

Substandard and falsified antibiotics: neglected drivers of antimicrobial resistance?

Supplementary file 6. Main characteristics of prevalence surveys of antibiotic quality in order of date of publication

Reference	Journal/Publisher	Sampling method	Countries	Active Pharmaceutical Ingredients (API) Sampled	Data points	Failed samples n/N (%)
Iwuagwu, 1992[1]	International Journal of Pharmacy Practice	Convenience	Nigeria	Ampicillin	1	3/13 (23.1 %)
Muritu, 1994[2]	Journal of Pharmaceutical and Biomedical Analysis	Convenience	Kenya	Tetracycline	1	0/50 (0 %)
Okeke, 1995[3]	International Journal of Antimicrobial Agents	Convenience	Nigeria	Tetracycline	1	6/7 (85.7 %)
Taylor, 1995[4]	The Lancet	Convenience	Nigeria	Amoxicillin	1	5/9 (55.6 %)
Reseau Medicament et Developpement, 1995[5]	The World Health Organization	Convenience	Cameroon, Chad, Madagascar	Amoxicillin, Ampicillin, Chloramphenicol, Metronidazole, Penicillin-unspecified, Sulfamethoxazole-Trimethoprim, Tetracycline	21	47/180 (26.1 %)
Nazerali, 1996[6]	WHO Action Programme on Essential Drugs	Convenience	Zimbabwe	Amoxicillin, Ampicillin, Benzylpenicillin (penicillin G), Doxycycline, Phenoxymethylpenicillin (penicillin V), Tetracycline	13	9/299 (3.0%)
Gimenez, 1997[7]	Medecine et Maladies Infectieuses	Convenience	Cambodia	Amoxicillin, Chloramphenicol, Metronidazole, Sulfamethoxazole-Trimethoprim, Tetracycline	5	23/82 (28.0 %)
Shakoor, 1997[8]	Tropical Medicine and International Health	Convenience	Nigeria, Thailand	Amoxicillin, Ampicillin-Cloxacillin, Sulfamethoxazole-Trimethoprim, Tetracycline	12	21/59 (35.6 %)
Kibwage, 1998[9]	East and Central African Journal of Pharmaceutical Sciences	Convenience	Kenya	Sulfamethoxazole-Trimethoprim	2	14/37 (37.8 %)
Nazerali, 1998[10]	The British Medical Journal (BMJ)	Convenience	Zimbabwe	Ampicillin	1	2/10 (20.0 %)
Wondemagegnehu, 1999[11]	The World Health Organization	Random	Myanmar, Viet Nam	Amoxicillin, Ampicillin, Chloramphenicol, Metronidazole, Sulfamethoxazole-Trimethoprim, Tetracycline	15	46/313 (14.7 %)
Kamau, 2001[12]	East and Central African Journal of Pharmaceutical Sciences	Convenience	Kenya	Ampicillin	1	11/45 (24.4 %)
Taylor, 2001[13]	The Lancet	Random	Nigeria	Amoxicillin, Ampicillin, Ampicillin-Cloxacillin, Benzylpenicillin (penicillin G), Cloxacillin, Doxycycline, Metronidazole, Streptomycin, Sulfamethoxazole-Trimethoprim	9	136/273 (49.8 %)
Kolawole, 2002[14]	Nigerian Journal of Pharmaceutical Science	Convenience	Nigeria	Ampicillin	1	14/31 (45.2%)

Prazuck, 2002[15]	Sexually Transmitted Diseases	Combination *	Myanmar	Benzylpenicillin (penicillin G), Ceftriaxone, Chlortetracycline, Ciprofloxacin, Doxycycline, Erythromycin, Sulfamethoxazole-Trimethoprim	7	7/19 (36.8 %)
Sow, 2002[16]	International Journal of Infectious Disease	Convenience	Senegal	Ampicillin, Oxytetracycline, Phenoxymethylpenicillin (penicillin V), Sulfamethoxazole-Trimethoprim	4	27/47 (57.4 %)
Ahmed, 2003[17]	Journal of Biological Sciences	Random	Bangladesh	Metronidazole	1	9/40 (22.5%)
Kamau, 2003[18]	East and Central African Journal of Pharmaceutical Sciences	Convenience	Kenya	Amoxicillin	1	4/57 (7.0 %)
Risha, 2003[19]	Ghent University Faculty of Pharmaceutical Sciences	Convenience	Tanzania	Amoxicillin, Ciprofloxacin, Metronidazole, Sulfamethoxazole-Trimethoprim	4	2/25 (8.0 %)
Basco, 2004[20]	The American Journal of Tropical Medicine and Hygiene	Convenience	Cameroon	Sulfamethoxazole-Trimethoprim	1	0/1 (0.0 %)
Kayumba, 2004[21]	Journal of Clinical Pharmacy and Therapeutics	Convenience	Rwanda, Tanzania	Amoxicillin, metronidazole, sulfamethoxazole-trimethoprim	6	4/25 (16.0%)
Syhakhang, 2004[22]	Pharmaceutical World Science	Random	Lao People's Democratic Republic	Ampicillin, Tetracycline	4	124/356 (34.8 %)
Legris, 2005[23]	Universite Henri Poincare – Nancy I	Random	Ivory Coast	Ampicillin, amoxicillin, metronidazole, sulfamethoxazole-trimethoprim	4	33/65 (50.8%)
Phanouvong, 2005[24]	United States Pharmacopeia (USP)	Convenience	Cambodia, Lao People's Democratic Republic, Thailand	Tetracycline	3	3/168 (1.8 %)
Weir, 2005[25]	British Journal of Ophthalmology	Convenience	India	Ciprofloxacin	1	30/30 (100.0 %)
Lon, 2006[26]	Transactions of the Royal Society of Tropical Medicine and Hygiene	Convenience	Cambodia	Tetracycline	1	34/128 (26.6 %)
Obodozie, 2006[27]	Journal of Clinical Pharmacy and Therapeutics	Convenience	Nigeria	Ampicillin-Cloxacillin	2	23/40 (57.5 %)
Vijaykadga, 2006[28]	The Southeast Asian Journal of Tropical Medicine and Public Health	Convenience	Thailand	Tetracycline	1	0/19 (0.0 %)
Okoro, 2007[29]	Research Journal of Pharmacology	Convenience	Nigeria	Ampicillin	1	5/10 (50.0 %)
Sheth, 2007[30]	South East Asian FIP-WHO Forum of Pharmaceutical Associations	Convenience	India	Amikacin, Amoxicillin, Amoxicillin-Clavulanic acid, Ampicillin-Cloxacillin, Cefadroxil, Cefalexin, Cefotaxime, Ceftazidime, Cefuroxime, Ciprofloxacin, Erythromycin, Gentamicin, Roxithromycin	14	8/195 (4.1%)

Camara, 2008[31]	Ministere de l'Education Nationale, Universite de Bamako	Convenience	Mali	Erythromycin, gentamicin, tetracycline	3	6/30 (20.0%)
Kyriacos, 2008[32]	Journal of Clinical Pharmacy and Therapeutics	Random	Egypt, Jordan, Lebanon, Saudi Arabia	Amoxicillin	5	14/32 (43.8 %)
Meos, 2008[33]	Drug Development Research	Convenience	Estonia, Russian Federation	Doxycycline	2	2/8 (25.0 %)
Pouillot, 2008[34]	Bulletin de la Societe de Pathologie exotique	Convenience	Cameroon, Niger	Amoxicillin, Ampicillin, Chloramphenicol, Gentamicin, Metronidazole, Norfloxacin, Oxacillin, Sulfamethoxazole-Trimethoprim, Tetracycline	11	45/102 (44.1 %)
Bate, 2009[35]	PLoS ONE	Convenience	India	Ciprofloxacin, Erythromycin	4	17/220 (7.8 %)
Central Drug Standard Control Organisation, 2009[36]	Central Drugs Standard Control Organisation CDSCO, India	Convenience	India	Amoxicillin, Ciprofloxacin, Sulfamethoxazole-Trimethoprim	3	0/165 (0.0 %)
Diop, 2009[37]	Medecine Tropicale	Unknown	Senegal	Amoxicillin, Ampicillin, Ciprofloxacin, Erythromycin, Phenoxymethylpenicillin (penicillin V)	5	10/34 (29.4 %)
Mak, 2009[38]	Universite de la mediterranee aix-marseille II	Random	Cambodia	Amoxicillin	6	3/39 (7.7%)
Obaid, 2009[39]	Pakistan Journal of Pharmaceutical Sciences	Convenience	Pakistan	Ceftriaxone	1	16/96 (16.7 %)
Zaheer, 2009[40]	Pakistan Journal of Scientific and Industrial Research	Unknown	Pakistan	Ciprofloxacin, Levofloxacin, Ofloxacin	3	1/12 (8.3 %)
Hadi, 2010[41]	BMC Infectious Diseases	Convenience	Indonesia	Amoxicillin, Chloramphenicol, Ciprofloxacin, Sulfamethoxazole-Trimethoprim, Tetracycline	5	19/104 (18.3 %)
Khan, 2010[42]	Tropical Medicine and International Health	Random	Cambodia	Metronidazole	1	1/79 (1.3 %)
Bate, 2011[43]	Journal of Health Economics	Convenience	Democratic Republic of the Congo	Ciprofloxacin, Erythromycin	2	34/304 (11.2 %)
Haider, 2011[44]	Journal of Applied Pharmaceutical Science	Convenience	Bangladesh	Amoxicillin	1	3/10 (30.0 %)
Idries, 2011[45]	University of Khartoum	Convenience	Sudan	Amoxicillin, Ceftriaxone, Ciprofloxacin, Metronidazole	4	1/11 (9.1 %)
Kamuhabwa, 2011[46]	International Journal of Pharmaceutical Research	Convenience	Tanzania	Sulfamethoxazole-Trimethoprim	1	4/17 (23.5 %)
Nair, 2011[47]	Journal of Pharmaceutical Sciences	Random	Papua New Guinea	Amoxicillin	1	8/8 (100.0 %)
Seear, 2011[48]	Journal of Clinical Pharmacy and Therapeutics	Convenience	India	Ciprofloxacin	1	9/100 (9.0 %)

World Health Organization, 2011[49]	The World Health Organization	Convenience	Armenia, Azerbaijan, Belarus, Kazakhstan, Ukraine, Uzbekistan	Ofloxacin	6	6/50 (12.0 %)
Yusuf, 2011[50]	Management Sciences for Health		Afghanistan	Amoxicillin, Ceftriaxone, Ciprofloxacin, Gentamicin	4	5/125 (4.0%)
Karlage, 2012[51]	Drug Development and Industrial Pharmacy	Random	Mexico, United States	Amoxicillin, Ampicillin, Ciprofloxacin, Sulfamethoxazole-Trimethoprim	6	7/11 (63.6 %)
Patel, 2012[52]	BMC Health Services Research	Convenience	South Africa	Amoxicillin	3	0/46 (0 %)
Akinkunmi, 2013[53]	Annals of Tropical Medicine and Parasitology	Convenience	Nigeria	Chloramphenicol, Gentamicin	2	0/2 (0 %)
Khan, 2013[54]	BMC Pharmacology and Toxicology	Random	Cambodia	Amoxicillin-Clavulanic acid	1	26/59 (44.1 %)
Khojah, 2013[55]	Pharmacology & Pharmacy	Lot Quality Assurance Sampling	Saudi Arabia	Amoxicillin	1	9/83 (10.8%)
Phanouvong, 2013a[56]	The Southeast Asian Journal of Tropical Medicine and Public Health	Random	Thailand	Tetracycline	1	1/242 (0.4 %)
Phanouvong, 2013b** [57]	The Southeast Asian Journal of Tropical Medicine and Public Health	Random	Cambodia	Tetracycline	1	unknown (5.0%)
Ramachandran, 2013[58]	Tropical Medicine and International Health	Convenience	India	Levofloxacin	1	9/67 (13.4 %)
Food and Drug Quality Control Center (Lao PDR), 2014[59]	Ministry of Health, Lao PDR	Random	Lao PDR	Amoxicillin, Cloxacillin	11	0/15 (0%)
Hetzel, 2014[60]	PLoS ONE	Random	Papua New Guinea	Amoxicillin, Doxycycline	2	1/59 (1.7 %)
Khuluza, 2014[61]	Malawi Medical Journal	Random	Malawi	Sulfamethoxazole-Trimethoprim	1	5/11 (45.4 %)
Khurelbat, 2014[62]	SpringerPlus	Random	Mongolia	Amoxicillin, Ampicillin, Doxycycline, Metronidazole, Sulfamethoxazole-Trimethoprim	10	55/699 (7.8 %)
Nagaraj, 2014[63]	Journal of Research in Pharmacy Practice	Convenience	India	Amoxicillin, Cefuroxime, Ofloxacin	3	0/10 (0.0 %)
Yoshida, 2014[64]	BMC Pharmacology and Toxicology	Random	Cambodia	Cefixime, Clarithromycin, Sulfamethoxazole-Trimethoprim	3	32/190 (16.8 %)

Bate, 2015[65]	Journal of Economics & Management Strategy	Convenience	Angola, Brazil, China, Democratic Republic of the Congo, Egypt, Ethiopia, Ghana, India, Kenya, Mozambique, Nigeria, Russia, Rwanda, Tanzania, Thailand, Turkey, Uganda, Zambia	Ciprofloxacin	1	142/1437 (9.9 %)
Boadu, 2015[66]	Medicinal Chemistry	Convenience	Ghana	Amoxicillin, Cloxacillin, Flucloxacillin	3	23/54 (42.6 %)
Fadeyi, 2015[67]	The American Journal of Tropical Medicine and Hygiene	Convenience	Ghana, Nigeria, United Kingdom	Amoxicillin, Sulfamethoxazole-Trimethoprim	6	15/35 (42.8 %)
Tshilumba, 2015[68]	Pan African Medical Journal	Convenience	Democratic Republic of the Congo	Amoxicillin, Ampicillin, Ciprofloxacin, Metronidazole	4	14/47 (29.8 %)
Wang, 2015[69]	Journal of Clinical Pharmacy and Therapeutics	Convenience	China, Ethiopia, Lao People's Democratic Republic, Mexico, Nigeria, South Africa, Thailand, United States	Sulfamethoxazole-Trimethoprim	10	2/42 (4.8 %)
World Health Organization, 2015[70]	The World Health Organization	Convenience	Burkina Faso, Kenya, Madagascar, Nepal, Nigeria, Tajikistan, Tanzania, Uganda, Viet Nam, Zimbabwe	Amoxicillin, Ampicillin, Ceftriaxone, Gentamicin, Procaine benzylpenicillin (penicillin G)	49	23/106 (21.7 %)

Kaale, 2016[71]	PLoS ONE	Random	Tanzania	Amoxicillin, Sulfamethoxazole-Trimethoprim	2	0/124 (0 %)
Khan, 2016[72]	International Journal of Pharmacy and Pharmaceutical Sciences	Convenience	India	Amoxicillin	1	13/46 (28.3 %)
Nga, 2016[73]	International Journal of Innovation and Applied Studies	Random	Cameroon	Sulfamethoxazole-Trimethoprim	3	27/37 (73 %)
Osei-Safo, 2016[74]	International Journal of Pharmaceutical Sciences and Research	Convenience	Ghana, Nigeria	Azithromycin, Clindamycin, Erythromycin	6	36/45 (80.0 %)
Tshilumba, 2016[75]	International Journal of Pharmacy and Pharmaceutical Sciences	Random	Democratic Republic of the Congo	Metronidazole	1	4/15 (26.7 %)
Wafula, 2016[76]	Drugs - Real World Outcomes	Convenience	Kenya	Amoxicillin, Amoxicillin-Clavulanic acid, Erythromycin, Metronidazole, Sulfamethoxazole-Trimethoprim	5	2/21 (9.5 %)
Alhedethe, 2017[77]	Archives in Chemical Research	Convenience	Sierra Leone	Amoxicillin	1	0/9 (0.0%)
Bate, 2017[78]	Safe Medicines Coalition	Convenience	The Internet	Ciprofloxacin	1	11/244 (4.5 %)
Islam, 2017[79]	Journal of International Health	Convenience	Cambodia	Ceftriaxone, Cefuroxime, Ciprofloxacin, Clarithromycin, Gentamicin, Levofloxacin, Nalidixic acid, Ofloxacin, Phenoxymethylpenicillin (penicillin V), Roxithromycin, Sulfamethoxazole-Trimethoprim	11	115/590 (19.5 %)
Islam, 2017[80]	Graduate School of Medical Science & Technology Kanazawa University	Convenience	Myanmar	Ceftriaxone, Cefuroxime, Gentamicin	3	37/167 (22.2 %)
Khuluza, 2017[81]	The American Journal of Tropical Medicine and Hygiene	Random	Malawi	Amoxicillin, Amoxicillin-Clavulanic acid, Cefuroxime, Chloramphenicol, Ciprofloxacin, Phenoxymethylpenicillin (penicillin V)	6	3/23 (13.0 %)
Nabirova, 2017[82]	The International Journal of Tuberculosis and Lung Disease	Random	Kazakhstan	Amoxicillin-Clavulanic acid, Levofloxacin, Moxifloxacin, Ofloxacin	4	1/8 (12.5 %)
Ononna, 2017[83]	Bangladesh Medical Research Council Bulletin	Random	Bangladesh	Amoxicillin, Azithromycin, Cefixime, Cephadrine, Ciprofloxacin, Metronidazole	6	36/39 (92.3 %)
Petersen, 2017[84]	PLoS ONE	Convenience	Democratic Republic of the Congo	Amoxicillin, Amoxicillin-Clavulanic acid, Ampicillin, Ampicillin-Cloxacillin, Azithromycin, Cefalexin, Cefixime, Ceftriaxone, Cefuroxime, Chloramphenicol, Ciprofloxacin, Clarithromycin, Cloxacillin, Doxycycline, Erythromycin, Levofloxacin, Metronidazole, Moxifloxacin, Ofloxacin, Phenoxymethylpenicillin (penicillin V), Sulfamethoxazole, Sulfamethoxazole-Trimethoprim, Tetracycline	23	5/426 (1.2 %)

Bate, 2018[85]	The B.E. Journal of Economic Analysis & Policy	Convenience	Argentina, Bolivia, Brazil, Ecuador, Guatemala, Honduras, Paraguay, Peru, Uruguay, Venezuela	Ciprofloxacin	10	48/687 (7.0 %)
Chikowe, 2018[86]	The American Journal of Tropical Medicine and Hygiene	Convenience	Malawi	Amoxicillin	1	0/42 (0.0 %)
Ernest, 2018[87]	International Journal of Recent Innovations in Academic Research	Convenience	Cameroon	Metronidazole	3	2/10 (20.0%)
Frimpong, 2018[88]	Journal of Tropical Medicine	Random	Ghana	Amoxicillin, Cefuroxime, Ciprofloxacin, Flucloxacillin, Metronidazole, Sulfamethoxazole-Trimethoprim	6	21/29 (72.4 %)
Joda, 2018[89]	Ife Journal of Science	Random	Nigeria	Ciprofloxacin	1	4/16 (25.0 %)
Lehmann, 2018a[90]	Journal of Pharmaceutical Sciences	Random	South Africa	Amoxicillin, Amoxicillin-Clavulanic acid	2	25/138 (18.1 %)
Lehmann, 2018b[91]	Journal of Pharmacy and Pharmacology	Convenience	Germany, South Africa	Amoxicillin-Clavulanic acid	2	0/2 (0.0 %)
Nga, 2018[92]	Health Sciences and Diseases	Random	Cameroon	Sulfamethoxazole-trimethoprim	2	21/81 (25.9%)
Schafermann, 2018[93]	PLoS ONE	Convenience	Togo	Amoxicillin, Amoxicillin-Clavulanic acid, Ciprofloxacin, Doxycycline, Metronidazole, Phenoxymethylpenicillin (penicillin V), Sulfamethoxazole-Trimethoprim	25	6/64 (9.4 %)
Schiavetti, 2018[94]	The American Journal of Tropical Medicine and Hygiene	Random	Democratic Republic of the Congo	Amoxicillin	1	9/80 (11.2 %)
Tshilombo, 2018[95]	American Journal of Analytical Chemistry	Convenience	Democratic Republic of the Congo	Amoxicillin, Amoxicillin-Clavulanic acid	2	55/200 (27.5%)
Lawal, 2019[96]	Asian Journal of Pharmaceutical Research and Development	Convenience	Nigeria	Ampicillin-Cloxacillin, Amoxicillin, Amoxicillin-Clavulanic acid, Ciprofloxacin, Metronidazole, Sulfamethoxazole-Trimethoprim	6	43/112 (38.4%)
Myers, 2019[97]	Analytical Methods	Convenience	Kenya	Amoxicillin, Amoxicillin-Clavulanic acid, Ampicillin	3	46/189 (24.3 %)

Scrimgeour, 2019[98]	Journal of Pharmacy Practice and Research	Convenience	Papua New Guinea, Solomon Islands, Vanuatu	Amoxicillin, Ampicillin, Benzylpenicillin (penicillin G), Ceftriaxone, Cloxacillin, Doxycycline, Erythromycin, Flucloxacillin, Metronidazole, Phenoxymethylpenicillin (penicillin V), Sulfamethoxazole-Trimethoprim	11	6/33 (18.2 %)
Taberner, 2019[99]	Journal of Antimicrobial Chemotherapy	Random	Lao People's Democratic Republic	Amoxicillin, Ampicillin, Ceftriaxone, Ciprofloxacin, Doxycycline, Ofloxacin, Sulfamethoxazole-Trimethoprim, Tetracycline	8	129/905 (14.3%)
Bekoe, 2020[100]	Tropical Medicine and International Health	Convenience	Ghana	Ampicillin, Amoxicillin, Amoxicillin-Clavulanic acid, Benzylpenicillin, Cefuroxime, Ceftriaxone, Ciprofloxacin, Erythromycin, Gentamicin, Metronidazole, Phenoxymethylpenicillin, Sulfamethoxazole-Trimethoprim, Tetracycline	13	231/342 (67.5%)
Hand, 2020[101]	Pharmacology Research and Perspectives	Unknown	Unknown	Benzathine Benzylpenicillin	1	0/35 (0.0%)
Husaini, 2020[102]	PLoS ONE	Random	Belize	Amoxicillin, Ciprofloxacin, Sulfamethoxazole-Trimethoprim	3	12/17 (70.6%)
Jean-Baptiste, 2020[103]	MDPI	Random	Haiti	Amoxicillin, Amoxicillin-Clavulanic acid, Azithromycin, Ciprofloxacin, Clarithromycin, Cloxacillin, Erythromycin, Metronidazole, Sulfamethoxazole-Trimethoprim, Tetracycline	10	45/180 (25.0%)
Khurelbat, 2020[104]	BMC Public Health	Random	Mongolia	Amoxicillin, Ciprofloxacin, Metronidazole	3	47/354 (13.3%)
Koech, 2020[105]	Hindawi BioMed Research International	Convenience	Kenya	Amoxicillin, Amoxicillin-Clavulanic acid	2	4/53 (7.6%)
Sakuda, 2020[106]	Pharmacy (MDPI)	Unknown	Myanmar	Ciprofloxacin, Levofloxacin	2	20/86 (23.3%)
Schafermann, 2020[107]	The Journal of Tropical Medicine and Hygiene	Random	Cameroon, Democratic Republic of the Congo	Amoxicillin, Amoxicillin-Clavulanic acid, Ciprofloxacin, Doxycycline, Metronidazole, Phenoxymethylpenicillin, Sulfamethoxazole-Trimethoprim	14	45/348 (12.9%)
* Combination of convenience and randomized						
** Number of samples unknown						

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