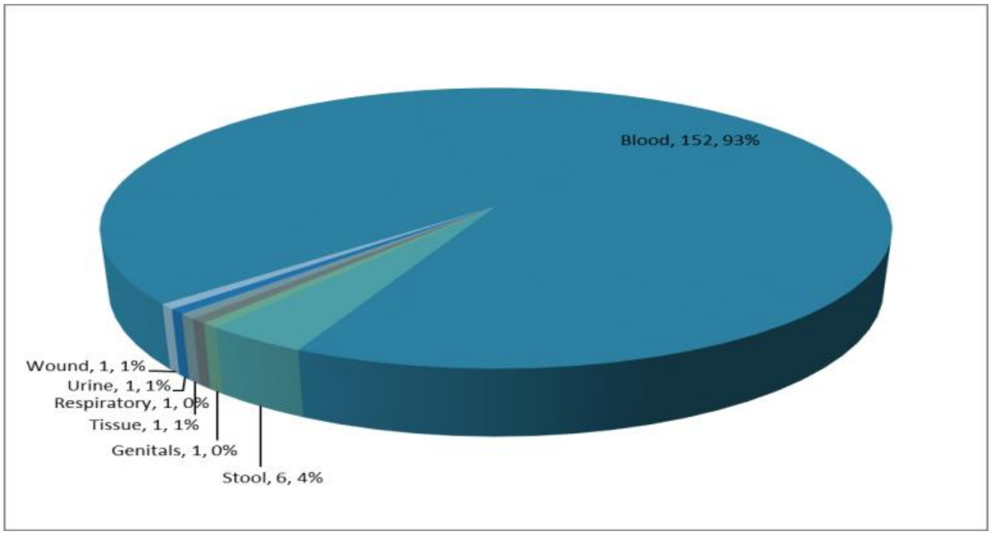


Figure 13. Percent resistance *S.* Typhi, DOH ARSP, 2017

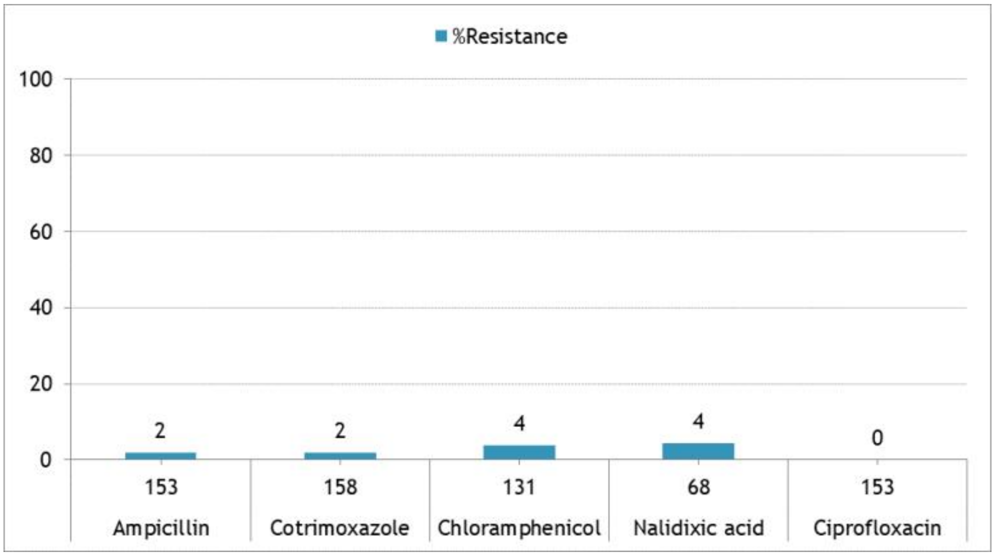
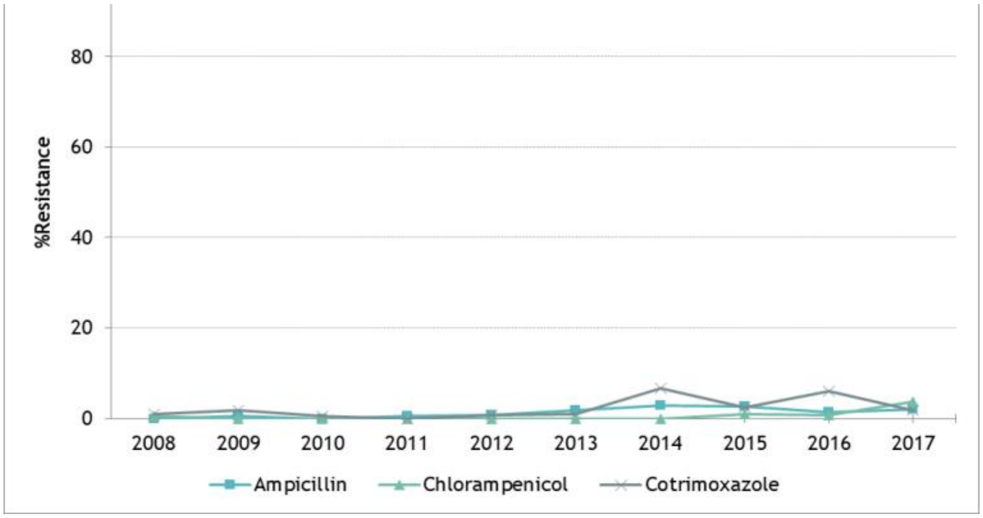


Figure 14. Yearly resistance rates of *S.* Typhi, DOH ARSP, 2008-2017



Nontyphoidal Salmonella (NTS) species

The Isolates

There were 211 reported nontyphoidal Salmonella for 2017. This is 20% less than the 263 reported nontyphoidal Salmonella isolates for 2016. The largest contributor of the 2017 isolates were PGH (48 isolates), DMC (33 isolates) and CVM (24 isolates) as seen Figure 15. Most of the isolates were from blood specimens (47%). Other specimens from which nontyphoid Salmonella were isolated are: stool, wound, respiratory, urine, tissue and other body fluids Figure 16.

Nontyphoidal Salmonella (NTS) Serotypes and Antimicrobial Resistance

For 2017, cumulative rates of resistance for nontyphoid Salmonella resistance rates were highest for ampicillin at 33% (n=184; 95% CI: 26-39.9); followed by co-trimoxazole at 18% (n=179; 95% CI: 12.7-24.5) and ceftriaxone at 12% (n=192; 95% CI: 7.9-17.7). Rates of resistance for 2017 against ciprofloxacin is 9% (n=165; 95% CI: 5.4-14.8) but as much as 41% of the total number of isolates tested had MICs with intermediate or resistant results against ciprofloxacin (Figure 17). These 2017 rates did not differ significantly from those reported for 2016 (Figure 18 and Figure 19).

There were 60 nontyphoidal Salmonella isolates referred for serotyping at the reference laboratory. The most common NTS serotypes identified were *Salmonella enterica* serotype Enteritidis (31 isolates) and *Salmonella enterica* serotype Typhimurium (9 isolates) which were also the most commonly reported for the past 4 years. Table 4 summarizes the serotype data for Salmonella referred isolates for 2017. Antimicrobial resistance for NTS varies by serotype. Overall changes in resistance among NTS may reflect changes in resistance within serotypes, changes in serotype distribution, or both.

Figure 15. Percent sentinel site contribution for NTS, DOH ARSP, 2017 (n=211)

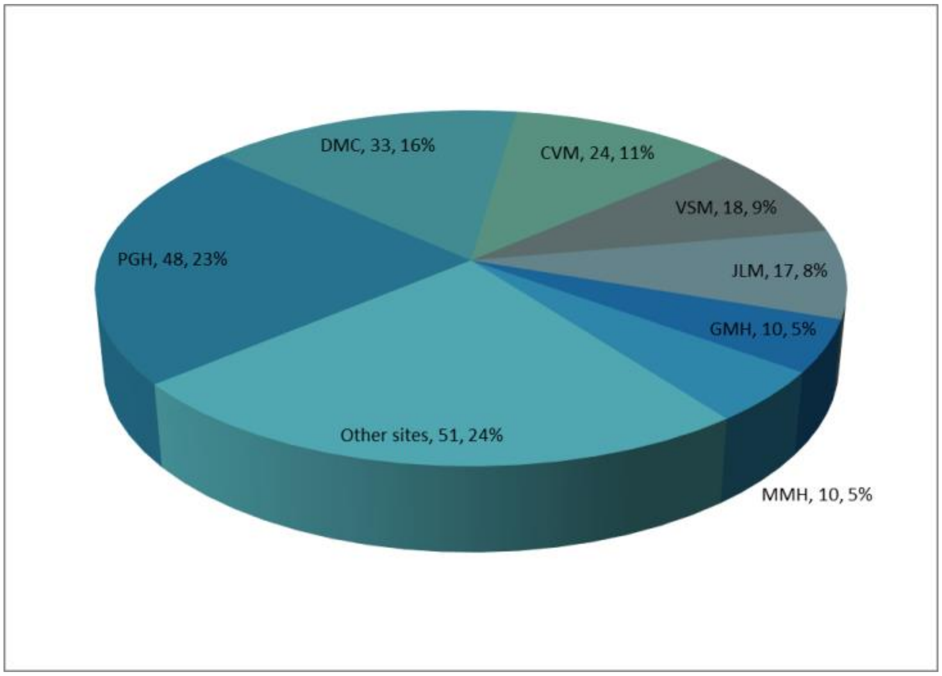


Figure 16. Distribution of NTS by specimen type, DOH ARSP, 2017 (n=211)

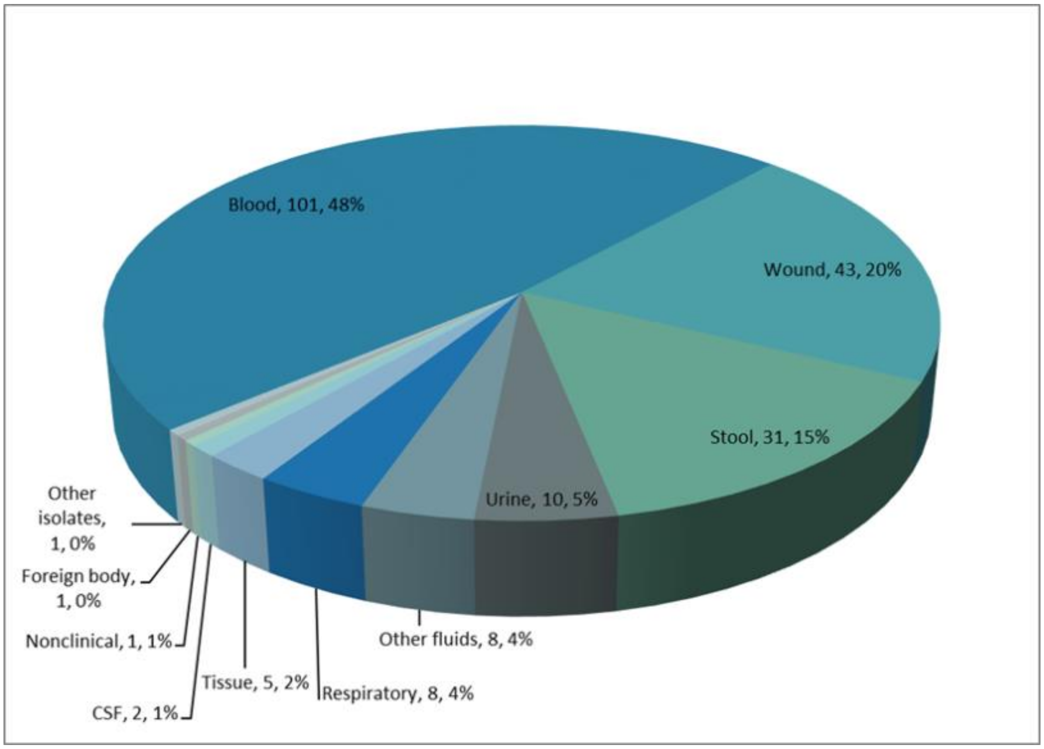


Figure 17. Percent resistance of NTS, DOH ARSP, 2017

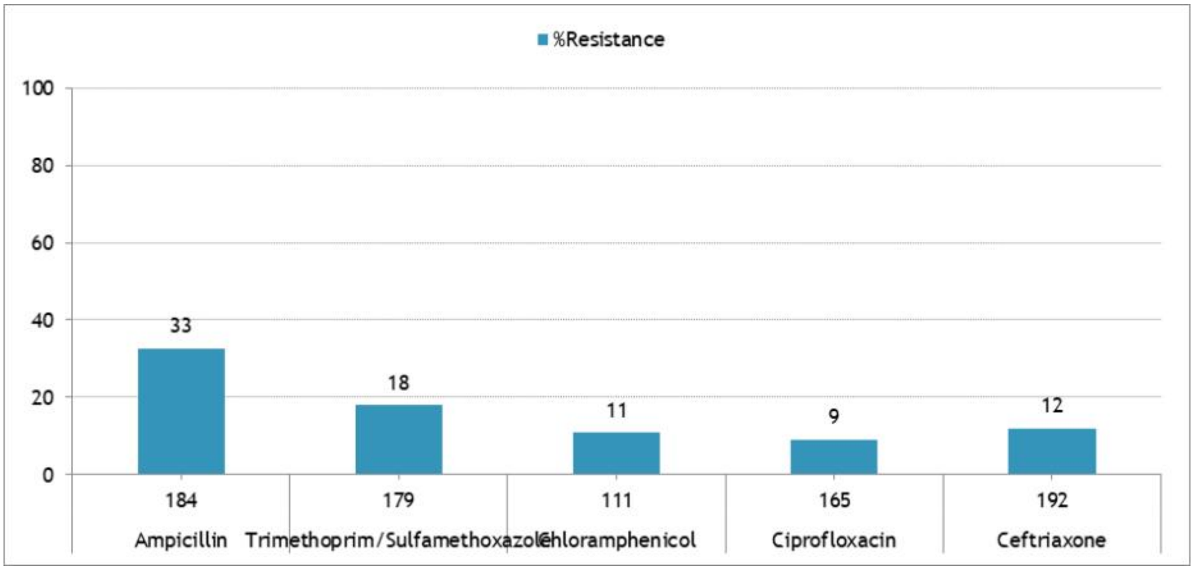


Figure 18. Yearly ampicillin, chloramphenicol and co-trimoxazole resistance rates of NTS, DOH ARSP, 2008-2017

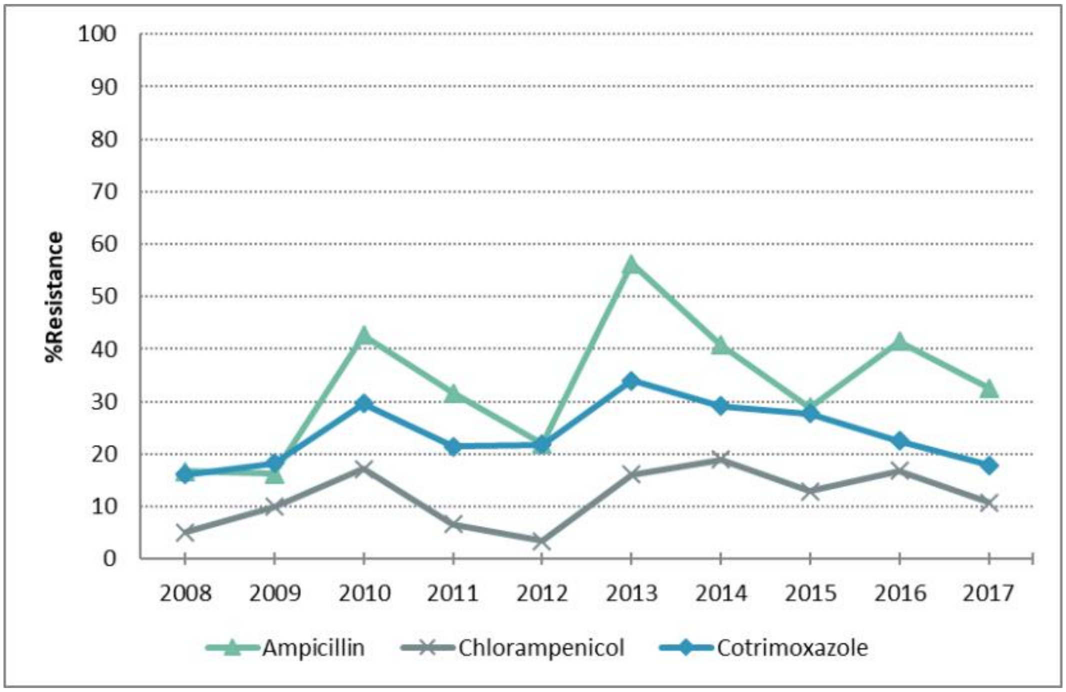


Figure 19. Yearly ciprofloxacin and ceftriaxone resistance rates of NTS, DOH ARSP, 2008-2017

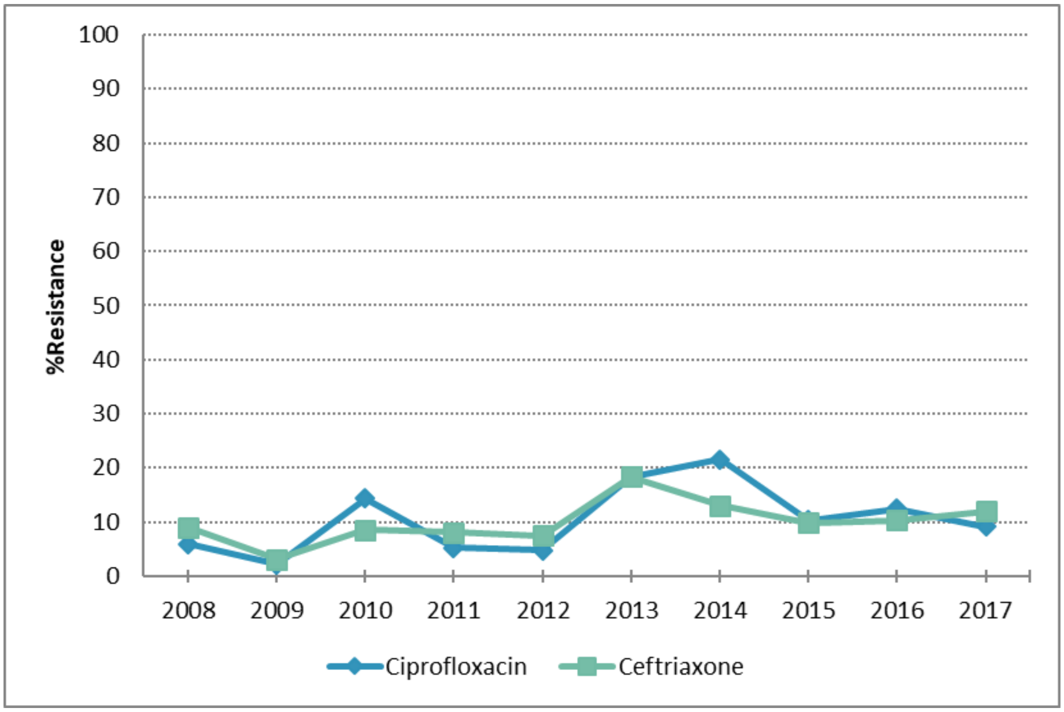


Table 4. Confirmed Salmonellae serotypes, DOH ARSP, 2017

Organism	Number of isolates
Salmonella Typhi	122
Salmonella Enteritidis	31
Salmonella Typhimurium	9
Salmonella Weltevreden	4
Salmonella Anatum	2
Salmonella Group B	2
Salmonella Stanley	2
Salmonella Group A	1
Salmonella Haifa	1
Salmonella Kentucky	1
Salmonella London	1
Salmonella Paratyphi A	1
Salmonella Paratyphi B	1
Salmonella Rissen	1
Salmonella species	1
Salmonella Tallahassee	1
Salmonella Virchow	1
Grand Total	182

Shigella species

Isolates

For 2017 there were only 28 *Shigella species* isolates reported. Largest sentinel site contributors of the 2017 data were: VSM and PGH (11 and 5 isolates, respectively) as seen in Figure 20. Most of the isolates were from stool specimens (Figure 21).

Antimicrobial Resistance

As there were very few Shigella isolates reported for 2017, we combined the results of isolates from 2014 to 2017 to obtain a reasonable statistical estimate of the cumulative percentage resistance for *Shigella species*. High rates of resistance to the previous first line agents against Shigellosis: ampicillin at 67% (n=76; 95% CI: 55.3-77.2), co-trimoxazole at 58% (n=73; 95% CI: 45.4-68.8) and chloramphenicol at 46% (n=59; 95% CI: 33-59.2) were observed. Similarly, emerging resistance to newer agents are noted at 11% for ciprofloxacin (n=76; 95% CI: 5-20.2) and 10% for ceftriaxone (n=68; 95% CI: 4.6-20.7). These rates are seen in Figure 22.

Figure 20. Percent sentinel site contribution for *Shigella* sp., DOH ARSP, 2017 (n=28)

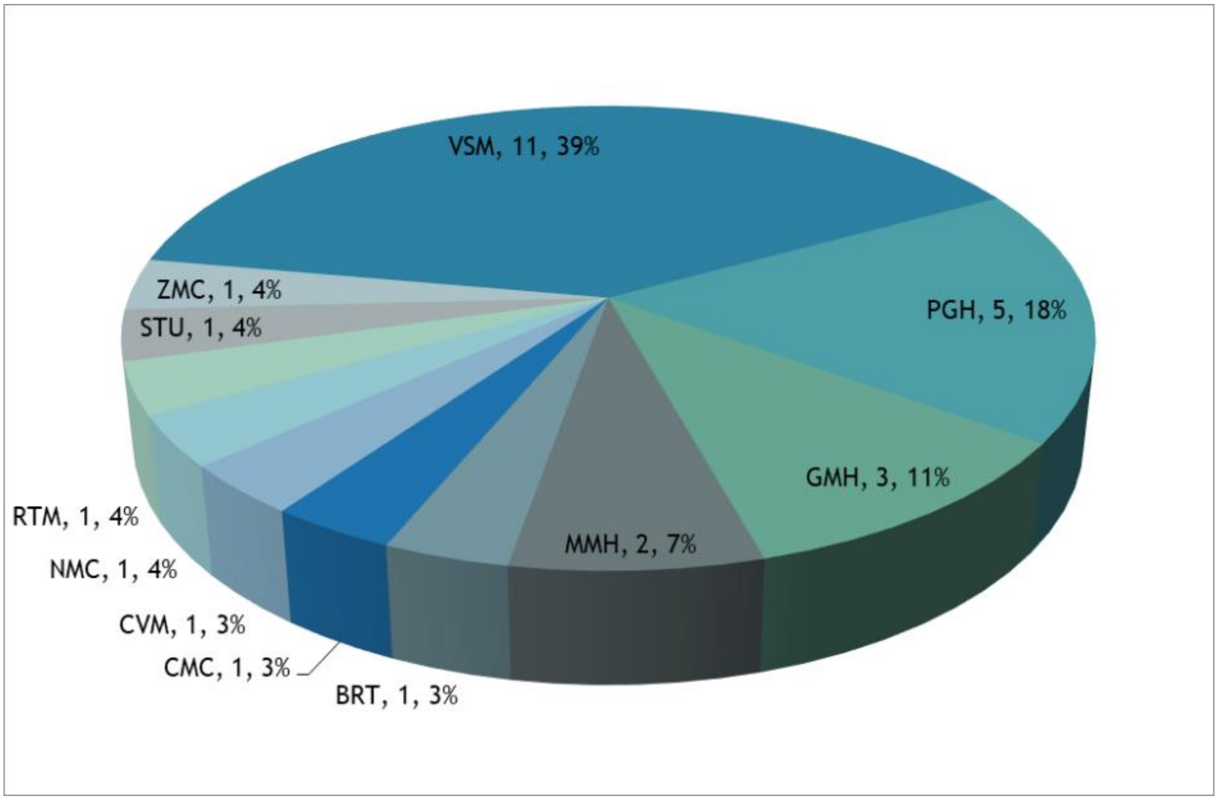


Figure 21. Distribution of *Shigella sp.* by specimen type, DOH ARSP, 2017 (n=28)

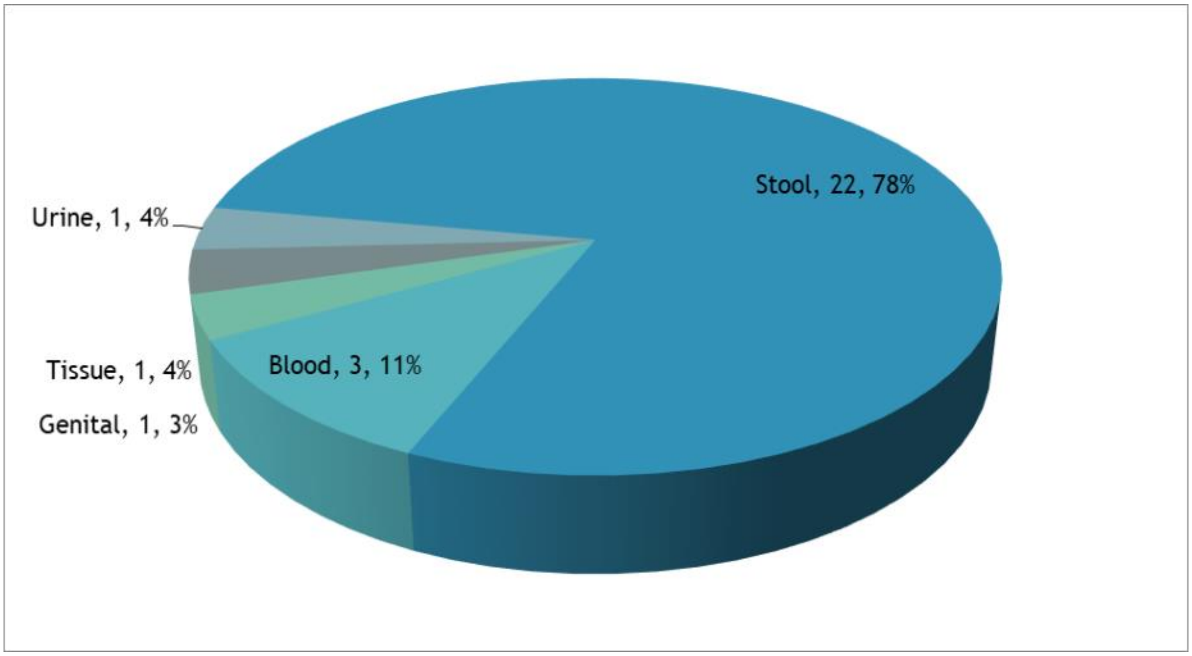
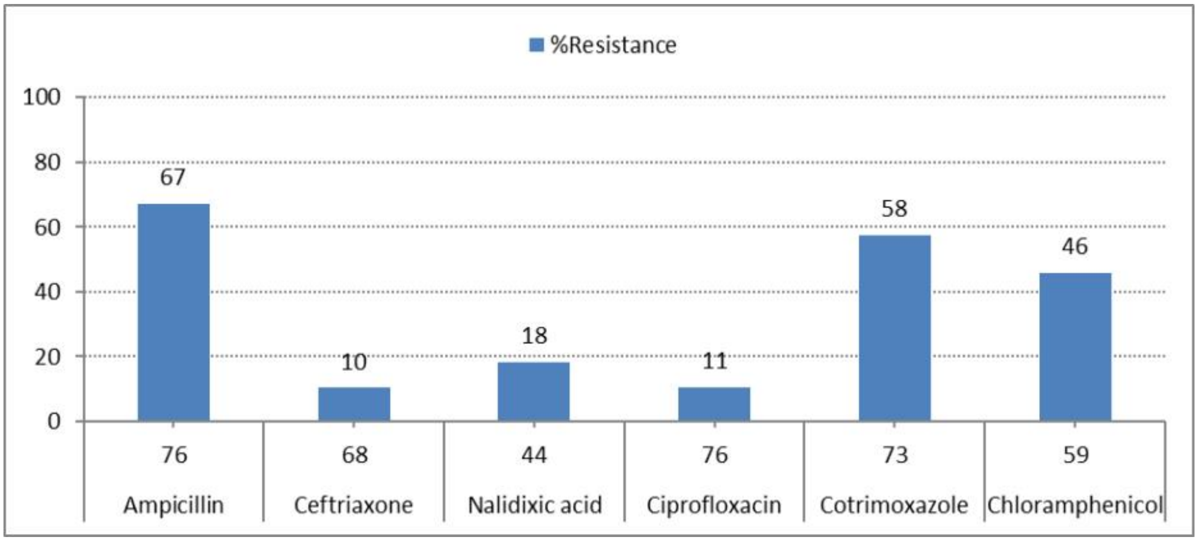


Figure 22. Percent resistance of *Shigella sp.,* DOH ARSP, 2014-2017



Vibrio cholerae

Isolates

There were only 103 isolates of *Vibrio cholerae* reported for 2017. The sentinel site VSM contributed majority (70%) of the *V. cholerae* 2017 isolates (Figure 23). Most of the isolates were from stool (101 isolates) with 2 isolates from blood specimens.

Antimicrobial Resistance

As in the past years, *V. cholerae* isolates have remained susceptible with resistance rates for co-trimoxazole at 2% (n=102; 95% CI: 0.4-7.6); chloramphenicol at 2% (n=99; 95% CI: 0.3-7.8); and no reported tetracycline resistant isolate for 2017 (Figure 24). These rates have remained stable for the past 10 years, with reported rates against each of these 3 antibiotics at 5% or less since 2007 (Figure 25).

Figure 23. Percent sentinel site contribution of *V. cholerae*, DOH ARSP, 2017 (n=103)

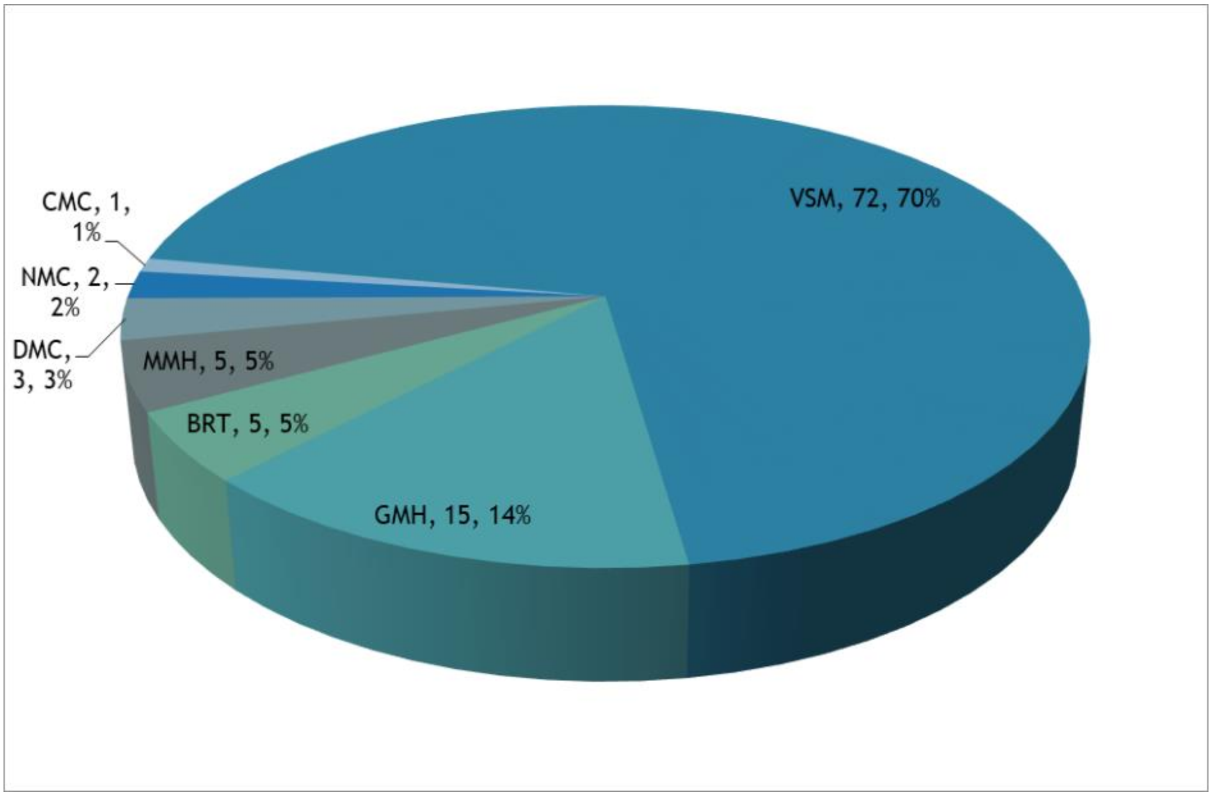


Figure 24. Percent resistant for *V. cholerae*, DOH ARSP, 2017

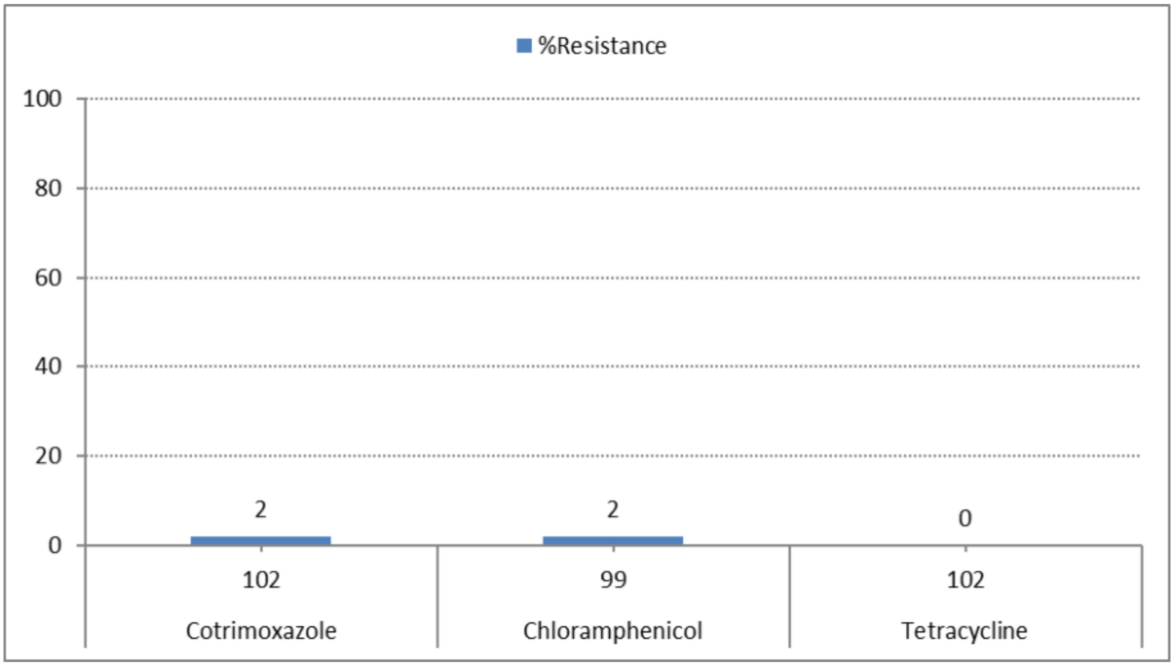
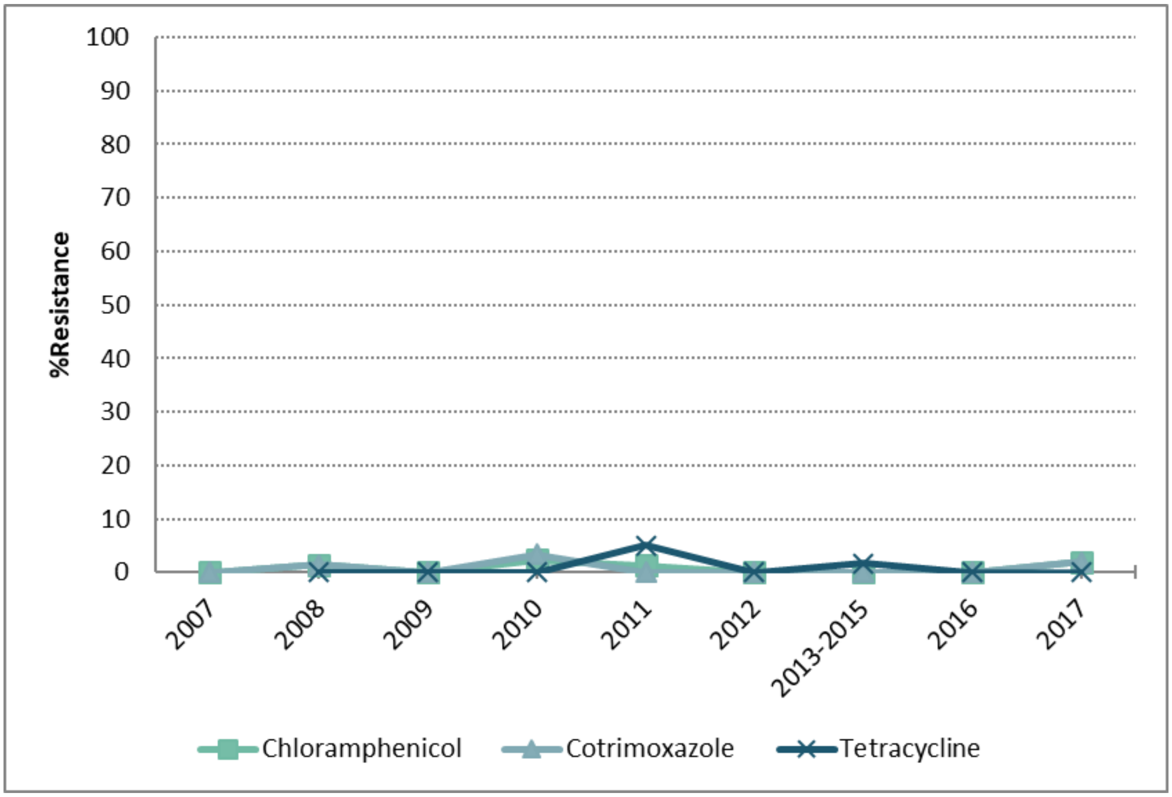


Figure 25. Yearly resistance rates of *V. cholerae*, DOH ARSP, 2007-2017



Neisseria gonorrhoeae

Isolates

There were only 160 *Neisseria gonorrhoeae* isolates reported for 2017. This was 20% less than those reported for 2016 (n=200 isolates). The largest contributors of the 2017 *N. gonorrhoeae* data were RTH (69 isolates), RTM (30 isolates) and JLM (18 isolates). Percent sentinel site contribution of 2018 *N. gonorrheae* data and specimen type distribution are depicted in Figure 26 and Figure 27**.**

Antimicrobial Resistance

Rates of resistance against penicillin have been at least 80% for the past decade with 2017 cumulative resistance rate at 85% (n=125; 95% CI: 77-90.4). Similarly, high rates of resistance are noted for *N. gonorrhoeae* against ciprofloxacin and tetracycline at 67% (n=156; 95% CI: 58.7-73.9) and 55% (n=153; 95% CI: 46.7-62.9), respectively. Rates of resistance to the antibiotic panel tested did not differ significantly from that of the 2016 data except for the statistically significant decrease in rates for penicillin from 94% in 2016 (n=198); to 85% in 2017 (n=125) (Figure 28 and Figure 29).

For 2017, there were 3 reported ceftriaxone non-susceptible gonococcal isolates reported. All these were not sent to the reference laboratory for confirmatory testing. One of the ceftriaxone-nonsusceptible strain also tested as both cefixime- nonsusceptible and spectinomycin-resistant. There was also 1 gonococcal isolate that when tested against azithromycin exhibited epidemiologic cut-off values within the non-wild-type category. This signifies in-vitro resistance of *N. gonorrhoeae* without established clinical relevance.

Figure 26. Percent sentinel site contribution of *N. gonorrhoeae*, DOH ARSP, 2017 (n=160)

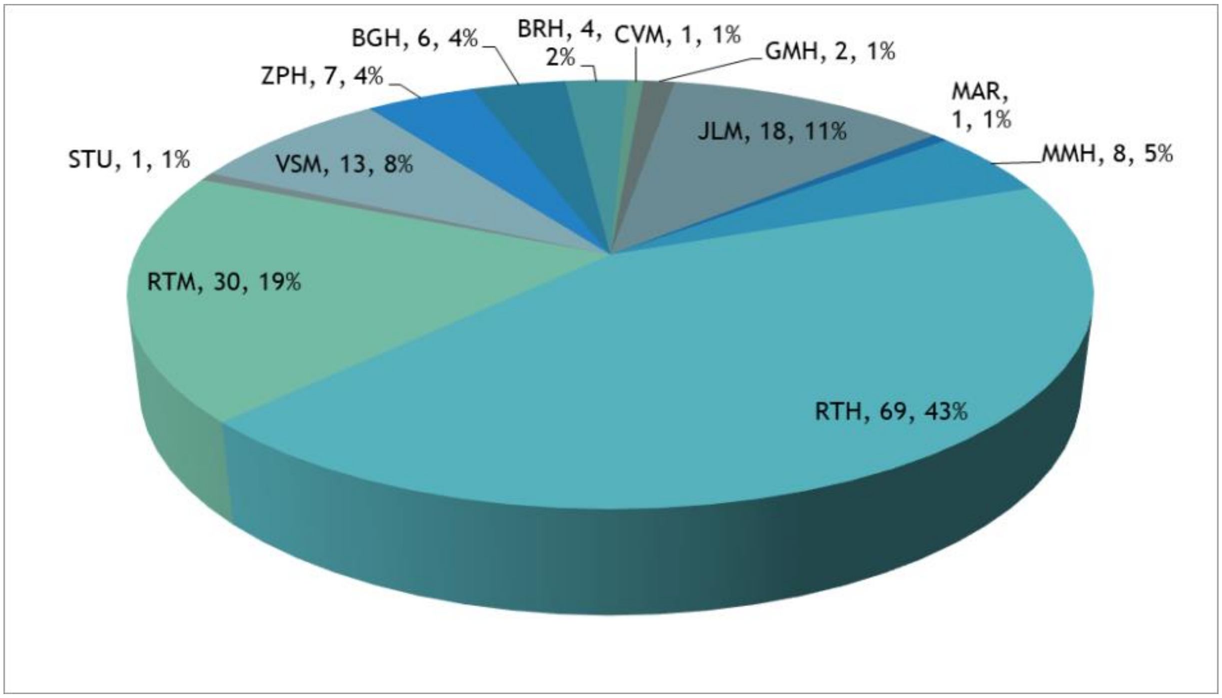


Figure 27. Percent specimen type distribution of *N. gonorrhoeae*, DOH ARSP, 2017 (n=160)

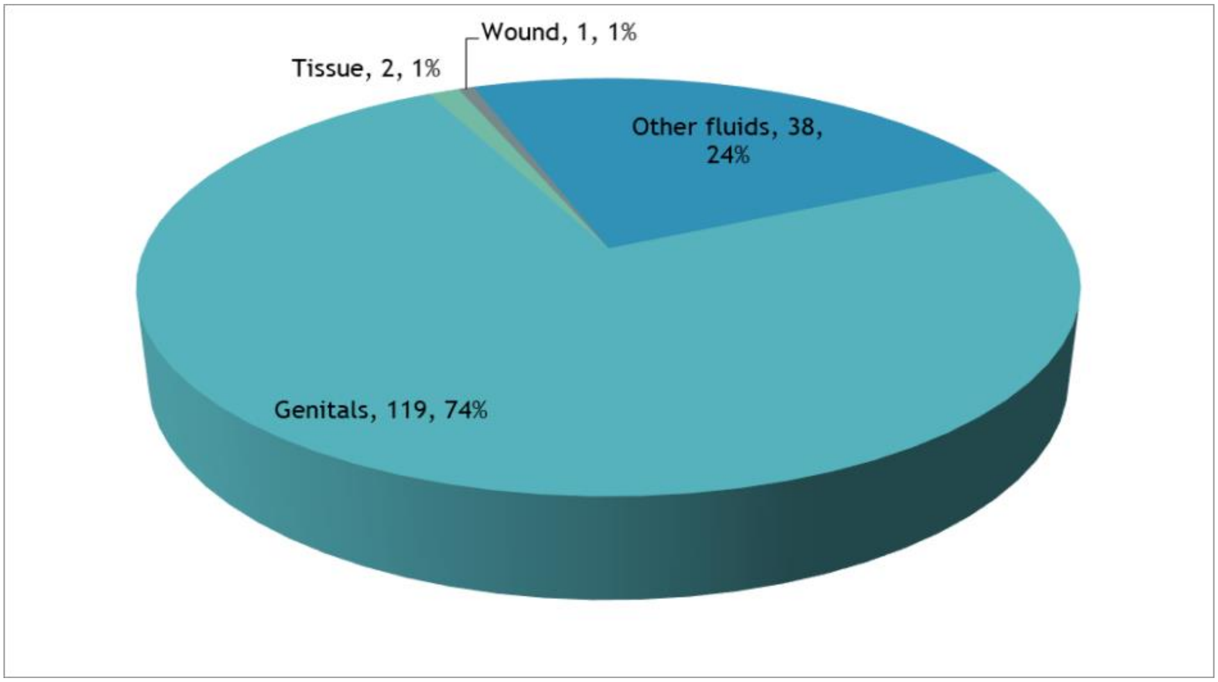


Figure 28. Percent resistance of *N. gonorrhoeae*, DOH ARSP, 2017

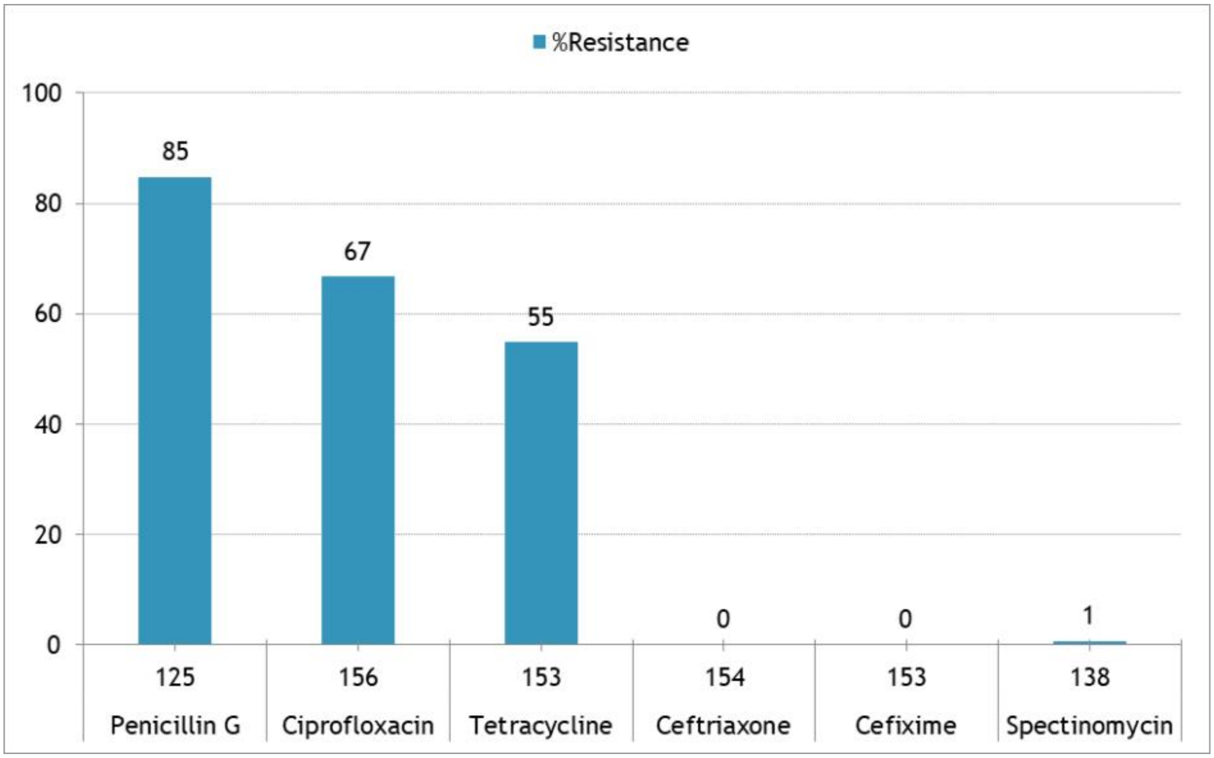
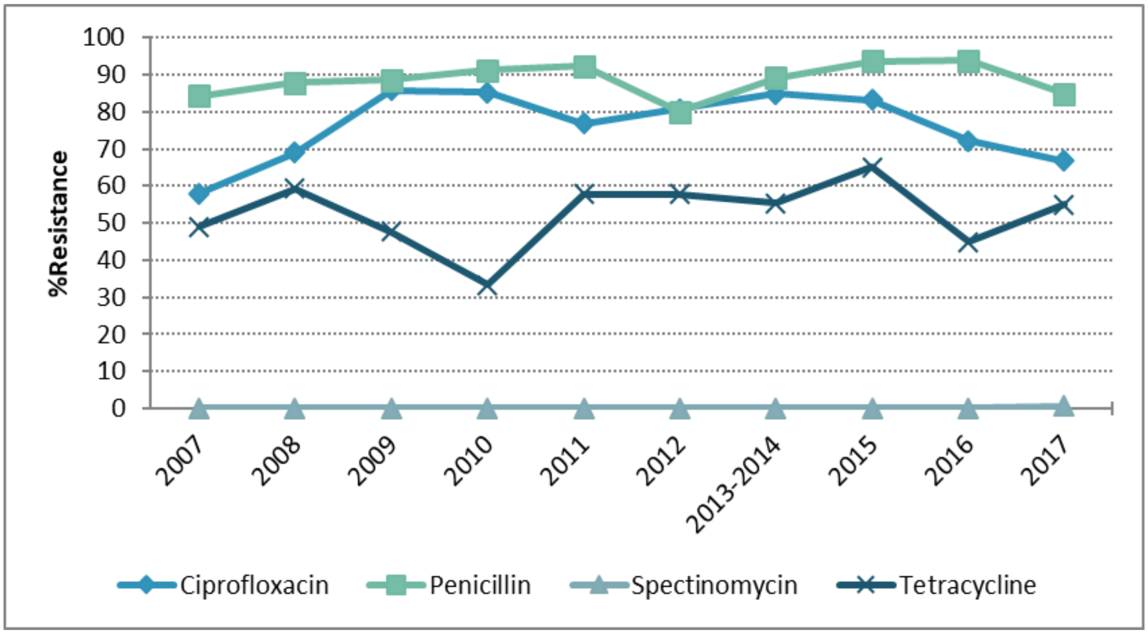


Figure 29. Yearly resistance rates of *N. gonorrhoeae*, DOH ARSP, 2007-2017



Staphylococcus aureus

The Isolates

For 2017, there were a total of 5,882 isolates of *Staphylococcus aureus* reported. These were most commonly isolated from cutaneous/wound, blood and respiratory specimens (Figure 30). *S. aureus* was the most common isolate from cutaneous or wound specimens for 2017.

Antimicrobial Resistance

The 2017 cumulative methicillin-resistant *S. aureus* (MRSA) rate is at 57% (n=5,267; 95% CI: 94.6-95.8). This reported MRSA rate for 2017 was a statistically significant decrease from the reported 2016 MRSA rate of 62% (p<0.001). Rates of resistance to the other antibiotics tested are seen in Figure 31. Although there were several isolates reported as either linezolid (1% resistant; n=4,964; 95% CI: 0.5-1.0); or vancomycin resistant (2% resistant; n=4,250; 95% CI: 1.2-1.9) for 2017, **none of these isolates were sent for confirmatory testing at the reference laboratory**. Resistance rates for *S. aureus* isolates against commonly used antibiotics for the past 10 years are illustrated in Figure 32 and Figure 33.

Methicillin-resistant *Staphylococcus aureus* (MRSA)

There were 2,981 MRSA isolates reported from the ARSP sentinel sites for 2017. Most of these isolates were isolated from cutaneous and blood culture isolates. The overall cumulative MRSA rate for 2017 was at 57% with variations by sentinel site MRSA rates ranging from as low as 20% (CRH, n=30) to as high as 69% (ZMC, n=65) as depicted in Figure 34.

MRSA rates for 2017 were also analyzed by specimen type with 55% MRSA rates in the subset of invasive (blood culture) isolates (n=1,102); 56% for respiratory isolates (n=1,116); and 59% MRSA rates in the subset collected from skin and wound specimens (n=2,409). Most of these MRSA isolates (58%) were also presumptively community-acquired or isolated from specimens taken from patients in the outpatient department, emergency room and during admission within their 1st 2 hospital days. Rates of resistance of these subset of MRSA isolates against antibiotics used for treatment showed highest rates against co-trimoxazole at 30% (n=2,879; 95% CI: 28.1-31.5) while lowest rates were seen against both linezolid at 1% (n=2,843; 95% CI: 0.7-1.5) and vancomycin 1% (n=2,529; 95% CI: 0.9-1.8). All reported linezolid and vancomycin resistant reports were not sent to the reference laboratory for confirmatory testing. Rates of resistance of these subsets of MRSA isolates as seen in Figure 35.

Figure 30. Distribution of *S. aureus* by specimen type, DOH ARSP, 2017 (n=5,882)

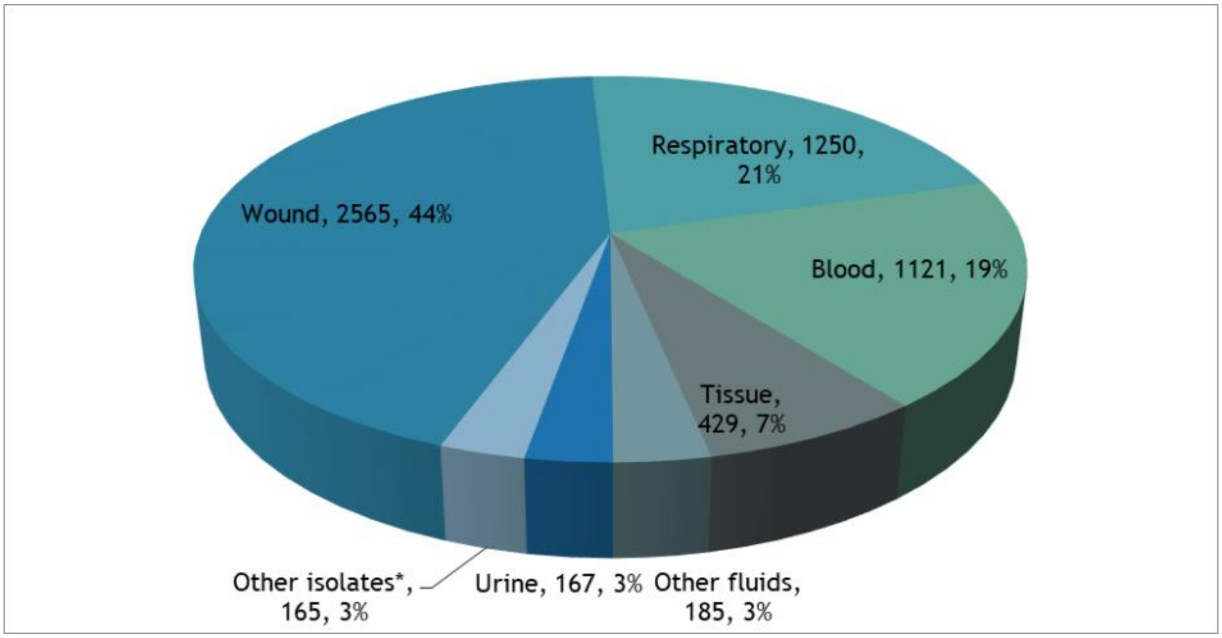


Figure 31. Percent resistance of *S. aureus*, DOH ARSP, 2017

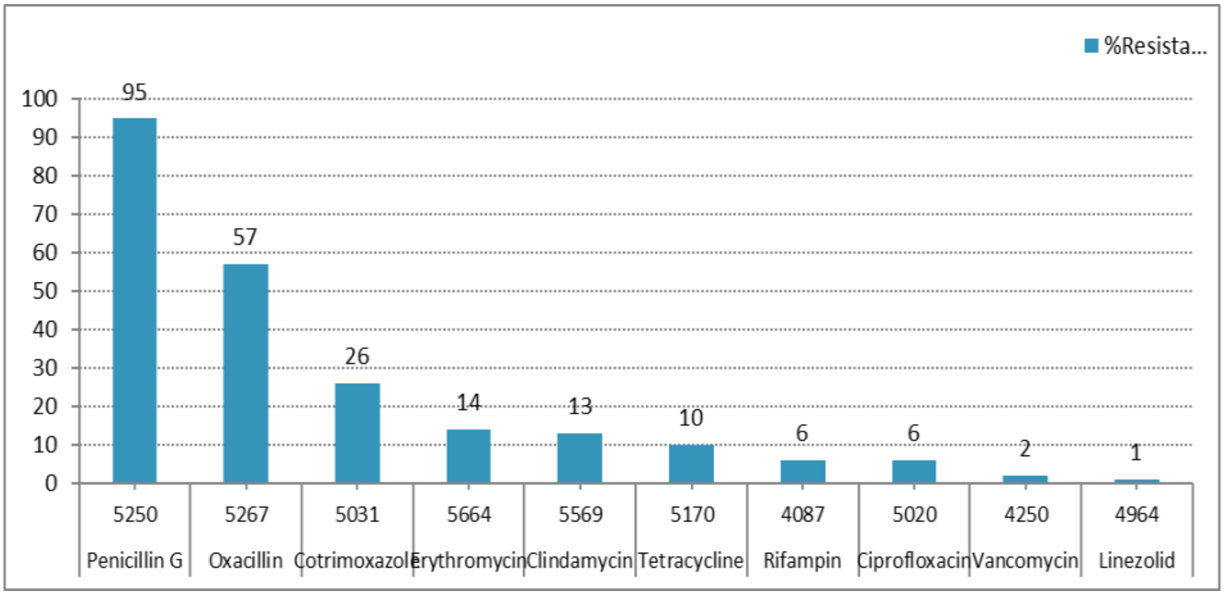


Figure 32. **Yearly penicillin, oxacillin and vancomycin resistance rates of *S. aureus*, DOH ARSP, 2008-2017**

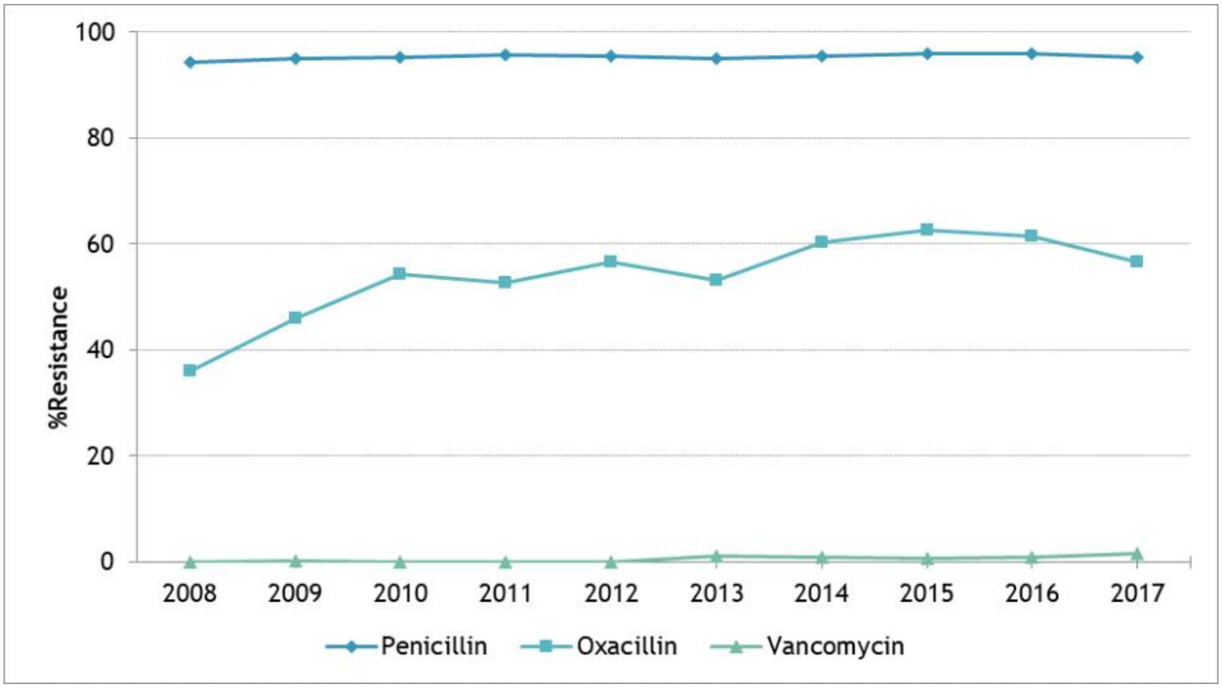


Figure 33. **Yearly clindamycin, co-trimoxazole and tetracycline resistance rates of *S. aureus*, DOH ARSP, 2008-2017**

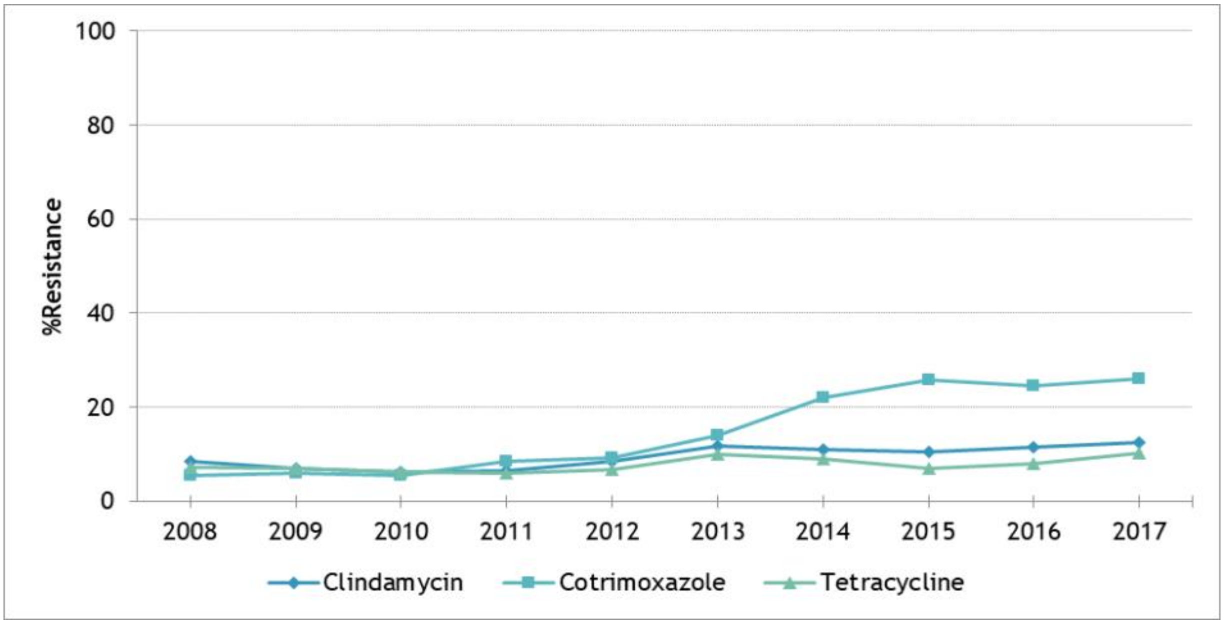


Figure 34. MRSA rates by sentinel site, DOH ARSP, 2017

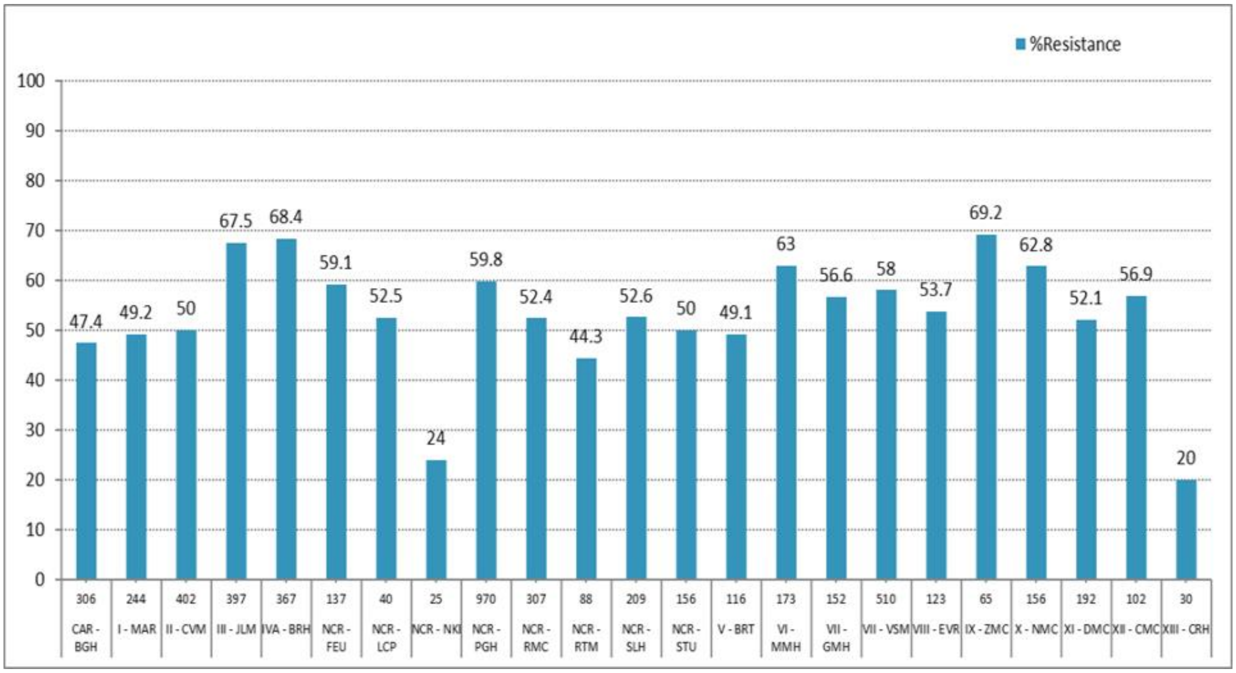
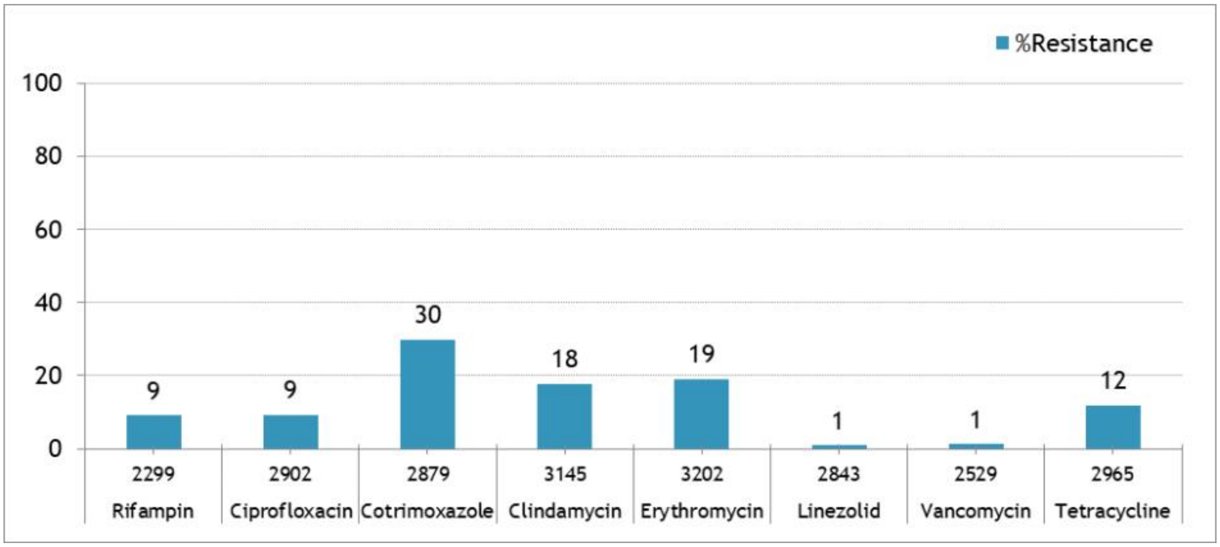


Figure 35. Percent resistance of MRSA isolates, DOH ARSP, 2017



Enterococcus species

The Isolates

For 2017, there were a total of 2,890 *Enterococcus species* reported of which the commonest were *Enterococcus faecalis* (1,524 isolates) and *Enterococcus faecium* (865 isolates). Most of the 2017 *E. faecalis* and *E. faecium* were isolated from urine (*E. faecalis* 728 isolates; *E. faecium* 590 isolates); wound (*E. faecalis* 300 isolates and E*. faecium* 74 isolates); and blood (*E. faecalis* 144 isolates and *E. faecium* 70 isolates) specimens (Figure 36 and Figure 37).

Antimicrobial Resistance

For 2017, ampicillin resistance among *E. faecalis* was at 9% (n=1,447; 95% CI: 7.4-10.4). Comparatively, ampicillin-resistance against *E. faecium* was reported higher at 88% (n=824; 95% CI: 85-89.6). High level gentamicin and streptomycin resistance for *E. faecalis* was at 27% (n=1,175; 95% CI: 24.2-29.3); and 26% (n=897; 95% CI: 23.8-29.6), respectively. Similarly, higher high-level gentamicin and streptomycin rates of resistance are seen with *E. faecium* with reports at 62% (n=676; 95% CI: 58.4-65.8) and 45% (n=413; 95% CI: 39.8-49.5), respectively. For 2017, we see the emergence of linezolid and vancomycin resistance in the local strains of enterococci. Rates of resistance against linezolid and vancomycin for *E. faecalis* is at 1% (n=1,342; 95% CI: 0.8-2.1) and 2% (=1,447; 95% CI: 1.0-2.3), respectively. For *E. faecium*, 2017 resistance rate is at 1% (n=804; 95% CI: 0.6-2.3) against linezolid; and 5% (n=791; 95% CI: 3.8-7.0) for vancomycin. Several of these multi-drug resistant strains were already confirmed as drug-resistant at the reference laboratory. The 2017 rates of resistance of *E. faecalis* and *E. faecium* are seen Figure 38 and Figure 39, respectively.

Figure 36. Distribution of *E. faecalis* by specimen type, DOH ARSP, 2017 (n=1,524)

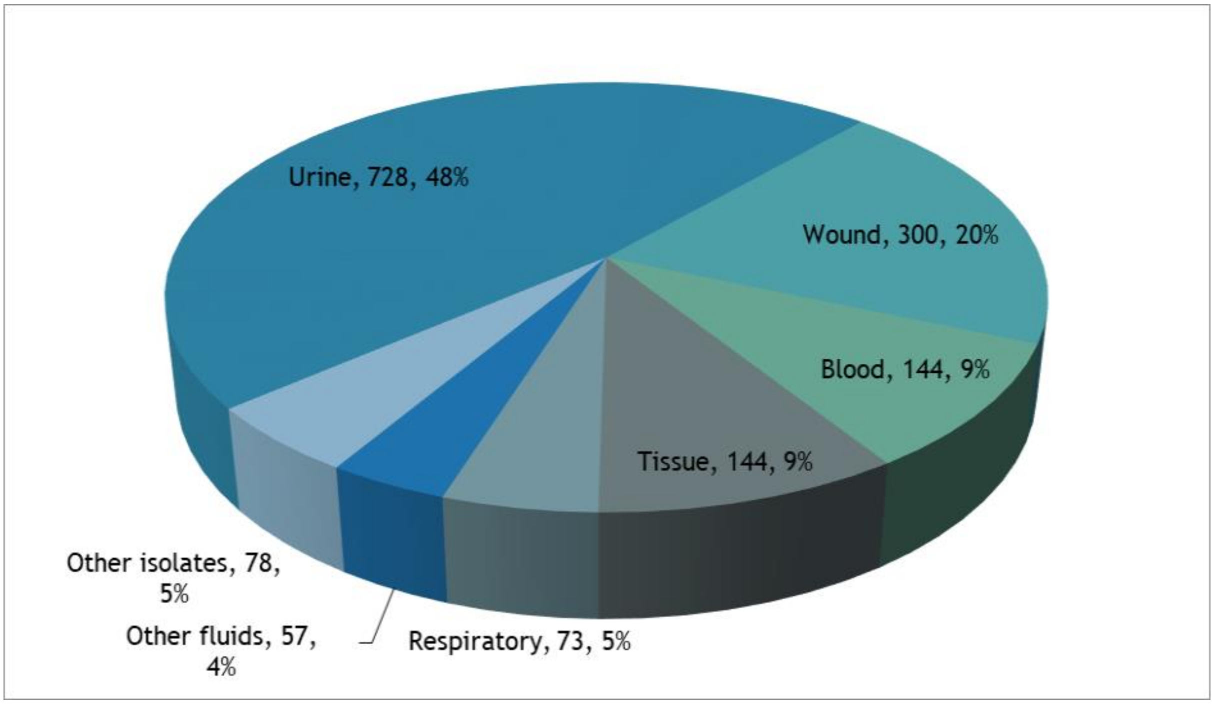


Figure 37. Distribution of *E. faecium* by specimen type, DOH ARSP, 2017 (n=865)

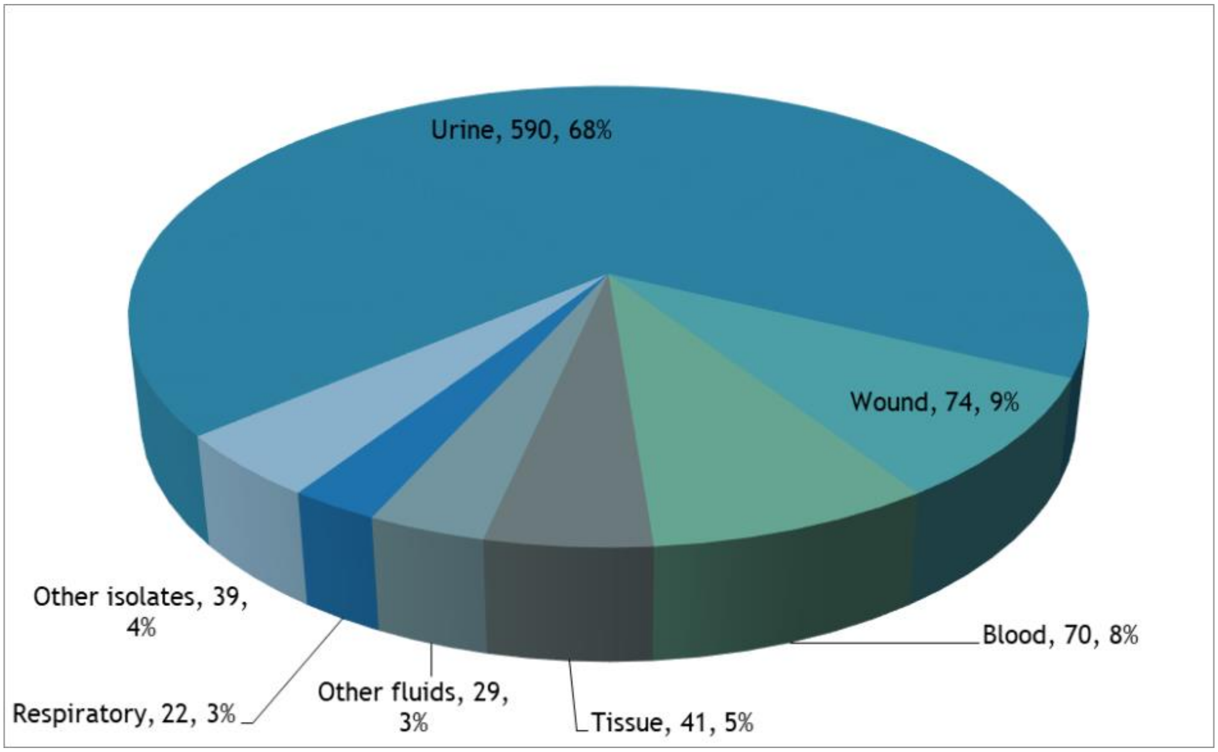


Figure 38. Percent resistance of *E. faecalis*, DOH ARSP, 2017

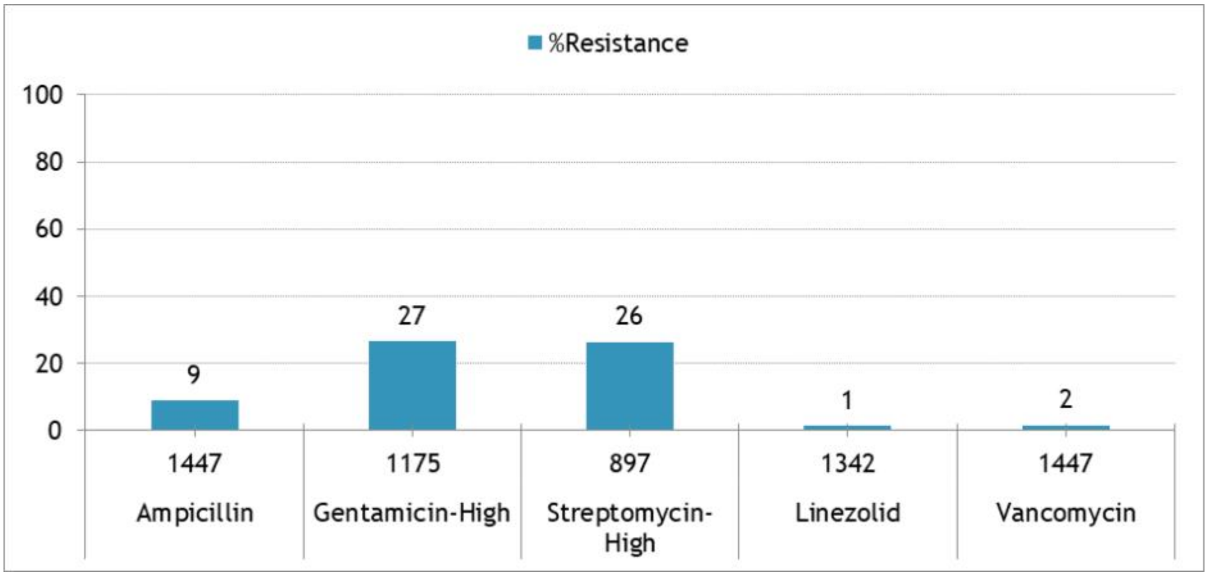
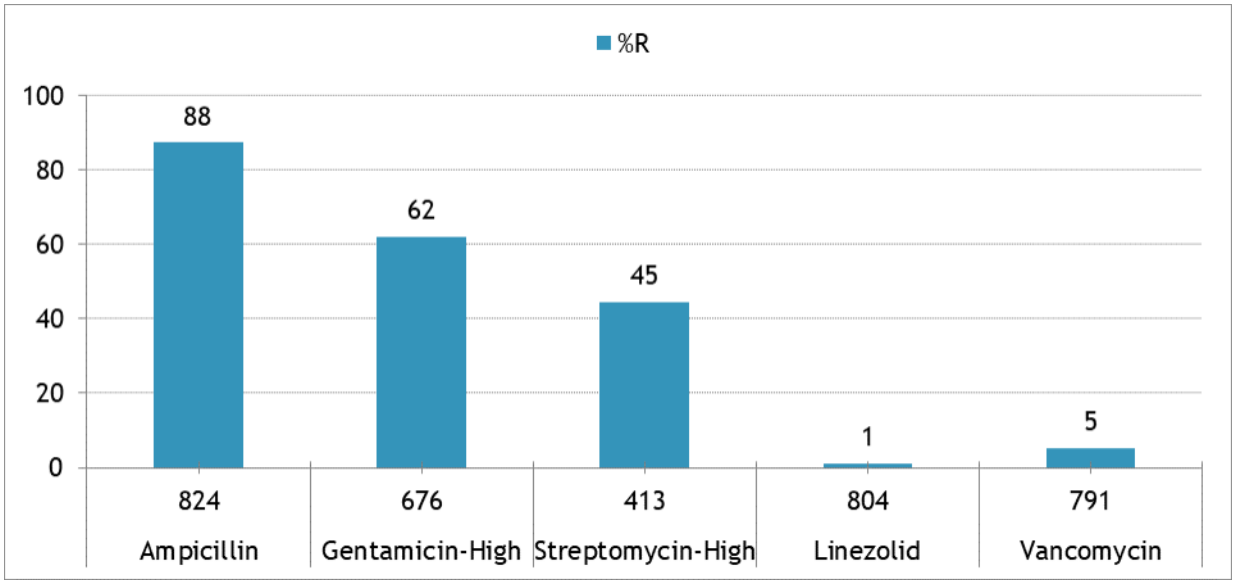


Figure 39. Percent resistance of *E. faecium*, DOH ARSP, 2017



Escherichia coli

The Isolates

A total of 8,939 *Escherichia coli* isolates were reported for 2017. Majority of the isolates were from urine specimens (49%). Others were isolated from wound, respiratory, blood, tissue and other body fluids (Figure 40).

Antimicrobial Resistance

For the 2017 *E. coli* isolates, highest rates of resistance are noted for ampicillin at 83% (n=7,792; 95% CI: 81.6-83.3), followed by co-trimoxazole at 61% (n=7,446; 95% CI: 60.3-62.5), ciprofloxacin at 41% (n=7,601; 95% CI: 40.2-42.4) and ceftriaxone at 39% (n=7,802; 95% CI: 38.1-40.3). Resistance to carbapenems are emerging with rates against ertapenem at 3% (n=4,775; 95% CI: 32.9-4.0); imipenem at 5% (n=7,539; 95% CI: 4.3-5.3) and meropenem at 5% (n=8,194; 95% CI: 4.4-5.3). Although there were sporadic reports of colistin-resistant *E. coli*, none of these were sent for confirmatory testing at the reference laboratory using broth microdilution, the only approved phenotypic method for testing colistin MIC [6]. Resistance rates for 2017 and the past 10 years to the antimicrobial agents tested against *E. coli* are seen in Figure 41, Figure 42 and Figure 43.

E. coli rates showed small statistically significant increases for 2017 when compared to reports from 2016 for the following antibiotics (*p* value <0.05): ceftriaxone from 36% in 2016 (n=6,437) to 39% in 2017 (n=7,802); and meropenem from 4% in 2016 (n=7,920) to 5% in 2017 (n=8,194). In contrast, the trends for resistance for the following antibiotics showed statistically significant decreasing rates *(p* value <0.05): from 85% in 2016 (n=7,868) to 83% in 2017 (n=7,792) for ampicillin; from 44% in 2016 (n=7,191) to 41% in 2017 (n=7,601) for ciprofloxacin; and from 23% in 2016 (n=7,340) to 21% in 2017 (n=7,620) for gentamicin.

E. coli isolates are commonly resistant to multiple classes of antimicrobials. In the subgroup of isolates with complete panel of antibiotics tested against *E. coli* (n=1,324 isolates), the most commonly reported phenotypes have resistance to at least 2 or more classes of antimicrobials. The commonest resistance phenotypes are as follows: 1) combined resistance to aminopenicillins and co-trimoxazole (12%); followed by 2) pan-susceptible isolates (12%); followed by 3) isolates resistant to aminopenicillins (8%); and then 4) combined resistance to cephalosporins (second, third and fourth generation), penicillins (including beta-lactam-beta-lactamase inhibitor combinations), fluoroquinolones and co-trimoxazole (7%).

From the subset of the 2017 isolates screened phenotypically for ESBL production, cumulative rate is at 41% (n=3,488). There is significant variability noted for the different sentinel sites with presumptive ESBL rates ranging from 9% in RTM (n=32) to as high as 52% in DMC (n=771) among those that tested at least 30 isolates for the analysis period. ESBL-suspect *E. coli* rates by sentinel site are seen in Figure 44.

There were 4,534 urinary *Escherichia coli* isolates reported for 2017 making this organism the most common bacterial isolate from urine specimens. Resistance data of outpatient urinary *E. coli* isolates against commonly used oral antibiotics for urinary tract infections showed lowest resistance rate against nitrofurantoin at 5% (n=1,023 urinary isolates tested; 95% CI: 3.5-6.2). In the subset of urinary *E. coli* isolated from admitted or hospitalized patients, rates of resistance against commonly used parenteral antibiotics for urinary tract infection was lowest against ertapenem at 4% (n=1,497 urinary isolates tested; 95% CI: 2.9-4.9) and amikacin at 4% (n=2,377 urinary isolates tested; 95% CI: 5.1-7.1). Percentage resistance of 2017 urinary *E. coli* isolates against the panel of antimicrobials are summarized in Table 5.

When the subset of invasive bloodborne *E. coli* isolates were analyzed, similar rates as that of over-all resistance rates are seen for ceftriaxone 37% (n=939), cefuroxime 34% (n=582), ciprofloxacin 37% (n=930), meropenem 5% (n=980), gentamicin 20% (n=921).

Figure 40. Distribution of *E. coli* by specimen type, DOH ARSP, 2017 (n=8,939)

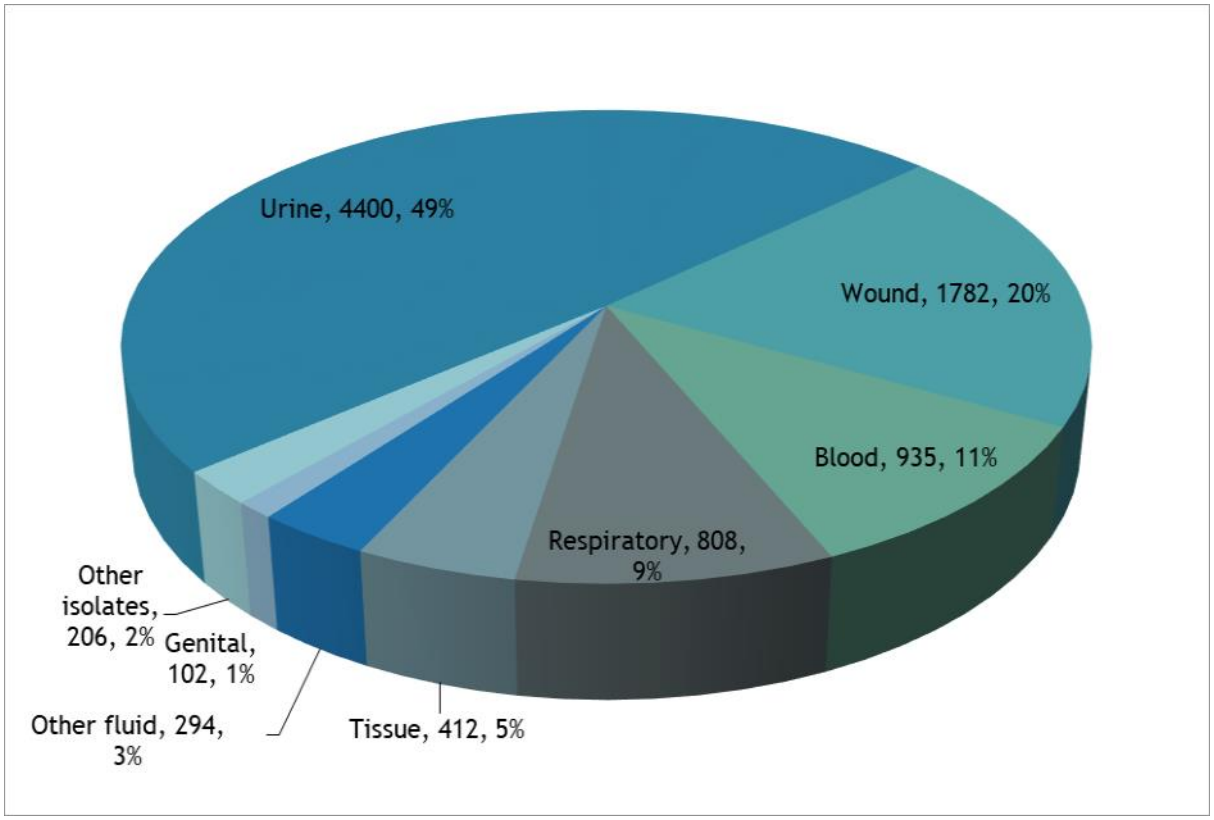


Figure 41. Percent resistance of *E. coli*, DOH ARSP, 2017

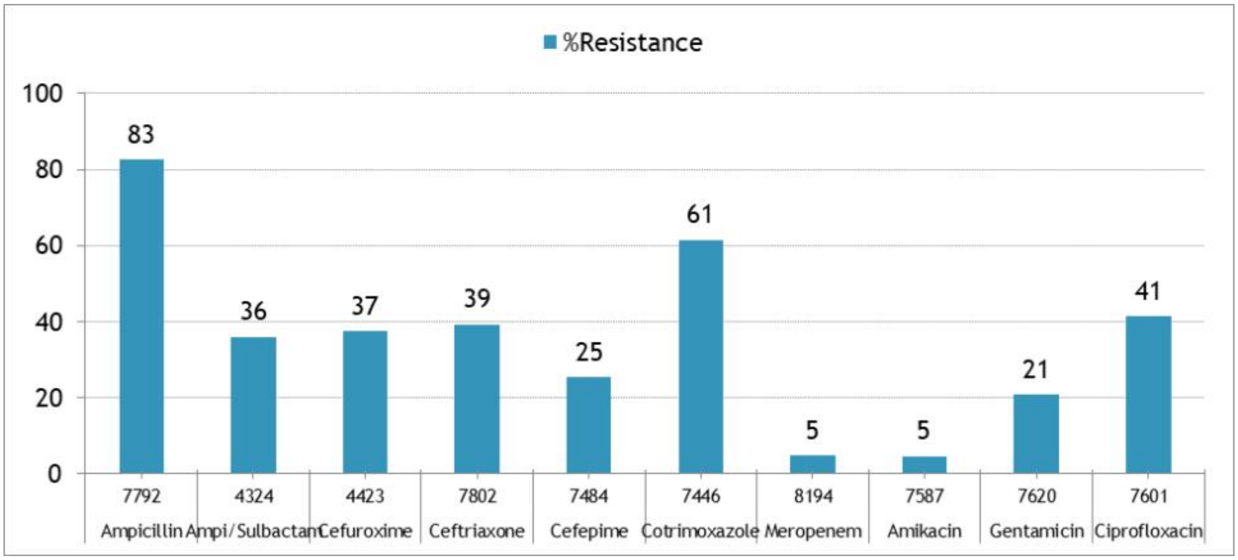


Figure 42 Yearly penicillins, ciprofloxacin and co-trimoxazole resistance rates of *E. coli*, DOH ARSP, 2008-2017

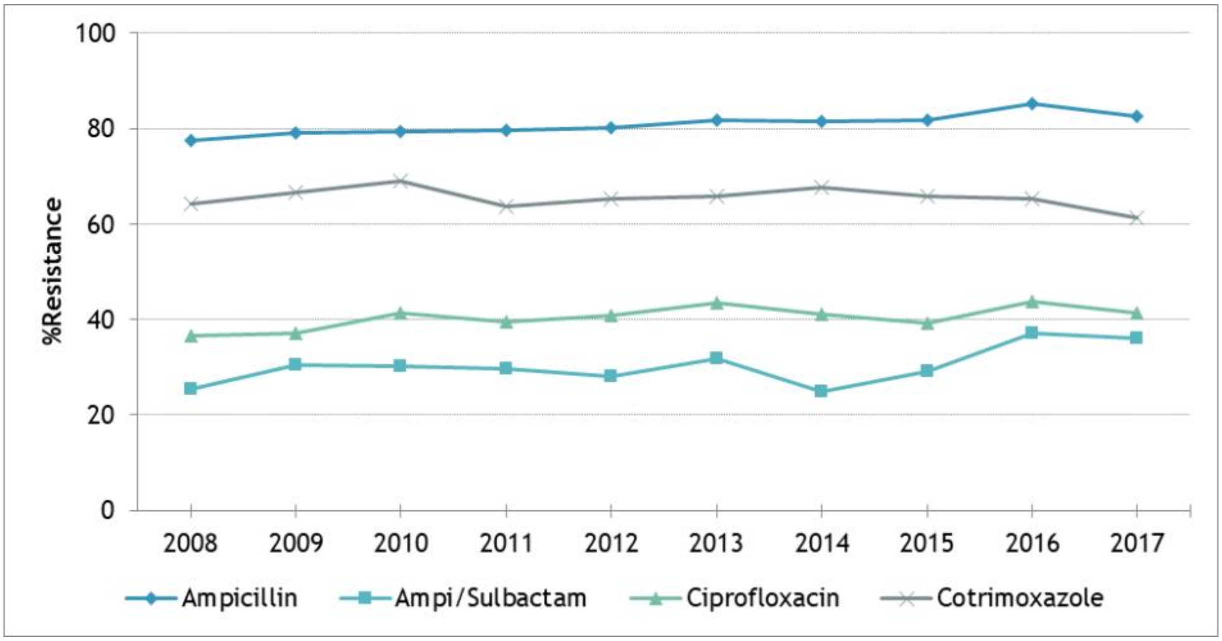


Figure 43. Yearly ceftriaxone, gentamicin and meropenem resistance rates of *E. coli*, DOH ARSP, 2008-2017

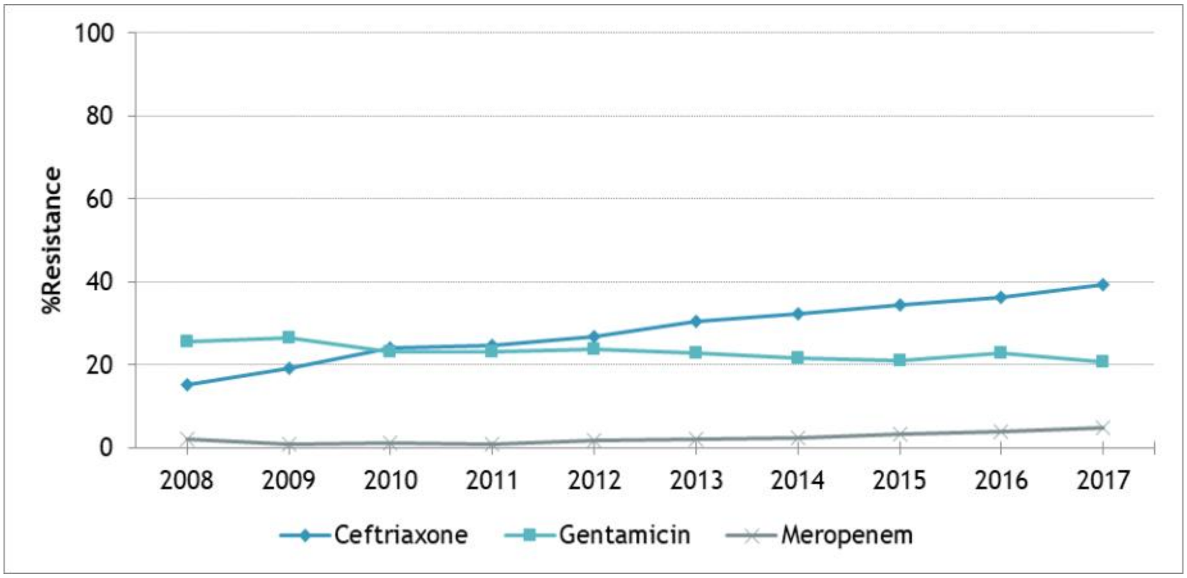


Figure 44. Percentage ESBL producing *E. coli*, DOH ARSP, 2017

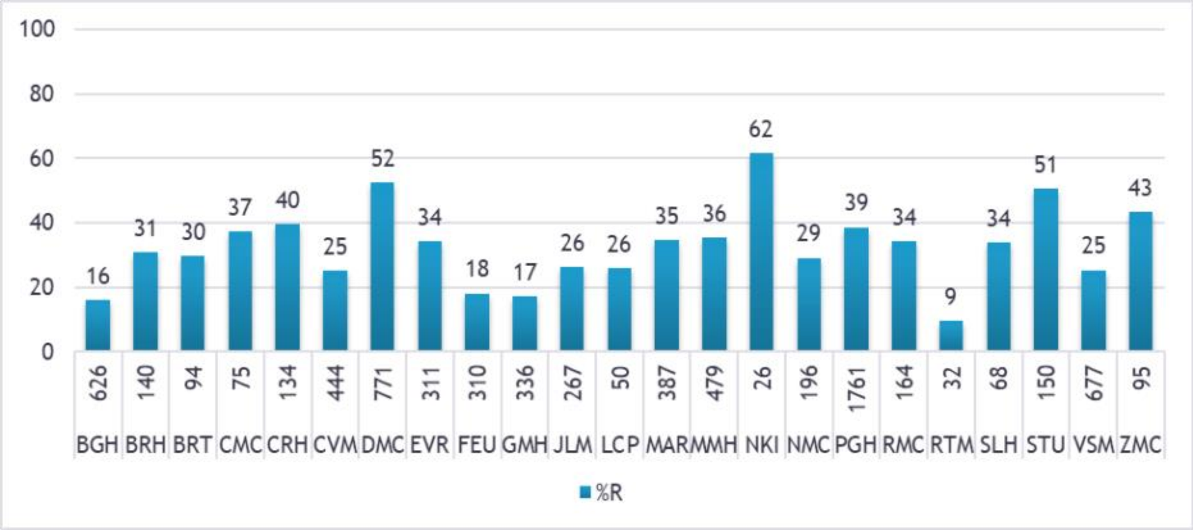


Table 5. Urinary *E. coli*, DOH ARSP, 2017

Antimicrobial	Outpatient		Inpatient	
	N	%R	N	%R
Ampicillin	1501	80.9	2413	84.7
Co-amoxiclav	1537	27.8	2514	34
Cefuroxime	859	30.5	1422	42.9
Ciprofloxacin	1464	45.6	2368	46.3
Co-trimoxazole	1460	60.8	2314	63.6
Nitrofurantoin	1023	4.7	1549	4.6
Intravenous Agents				
Piperacillin/Tazobactam	1420	6.1	2292	14.5
Ceftriaxone	1405	34.4	2413	46.7
Ertapenem	927	0.8	1497	3.8
Amikacin	1392	2.9	2377	6

Klebsiella pneumoniae

The Isolates

A total of 12,591 *Klebsiella pneumoniae* isolates reported for 2017. Majority of the isolates were from respiratory specimens (57%). Others were isolated from urine, wound or cutaneous and blood specimens (Figure 45).

Antimicrobial Resistance

For the 2017 *K. pneumoniae* isolates, highest rates of resistance are noted for co-trimoxazole at 61% (n=7,444), followed by cefuroxime at 50% (n=5,909; 95% CI: 48.9-51.5) and ceftriaxone at 46% (n=11,076; 95% CI: 45.2-47.0). Resistance to carbapenems are emerging with rates against ertapenem at 8% (n=6,637; 95% CI: 4.7-8.7); imipenem at 11% (n=10,496; 95% CI: 10.3-11.5) and meropenem at 11% (n=11,409; 95% CI: 10.3-11.5). There were 2 isolates confirmed at the reference laboratory to have non-wild type MICs for colistin as tested with broth microdilution. There are no clinical breakpoints established for colistin currently but non-wild type MICs based on CLSI epidemiologic cutoff values may signal emerging of resistance [6]. Resistance rates for 2017 and the past 10 years to the representative antimicrobial agents tested against *K. pneumoniae* are seen in Figure 46**,** Figure 47**,** and Figure 48**.**

K. pneumoniae isolates is more commonly resistant to multiple classes of antimicrobials. In the subgroup of isolates with complete panel of antibiotics tested against *K. pneumoniae* (n=1,644 isolates) most commonly reported phenotypes have resistance to at least 2 or more classes of antimicrobials. The commonest resistance phenotypes are as follows: 1) combined resistance to cephalosporins (second, third and fourth generation), penicillins (including beta-lactam-beta-lactamase inhibitor combinations), aminoglycosides, fluoroquinolones and co-trimoxazole (11%); followed by 2) combined resistance to cephalosporins (second, third and fourth generation), penicillins (including beta-lactam-beta-lactamase inhibitor combinations), aminoglycosides, fluoroquinolones, co-trimoxazole and carbapenem (9%); and 3) combined cephalosporins (second and third generation), penicillins (including beta-lactam-beta-lactamase inhibitor combinations), fluoroquinolones and co-trimoxazole (7%).

From the subset of the 2017 isolates screened phenotypically for ESBL production, cumulative rate is at 41% (n-6,239). There is significant variability noted for the different sentinel sites with presumptive ESBL rates ranging from 19% in RTM (n=47) to as high as 69% in STU (n=73) among those that tested at least 30 isolates for the analysis period. ESBL-suspect *K. pneumoniae* rates by sentinel site are seen in Figure 49**.**

When the subset of invasive bloodborne *E. coli* isolates were analyzed, relatively higher rates compared to over-all resistance rates among invasive *K. pneumoniae* isolates are seen for the following antimicrobials: ceftriaxone at 53% (n= 1,092); cefepime at 40% (n= 1,065); meropenem at 17% (n=1,116); amikacin at 12% (n= 1,066); and gentamicin at 31% (n= 1,032). Comparatively, similar resistance rates for invasive isolates are seen for cefuroxime at 51% (n= 661); ciprofloxacin at 22% (n= 1,021); and co-trimoxazole at 54% (n=1,016).

Figure 45. Distribution of *K. pneumoniae* by specimen type, DOH ARSP, 2017 (n=12,591)

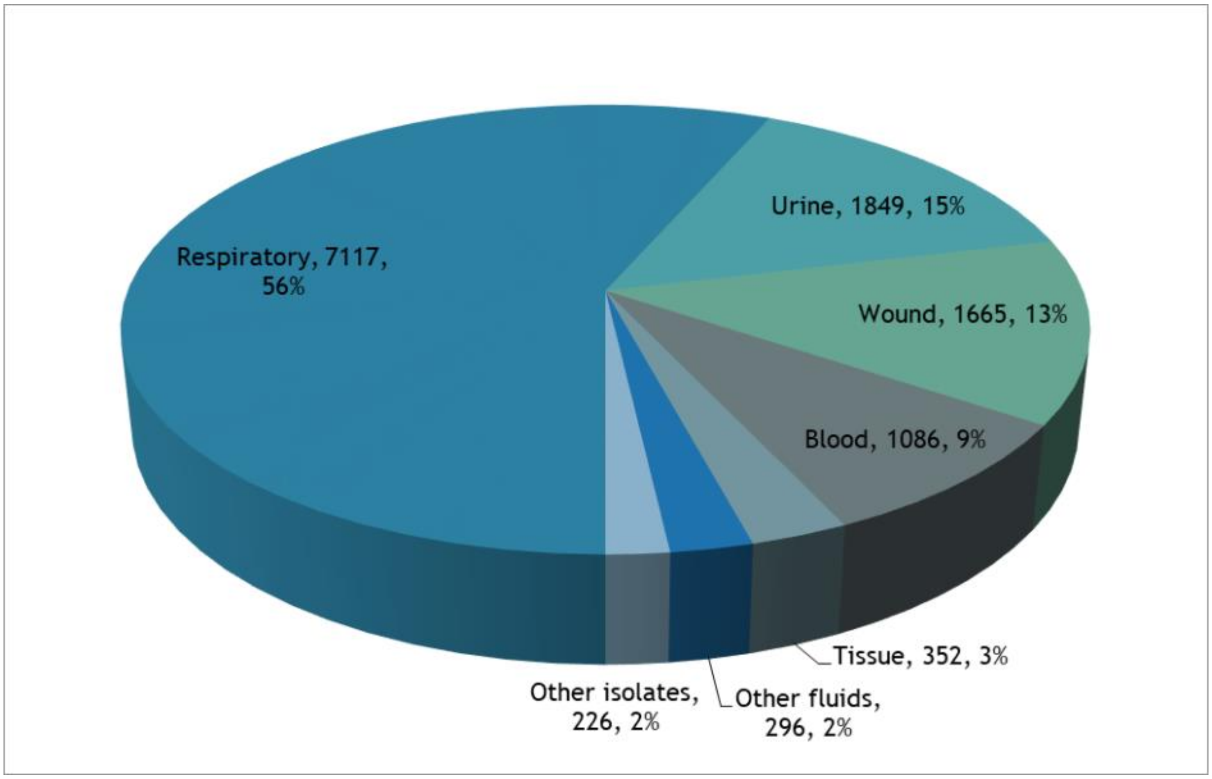


Figure 46. Percent resistant of *K. pneumoniae*, DOH ARSP, 2017

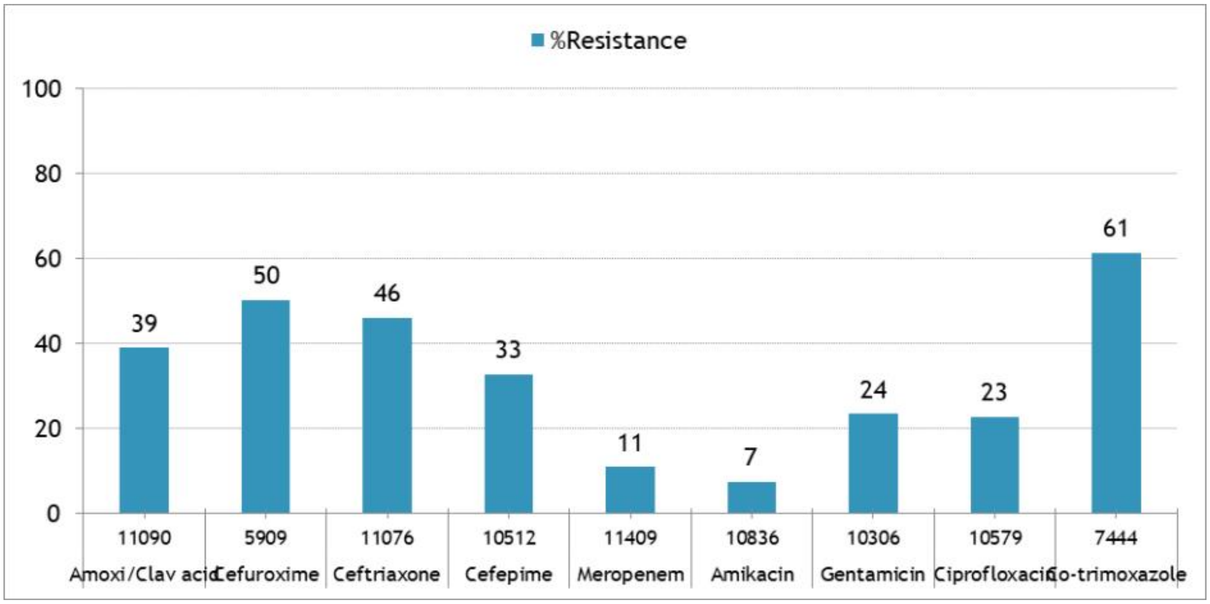


Figure 47. Yearly beta-lactams resistance rates of *K. pneumoniae*, DOH ARSP, 2008-2017

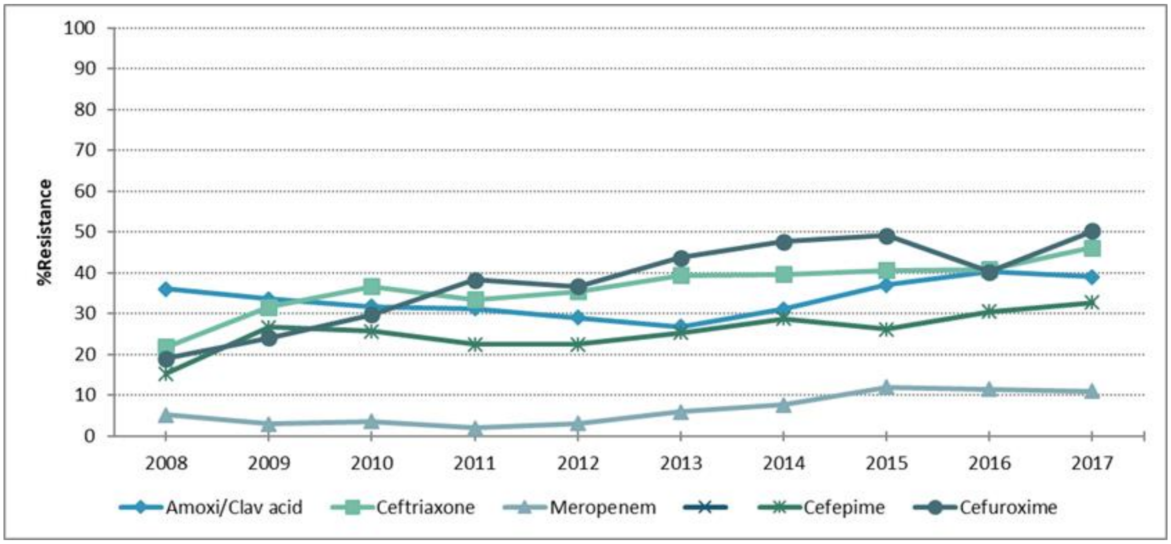


Figure 48. Yearly aminoglycoside, co-trimoxazole and ciprofloxacin resistance rates of *K. pneumoniae*, DOH ARSP, 2008-2017

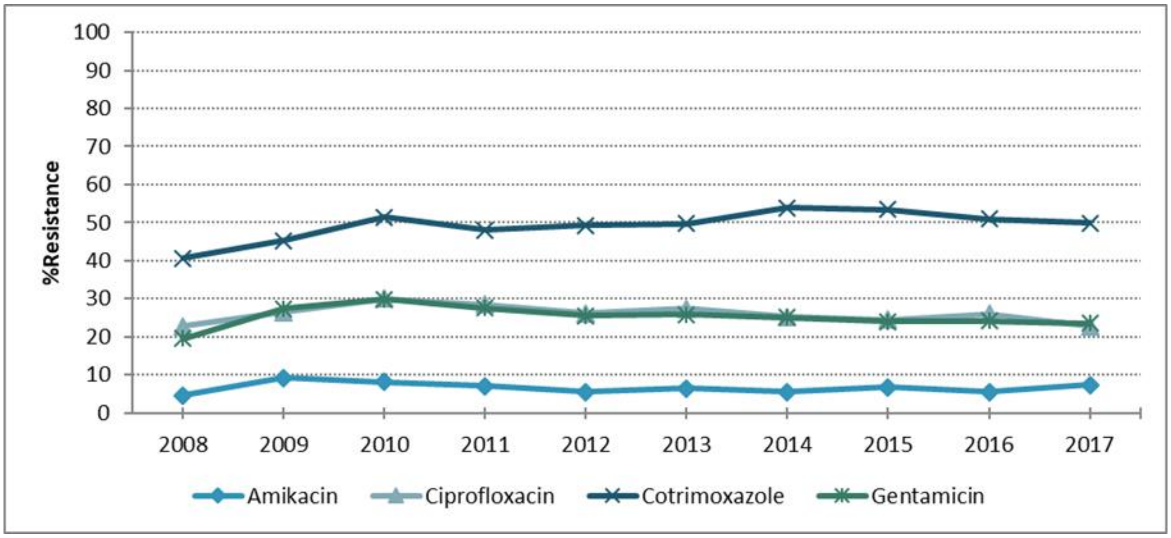
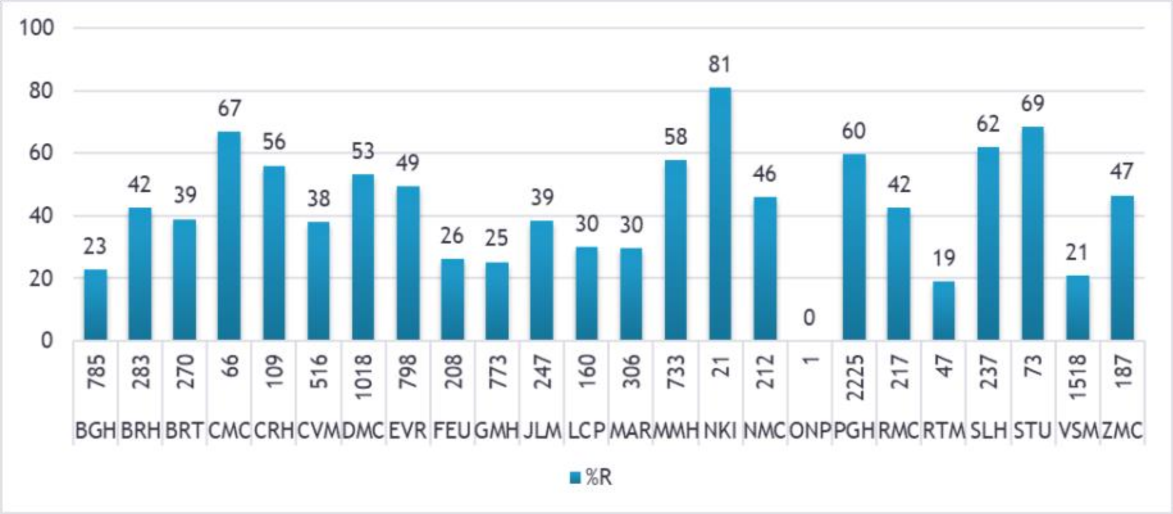


Figure 49. Percentage ESBL producing *K. pneumoniae*, DOH ARSP, 2017



Pseudomonas aeruginosa

The Isolates

For 2017, there were 6,776 *P. aeruginosa* isolates which were most commonly isolated from respiratory, wound, urine, tissue and blood specimens (Figure 50).

Antimicrobial Resistance

For the 2017 *P. aeruginosa* isolates, highest rates of resistance are noted for aztreonam at 17% (n=3,680; 95% CI: 15.9-18.4) and imipenem at 17% (n=5,780; 95% CI: 16.2-18.2) while lowest reported rate was for amikacin at 8% (n=6,094; 95% CI: 7.2-8.6). Although there were sporadic reports of colistin-resistant *P. aeruginosa*, only 1 isolate was confirmed as colistin-resistant using broth microdilution at the reference laboratory. All other reports were based on either disk diffusion or MIC testing using commercial susceptibility testing methods with unestablished correlation between MICs and clinical outcome. Resistance rates for 2017 to the representative antimicrobial agents tested against *P. aeruginosa* are seen in Figure 51.

When the 2017 reported resistance data for *P. aeruginosa* are compared to those from 2016, statistically significant decrease in rates were noted for cefepime from 15% (n=5,308) in 2016 to 14% (n=6,004) in 2017; ceftazidime from 18% (n=5,416) in 2016 to 16% (n=6,206) in 2017; ciprofloxacin from 15% (n=5,266) in 2016 to 13% (n=5,789) in 2017; imipenem from 19% (n=5,233) in 2016 to 17% (n=5,780) in 2017; and meropenem from 17% (n=5,377) in 2016 to 14% (n=6,279) in 2017. The rest of the antimicrobials resistance rates for 2017 did differ statistically from those reported the year prior. Resistance rates of *P. aeruginosa* for 2017 and the past 10 years are illustrated in Figure 52 and Figure 53.

P. aeruginosa isolates is more commonly resistant to multiple classes of antimicrobials. In the subgroup of isolates with complete panel of antibiotics tested against *P. aeruginosa* (n=2,406 isolates), the commonest profile are the pan-susceptible strains at 58% (n=2,406). Other common resistance phenotypes are 1) strains resistant to aztreonam (9%); then 2) strains with combined resistance to cephalosporins (ceftazidime and cefepime), piperacillin-tazobactam and aztreonam (5%); and then 3) strains with combined resistance to cephalosporins (ceftazidime and cefepime), piperacillin-tazobactam, aztreonam, amikacin, ciprofloxacin and meropenem (5%).

When the subgroup of blood culture isolates (invasive) were analyzed and compared to cumulative rates of resistance for all isolates combined, invasive *P. aeruginosa* had relatively higher rates of resistance for amikacin at 18% (n=434) and gentamicin at 19% (n=400); similar rates of resistance for the following antibiotics: cefepime, imipenem and meropenem; and lower rates for piperacillin-tazobactam at 12% (n=416); ceftazidime at 14% (n-=430); aztreonam at 10% (n=265); and ciprofloxacin at 12% (n=409).

Figure 50. Distribution of P. aeruginosa by specimen type, DOH ARSP, 2017 (n=6,776)

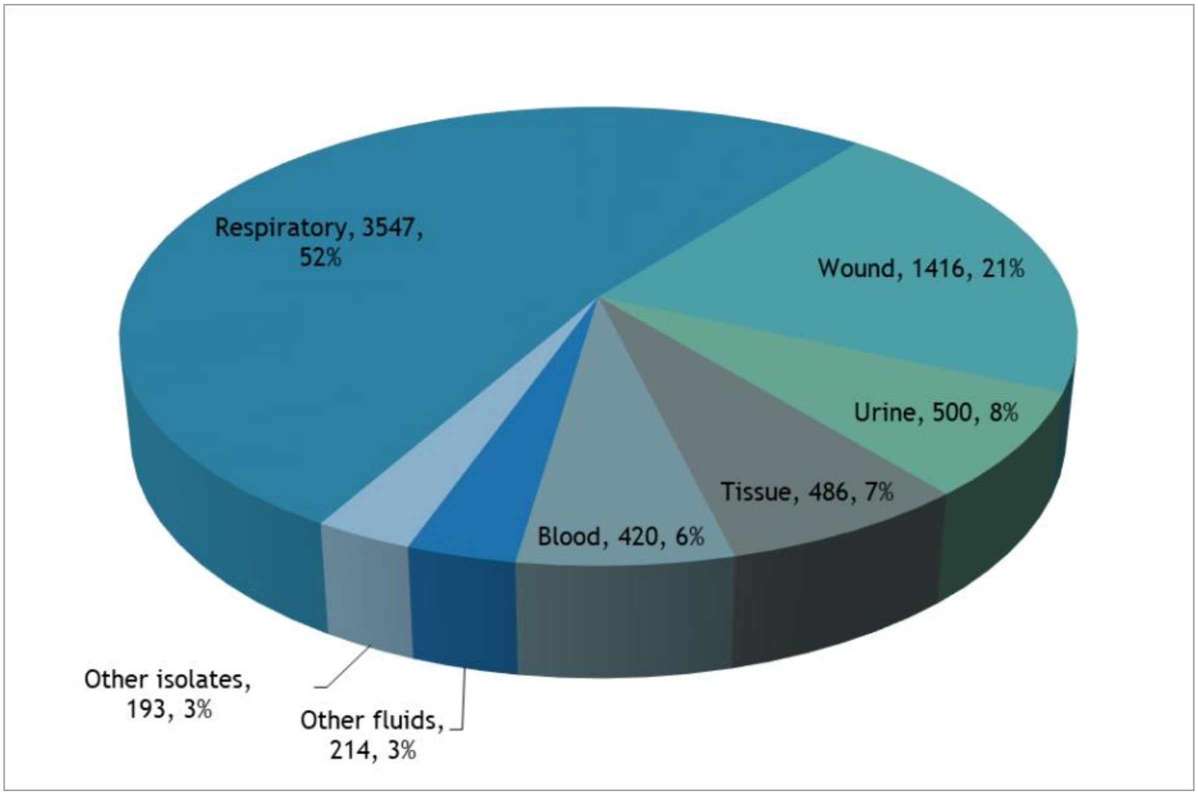


Figure 51. Percent resistance of *P. aeruginosa*, DOH ARSP, 2017

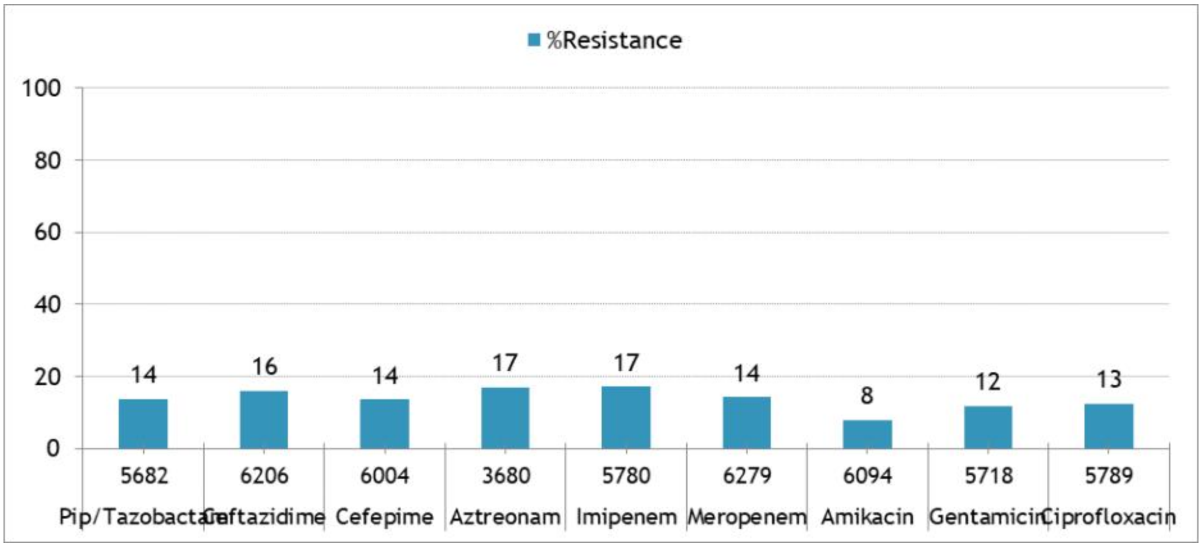


Figure 52. Yearly aztreonam, cephalosporin and piperacillin-tazobactam resistance rates of *P. aeruginosa*, DOH ARSP, 2008-2017

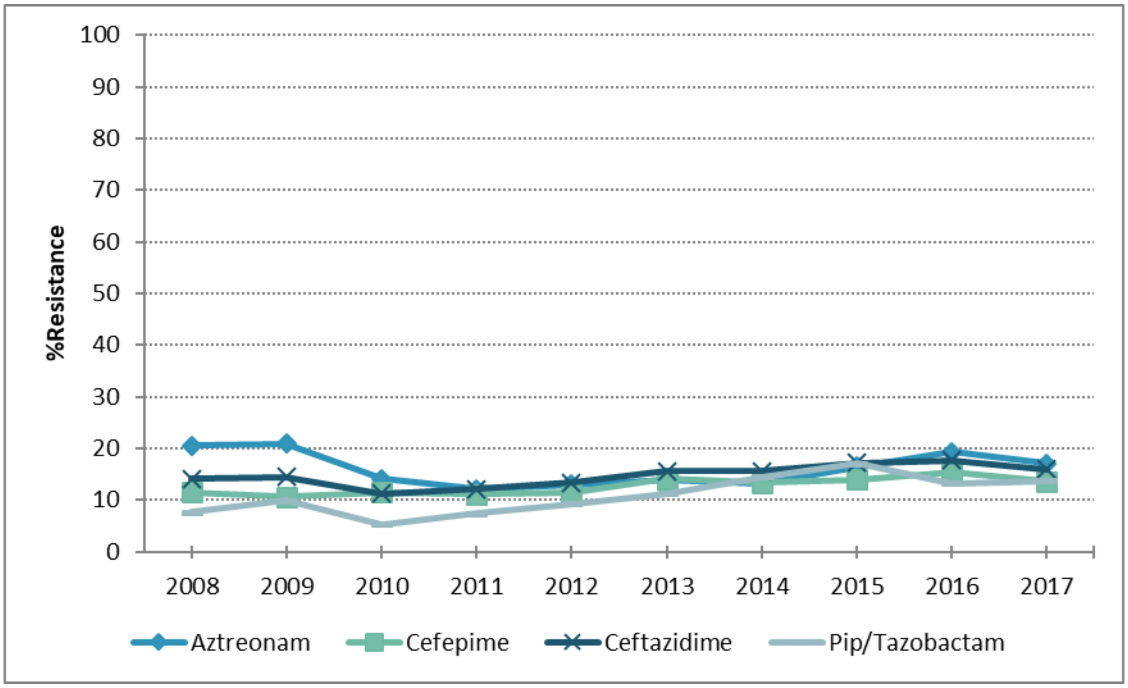
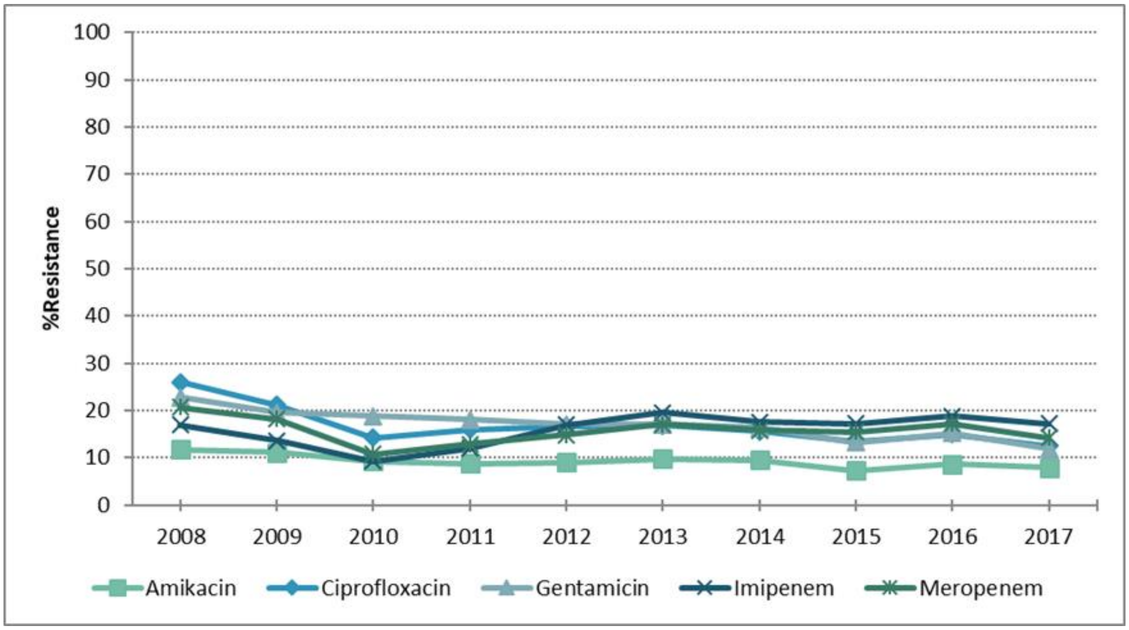


Figure 53. Yearly aminoglycosides, ciprofloxacin and carbapenem resistance rates of *P. aeruginosa*, DOH ARSP, 2008-2017



Acinetobacter baumanii

The Isolates

For 2017, there were 5,043 *A. baumannii* isolates which was higher than the total number reported for 2016 (4,719 isolates). As in the previous year, these were most commonly isolated from respiratory (63%), blood (13%), urine (8%) and cutaneous/wound specimens (6%) (Figure 54).

Antimicrobial Resistance

For the 2017 data, more than 50% of all reported *A. baumannii* isolates were already resistant to the following antibiotics: cefepime at 59% (n=4,378; 95% CI: 57.5-60.5); imipenem at 57% (n=4,266; 95% CI: 55.6-58.6); meropenem at 56% (n=4,643); ciprofloxacin at 55% (n=4,273; 95% CI: 53.1-56.1); and co-trimoxazole at 52% (n=4,231; 95% CI: 50.9-53.9). Although a few isolated reports of colistin-resistant isolates were reported for 2017, none of these were identified and confirmed using the only recommended phenotypic testing, broth microdilution. Rates of resistance for the antibiotics on the panel tested for *A. baumannii* are seen in Figure 55**.**

When 2017 data were compared to reported rates for 2016, statistically significant decrease in resistance rates were noted for both aminoglycosides tested: amikacin from 38.4% in 2016 to 29% in 2017 (n=2,362) and gentamicin from 45.5% in 2016 (n=4,064) to 40% in 2017 (n=4,377) (p value <0.0001). Comparatively, increase in rates were observed for the carbapenems tested: from 52% (n=3,967) in 2016 to 57% (n=4,266) in 2017 for imipenem; and from 51% (n=4,209) in 2016 to 56% (n=4,643) in 2017 for meropenem (p value < 0.0001). The rest of the other antibiotics tested did not differ significantly from that of 2016. Resistance rates of *A. baumannii* to antimicrobials for treatment for the past 10 years are illustrated in Figure 56 and Figure 57**.**

In the subgroup of isolates with complete panel of antibiotics tested, the most common resistant phenotype had a multi-drug resistant profile with combined resistance to aminoglycosides, fluoroquinolones, carbapenems and sulbactam at 42% of the isolates (n= 1,682 isolates). Only 23% of these isolates remained pan-susceptible to the panel of antibiotic analyzed.

When the subset of blood culture *A. baumannii* isolates were analyzed, highest resistance rates were seen for imipenem at 50% (n=628); cefepime at 49% (n=652); and ampicillin-sulbactam at 45% (n=288). Although resistance against common antibiotics for treatment is commonly seen in these invasive isolates, rates are relatively lower when compared to cumulative rates when all *A. baumannii* isolates are analyzed (Figure 58).

Figure 54. Distribution of ***A. baumannii*** by specimen type, DOH ARSP, 2017 (n=5,043)

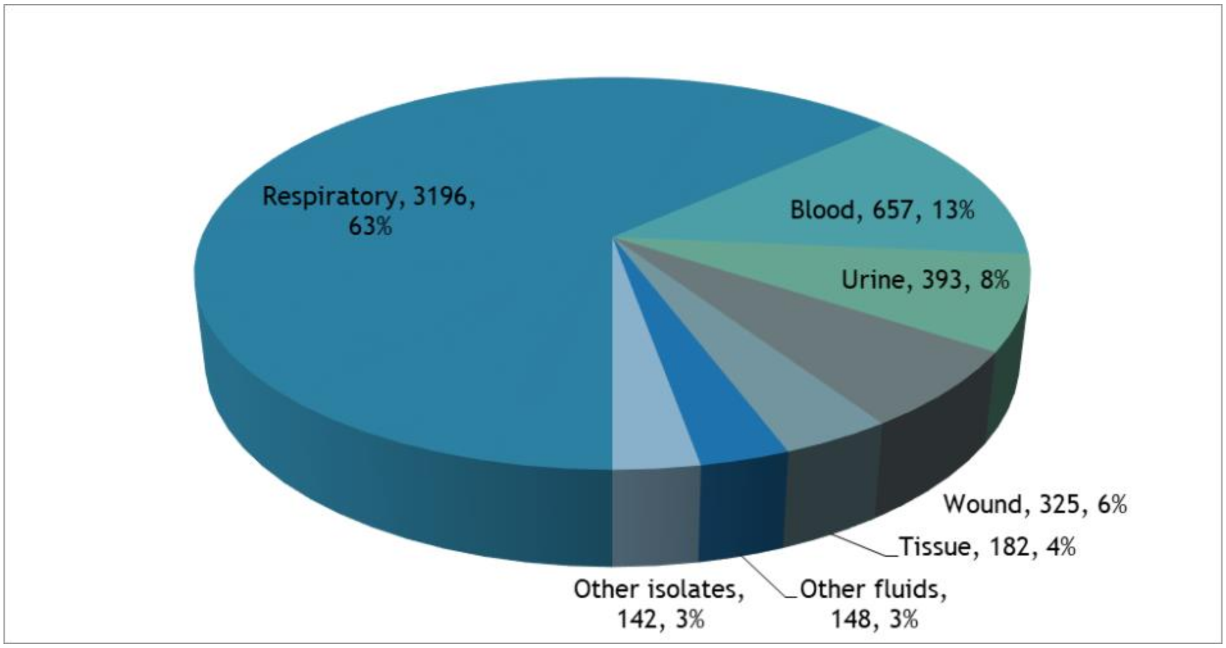


Figure 55. Percent resistance of ***A. baumannii***, DOH ARSP, 2017

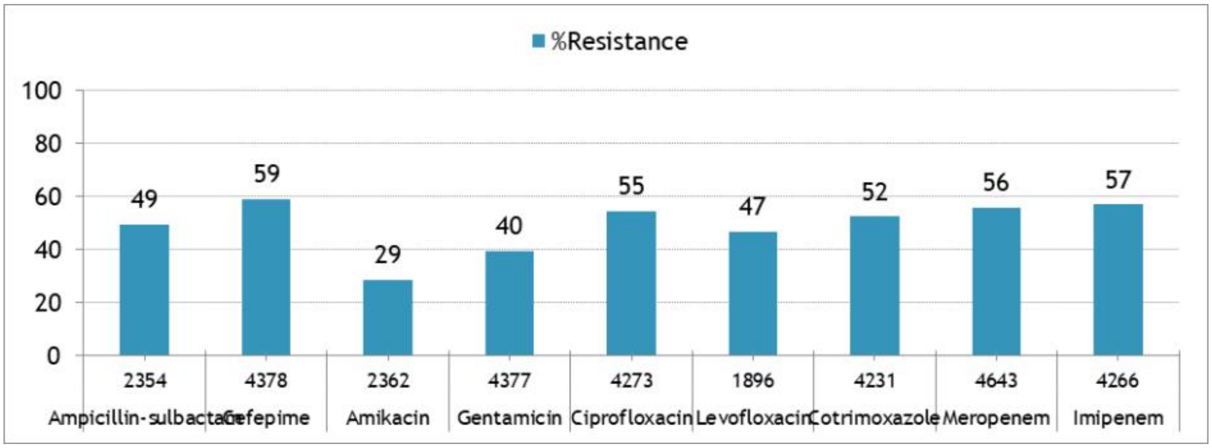


Figure 56. Yearly sulbactam, cefepime and aminoglycosides resistance rates of A. baumannii, DOH ARSP, 2008-2017

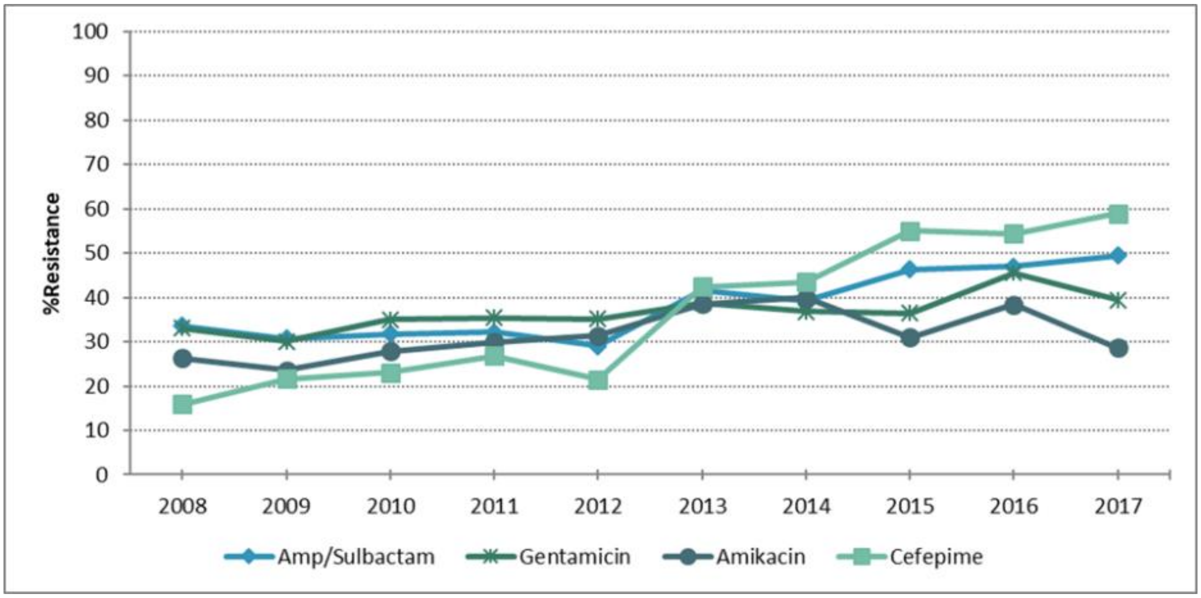


Figure 57. Yearly ciprofloxacin, co-trimoxazole and carbapenem resistance rates of A. baumannii, DOH ARSP, 2008-2017

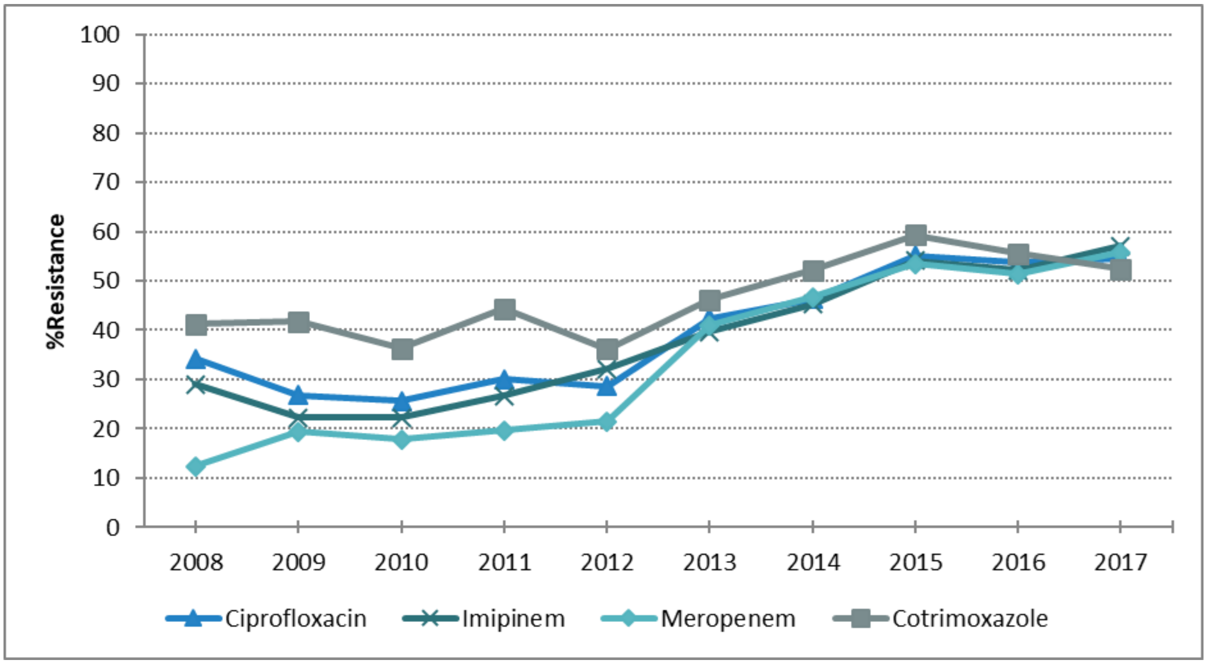
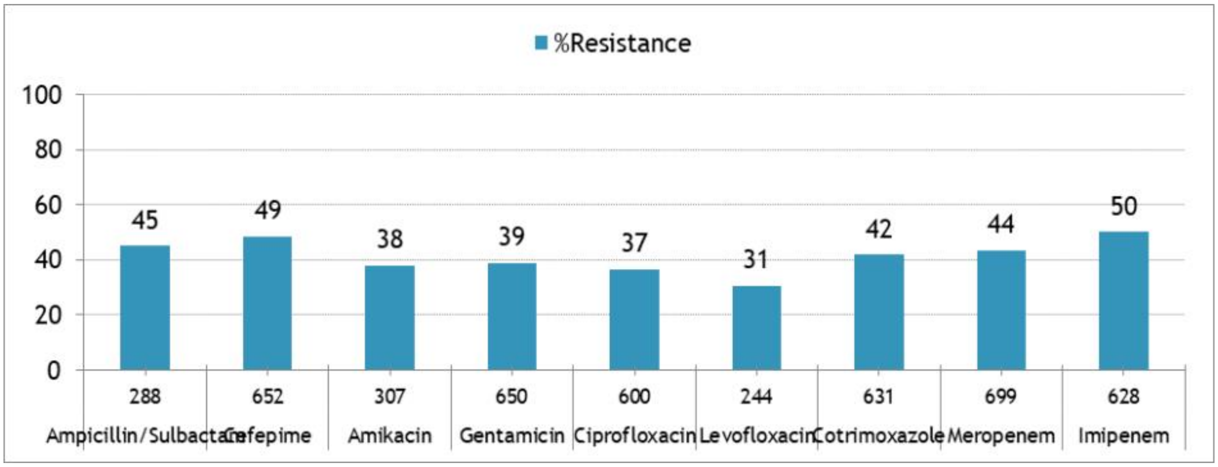


Figure 58. Percent resistance of blood culture A. baumannii isolates, DOH ARSP, 2017



Multidrug-resistant Pseudomonas aeruginosa & Acinetobacter baumanii

Multidrug-resistant pathogens are increasingly recognized globally. Terminologies are summarized in Table 6. Multidrug-resistant, extensively-drug resistant and pandrug-resistant bacteria. *P. aeruginosa* and *A. baumannii* MDR and possible-XDR rates are summarized in Table 7.

Table 6. Definition of Multidrug-resistant, extensively-drug resistant and pandrug-resistant bacteria [6]

Term	Definition
MDR (Multidrug-resistant)	Acquired non-susceptibility to at least one agent in three or more antimicrobial categories
XDR (Extensively drug-resistant)	Non-susceptibility to at least one agent in all but two or fewer antimicrobial categories (i.e. bacterial isolates remain susceptible to only one or two categories)
PDR (Pandrug-resistant)	Non-susceptibility to all agents in all antimicrobial categories.

Table 7. MDR and possible XDR P. aeruginosa and A. baumannii, ARSP, 2017

Organism	Number of isolates tested	Percentage MDR	Percentage Possible XDR
Pseudomonas aeruginosa			
All isolates	6,776	21%	16%
Blood isolates	420	18%	13%
Acinetobacter baumannii			
All isolates	5,030	63%	52%
Blood isolates	657	47%	33%

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