Supplementary material

Quaternary Ammonium Compounds of Emerging Concern: Classification, Occurrence, Fate, Toxicity and Antimicrobial Resistance

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Table S1: Acronym, molecular mass and formula of QACs

Name	**Acronym**	**Molecular Mass**	**Formula**
Dialkyldimethylammonium compounds (DADMACs)			
Dioctyldimethylammonium bromide	DADMAC C8	350	$[CH_3(CH2)_7]_2N(CH3)_2$ Br
Didecyldimethylammonium chloride	DADMAC C10	362	$[CH_3(CH2)_9]_2N(CH3)_2$ Cl
Didodecyldimethylammonium chloride	DADMAC C12	418	$[CH_3(CH2)_{11}]_2N(CH3)_2Cl$
Ditetradecyldimethylammonium bromide	DADMAC C14	518	$[CH_3(CH2)_{13}]_2N(CH3)_2$ Br
Dihexadecyldimethylammonium bromide	DADMAC C16	574	$[CH_3(CH2)_{15}]_2N(CH3)_2$ Br
Dioctadecyldimethylammonium chloride	DADMAC C18 (DODMAC)	586	$[CH_3(CH2)_{17}]_2N(CH3)_2Cl$
Alkyltrimethylammonium compounds (ATMACs)			
Dodecyltrimethylammonium chloride	ATMAC C12 (DTAC)	264	$CH_3(CH2)_{11}N(CH3)_3Cl$
Tetradecyltrimethylammonium chloride	ATMAC C14 (TTAC)	292	$CH_3(CH2)_{13}N(CH3)_3Cl$
Hexadecyltrimethylammonium chloride	ATMAC C16 (CTAC)	320	$CH_3(CH2)_{15}N(CH3)_3Cl$
Octadecyltrimethylammonium chloride	ATMAC C18 (OTAC)	348	$CH_3(CH2)_{17}N(CH3)_3Cl$
Benzylalkyldimethylethylammonium compounds (BACs)			
Dodecylbenzyldimethylammonium chloride	BAC C12	339	$CH_3(CH2)_{11}N(Cl)(CH3)_2CH_2C_6H_5$
Tetradecylbenzyldimethylammonium chloride	BAC C14	368	$CH_3(CH2)_{13}N(Cl)(CH3)_2CH_2C_6H_5$
Hexadecylbenzyldimethylammonium chloride	BAC C16	396	$CH_3(CH2)_{15}N(Cl)(CH3)_2CH_2C_6H_5$
Octadecylbenzyldimethylammonium chloride	BAC C18	424	$CH_3(CH2)_{17}N(Cl)(CH3)_2CH_2C_6H_5$

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Table S2: List of disinfectants with QACs as active ingredients against SARS-CoV-2 with less than 1 minute contact time (Ref: https://cfpub.epa.gov/wizards/disinfectants/; accessed on 27 December 2021**)**

EPA Registration Number	Active Ingredient(s)	Product Name	Contact Time (in minutes)	Formulation Type	Use Site
10324-85	Quaternary ammonium	Maquat 86-M	1	Ready-to-use	Healthcare; Institutional; Residential
1839-175	Quaternary ammonium	Solvent Free Detergent Disinfectant Pump Spray	0.5	Ready-to-use	Healthcare; Institutional; Residential
1839-190	Quaternary ammonium	Stepan Disinfectant Wipe	0.5	Wipe	Healthcare; Institutional; Residential
1839-220	Quaternary ammonium	SC-RTU Disinfectant Cleaner	0.5	Ready-to-use	Healthcare; Institutional; Residential
1839-83	Quaternary ammonium	Detergent Disinfectant Pump Spray	1	Ready-to-use	Healthcare; Institutional; Residential
1839-86	Quaternary ammonium	BTC 2125M 10% Solution	0.5	Dilutable	Healthcare; Institutional; Residential
4091-20	Quaternary ammonium	Phoenix 2	1	Ready-to-use	Healthcare; Institutional; Residential
4091-21	Quaternary ammonium	Condor 2	1	Ready-to-use	Healthcare; Institutional; Residential
4091-26	Quaternary ammonium	Emu	1	Ready-to-use	Healthcare; Institutional; Residential
42182-13	Quaternary ammonium; Ethanol (Ethyl alcohol)	Ironman Wipe	0.1	Wipe	Healthcare; Institutional; Residential
42182-9	Quaternary ammonium; Ethanol (Ethyl alcohol)	Firebird F130	0.1	Ready-to-use	Healthcare; Institutional; Residential
46781-12	Quaternary ammonium; Ethanol (Ethyl alcohol); Isopropanol (Isopropyl alcohol)	Cavicide 1	1	Ready-to-use	Healthcare; Institutional; Residential
46781-13	Quaternary ammonium; Ethanol (Ethyl alcohol); Isopropanol (Isopropyl alcohol)	Caviwipes 1	1	Wipe	Healthcare; Institutional; Residential
47371-129	Quaternary ammonium	Formulation HWS- 256	1	Dilutable	Healthcare; Institutional; Residential
47371-130	Quaternary ammonium	Formulation HWS-128	1	Dilutable	Healthcare; Institutional; Residential
47371-131	Quaternary ammonium	HWS-64	1	Dilutable	Healthcare; Institutional; Residential
47371-192	Quaternary ammonium	Formulation HWS-32	1	Dilutable	Institutional; Residential
5813-113	Quaternary ammonium	CDW	0.25	Wipe	Institutional; Residential
5813-73	Quaternary ammonium	Clorox Everest	0.5	Ready-to-use	Institutional; Residential
5813-79	Quaternary ammonium	Clorox Disinfecting Wipes	0.25	Wipe	Healthcare; Institutional; Residential
67619-10	Quaternary ammonium	Clorox Commercial Solutions Formula 409 Cleaner Degreaser Disinfectant	0.5	Dilutable	Healthcare; Institutional; Residential
67619-31	Quaternary ammonium	Clorox Commercial SolutionsÂ® CloroxÂ® Disinfecting Wipes	0.25	Wipe	Healthcare; Institutional; Residential
67619-37	Quaternary ammonium	Clorox HealthcareÂ® VersaSureÂ® Wipes	0.5	Wipe	Healthcare; Institutional; Residential
67619-43	Quaternary ammonium	Libertad	0.5	Wipe	Healthcare; Institutional; Residential

6836-136	Quaternary ammonium	Lonza Formulation S-18F	1	Dilutable	Healthcare; Institutional; Residential
6836-138	Quaternary Ammonium Compounds	Lonza Formulation S-38-F	1	Dilutable	Institutional; Residential
6836-139	Quaternary ammonium	Lonza Formulation R-82F	1	Dilutable	Healthcare; Institutional; Residential
6836-140	Quaternary ammonium	Lonza Formulation S-21F	1	Dilutable	Healthcare; Institutional; Residential
6836-152	Quaternary ammonium	Lonza Formulation DC-103	1	Ready-to-use	Healthcare; Institutional; Residential
6836-346	Quaternary ammonium	Lonzagard RCS-256	1	Dilutable	Healthcare; Institutional; Residential
6836-347	Quaternary ammonium	Lonzagard RCS-128	1	Dilutable	Healthcare; Institutional; Residential
6836-348	Quaternary ammonium	Lonzagard RCS-128 PLUS	1	Dilutable	Healthcare; Institutional; Residential
6836-349	Quaternary ammonium	Lonzagard RCS-256 Plus	1	Dilutable	Healthcare; Institutional; Residential
6836-361	Quaternary ammonium	Nugen MB5A-256	1	Dilutable	Healthcare; Institutional; Residential
6836-362	Quaternary ammonium	Nugen MB5A-128	1	Dilutable	Healthcare; Institutional; Residential
6836-363	Quaternary ammonium	Nugen MB5A-64	1	Dilutable	Healthcare; Institutional; Residential
6836-381	Quaternary ammonium	Lonzagard R-82G	1	Dilutable	Healthcare; Institutional; Residential
6836-73	Quaternary Ammonium Compounds	Lonza Formulation S-38	1	Dilutable	Institutional; Residential
6836-75	Quaternary ammonium	Lonza Formulation S-21	1	Dilutable	Healthcare; Institutional; Residential
6836-77	Quaternary ammonium	Lonza Formulation S-18	1	Dilutable	Healthcare; Institutional; Residential
6836-78	Quaternary ammonium	Lonza Formulation R-82	1	Dilutable	Healthcare; Institutional; Residential
70144-4	Quaternary ammonium; Ethanol (Ethyl alcohol)	Opti-cide Max Wipes	1	Wipe	Healthcare; Institutional; Residential
70144-5	Quaternary ammonium; Ethanol (Ethyl alcohol)	Opti-cide Max	1	Ready-to-use	Healthcare; Institutional; Residential
88897-1	Quaternary ammonium; Ethanol (Ethyl alcohol); Isopropanol (Isopropyl alcohol)	Panther Disinfectant Towelette	1	Wipe	Healthcare; Institutional
89833-3	Quaternary ammonium	D7 Part 1	1	Dilutable	Healthcare; Institutional; Residential
92378-2	Quaternary ammonium	Atmosphere	1	Dilutable	Healthcare; Institutional; Residential
9480-10	Quaternary ammonium; Ethanol (Ethyl alcohol); Isopropanol (Isopropyl alcohol)	Sani-Prime Germicidal Spray	1	Ready-to-use	Healthcare; Institutional
9480-11	Quaternary ammonium	BackSpray RTU	1	Ready-to-use	Healthcare; Institutional; Residential
9480-13	Quaternary ammonium	Backspin No-Rinse FCSS	1	Wipe	Healthcare; Institutional; Residential
9480-4	Quaternary ammonium; Isopropanol (Isopropyl alcohol)	Super Sani-Cloth Germicidal Disposable Wipe	1	Wipe	Healthcare; Institutional
96706-1	Quaternary ammonium; Isopropanol (Isopropyl alcohol)	MBS MedTech Germicidal* Disposable Wipes	1	Wipe	Healthcare; Institutional

Table S3: Variation in the concentration of QACs before and during Covid19 in residential dust (Zheng et al., 2020)

QACs		**Before COVID-19**			**During COVID-19**			**Change (%)**
		Min	**Max**	**Median**	**Min**	**Max**	**Median**	
BACs	C6-BAC	<MDL	0.015	0.00171	<MDL	0.084	0.004	134
	C8-BAC	0.0022	12.2	0.0496	0.0022	7.58	0.058	17
	C10-BAC	0.004	0.329	0.0213	0.0005	0.787	0.054	154
	C12-BAC	1.4	32.5	5.89	0.244	181	12.6	114
	C14-BAC	0.863	30.9	3.88	0.76	154	9.55	146
	C16-BAC	0.181	9.73	1.03	0.203	75.6	3.17	208
	C18-BAC	0.0393	6.07	0.431	0.061	34.8	1.16	169
	∑BAC	3.19	74.2	14.2	1.66	421	27.1	91
DDACs	C8-DDAC	0.056	7.33	1.1	0.0148	20.2	1.63	48
	C10-DDAC	1.09	24.1	5.53	0.0219	32.8	4.3	-22
	C12-DDAC	<MDL	0.139	0.0495	<MDL	2.91	0.047	-5
	C14-DDAC	<MDL	0.05	0.0147	0.0002	0.462	0.016	9
	C16-DDAC	0.0355	4.67	0.231	0.0031	4.24	0.374	62
	C18-DDAC	0.0809	22.1	1.71	0.0192	33.1	3.47	103
	∑DDAC	1.35	41.4	8.87	0.0595	68.9	12.3	39
ATMACs	C8-ATMAC	0.0007	0.253	0.0223	<MDL	0.507	0.057	156
	C10-ATMAC	0.0146	2.41	0.196	<MDL	6.76	0.266	36
	C12-ATMAC	0.0166	22.5	0.758	0.0281	13.1	1.25	65
	C14-ATMAC	<MDL	4.05	0.131	0.0034	2.51	0.275	110
	C16-ATMAC	0.246	14	2.2	0.0116	61.3	4.59	109
	C18-ATMAC	0.03	6.32	0.546	0.0096	9.8	0.841	54
	∑ATMAC	0.698	26.1	6.36	0.235	66.5	8.78	38
∑QAC		6.55	127	36.3	1.95	531	58.9	62

Table S4: Efficacy of QACs against different viruses

QACs	Concentration (% w/v)	Type of assay	Virus tested	Exposure Time	Viral Load reduction	effective viral load reduction (>99.9%)? (Y/N)	References
BAC	0.04	QCT	HCoV	1 min	3	N	(Sattar et al., 1989)
BAC, HCl	0.04 (pH 1.0	QCT	HCoV	1 min	>3.0	Y	
BAC, EtOH	0.04, 70	QCT	HCoV	1 min	>3.0	Y	
BAC	0.2	suspension	HCoV	10 min	0	N	(Wood and Payne, 1998)
BAC	1	suspension	SARS-CoV	5–30 min	Reduced growth; RNA still detectable by RT-PCR	Y	(Ansaldi et al., 2004)
Mikrobac Forte (BAC)	0.5	suspension	SARS-CoV	30, 60 min	≥6.13	Y	(Rabenau et al., 2005)
Kohrsolin FF (BAC)	0.5	suspension	SARS-CoV	30, 60 min	≥3.75	Y	
BAC	0.01	suspension	TGEV	5 min	≥3.0	Y	(Schmidt et al., 2005)
CG	0.008	QCT	HCoV 229E	5 min	<3.0	N	
CG, EtOH	0.008, 70	QCT	HCoV229E	5 min	≥3.0	Y	
mix of BAC/CG	0.066	QCT	HCoV 229E	10 min	4	Y	
DDAC	0.0025	suspension	CCoV	3 d	>4.0	Y	(Pratelli, 2007)
BAC	0.00175	suspension	CCoV	3 d	3	N	
BAC, EtOH	0.1, 79	suspension	MHV	30 s	≥3.0	Y	(Dellanno et al., 2009)

Reused with permission from (Schrank et al., 2020)

Table S5: Experimental conditions and % removal of different classes of QACs

Compounds	Experiment conditions	% Removal		References
		Stage 1	**Stage 2**	
BAC C10	Lab Scale: Two step sequential anaerobic-aerobic digestion experiment was conducted with real wastewater collected from a WWTP equipped with activated sludge treatment	33.9	100	(Tomei et al., 2019)
BAC C12		27.4	77.3	
BAC C14		25	79.8	
BAC C16		9.9	76.6	
BAC C18		22.7	78.4	
DADMAC C10		22	53.7	
DADMAC C12		-	-	
DADMAC C14		3.4	61.6	
DADMAC C16		26	57.2	
DADMAC C18		18.1	59.7	
ATMAC C12		-	-	
ATMAC C14		22	100	
ATMAC C16		15.7	87.2	
ATMAC C18		0.4	100	
*LAS-C10		**A/O process**	**CAST process**	

	Anaerobic-oxic (A/O) and cyclic activated sludge (CAST) treatment process	100 (autumn), 98.57(winter)	98.9(autumn) 95.13(winter)	(Zhu et al., 2018)
*LAS-C11		A/O process 100(autumn), 98.17(winter)	CAST process 99.54(autumn), 99.48(winter)	
*LAS-C12		A/O process 100(autumn), 97.90(winter)	CAST process 100(autumn), 99.65(winter)	
*LAS-C13		A/O process 100(autumn), 99.16(winter)	CAST process 100(autumn), 99.84(winter)	
BAC C12		100	100	
BAC C14		100	100	
ATMAC C12	UV degradation was conducted using low- pressure Hg lamps at 254 nm in UV/PS system with PS dosage of 75.6 µM (UV/PS)	91		(Lee et al., 2019)
BAC	Biodegradation was conducted in synthetically prepared wastewater samples at an initial concentrations of BAC 100 mg L^{-1} to maximum value of 1200 mg/L	99.3		(Fortunato et al., 2019)
BAC C12		**Bromma STP** 99.83	**RYA STP** | **ÖN STP** 99.72	(Östman et al., 2018)

	Bromma STP equipped with mechanical, chemical, and biological steps with nitrogen removal facility. It receives wastewater from 350,000 inhabitants		99.7		
BAC C14		99.14	99.14	99.2	
ATMAC C16		99.52	98.96	99.34	
DADMAC C10	Rya STP equipped with mechanical screening, primary clarifier, activated sludge treatment and nitrogen removal units serves 737,000 inhabitants	98.62	99.41	99.23	
Hexadecylpyridinium chloride (CPC)	Ön STP without any nitrogen removal units treats wastewater through activated sludge and chemical unit of 96,000 people	100	0.98	95.65	
Tetradecyltrimethylammonium (TTAB)	Adsorption of different QACs to the activated sludge obtained from a WWTP treating poultry industry wastewater	81			(Bergero and Lucchesi, 2018)
BAC C14		90			
BAC C16		98			
TTAB	Biodegradation of QACs-degrading microorganisms *Pseudomonas putida*	90			
Polydiallyldimethylammonium chloride-acrylic-acrylamide-hydroxyethyl acrylate (PDM)	Biodegradation of PDM was conducted in 5-L reactors in Activated sludge for varying concentration of PDM (100, 200, and 300 mg/L)	44.5			(Zhao et al., 2020)
	Biodegradation + Fenton Oxidation	85.5			

*Linear alkylbenzene sulfonates (LASs)

Table S6: Concentration of QACs in different types of surface water samples

Country	Type of sample	Types and concentration of QACs (μg/L)															References
		DADMAC							ATMAC				BAC				
		C10:10	C12:12	C14:14	C14:C16	C16:16	C16:C18	C18:18	C12	C14	C16	C18	C12	C14	C16	C18	
#Taiwan	river water	-	-	-	-	-	-	-					<LOD–4.2	<LOD –0.8	1.2–5.3	2.6–55	(Ding and Liao, 2000)
	river water	-	-	-	-	-	-	-	<LOD–0.66	<LOD–0.26	<LOD–0.23	<LOD–0.17	-	-	-	-	(Ding and Tsai, 2003)
#USA.	river water	-	-	-	-	-	-	-	<LOD–1.34	<LOD–2.38		2	-	-	-	-	(Ferrer and Furlong, 2001)
#Poland	water reservoir	-	-	-	-	-	-	-	-	-	-	-	<LOD–99.6	<LOD–157	<LOD–243		(Olkowska et al., 2013)
#Austria	river water (June 2004)	0.012–0.15	0.011–0.022		-	<LOD–0.05	-	<LOD–0.19	-	-	-	-	0.015–1.9	<LOQ–0.510	<LOQ–0.110	<LOD–0.094	(Uhl et al., 2005)
	river water (August 2004)	<LOD–0.120	-	-	-	<LOD–0.021	-	<LOD–0.054	-	-	-	-	<LOD–0.140	<LOD–0.076	<LOD–0.044	<LOD–0.018	
#Germany	river water	-	-	-	-	0.11	0.34	0.41	-	-	-	-	-	-	-	-	(Radke et al., 1999)
#Japan	river water 1998 mean	-	-	-	-	0.25			-	-	-	-	-	-	-	-	(Miura et al., 2008)
	river water 1999 mean	-	-	-	-	0.67			-	-	-	-	-	-	-	-	
	river water 2000 mean	-	-	-	-	0.52			-	-	-	-	-	-	-	-	
	river water 2001 mean	-	-	-	-	0.42			-	-	-	-	-	-	-	-	
	river water 2002 mean	-	-	-	-	0.54			-	-	-	-	-	-	-	-	
	river water 2003 mean	-	-	-	-	0.08			-	-	-	-	-	-	-	-	
	river water 2004 mean	-	-	-	-	0.07			-	-	-	-	-	-	-	-	
	river water 2005 mean	-	-	-	-	0.09			-	-	-	-	-	-	-	-	
	river water 2006 mean	-	-	-	-	0.05			-	-	-	-	-	-	-	-	
England	Seawater	0.12-0.27	-	-	-	-			-	-	-	-	-	-	-	-	(Bassarab et al., 2011)
France	Stormwater samples		0.1-0.3			-			-	-	-	-	-	-	-	-	(Van De Voorde et al., 2012)
	Roof runoff		6-22,593			-			-	-	-	-	-	-	-	-	
Austria	Surface water	-	-		-	-			-	-	4-19			-	-	-	(Martínez-Carballo et al., 2007)

#Reused from the open access publication (Mulder et al., 2018)

Table S7: Toxicity to QACs by different aquatic species (Reused with permission from (Zhang et al., 2015) (Di Nica et al., 2017))

QACs	Species	Test (endpoint)	Value(mg/L)
Alkyltrimethylammonium halides (ATMAC C12–16)	Daphnia magna	IC50	0.13–0.38
	Photobacterium phosphoreum	EC50	0.24–0.63
DADMAC C12	D. magna	24 h-EC50	0.37
	Rainbow trout	24 h-LC50	40.53
	C. vulgaris	96 h EC50	0.188
ATMAC C14	D. magna	24 h-EC50	0.091
	Rainbow trout	24 h-LC50	2.51
	C. vulgaris	96 h EC50	0.182
ATMAC C16	D. magna	24 h-EC50	0.058
	Rainbow trout	24 h-LC50	0.6
	C. vulgaris	96 h EC50	0.156
	C. vulgaris	96 h EC50	0.137
	C. vulgaris	96 h EC50	0.15
ATMAC C18	C. vulgaris	96 h EC50	0.11
Alkylbenzyldimethylammonium halides (BAC C12–16)	Daphnia magna	IC50	0.13–0.22
	Photobacterium phosphoreum	EC50	0.15–0.55
Benzalkonium chlorides (BAC)	P. subcapitata	72-h EC50	0.041
	D. magna	48-h EC50	0.041
	B. calyciflorus	48-h EC50	0.13
	T. thermophila	24-h EC50	2.94
BAC C12	C. vulgaris	96 h EC50	0.203
BAC C14	C. vulgaris	96 h EC50	0.174
BAC C16	C. vulgaris	96 h EC50	0.161
DADMAC C14	P. subcapitata	72-h EC50	0.021
	D. magna	48-h EC50	0.023

	B. calyciflorus	48-h EC50	0.025
	T. thermophila	24-h EC50	4.43
BAC C12		IC10	0.07[0.05; 0.08]
		IC50	0.17[0.14; 0.2]
DADMAC C10		IC10	0.08[0.04; 0.11]
		IC50	0.4[0.33; 0.46]
ATMAC C14	*Aliivibrio fischeri*	IC10	0.19 [0.11; 0.28]
		IC50	0.74 [0.63; 0.84]
ATMAC C16		IC10	0.47[0.37; 0.56]
		IC50	0.99[0.92; 1.06]
ATMAC C10		IC10	0.91[0.62; 1.21]
		IC50	2.83[2.11; 3.55]

Table S8: Mixture toxicity of QACs *Vibrio fischeri* species (Di Nica et al., 2017)

QACs	Test	Value (mg/L)
BAC C12+DADMAC C10	IC10	0.10 [0.07−0.12]
	IC50	0.33 [0.30−0.37]
BAC C12+ATMAC C16	IC10	0.41 [0.36−0.46]
	IC50	0.95 [0.90−1.00]
BAC C12+C14TAB	IC10	0.11 [0.09–0.14]
	IC50	0.36 [0.33−0.38]
BAC C12+C10TAB	IC10	0.10 [0.04−0.15]
	IC50	0.98 [0.80−1.16]
DADMAC C10+ATMAC-16	IC10	1.13 [1.05−1.20]
	IC50	1.58 [1.51−1.64]
DADMACC10+C14TAB	IC10	0.35 [0.27−0.42]
	IC50	1.10 [1.02−1.18]
DADMAC C10+C10TAB	IC10	1.108 [0.79–1.43]
	IC50	4.37[3.87–4.87]
ATMAC C16+C14TAB	IC10	0.33 [0.22−0.44]
	IC50	0.81 [0.71−0.92]
ATMAC C16+C10TAB	IC10	0.87 [0.65−1.09]
	IC50	2.42 [2.20–2.63]
C14TAB+C10TAB	IC10	0.38 [0.28−0.49]
	IC50	2.58 [2.37–2.79]
BAC C12+DADMAC C10+ATMAC C16+C14TAB+C10TAB	IC10	0.68 [0.54−0.82]
	IC50	1.89 [1.74–2.05]

Table S9. Effect of QAC exposure on BAC and antibiotic MICs in different bacterial species

Species	Strain(s)	MIC Increase (BAC)	Antibiotic(s)	Increase in MIC for antibiotics	Genes/proteins associated with QAC adaptation	References
Escherichia coli	ATCC 25922 and 9 avian and porcine strains	2.6 fold	Florfenicol	7 fold	Not tested	(Soumet et al., 2012)
			Cefotaxime	6.3 fold		
			Chloramphenicol	6.1 fold		
			Ceftazidime	4.8 fold		
			Nalidixic acid	4.4 fold		
			Ampicillin	4.3 fold		
			Tetracycline	4.2 fold		
			Ciprofloxacin	3.8 fold		
			Sulfamethoxazole	3.7 fold		
			Trimethoprim	3.3 fold		
	ATCC 11775	6 fold	Ampicillin	5 fold	*mipA*, MltA, flagellin protein encoded in *Salmonella* spp.	(Langsrud et al., 2004)
			Chloramphenicol	24 fold		
			Erythromycin	1.28 fold		
			Gentamicin	2 fold		
			Kanamycin	2 fold		
			Nalidixic acid	3.75 fold		
			Norfloxacin	2.6 fold		
			Penicillin	1.6 fold		
			Tetracycline	4 fold		

	DSM 682	6 fold	Ampicillin	4 fold		(Langsrud et al., 2004)
			Chloramphenicol	12 fold		
			Erythromycin	1.6 fold		
			Gentamicin	2 fold		
			Kanamycin	–		
			Nalidixic acid	7.5 fold		
			Norfloxacin	1.5 fold		
			Penicillin	2 fold		
			Tetracycline	1.5 fold		
	ATCC 47076	6–7 fold	Chloramphenicol	116 fold	*sox*S, *mar*A, *nfn*B, *ybj*C, *fld*A, *zwf*, *gcd*, *gap*A, *yee*F, *yhi*Y, *acr*A, *acr*B, *tol*C, NfnB, Ssb, MnSOD, MdaB, FumC, WrbA, Dps, RpsF, OmpA,F,T,C, FecA	(Bore et al., 2007)
			Florfenicol	2–8 fold		
			Ciprofloxacin	4.16 fold		
			Nalidixic acid	4–8 fold		
			Ampicillin	2 fold		
			Cefotaxime	2–8.3 fold		
Klebsiella oxytoca	Strain from organic foods	3 fold	Ampicillin	No cross-tolerance to all antibiotics tested	acrB, sugE, n orC, qacE, qacH,	Gadea et al., 2017
			Cefotaxime			
			Ciprofloxacin			

			Imipenem Ceftazidime Tetracycline Trimethoprim-Sulfamethoxazol Sulfamethoxazol Nalidixic acid		aac(6_)-Ie-aph(2_)-Ia, aph(2_)-Ic, ant(4_)-Ia, lsa, mrsA/B, ereA, ermB, cat	
Chryseobacterium spp.	Strain from organic foods	20 fold	Ampicillin			
Enterobacter cloacae	Two strains from organic foods	12–30 fold	Cefotaxime Ampicillin			
Enterobacter ludwigii	Strain from organic foods	30 fold	Cefotaxime			
Staphylococcus aureus	Five strains	2 fold	Oxacillin	4–32 fold	Not tested	(Akimitsu et al., 1999)
			Cloxacillin	0–1024 fold		
			Moxalactam	4–16 fold		
			Flomoxef	2–16 fold		
			Cefmetazole	4–16 fold		
			Cefazolin	0–2 fold		
			Cephalothin	2 fold		
			Ampicillin	0–2 fold		
			Chloramphenicol	–		
			Ofloxacin	2–4 fold		
			Tetracycline	–		

			Kanamycin	0–2 fold		
Listeria monocytogenes	Twenty-five strains from cooked meat, raw vegetables, and food production environments	0.5–5 fold	Ampicillin	–	*mdr*L	Yu et al., 2018
			Cefotaxime	2–8 fold		
			Cephalothin	2–8 fold		
			Chloramphenicol	–		
			Ciprofloxacin	2–4 fold		
			Erythromycin	–		
			Kanamycin	–		
			Tetracycline	–		

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