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Global Strategies to Combat Antimicrobial Resistance: A One Health Perspective

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Abstract

Background: Antimicrobial resistance (AMR) is a global health challenge that has escalated due to the inappropriate use of antimicrobials in humans, animals, and the environment. Developing and implementing strategies to reduce and combat AMR is critical. **Purpose:** This study aimed to highlight some global strategies that can be implemented to address AMR using a One Health approach. **Methods:** This study employed a narrative review design that included studies published from January 2002 to July 2023. The study searched for literature on AMR and antimicrobial stewardship (AMS) in PubMed and Google Scholar using the 2020 PRISMA guidelines. **Results:** This study reveals that AMR remains a significant global public health problem. Its severity has been markedly exacerbated by inappropriate use of antimicrobials in humans, animals, and the broader ecological environment. Several strategies have been developed to address AMR, including the Global Action Plan (GAP), National Action Plans (NAPs), AMS programs, and implementation of the AWaRe classification of antimicrobials. These strategies also involve strengthening surveillance of antimicrobial consumption and resistance, encouraging the development of new antimicrobials, and enhancing regulations around antimicrobial prescribing, dispensing, and usage. Additional measures include promoting global partnerships, combating substandard and falsified antimicrobials, advocating for vaccinations, sanitation, hygiene and biosecurity, as well as exploring alternatives to antimicrobials. However, the implementation of these strategies faces various challenges. These challenges include low awareness and knowledge of AMR, a shortage of human resources and capacity building for AMR and AMS, in adequate funding for AMR and AMS initiatives, limited laboratory capacities for surveillance, behavioural change issues, and ineffective leadership and multidisciplinary teams. **Conclusion:** In conclusion, this study established that AMR is prevalent among humans, animals, and the environment. Successfully addressing AMR calls for a collaborative, multifaceted One Health approach. Despite this, some gaps remain effectively implementing strategies currently recommended to combat AMR. As a result, it is essential to reinforce the strategies that are deployed to counter AMR across the human, animal, and environmental sectors.

Keywords

Antimicrobial Resistance, Antimicrobial Stewardship, AWaRe Classification, One Health Approach, One Health Perspective, Strategies, Surveillance

1. Introduction

Antimicrobial resistance (AMR) is a public health problem affecting humans, animals, and the environment [1] [2] [3] [4] [5]. This phenomenon occurs when microorganisms resist the lethal effects of antimicrobials [6] [7]. The consequences of AMR include difficulty or impossibility in treating infections and increased morbidity and mortality [8] [9] [10]. If this problem remains unaddressed, then annual deaths due to AMR will be 10 million by the year 2050 [9] [10] [11] [12]. Additionally, it leads to a negative impact on medical costs and the global economy [13] [14] [15] [16]. Furthermore, drug-resistant infections can be difficult, and sometimes impossible to treat [17] [18]. These negative impacts are worsened by the emergence of multidrug-resistant (MDR) pathogens [10] [19] [20] [21] [22]. Due to these global consequences, AMR is now termed a pandemic [23]-[32] and is among the top 10 threats to global public health [33] [34] [35].

It is noted that increases in AMR are driven by a combination of microorganisms being exposed to antimicrobials and natural resistance [36] [37] [38] [39]. Additionally, the drivers of AMR include the overuse and misuse of antimicrobials in humans, animals, and the environment [40]-[49]. These inappropriate practices were also noted during the coronavirus pandemic (COVID-19) pandemic [50]-[57]. Consequently, antimicrobial-resistant organisms can be transmitted across animals and from animals to humans [40] [58] [59] [60] [61], even during animal transportation [62]. This has public health consequences for animals and humans [49].

The increased burden of AMR has necessitated the development and implementation of strategies to combat this problem globally [24] [63]-[71]. In this paper, we have proposed some strategies that are recommended to address AMR. Globally, the Global Action Plan (GAP) on AMR was developed to address AMR [72]. Additionally, countries across the globe were urged to develop and implement the National Action Plans (NAPs) on AMR to address the problem of antimicrobial-resistant infections [72]. In doing so, these efforts contribute to antimicrobial stewardship (AMS) programmes that are well-coordinated and promote the rational use of antimicrobials and reduce the occurrence of AMR in humans, animals, and the environment [73]. Subsequently, surveillance systems are critical in monitoring AMR across humans, animals, and the environment [74] [75]. Therefore, tackling this problem requires a collaborative multidisciplinary approach involving professionals from human, animal, and environmental health [76] [77] [78]. A strengthened collaborative approach is recommended to promote the rational use of antimicrobials and reduce AMR [79]-[84]. This multifaceted approach to addressing AMR is referred to as a One Health approach [85] [86] [87]. This paper highlights the global strategies and some challenges experienced in combating AMR.

2. Materials and Methods

This study utilised a narrative review design, and a literature search was performed using PubMed and Google Scholar databases. We used Boelean operators using key terms "antimicrobial resistance", "antimicrobials", "antibiotics", "animals", "awareness", "environment", "humans", "One Health", "antimicrobial stewardship", "strategies", collaboration", "AWaRe", "drug discovery", "surveillance", "alternatives", "challenges", "drivers", AND "combating antimicrobial resistance". This paper included all publications that were published between January 2002 and July 2023. The paper also included publications that were only published in the English language. All the publications in this paper were included following the 2020 PRISMA guidelines [88]. Abstracts and articles not written in English were excluded from the study. Eight authors independently verified that the selected studies met the inclusion criteria in a blinded manner while any discordances were resolved by the principal author (SM).

3. Global Strategies to Combat Antimicrobial Resistance (AMR)

3.1. Global Action Plan (GAP) on AMR

The GAP on AMR was established in May 2015 during the World Health Assembly by the WHO in collaboration with the Food and Agriculture Organization of the United Nations (FAO) and the World Organization for Animal Health (OIE) to address AMR in a "One Health" approach [72]. At this meeting, the leaders agreed and committed to their countries to develop multisectoral national action plans (NAPs) on AMR [72]. Subsequently, countries committed to implementing the NAPs once developed and helped respond to AMR. The GAP on AMR focuses on five (5) objectives to tackle AMR, and these include: 1) to improve the awareness and understanding of AMR through effective communication, education and training; 2) to strengthen the knowledge and evidence base through surveillance and research; 3) to reduce the incidence of infection through effective sanitation, hygiene and infection prevention measures; 4) to optimise the use of antimicrobial medicines in human and animal health; and 5) to develop the economic case for sustainable investment that takes account of the needs of all countries and to increase investment in new medicines, diagnostic tools, vaccines and other interventions [72]. Therefore, there is a need for global collaborations among stakeholders involved in human health, animal health, agriculture, and the environment to monitor AMR, undertake more research, and reduce the spread of AMR [79]. These objectives indicate the need for addressing AMR using a "One Health" approach involving AMR in humans, animals, agriculture, and the environment [72].

3.2. National Action Plan (NAP) on AMR

The NAPs on AMR have been developed by many countries across the globe to address AMR in line with the GAP on AMR [72] [89] [90]. These NAPs have been developed based on the objectives set by the GAP on AMR and are used by countries to monitor AMR using a "One Health" approach [91]. With the GAP on AMR having five (5) objectives, most NAPs on AMR have been developed focusing on the five objectives indicated in the GAP on AMR above.

Some countries developed their NAPs on AMR in line with the GAP on AMR and addressed AMR using a One Health approach [89] [90] [92] [93] [94] [95]. Tentatively, countries that have developed and implemented their NAPs must conduct evaluations to monitor their performance and effectiveness in curbing AMR [93]. So far, countries that have effectively implemented their NAPs on AMR have made good progress in reducing AMR and its consequences. The lack of resources and capacity may cause LMICs to have challenges in implementing their NAPs on AMR [84] [96] [97]. Moreover, despite the availability of NAPs, the response to AMR is considered inadequate [94]. This may be due to poor alignment of the NAPs with GAP, inadequate capacity for implementation or poor awareness of the need for addressing AMR. The level and strength of commitment to NAPs, as well as the capacity of individual countries to develop NAP objectives, is integral to their delivery [94]. Therefore, to harness political engagement and commitment, NAPs need to include objectives that evaluate the economic effect of strategies implemented to optimize antimicrobial use (AMU) in different countries [94].

3.3. Antimicrobial Stewardship (AMS) Programmes

Antimicrobial stewardship (AMS) programmes promote the rational use of antimicrobials by emphasising the optimal selection, dose, frequency, and duration of therapy with antimicrobials [98] [99] that leads to the best clinical outcome in infection prevention or treatment and subsequent minimal or no toxicity to the patient and reduction in AMR [100] [101]. AMS programmes are critical in combating AMR [64] [98] [102] [103] [104] [105] [106], and their effective implementation has demonstrated an improvement in AMU and patient treatment outcomes [107] [108] [109] [110] [111]. AMS programmes include public health campaigns or awareness sensitisation, Hospital-based AMS programmes, NAPs, and the GAP [72] [90] [100] [101] [112]-[119].

AMS programmes also raise awareness of AMR through World Antimicrobial Awareness Week (WAAW), previously called World Antibiotic Awareness Week (WAAW), until 2020 [23] [120] [121] [122]. Since 2015, the WAAW has raised awareness of AMR and its consequences globally [120] [122] [123]. The awareness campaigns promote best practices to reduce AMR and its spread across populations, and these campaigns are targeted at the general public, policy-makers, farmers, animal health professionals, and healthcare workers [121] [123]. The WAAW is held annually from the 18th to the 24th of November [122]. The FAO, OIE, and WHO strongly support the WAAW as it promotes awareness and understanding of AMR [124].

Hospital-based AMS programmes include managing the prudent use of antimicrobials as an instrument in fighting AMR [125] [126] [127]. AMR is a complex issue, and there is no one-size-fits-all approach to creating AMS programmes. These programmes vary based on resources available, local context and setting (primary care, secondary care, or regional level, for example) [126]. These programmes focus on promoting the appropriate use of antimicrobials in hospital settings, including prescribing guidelines, monitoring AMU, and education of HCWs [126]. Alongside this, some outpatient AMS programmes focus on promoting the appropriate use of antibiotics in outpatient settings, including clinics and doctor's offices [128] [129] [130]. These activities typically involve the education of HCWs, patients and the monitoring of antimicrobial prescribing patterns [112] [131] [132].

Community pharmacy-based AMS programmes involve the active participation of pharmacists in promoting the appropriate use of antimicrobials within their communities [133] [134]. By collaborating with healthcare providers, pharmacists can actively engage in interventions such as medication therapy management, patient education, and antibiotic monitoring. Additionally, by leveraging their accessibility and expertise, community pharmacists can guide appropriate antibiotic selection, dosing, and duration to ensure optimal therapy and provide evidence-based recommendations [135]. Implementing a community pharmacy-based antimicrobial stewardship program can significantly contribute to the overall efforts in combating antibiotic resistance and preserving the effectiveness of these life-saving medications [136] [137].

AMS programmes are also implemented in animals globally [82] [138]. For example, at an international level, the GAP on AMR is an international plan that includes measures to address AMR in both human and animal health [72]. It includes promoting responsible use of antimicrobials in animals and developing alternative treatments for animal diseases [139]. Also, the Animal Disease Prevention and Control Program implemented by the WHO aims to promote the responsible use of antimicrobials in animals to prevent and control the spread of zoonotic diseases [140]. In the US, the Veterinary Feed Directive (VFD) Rule requires veterinary oversight for the use of antimicrobials in animal feed. It aims to reduce the use of antimicrobials for growth promotion in livestock [141] [142]. In the United Kingdom (UK), the Responsible Use of Medicines in Agriculture Alliance (RUMA) promotes the responsible use of antimicrobials in agriculture. It provides guidelines and education to farmers and veterinarians on appropriate antibiotic use [143] [144].

In 2017, the WHO developed a tool known as the Access, Watch, and Reserve (AWaRe) classification of antimicrobials [145]. This categorisation is intended to steer the use of antimicrobials towards a more sustainable and rational usage model and to minimise the development and spread of AMR [146]. The AWaRe framework categorises antimicrobials based on their spectrum of activity and their potential to contribute to antibiotic resistance [146] [147] [148] [149] [150]. The "Access" group contains narrow-spectrum antimicrobials that are effective against a specific type of microorganisms and have a lower potential for causing resistance. These are also antimicrobials that should be widely available, affordable, and quality-assured, given their importance for treating a wide range of common infections [148]. The "Watch" group contains broader-spectrum antimicrobials that have a higher potential for resistance [148]. The use of these antimicrobials should be closely monitored because their overuse and misuse pose significant risks for the emergence and spread of AMR. Lastly, the "Reserve" group includes last-resort antimicrobials that should be used sparingly and selectively for serious infections when all other alternatives have failed [148]. These antimicrobials are crucial for treating multi-drug resistant infections, but their use needs to be limited to preserve their effectiveness for as long as possible [148].

The AWaRe classification is more than just a categorisation; it is a framework to guide appropriate antibiotic use based on the diagnosed condition and the recommended drugs [150] [151]. It can inform policy and practice in AMS programmes, helping to define targets for optimizing the use of antimicrobial medicines. Monitoring antibiotic use in healthcare facilities plays a crucial role in promoting the rational use of these medicines. By ensuring adherence to appropriate prescribing patterns, we can combat the misuse and overuse of antimicrobials, two key drivers of AMR. Adherence to AWaRe classifications could therefore contribute significantly to global efforts to keep antimicrobials effective for future generations [152] [153].

In conclusion, we recommend continuous research that improves the awareness, knowledge, attitudes, and practices of individuals on AMU, AMR, and AMS. Some studies have been conducted to promote these issues [48] [154]-[181]. By doing so, these studies and campaigns will contribute towards the attainment of the objectives set by the GAP and NAPs on AMR.

3.4. AMU and AMR Surveillance Systems

Surveillance is one of the strategic priorities of the GAP on AMR that helps countries to collect data on the prevalence of AMR and AMU, which is critical in improving patient outcomes, informing policy, identifying people at risk, and recommending interventions [72] [182]. According to surveillance findings, the increased and inappropriate contributes to the emergence and spread of AMR in humans, animals, and the environment [10] [16]. Globally, there has been an increase in AMU, with evidence indicating that there was an increase in AMU expressed as the defined daily (DDD) AMU between 2010 and 2015 by 65% (21.1 - 34.8 billion DDDs) [183]. If this consumption of antimicrobials is not regulated, then by 2030, the AMU would increase to 42 billion DDDs, although an increase of more than 200% was projected compared to the later reported [183].

Surveillance systems are important in monitoring AMR in humans, animals, agriculture and the environment [184] [185]. Well-implemented surveillance systems demonstrate whether there is the presence of AMR or not in a particular population [186]. The surveillance of AMR requires a strengthened multisectoral approach and efficient coordination [186] [187]. Surveillance strategies help monitor AMR in food-producing animals such as cattle, pigs, chickens, goats, and other animal products [188]-[193]. Comprehensive surveillance of AMU is highly recommended to reduce or prevent cases of antibiotic-resistant bacteria and their genes [194] [195]. Finally, surveillance of AMR indicates the size of the problem associated with AMR, the emergence of new AMR, whether the AMR problem is increasing or decreasing, whether there is a spread of a particular resistance, and whether a certain outbreak is due to a particular resistance [196].

A study in South Korea reported a critical need for comprehensive surveillance of third-generation cephalosporin-resistant *E. coli* at all levels of the layer-production pyramid and provided important considerations for controlling infection in large poultry production [197]. In Africa, a study in Egypt reported a need to call for nationwide surveillance programmes to monitor AMR [198].

Accordingly to the WHO, integrated surveillance of AMR in food-borne bacteria must have the following elements; sources of samples, targeted bacteria, sampling design, laboratory testing methodology, data management, validation, analysis and reporting [199]. This has been supported by other published protocols [188] [200] [201]. In addition, an integrated system should have adequate resources, which should come from sustainable investment by governments, prioritisation of which AMR problems to do first, integration into already existing surveillance systems, coordinated activities by different sectors, and available and comparable good quality data [182].

Concerning sample sources, food-producing animals are an important source of AMR that can be transmitted to humans [40]. Samples from food-producing animals should be collected from healthy animals rather than sick ones [199].

Besides, it is recommended to collect one sample per farm, which allows researchers to collect samples from many farms [188]. Samples should be collected from the national level, surveillance area, FAO sector level, and sampling location level using a well-designed sampling plan based on the number of laboratories, sampling sites, target bacteria, available antimicrobials and all necessary resources, and taking into consideration the schedule [188].

According to WHO Global AMR Surveillance System (GLASS), surveillance systems must use recommended indicator microorganisms such as *E. coli*, which is a priority microorganism and *Enterococcus* spp whose presence in samples indicates the resistance patterns of Gram-positive bacteria [199]. This has been supported by other protocols [200] [201]. Other recommended indicator microorganisms for AMR surveillance in food-producing animals like chickens include *Salmonella* spp and *Campylobacter* spp [188]. Therefore, their use as indicator organisms in AMR surveillance in poultry systems is highly recommended. Sampling directly from food-producing animals has been reported to produce reliable inferences that can be made about a particular component of integrated surveillance of AMR in food-borne bacteria [199]. Therefore, the current study focused on sampling from food-producing animals at the farm level so that epidemiological data was also gathered adequately. A sampling at the farm level is very significant as it provides an estimation of the use of antimicrobials in poultry and identifies certain risk factors that can contribute to AMR [199].

The laboratory used for AMR surveillance must have adequate resources for bacterial culture and isolation of target bacteria [188] [202]. This implies that the target bacteria must be isolated and identified using internationally accepted microbiological methods [199]. Therefore, governments must sustainably invest in AMR surveillance by providing adequate human, funding, and laboratory resources [182]. Additionally, antimicrobial susceptibility tests (AST) must be conducted using the European Committee on Antimicrobial Susceptibility Testing (EUCAST) or the Clinical and Laboratories Standards Institute (CLSI) [188] [199]. The WHO has recommended classes of antimicrobials for AMR surveillance in poultry and other food-producing animals [188] [199], and these include aminoglycosides, carbapenems, amphenicols, cephalosporins, macrolides, glycopeptides, quinolones, tetracyclines, oxazolidinones, polymixins, streptogramins, penicillins, glycylcyclines, and sulfonamides [188] [203].

The entire process of AMR surveillance should produce good quality data that is available and comparable across sectors and countries [182]. There must be a comprehensive data analysis of all data obtained for AMR surveillance [199]. This should be well coordinated and involve experts so that integrated data analysis, reporting and risk communication are done effectively and efficiently. Epidemiological data should also be entered properly and match the laboratory data [199]. This is important because the findings should be communicated to the stakeholders to help come up with interventions for the risks of AMR. Additionally, there should be adequate databases for data entry, analysis, reporting, and sharing [199].

3.4.1. Surveillance of AMR in Humans

Surveillance of antimicrobial resistance (AMR) in humans is crucial for monitoring the development and spread of resistant infections, as well as for informing strategies to combat the problem [30] [72] [204] [205]. The Global Antimicrobial Resistance and Use Surveillance System (GLASS), established in 2015, aims to promote the monitoring of AMR in bacteria that cause common infections in humans and to develop strategies to overcome this problem [201] [206] [207] [208]. Over time, fungal infections, antimicrobial consumption, and a One Health approach have been added to the items monitored by GLASS [193] [201] [206] [209]. GLASS supports the implementation of the GAP on AMR, which seeks to reduce AMU and AMR [201] [206]. As of 2018, 71 countries had registered as GLASS members to share data on AMU and AMR [206] [210]. The number of registered member states increased to 127 countries at the end of 2022 [206], demonstrating a global commitment to sharing information and collaborating with other countries to tackle AMR [206]. However, surveillance of drug-resistant infections can be challenging in low- and middle-income countries (LMICs) where there is a lack of resources and capacity to undertake AMR intervention activities [30] [84] [211] [212]. The overuse and inappropriate use of antimicrobials in humans have contributed to the development of AMR, leading to increased health costs, morbidity, and mortality across the human population [10] [67] [213] [214] [215]. To combat this problem, strategies and interventions coupled with surveillance have been proposed to reduce the transmission of AMR from humans to animals and the environment [63] [216] [217] [218]. Therefore, some countries have developed and implemented NAPs on AMR and surveillance frameworks to monitor AMU and AMR, as guided by the WHO and other stakeholder organizations [30] [89] [90] [93] [94] [219] [220]. These frameworks are critical for tracking the development and spread of AMR and informing effective interventions to combat this global health crisis [72] [82]. However, continued investment in surveillance systems and infrastructure is necessary to ensure that all countries, including LMICs, are equipped to monitor and tackle AMR effectively.

3.4.2. Surveillance of AMR in Food-Producing Animals

Significant work on AMR surveillance has been done in humans compared to food-producing animals [24] [221]. There is substantial use of antimicrobials in food-producing animals which may promote the development of AMR, thereby necessitating surveillance programmes [190] [222] [223]. The surveillance of AMU and AMR in food-producing animals is provided by guidelines from the World Organization for Animal Health (OIE) Terrestrial Animal Health Code [200]. The FAO also supports the development and implementation of AMR surveillance programmes across the globe. Additionally, FAO guidelines recommend that countries develop AMR surveillance systems irrespective of their capacity to do so [193].

Further, as a food safety priority, FAO encourages monitoring AMR in healthy food-producing animals because people consume them [193]. The FAO guidelines provide detailed guidance on how to design an AMR monitoring and surveillance program, with an emphasis on how sampling and epidemiological data should be collected, laboratory methods to employ, and the management of AMR data [193]. Besides, the guidelines provided detailed information on bacteria to use as indicators in AMR surveillance [193]. Countries can use the provided guidelines to compare the AMR trends across pathogens and report to the OIE for further decision-making [193].

The OIE, FAO, and WHO have provided guidelines on the surveillance of AMR in poultry [188] [193] [200]. Countries need harmonised procedures (data collection, laboratory techniques, data analysis, data management, and data sharing) that will help produce comparable data in AMR surveillance in animal health [224]. Therefore, the surveillance of AMR in food-producing animals should follow laid-down procedures for data collection, laboratory analysis, and data management [188]. Subsequently, there must be heightened regulation and restriction of AMU in food-producing animals [203] [225]. Consequently, this would help to combat AMR [226] [227] [228] [229].

Studies have shown that implementation of AMR surveillance in chickens can help detect antimicrobial-resistant pathogens and inform policy [230] [231]. Through national surveillance, countries would know if the poultry products that humans consume are contaminated with pathogens [230]. In Colombia, a study reported that the surveillance of AMR in poultry was critical as it helped authorities understand the trends in resistance patterns of microorganisms to common antimicrobials used in humans and poultry [202]. Additionally, the surveillance of AMR food-producing animals must be integrated into the national AMR surveillance systems, including the human AMR surveillance system [202]. Therefore, it is recommended to use a One Health approach to effectively conduct AMR surveillance globally [189] [190] [192].

3.4.3. The Roles of Laboratories in AMR Surveillance

Efficient laboratories play a very important role in AMR surveillance through the detection, isolation and monitoring of emerging antimicrobial-resistant pathogens in humans, animals and the environment [185] [232]. Other laboratory activities include antimicrobial susceptibility testing (AST) and molecular characterization using advanced molecular techniques, such as polymerase chain reaction (PCR) and whole-genome sequencing (WGS), to study the genetic basis of AMR [185] [232].

A robust and efficient laboratory network both for diagnostic and public health laboratories is integral to identifying and monitoring AMR in humans, animals and the environment [233] [234]. The routine utilisation of microbiology-based diagnostics in hospital settings has contributed to the containment of AMR by supporting AMS [195] [235] [236]. This, together with the use of public health laboratories, provides data that influence treatment guidelines, and public health policies and has strengthened laboratory-based AMR surveillance [185] [235].

Systematic evaluation of integrated surveillance for AMU and AMR in One Health paradigms is imperative to ensure the effectiveness of the systems [237] [238]. Laboratory-generated data has driven evidence-based interventions in AMR [234]. To assess progress towards targets of interventions in food and agriculture, FAO developed the Assessment Tool for Laboratories and AMR Surveillance Systems (ATLASS) [83]. Additionally, the standardisation of laboratory methods for culture, identification and sensitivity testing has also helped to generate comparable data across distinctly different settings supported by strong and reliable case definitions [30]. Further, it is highly recommended that whenever necessary, laboratories conduct detailed molecular epidemiology of isolates [239]. Alongside this, standardisation of analysis of antimicrobial susceptibility testing (AST) results, especially using WHONET as recommended by the WHO [44] [45] [240] [241] [242] [243] [244]. Capacity-building for laboratory personnel is also critical in improving surveillance of AMR [245] [246].

3.5. Biosecurity and Infection Prevention and Control Practices

Biosecurity is the implementation of measures that serve to prevent the introduction of disease-causing agents and their spread [247] [248] [249]. Some biosecurity measures include isolation of animals (preventing contamination of animals from housing and personal protective equipment, control of traffic (restricting the movement of people, animals, and other products into the farm area where animals are reared), and sanitation (disinfection and cleanliness) [250]. Therefore, biosecurity is a part of the One Health concept that aims to prevent and survey the occurrence of infections across human, animal, and environmental ecological systems [247].

Biosecurity measure recommends the separation of chickens by age and species, *i.e.* keeping livestock animals of different ages in separate houses and not rearing different animal species in the housing environment, *i.e.*, separating ducks from chickens [251]. This is because rearing chickens of different ages and species in the same poultry increases the risk of infection transmission across flocks [252]. Additionally, restriction of entry of people into the poultry houses has also been recommended as a good biosecurity measure that prevents transmission of pathogens from humans to food-producing animals and vice-versa [253].

Commercialisation has added pressure on the livestock industry hence creating increased demand in the production areas to control and regionally eradicate infectious diseases to preserve the marketability of livestock and animal products [254] [255]. Measures have been put in place to reduce the risks of the introduction and transmission of infectious agents, which include bioexclusion and biocontainment [254] [255].

In Belgium, previous studies reported that the implementation of good- quality biosecurity measures led to a reduction in the use of antimicrobials in piggery which resulted in reduced mortality and improved production [256] [257]. Therefore, the implementation of biosecurity is critical in preventing the development of AMR by reducing the use of antimicrobials [249] [258] [259].

To tackle AMR, preventing and controlling the disease of resistant bacteria is of critical importance [260] [261]. Infections Prevention and Control (IPC) practices work to limit the spread of infections and resistant bacteria in congregate settings, healthcare facilities, public spaces and animal farming [262] [263] [264]. Failure of IPC can lead to prolonged illness, increased hospitalisations and increased costs in both healthcare-related needs as well as animal-related foods [265] [266]. One of the main objectives of the GAP on AMR is to reduce or prevent infection through effective wash, sanitation, and hygiene (WASH) [123]. WASH practices must be promoted, especially in hospital environments, schools, universities, markets, and other communities [267] [268] [269] [270]. Therefore, compliance and adherence to hygiene measures are very critical in preventing the occurrence of infections [271] [272].

3.6. Use of Vaccines in Curbing AMR

Vaccines meant for veterinary use include both attenuated live vaccines and those that are inactivated [273] [274]. Vaccines are capable of providing mucosal immunity thereby protecting animals from severe infection, and limiting the infection caused by live pathogens [274]. Therefore, by preventing the occurrence of infections in animals, vaccines lead to a reduction in the consumption of antimicrobials in animal health [274]. The reduced use of antimicrobials prevents the exposure of microorganisms found in food-producing animals to these medicines leading to reduced risks of AMR development in food-producing animals. For this reason, there is a need to promote the use of vaccines in animal husbandry as a means of preventing the occurrence of infections. Similarly, vaccines are used in humans to prevent or reduce the severity of infections, thereby reducing the use of antimicrobials and preventing the occurrence of AMR in the future [275] [276] [277]. The WHO developed a Framework to reduce AMU and promote vaccinations [278].

3.7. One Health Concept for Surveillance and Management of AMR

One Health is an integrated and unified approach aimed at sustainably balancing and optimising the health of humans, animals, and the environment [279]. This approach recognises the interconnection and link between the health of humans, animals, plants, the environment and ecosystems, as shown in **Figure 1** [279]. Therefore, a One Health approach emphasises the need for a holistic, collaborative, transdisciplinary, and multisectoral approach in addressing AMR across humans, animals, and the environment [191] [280] [281] [282] [283].

The concept of one health is central to the global action plan of the WHO on AMR and the Food and Agriculture Organization (FAO)/Organization for Animal Health (OIE)/WHO Tripartite Collaboration on AMR [72]. On a global scale, efforts have been made recently to develop guidance for the integrated Surveillance of AMR, and several systems have been developed worldwide [74]

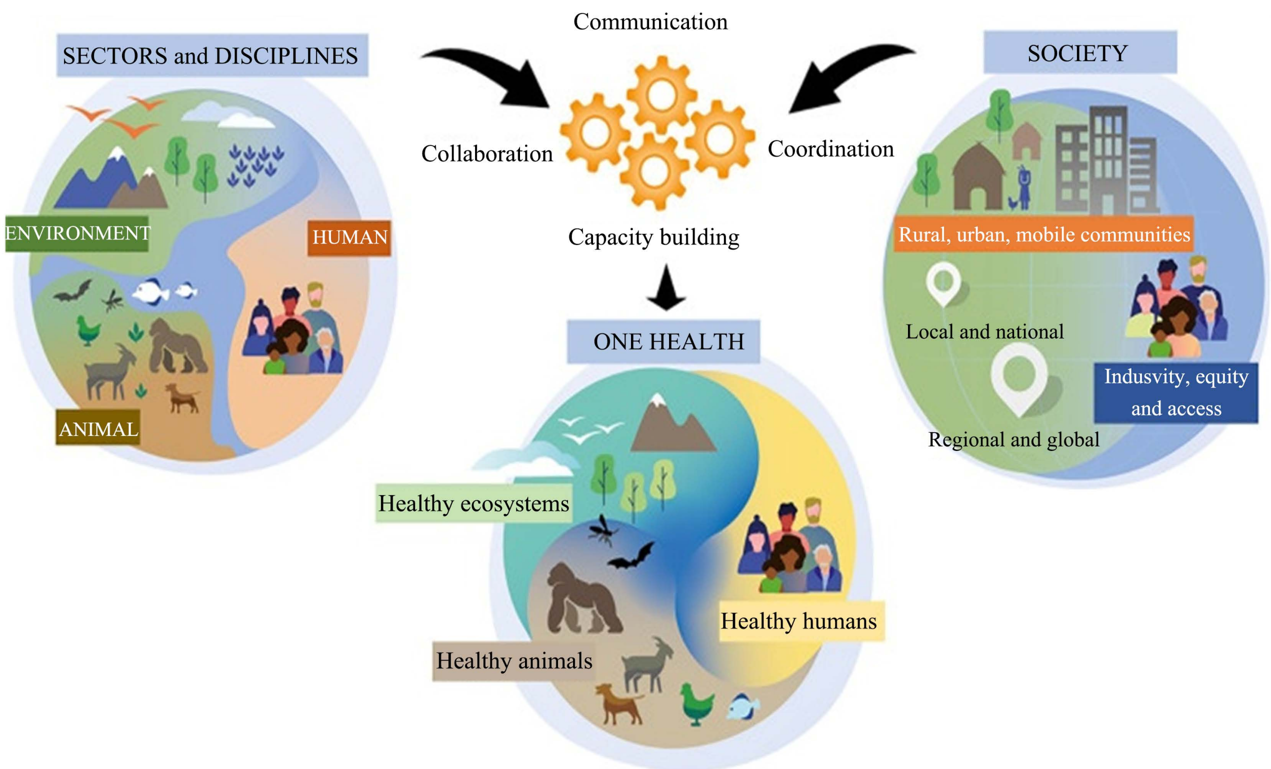

Figure 1. One health approach (Source: [279]).

[199]. The need for new knowledge about the effectiveness and economic efficiency of integrated AMR surveillance systems has been outlined in Canada, where the Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARs) has been operational since 2002 [284]. This is a national programme coordinated by the Public Health Agency of Canada (PHAC) which is dedicated to the Collection, Integration, Analysis and Communication of trends in AMU and AMR in selected bacteria from humans, animals and animal- derived food sources in Canada [284]. The program aims at providing an Integrated approach to monitor trends of AMU and AMR in humans and animals, to facilitate the assessment of the public health impact of AM used in human and agricultural sectors, and to allow accurate comparisons with Data from other countries that use similar surveillance systems [284].

According to the United Nations, addressing AMR using a One Health approach may help to achieve sustainable development goals [280]. A One Health approach has been reported to be effective in promoting the rational use of antimicrobials, strengthening AMS programmes [283], and promoting global food safety [285]. In this case, an integrated surveillance system would be necessary as it focuses on AMR in humans, food-producing organisms, and the environment [199].

A One Health approach is recommended in tackling AMR because resistant microbes exist in humans, animals, and the environment [74] [78]. Additionally, the transmission of antimicrobial-resistant pathogens from animals to humans and vice-versa, from animals to the environment and vice-versa, and from humans to the environment and vice-versa, necessitates the need for a One Health approach to address AMR [91] [286] [287]. Therefore, incorporating AMR programmes in a One Health approach is critical in addressing AMR across humans, animals, and the environment [283] [284].

A One Health approach to report AMR using the Delphi method has been proposed [288]. This Delphi method states that there must be strategic and standardised ways of reporting surveillance data which must be used to monitor AMR, provide interventional measures, and inform policy [288]. There is also a strong emphasis on monitoring antimicrobial consumption in humans and food-producing animals, antimicrobial residues in food-producing animals and the environment [288]. Therefore, a One Health approach is critical in quantifying AMU and AMR through surveillance data collected from humans, animals, and the environment and thus provides points of integration across these sectors [195].

3.8. Alternative to Antibiotics

Antimicrobial resistance (AMR) has become a significant public health concern worldwide, mainly due to the overuse and misuse of antibiotics [289]. In combating AMR, the development of alternative approaches to antibiotics is crucial [290]. Various strategies have been proposed, including the use of probiotics, phages, and bacteriocins [291]. Probiotics are beneficial microorganisms that can help restore the gut microbiota and prevent the growth of pathogenic bacteria [292]. Phages are viruses that specifically target and kill bacteria, while bacteriocins are antimicrobial peptides produced by bacteria that can inhibit the growth of other bacteria [293] [294] [295] [296]. These alternative approaches have shown promising results in vitro and animal models. However, more research is needed to assess their efficacy and safety in human populations [297] [298]. Implementing alternative approaches to antibiotics requires a One Health approach, recognizing the interconnectedness of human, animal, and environmental health. Collaboration between human and animal health professionals, as well as researchers in various disciplines, is essential in developing and implementing effective strategies to combat AMR and protect public health [78] [86] [282].

3.9. Promoting Access to Quality-Assured Antibiotics

Ensuring access to quality-assured antibiotics is a critical aspect of combating AMR in humans and animals [299]. The lack of access to quality-assured antibiotics can lead to the use of ineffective or even harmful antibiotics, which, in turn, drives excess mortality, particularly in LMICs [300] [301] [302]. Antibiotic shortages can result in the use of suboptimal drug combinations, increasing the risk of treatment failure and the development of resistance [301]. In addition to directly affecting healthcare outcomes, antimicrobial shortages also pose a public health threat in the form of increased costs [10] [301]. The use of alternative antimicrobials, necessitated by the unavailability of the most appropriate agents, may result in higher expenses and economic losses [9] [13] [301] [303].

Antibiotic shortages may lead to people purchasing substandard and falsified (SF) antibiotics which can exacerbate the spread of resistant bacteria, undermining the One Health approach to addressing AMR [300] [304]. SF antibiotics, which may contain insufficient or incorrect active pharmaceutical ingredients (APIs), can fail to treat infections and promote the development of resistance [302] [305]. A lack of quality control and regulatory oversight contributes to the circulation of SF antibiotics, particularly in low-resource settings [306] [307]. In LMICs, shortages of quality are often due to several factors, such as weak supply chains, inadequate infrastructure, challenges with policy and regulatory processes, and poorly functioning systems of financing and drug pricing [301] [307] [308].

Promoting access to quality-assured antibiotics requires a multi-faceted approach that encompasses various strategies. Firstly, it is essential to strengthen regulatory frameworks and enforcement mechanisms to ensure the availability of safe and effective antibiotics [309]. This involves implementing stringent quality control measures, conducting regular inspections of manufacturing facilities, and cracking down on counterfeit and substandard drugs [310] [311]. Additionally, raising awareness among healthcare professionals, patients, and the general public about the appropriate use of antibiotics is crucial. Educational campaigns can emphasize the importance of completing the full course of treatment, the dangers of antibiotic resistance, and the need for responsible prescribing practices [312]. Furthermore, improving healthcare infrastructure and training healthcare workers in proper diagnosis and prescribing practices can contribute to rational antibiotic use [313] [314]. Finally, fostering research and development in new antibiotics, as well as promoting the use of alternative therapies and preventive measures, such as vaccines, can help reduce the reliance on antibiotics and preserve their efficacy for future generations [315] [316]. By employing these strategies, we can strive to ensure that everyone has access to high-quality antibiotics when needed while also addressing the growing threat of antibiotic resistance.

3.10. Increasing Investment in the Development of New Antimicrobials

The development of new antimicrobials is a slow and expensive process, taking up to 10 - 15 years and costing billions of dollars to bring a new antibiotic to market [317] [318] [319]. In recent years, there has been a decline in investment in the development of new antibiotics due to factors such as low-profit margins, no new markets, and the perception that AMR is a problem for the future [317] [320] [321]. To ensure the availability of new antibiotics to treat AMR, increased investment in this area is essential, with governments, pharmaceutical companies, and foundations all having a role to play [317] [322] [323]. To encourage companies to produce antibiotics, it is crucial to provide incentives, especially when market forces do not sufficiently drive innovation [323]. Alternative incentive mechanisms can be employed to either push innovation through subsidizing at-risk investments, like government grants or pull innovation by offering rewards, such as guaranteed revenue, for successful outcomes [317] [321] [324] [325]. Other innovative models, such as subscription models (e.g., Netflix models), have been proposed by stakeholders [25]. These models suggest options such as fixed yearly payments for guaranteed supply, incentives to maintain or expand production, and tenders that ensure allocation to multiple suppliers to sustain a healthy market. More recently, several countries, including the UK and Sweden, have started to explore alternative payment models for both new and older antibiotics, indicating a growing interest in finding innovative solutions to address the challenges associated with antibiotic development and access [322] [326]. Such models need to be explored and piloted by LMICs to address the challenges of antibiotic development and ensure a sustainable supply of effective treatments for AMR. Moreover, by prioritizing and increasing investment in the development of new antibiotics, we can address the growing threat of microbial resistance and ensure the availability of effective treatments for future generations [322] [327].

There has been an urge to support and strengthen the discovery of antibiotics from natural sources like traditional medicines [328]-[333]. The rise in resistance to conventional antimicrobials has caused a realisation of the significance of natural products like plants as sources of antimicrobials [322] [334] [335] [336] [337]. Further, the WHO has recommended heightened discovery of antimicrobials from natural sources, and some are undergoing clinical and preclinical development [333].

3.11. Strengthening Regulatory Systems and Their Roles in Prudent Use of Antimicrobials

Regulatory systems play an important role in ensuring the quality and safety of medicines. To combat AMR, all antimicrobials must meet international quality standards [302]. Achieving this requires strengthening regulatory systems in all countries and ensuring that antimicrobials are manufactured and distributed following these standards [209] [302]. Collaborative regulatory approval processes through regional harmonisation, such as the ZAZIBONA initiative in the SADC region [338], supported by organizations like the WHO through initiatives such as the prequalification program and the collaborative registration system, have been instrumental in ensuring timely access to quality-assured medicines [302] [339]. These efforts have had a positive impact on public health and cost savings.

In Africa, it is hoped that the establishment of the African Medicines Agency (AMA) can help improve the regulatory environment and harmonize standards across the continent [340] [341]. This, in turn, can have massive impacts on the availability of quality-assured antimicrobials, facilitating a more robust response to AMR. By streamlining the regulatory process and fostering cooperation among countries, AMA can contribute to the faster approval of new antimicrobials, the elimination of substandard and falsified medicines, and the promotion of best practices in manufacturing and distribution. Ultimately, these efforts can lead to better healthcare outcomes and more effective strategies in combating AMR.

Regulatory authorities play a pivotal role in promoting the prudent use of antimicrobials across various sectors, including human, veterinary, agriculture, and environmental health [313] [342]. Regulatory authorities establish comprehensive guidelines, policies, and regulations to govern the use of antimicrobials. These regulations encompass various aspects such as the sale, distribution, and usage of antimicrobials. They provide the legal framework necessary to enforce appropriate prescribing practices, dosage regulations, and duration of treatment. By ensuring compliance, regulatory authorities aim to curb the indiscriminate use of antimicrobials and limit the emergence of AMR [343] [344].

The approval and oversight of antimicrobial products are essential tasks performed by regulatory authorities. These authorities thoroughly evaluate the safety, efficacy, and quality of antimicrobial agents, including antimicrobials, antivirals, and antifungals. A rigorous assessment of data provided by pharmaceutical companies is conducted to determine whether these products can be marketed and used safely. By approving only those products that meet stringent standards, regulatory authorities contribute to the rational and judicious use of antimicrobials [209].

Regulatory authorities establish surveillance programmes to monitor the sale, distribution, and consumption patterns of antimicrobials. Through systematic data collection, they track antimicrobial consumption in diverse settings such as human healthcare, animal husbandry, and agriculture. This information enables authorities to identify trends, patterns, and potential areas of misuse or overuse. Such surveillance programmes play a crucial role in evaluating the effectiveness of interventions and shaping evidence-based policies to promote the responsible use of antimicrobials [313].

Collaboration with healthcare professionals, veterinarians, and agricultural stakeholders is a key aspect of the role of regulatory authorities [345] [346]. Together, they develop guidelines and educational campaigns to foster responsible use practices. These initiatives aim to raise awareness among healthcare providers, farmers, and the general public about the risks associated with AMR, appropriate prescribing practices, and the importance of considering alternatives to antimicrobials whenever possible. By disseminating accurate information, regulatory authorities actively contribute to changing behaviours and promoting a more cautious approach to AMU [347].

Additionally, regulatory authorities also engage in international collaborations and harmonization efforts to tackle the global challenge of AMR. By working closely with organizations such as the World Health Organization (WHO) and the World Organisation for Animal Health (OIE), regulatory authorities facilitate the development of standardized guidelines, the sharing of data, and the coordination of efforts across borders. These collaborative initiatives enhance global cooperation and enable a more unified response to combat AMR [86] [348] [349].

3.12. Improving Local Drug Manufacturing

Local drug manufacturing has gained traction as a means to assure supply and access to medicines, especially in response to shortages linked to the COVID-19 pandemic [301] [350]. Government-funded local or regional manufacturing can provide an avenue for improving access to medicines [351] [352] [353]. A portfolio of strategic antimicrobials at risk of shortages could be targeted for manufacturing and supply through such regional hubs. Furthermore, these regional hubs could be developed to facilitate the prioritization and manufacturing of active pharmaceutical ingredients (APIs), where needed [63].

Expanding local and regional production hubs to manufacture and supply APIs can shift the current dominance of API production from China and medicine manufacturing from India [354]. This would prevent the monopolization of manufacturing capacities and could also introduce competitive pricing of APIs, ultimately reducing the cost of goods [355]. Increased public-private partnerships for antimicrobial manufacture and building capacity for public sector manufacture of antimicrobials can further support these efforts [317] [356].

Improving local manufacturing has the potential to reduce the cost of antimicrobials in the future, addressing a barrier to access, particularly in low- and middle-income countries [323] [357]. To improve access to antimicrobials in these countries, it is essential to reduce the cost of these drugs, which can be achieved through the collaborative efforts of governments, pharmaceutical companies, and non-governmental organizations [358]. Enhancing local and regional manufacturing capabilities helps overcome supply chain disruptions and shortages, ensuring a stable and sustainable supply of essential antimicrobials. This contributes to the effective management of infectious diseases and the containment of AMR. This should be accompanied by the allocation of adequate funding for the development of new antimicrobials [359].

3.13. Promoting Global Collaborations on AMR

Promoting global collaboration on AMR is crucial in addressing its urgent public health threats [81] [360] [361]. AMR is a global challenge that requires a coordinated effort involving governments, healthcare professionals, researchers, and international organizations. Initiatives like the GLASS and the GAP on AMR provide a framework for monitoring and addressing the issue on a global scale [82] [124] [362]. Additionally, collaborations such as the Fleming Fund and the Combating Antibiotic-Resistant Bacteria Biopharmaceutical Accelerator (CARB-X) bring together stakeholders from multiple sectors to support research, development, and innovation in combating AMR [363] [364] [365]

[366]. These coordinated collaborative efforts foster knowledge sharing, resource allocation, and capacity building, enabling countries worldwide to work together towards effective prevention, surveillance, and control of AMR [187]. By promoting global collaboration, we can collectively tackle AMR and safeguard the effectiveness of antimicrobial drugs for future generations [361] [367].

4. Challenges in Implementing Strategies to Address AMR

Addressing AMR is hampered by various challenges. This paper discusses some significant impediments that affect the successful implementation of strategies that address AMR.

4.1. The Burden of Disease

The fight against AMRis challenging, especially in resource-limited settings, where the high burden of bacterial infections, poverty, weak governance and frail health systems, and limited awareness of drug-resistant infections pose substantial hurdles [240] [368]-[375]. These issues are particularly prevalent in many LMICs posing major challenges in the fight against AMR [376] [377] [378].

To effectively address these systemic issues, LMICs must strengthen their health systems to address these systems issues, focusing on developing regulatory strategies against unauthorised AMU, AMS programmes, standard treatment guidelines for common infections, and sustainable public awareness campaigns to change health-seeking behaviour [379]. Additionally, heightened investment in research and development of vaccines, newer drugs and improvement in water, sanitation and hygiene to prevent common infections, together with the promotion of diagnostic tests to timely detect and treat infections, are essential to curb the current AMR trends [132] [376].

4.2. Human Resource and Inadequate Capacity Building for AMR

One of the major challenges in implementing strategies to address AMR is the need for more human resources, especially in low- and middle-income countries [238] [377] [380]. These countries often have limited resources and insufficient staffing to implement effective AMR programmes and address community infections [381]. Additionally, there is a shortage of trained healthcare professionals who can effectively diagnose and treat AMR infections [89] [382]. The challenges of resources include insufficient financial support for antimicrobial stewardship, a shortage of microbiologists, chemists, and infectious disease specialists, and a lack of technological support for intervention administration [99]. Due to shortage of the human resource, AMR stewardship programmes and infection prevention control (IPC) in NAPs require specialised human resources, which both countries lack [96] [383]. A USA report from the National Department of Health background paper on AMR indicated that AMS and IPC programme knowledge was low [97]. The GAP on AMR recommends prioritising human resources for stewardship programmes to preserve antibiotic efficacy

[72] [96].

Lack of healthcare professional capacity building prevents effective AMR surveillance and AMS implementation [384] [385]. Additionally, there has been a global shortage of human resources with the necessary education and training for AMR [384]. These challenges continue to affect the effective implementation of successful strategies to combat AMR.

4.3. Funding Challenges for AMR and AMS Costs

Securing sufficient funding for AMR and AMS initiatives often poses a significant challenge [33] [385]. Some governments may not prioritise funding for these initiatives, perceiving them as less urgent compared to other public health concerns [211]. This issue is particularly notable in LMICs, most countries mainly depend on external funding to develop and implement AMR activities [212]. Moreover, the decision to prioritise health in some countries is a political issue [386]. Besides the involvement of multiple government agencies in AMR initiatives can complicate the coordination and monitor spending. The private sector's participation is often limited by a lack of financial incentives to invest in the research and development of new antimicrobials [245]. Finally, despite the need for global coordination and cooperation to address AMR, this can be difficult to achieve due to competing interests and priorities among different countries

4.4. Behavioural Change Issues Concerning Antimicrobial Use

Since humans are the ones that handle and utilize antimicrobials, their behaviour affects every element of AMR, including its prevention [387] [388] [389] [390] [391]. AMR is attributable to the excessive use and misuse of antimicrobials in animal and human health [29] [387], usually due to behavioural issues. Consequently, lack of behaviour change causes humans to continue self- prescription practices which are major contributing drivers to the emergence of antimicrobial-resistance infections [392]-[408]. Changing behaviour is difficult, and it can be challenging to convince people to adopt new practices and habits [409]. Therefore, we believe that the inappropriate prescribing, dispensing, administration, and use of antimicrobials will continue if behavioural change is not addressed.

4.5. Laboratory Incapacities and Ineffective Surveillance Systems

LMICs face significant challenges in securing of supply chain and allocating resources for equipment, diagnostics, and reagents [384]. These challenges are compounded by environmental, logistical, and budgetary constraints [30] [410] [411]. Regulatory issues, such as strict regulations for air shipment delivery, can lead to long delays and affect secure cold chain storage.

Laboratory Guidance for the selection, sampling, and transport of specimens is often absent [410]. Leading to a lack of quality assurance and no systematic monitoring of quality indicators [238]. In many LMICs, basic requirements for a functional laboratory infrastructure remain unmet [410].

The lack of high-quality microbiological data, the disconnection between existing data and clinical outcomes, and the unrepresentative nature of available data constitute major obstacles in estimating the global burden of AMR [377]. The quality of data particularly in evaluating bacterial control strains, is another significant issue [412].

To accurately assess the burden of AMR, it is crucial to have individual patient data, high-quality microbiological data, representative catchment populations, and a link to clinical outcomes. However, problems with data sharing between institutions and conflicts with ongoing research projects of data custodians often hamper this process [377].

In many low-income countries, there is an inconsistent supply of antimicrobials to the microbiology laboratory which could contribute to data availability bias [385]. Furthermore, the absence of crucial elements such as working relationships, political support, and resources could result in an inability to link data [413].

Reliable surveillance data is crucial for estimating the spread of AMR, identifying its causes, developing targeted control methods, and evaluating the success of implemented strategies. However, many LMICs struggle to obtain representative, high-quality surveillance data [414]. Additionally, there is a paucity of reliable surveillance data in LMIC settings due to the limited application of microbiological diagnostics in clinical practice. It is worsened in settings where culture and sensitivity tests are not done [411] [414]. Further, other challenges such as technical, infrastructural, and behavioural issues also affect the implementation of AMR surveillance data in clinical microbiology [83] [204] [212] [411]. Furthermore, a lack of microbiological diagnostics in patient care guides would negatively affect AMS, IPC practices in healthcare facilities, and laboratory-based AMR surveillance [235]. Of note is the lack of skilled personnel in the microbiology laboratory in many LMICs [415]. This is coupled with a lack of consistent laboratory supplies which may lead to inadequate good data which is required for AMR surveillance [246]. Lack of data management in the laboratory and healthcare system has been shown to affect the overall surveillance of AMR [212] [416]. Lack of government funding will have an impact on AMR surveillance programmes. The political will to combat AMR is a major challenge [385]. Funding for AMR national action plans and surveillance programmes could help efforts to combat AMR [72] [201]. In addition, a lack of awareness among healthcare professionals regarding the significance of reporting may contribute to the inadequate surveillance system [379]. These deficiencies might prevent efforts to monitor and control the spread of AMR, a growing threat to global health.

4.6. Development of Natural Resistance and Other Predisposing Factors

The problem of AMR has been worsened by the development of natural resistance to antimicrobials by various microorganisms [36] [39]. Natural or intrinsic resistance is a phenomenon that occurs naturally but has been accelerated by the exposure of microorganisms to antimicrobials [11] [417]. Additionally, a lack of awareness regarding AMR and its consequences among the general public, farmers, healthcare professionals, and policymakers remains a contributing factor to the development of antimicrobial-resistant infections [418]. This has resulted in the inappropriate use of antimicrobials in human, animal, and environmental health sectors [387]. The result has been the emergence of multidrug-resistant infections [419] [420]. Limited availability of new antimicrobials and other antimicrobial agents [211]. Inadequate surveillance systems to monitor the development and spread of AMR [30]. In healthcare facilities, infection prevention and control procedures must be improved. Inadequate written guidelines and processes for maintaining cleanliness contribute to poor healthcare environments. As a result, AMR's emergence and spread are made more accessible [421]. The inaccurately diagnosing of an infection, such as prescribing an antibiotic "just in case" or a broad-spectrum antibiotic, is given to the patient when a specific narrow-spectrum antibiotic may be more appropriate. These conditions increase selective pressure and promote the emergence of AMR [422] [423] [424].

Antimicrobials are widely used in agriculture as growth enhancers and growth boosters for animals worldwide. Animal manure widely disperses antibiotic- resistant bacteria in cattle across the ecosystem and can be hazardous to humans. These bacteria are also easily transmitted to humans through food chains. It could result in complicated, incurable, and chronic infections in people [423] [425] [426] [427].

4.7. Data Sharing Challenges

Efficient data sharing necessitates strong collaboration with influential figures across local to international levels, within and beyond the health industry. However, there is a lack of robust laws protecting the privacy of medical and genetic data [428]. In many LMICs, limited resources and a lack of infrastructure result in fragmented and unrepresentative data. This diminishes its usefulness for informing health policymakers and guiding the efficient allocation of financial resources to surveillance programmes designed to combat AMR [211] [212] [238]. The scarcity of high-quality data hinders the monitoring and mapping of resistance spread, early outbreak detection, and the development of national health policies to combat AMR [429]. In LMICs, healthcare providers and institutions often lack the financial and technical resources necessary to effectively collect, manage, and share information [211] [381].

The implementation and maintenance of the infrastructure required for data exchange, such as robust information systems and interoperability standards, can be cost-prohibitive, thereby limiting data sharing [212] [376] [384] [430]. Furthermore, academic institutions often under-share data due to a lack of incentives [319]. While these institutions produce vast amounts of research data, funding constraints present major obstacles to disseminating these findings [319]. Addressing these issues is critical for effectively combating AMR and promoting public health.

4.8. Ineffective Leadership, Governance, and Coordinated AMS Programmes

The lack of commitment to combat AMR among government leaders is a huge problem [431] [432] [433]. For instance, the implementation of NAPs on AMR requires the involvement of leaders at all levels [204] [385] [434] [435], which is not the case in most healthcare facilities and government units. Further, the implementation of all AMS activities requires commitment from governments, of which if not committed, the fight against AMR fails. Unfortunately, some leaders are not aware of AMS programmes [436]. Hence, this makes the initiation and implementation of AMS activities challenging.

The fight against AMR is affected by uncoordinated or consistently implemented AMS activities [433] [437]. Infective multidisciplinary teams have been reported to be among the hindrances of successful AMS programmes in healthcare facilities [431]. Subsequently, some healthcare facilities do not have functional AMS programmes thereby promoting irrational prescribing, dispensing, and administration of antimicrobials [380] [438]. Some facilities do not have treatment guidelines to guide prescribers on rational prescribing [439] [440]. Consequently, most facilities lack reliable antibiograms for effective surveillance of AMR trends [385] [440].

We believe when these challenges are addressed, it will be easy to combat AMR in sectors and levels of AMU. In this regard, we emphasise the need for more collaborations, leadership commitment, and capacity building to win the fight against AMR.

5. Conclusion

This review paper found that the effective implementation of various strategies to combat AMR is critical in addressing this problem. However, many challenges impede the establishment and implementation of strategies to combat AMR. Some countries still have challenges towards fighting this silent pandemic, including inadequate human resources for AMR, financial challenges, limited surveillance of AMU and AMR, inadequate data sharing resources, lack of awareness and knowledge of AMR, inadequate disease diagnostic resources, behavioural issues concerning prescribing, dispensing, and use of antimicrobials, lack of capacity building and effective AMS. Therefore, there is a need to develop, implement, and strengthen the strategies for combating AMR. Finally, all healthcare facilities should develop and implement sustainable AMS programmes to promote the rational use of antimicrobials and reduce AMR and its consequences in the future.

Conflicts of Interest

All authors declare no conflict of interest.

References

[1] Frieri, M., Kumar, K. and Boutin, A. (2017) Antibiotic Resistance. *Journal of Infection and Public Health*, **10**, 369-378. https://doi.org/10.1016/j.jiph.2016.08.007

[2] Ferri, M., Ranucci, E., Romagnoli, P. and Giaccone, V. (2017) Antimicrobial Resistance: A Global Emerging Threat to Public Health Systems. *Critical Reviews in Food Science and Nutrition*, **57**, 2857-2876. https://doi.org/10.1080/10408398.2015.1077192

[3] Amann, S., Neef, K. and Kohl, S. (2019) Antimicrobial Resistance (AMR). *European Journal of Hospital Pharmacy*, **26**, 175-177. https://doi.org/10.1136/ejhpharm-2018-001820

[4] Otieku, E., Fenny, A.P., Labi, A.K., Owusu-Ofori, A.K., Kurtzhals, J. and Enemark, U. (2023) Knowledge, Attitudes and Practices Regarding Antimicrobial Use and Resistance among Healthcare Seekers in Two Tertiary Hospitals in Ghana: A Quasi-Experimental Study. *BMJ Open*, **13**, e065233. https://doi.org/10.1136/bmjopen-2022-065233

[5] Ghaffoori Kanaan, M.H., Tarek, A.M. and Abdullah, S.S. (2021) Knowledge and Attitude among Samples from Community Members, Pharmacists and Health Care Providers about Antibiotic Resistance in Al-Suwaria City/Wassit Province/Iraq. *IOP Conference Series: Earth and Environmental Science*, **790**, Article ID: 012059. https://doi.org/10.1088/1755-1315/790/1/012059

[6] Impey, R.E., Hawkins, D.A., Sutton, J.M. and Soares da Costa, T.P. (2020) Overcoming Intrinsic and Acquired Resistance Mechanisms Associated with the Cell Wall of Gram-Negative Bacteria. *Antibiotics*, **9**, Article No. 623. https://doi.org/10.3390/antibiotics9090623

[7] Kapoor, G., Saigal, S. and Elongavan, A. (2017) Action and Resistance Mechanisms of Antibiotics: A Guide for Clinicians. *Journal of Anaesthesiology Clinical Pharmacology*, **33**, 300-305. https://doi.org/10.4103/joacp.JOACP_349_15

[8] Prestinaci, F., Pezzotti, P. and Pantosti, A. (2015) Antimicrobial Resistance: A Global Multifaceted Phenomenon. *Pathogens and Global Health*, **109**, 309-318. https://doi.org/10.1179/2047773215Y.0000000030

[9] de Kraker, M.E.A., Stewardson, A.J. and Harbarth, S. (2016) Will 10 Million People Die a Year Due to Antimicrobial Resistance by 2050? *PLOS Medicine*, **13**, e1002184. https://doi.org/10.1371/journal.pmed.1002184

[10] Murray, C.J., Ikuta, K.S., Sharara, F., Swetschinski, L., Robles Aguilar, G., Gray, A., *et al.* (2022) Global Burden of Bacterial Antimicrobial Resistance in 2019: A Systematic Analysis. *The Lancet*, **399**, 629-655. https://doi.org/10.1016/S0140-6736(21)02724-0

[11] Mancuso, G., Midiri, A., Gerace, E. and Biondo, C. (2021) Bacterial Antibiotic Resistance: The Most Critical Pathogens. *Pathogens*, **10**, Article No. 1310. https://doi.org/10.3390/pathogens10101310

[12] Merker, M., Tueffers, L., Vallier, M., Groth, E.E., Sonnenkalb, L., Unterweger, D., *et al.* (2020) Evolutionary Approaches to Combat Antibiotic Resistance: Opportunities and Challenges for Precision Medicine. *Frontiers in Immunology*, **11**, Article No. 1938. https://doi.org/10.3389/fimmu.2020.01938

[13] Pulingam, T., Parumasivam, T., Gazzali, A.M., Sulaiman, A.M., Chee, J.Y., Lakshmanan,

M., *et al.* (2022) Antimicrobial Resistance: Prevalence, Economic Burden, Mechanisms of Resistance and Strategies to Overcome. *European Journal of Pharmaceutical Sciences*, **170**, Article ID: 106103. https://doi.org/10.1016/j.ejps.2021.106103

[14] Ansari, M.M., Kuche, K., Ghadi, R., Date, T., Chaudhari, D., Khan, R., *et al.* (2022) Socioeconomic Impact of Antimicrobial Resistance and Their Integrated Mitigation by One Health Approach. In: Akhtar, N., Singh, K.S., Prerna and Goyal, D., Eds., *Emerging Modalities in Mitigation of Antimicrobial Resistance*, Springer, Cham, 135-156. https://doi.org/10.1007/978-3-030-84126-3_7

[15] Gandra, S., Barter, D.M. and Laxminarayan, R. (2014) Economic Burden of Antibiotic Resistance: How Much Do We Really Know? *Clinical Microbiology and Infection*, **20**, 973-979. https://doi.org/10.1111/1469-0691.12798

[16] Dadgostar, P. (2019) Antimicrobial Resistance: Implications and Costs. *Infection and Drug Resistance*, **12**, 3903-3910. https://doi.org/10.2147/IDR.S234610

[17] Ramírez-Castillo, F.Y., Moreno-Flores, A.C., Avelar-González, F., Márquez-Díaz, F., Harel, J. and Guerrero-Barrera, A.L. (2018) An Evaluation of Multidrug-Resistant *Escherichia coli* Isolates in Urinary Tract Infections from Aguascalientes, Mexico: Cross-Sectional Study. *Annals of Clinical Microbiology and Antimicrobials*, **17**, Article No. 34. https://doi.org/10.1186/s12941-018-0286-5

[18] Economou, V. and Gousia, P. (2015) Agriculture and Food Animals as a Source of Antimicrobial-Resistant Bacteria. *Infection and Drug Resistance*, **8**, 49-61. https://doi.org/10.2147/IDR.S55778

[19] Roca, I., Akova, M., Baquero, F., Carlet, J., Cavaleri, M., Coenen, S., *et al.* (2015) The Global Threat of Antimicrobial Resistance: Science for Intervention. *New Microbes and New Infections*, **6**, 22-29. https://doi.org/10.1016/j.nmni.2015.02.007

[20] Paramythiotou, E. and Routsi, C. (2016) Association between Infections Caused by Multidrug-Resistant Gram-Negative Bacteria and Mortality in Critically Ill Patients. *World Journal of Critical Care Medicine*, **5**, 111-120. https://doi.org/10.5492/wjccm.v5.i2.111

[21] Bassetti, M., Peghin, M., Vena, A. and Giacobbe, D.R. (2019) Treatment of Infections Due to MDR Gram-Negative Bacteria. *Frontiers in Medicine*, **6**, Article No. 74. https://doi.org/10.3389/fmed.2019.00074

[22] Serra-Burriel, M., Keys, M., Campillo-Artero, C., Agodi, A., Barchitta, M., Gikas, A., *et al.* (2020) Impact of Multi-Drug Resistant Bacteria on Economic and Clinical Outcomes of Healthcare-Associated Infections in Adults: Systematic Review and Meta-Analysis. *PLOS ONE*, **15**, e0227139. https://doi.org/10.1371/journal.pone.0227139

[23] Gautam, A. (2022) Antimicrobial Resistance: The Next Probable Pandemic. *Journal of Nepal Medical Association*, **60**, 225-228. https://doi.org/10.31729/jnma.7174

[24] Sharma, C., Rokana, N., Chandra, M., Singh, B.P., Gulhane, R.D., Gill, J.P.S., *et al.* (2018) Antimicrobial Resistance: Its Surveillance, Impact, and Alternative Management Strategies in Dairy Animals. *Frontiers in Veterinary Science*, **4**, Article No. 237. https://doi.org/10.3389/fvets.2017.00237

[25] Leonard, C., Crabb, N., Glover, D., Cooper, S., Bouvy, J., Wobbe, M., *et al.* (2023) Can the UK "Netflix" Payment Model Boost the Antibacterial Pipeline? *Applied Health Economics and Health Policy*, **21**, 365-372. https://doi.org/10.1007/s40258-022-00786-1

[26] Laxminarayan, R. (2022) The Overlooked Pandemic of Antimicrobial Resistance. *The Lancet*, **399**, 606-607. https://doi.org/10.1016/S0140-6736(22)00087-3

[27] Mendelson, M., Sharland, M. and Mpundu, M. (2022) Antibiotic Resistance: Calling

Time on the "Silent Pandemic". *JAC-Antimicrobal Resistance*, **4**, dlac016. https://doi.org/10.1093/jacamr/dlac016

[28] Delamare-deboutteville, J. and Mohan, C.V. (2021) Antimicrobial Resistance: Preventing the Silent Pandemic in Aquatic Food Systems. WorldFish. https://digitalarchive.worldfishcenter.org/handle/20.500.12348/4996

[29] Khurana, M.P., Essack, S., Zoubiane, G., Sreenivasan, N., Cordoba, G.C., Westwood, E., *et al.* (2023) Mitigating Antimicrobial Resistance (AMR) Using Implementation Research: A Development Funder's Approach. *JAC-Antimicrobal Resistance*, **5**, dlad031. https://doi.org/10.1093/jacamr/dlad031

[30] Matee, M., Mshana, S.E., Mtebe, M., Komba, E.V., Moremi, N., Lutamwa, J., *et al.* (2023) Mapping and Gap Analysis on Antimicrobial Resistance Surveillance Systems in Kenya, Tanzania, Uganda and Zambia. *Bulletin of the National Research Centre*, **47**, Article No. 12. https://doi.org/10.1186/s42269-023-00986-2

[31] Mahoney, A.R., Safaee, M.M., Wuest, W.M. and Furst, A.L. (2021) The Silent Pandemic: Emergent Antibiotic Resistances Following the Global Response to SARS-CoV-2. *iScience*, **24**, Article ID: 102304. https://doi.org/10.1016/j.isci.2021.102304

[32] Paneri, M., Sevta, P., Paneri, M. and Sevta, P. (2023) Overview of Antimicrobial Resistance: An Emerging Silent Pandemic. *The Global Journal of Medical Pharmaceutical and Biomedical Update*, **18**, Article No. 11. https://doi.org/10.25259/GJMPBU_153_2022

[33] Kakkar, A.K., Shafiq, N., Singh, G., Ray, P., Gautam, V., Agarwal, R., *et al.* (2020) Antimicrobial Stewardship Programs in Resource-Constrained Environments: Understanding and Addressing the Need of the Systems. *Frontiers in Public Health*, **8**, Article No. 140. https://doi.org/10.3389/fpubh.2020.00140

[34] Walsh, T.R., Gales, A.C., Laxminarayan, R. and Dodd, P.C. (2023) Antimicrobial Resistance: Addressing a Global Threat to Humanity. *PLoS Medicine*, **20**, e1004264. https://doi.org/10.1371/journal.pmed.1004264

[35] Coque, T.M., Cantón, R., Pérez-Cobas, A.E., Fernández-de-Bobadilla, M.D. and Baquero, F. (2023) Antimicrobial Resistance in the Global Health Network: Known Unknowns and Challenges for Efficient Responses in the 21st Century. *Microorganisms*, **11**, Article No. 1050. https://doi.org/10.3390/microorganisms11041050

[36] Sandner-Miranda, L., Vinuesa, P., Cravioto, A. and Morales-Espinosa, R. (2018) The Genomic Basis of Intrinsic and Acquired Antibiotic Resistance in the Genus Serratia. *Frontiers in Microbiology*, **9**, Article No. 828. https://doi.org/10.3389/fmicb.2018.00828

[37] Peterson, E. and Kaur, P. (2018) Antibiotic Resistance Mechanisms in Bacteria: Relationships between Resistance Determinants of Antibiotic Producers, Environmental Bacteria, and Clinical Pathogens. *Frontiers in Microbiology*, **9**, Article No. 2928. https://doi.org/10.3389/fmicb.2018.02928

[38] Lupo, A., Coyne, S. and Berendonk, T.U. (2012) Origin and Evolution of Antibiotic Resistance: The Common Mechanisms of Emergence and Spread in Water Bodies. *Frontiers in Microbiolog*, **3**, Article No. 18. https://doi.org/10.3389/fmicb.2012.00018

[39] Hollenbeck, B.L. and Rice, L.B. (2012) Intrinsic and Acquired Resistance Mechanisms in Enterococcus. *Virulence*, **3**, 421-569. https://doi.org/10.4161/viru.21282

[40] Iramiot, J.S., Kajumbula, H., Bazira, J., Kansiime, C. and Asiimwe, B.B. (2020) Antimicrobial Resistance at the Human-Animal Interface in the Pastoralist Communities of Kasese District, South Western Uganda. *Scientific Reports*, **10**, Article No.

14737. https://doi.org/10.1038/s41598-020-70517-w

[41] Booton, R.D., Meeyai, A., Alhusein, N., Buller, H., Feil, E., Lambert, H., *et al.* (2021) One Health Drivers of Antibacterial Resistance: Quantifying the Relative Impacts of Human, Animal and Environmental Use and Transmission. *One Health*, **12**, Article ID: 100220. https://doi.org/10.1016/j.onehlt.2021.100220

[42] Malijan, G.M., Howteerakul, N., Ali, N., Siri, S., Kengganpanich, M., Nascimento, R., *et al.* (2022) A Scoping Review of Antibiotic Use Practices and Drivers of Inappropriate Antibiotic Use in Animal Farms in WHO Southeast Asia Region. *One Health*, **15**, Article ID: 100412. https://doi.org/10.1016/j.onehlt.2022.100412

[43] Iskandar, K., Molinier, L., Hallit, S., Sartelli, M., Catena, F., Coccolini, F., *et al.* (2020) Drivers of Antibiotic Resistance Transmission in Low- and Middle-Income Countries from a "One Health" Perspective—A Review. *Antibiotics*, **9**, Article No. 372. https://doi.org/10.3390/antibiotics9070372

[44] Mudenda, S., Malama, S., Munyeme, M., Matafwali, S.K., Kapila, P., Katemangwe, P., *et al.* (2023) Antimicrobial Resistance Profiles of *Escherichia coli* Isolated from Laying Hens in Zambia: Implications and Significance on One Health. *JAC- Antimicrobal Resistance*, **5**, dlad060. https://doi.org/10.1093/jacamr/dlad060

[45] Mudenda, S., Matafwali, S.K., Malama, S., Munyeme, M., Yamba, K., Katemangwe, P., *et al.* (2022) Prevalence and Antimicrobial Resistance Patterns of Enterococcus Species Isolated from Laying Hens in Lusaka and Copperbelt Provinces of Zambia: A Call for AMR Surveillance in the Poultry Sector. *JAC-Antimicrobal Resistance*, **4**, dlac126. https://doi.org/10.1093/jacamr/dlac126

[46] Murphy, C.P., Carson, C., Smith, B.A., Chapman, B., Marrotte, J., McCann, M., *et al.* (2018) Factors Potentially Linked with the Occurrence of Antimicrobial Resistance in Selected Bacteria from Cattle, Chickens and Pigs: A Scoping Review of Publications for Use in Modelling of Antimicrobial Resistance (IAM.AMR Project). *Zoonoses Public Health*, **65**, 957-971. https://doi.org/10.1111/zph.12515

[47] Selvarajan, R., Obize, C., Sibanda, T., Abia, A.L.K. and Long, H. (2023) Evolution and Emergence of Antibiotic Resistance in Given Ecosystems: Possible Strategies for Addressing the Challenge of Antibiotic Resistance. *Antibiotics*, **12**, Article No. 28. https://doi.org/10.3390/antibiotics12010028

[48] Allabi, A.C., Agbo, A.G., Boya, B. and Mudenda, S. (2023) Antimicrobial Stewardship: Knowledge and Attitudes of Pharmacy Staff on Antibiotic Dispensing Patterns, Use and Resistance in Benin. *Journal of Pharmacy and Pharmacology*, **14**, 189-214. https://doi.org/10.4236/pp.2023.146014

[49] Mulchandani, R., Wang, Y., Gilbert, M. and Van Boeckel, T.P. (2023) Global Trends in Antimicrobial Use in Food-Producing Animals: 2020 to 2030. *PLOS Global Public Health*, **3**, e0001305. https://doi.org/10.1371/journal.pgph.0001305

[50] Daria, S. and Islam, M.R. (2022) Indiscriminate Use of Antibiotics for COVID-19 Treatment in South Asian Countries Is a Threat for Future Pandemics Due to Antibiotic Resistance. *Clinical Pathology*. https://doi.org/10.1177/2632010X221099889

[51] Mugada, V., Mahato, V., Andhavaram, D. and Vajhala, S.M. (2021) Evaluation of Prescribing Patterns of Antibiotics Using Selected Indicators for Antimicrobial Use in Hospitals and the Access, Watch, Reserve (Aware) Classification by the World Health Organization. *Turkish Journal of Pharmaceutical Sciences*, **18**, 282-288. https://doi.org/10.4274/tjps.galenos.2020.11456

[52] Lucien, M.A.B., Canarie, M.F., Kilgore, P.E., Jean-Denis, G., Fénélon, N., Pierre, M., *et al.* (2021) Antibiotics and Antimicrobial Resistance in the COVID-19 Era: Perspective from Resource-Limited Settings. *International Journal of Infectious Dis-*

eases, **104**, 250-254. https://doi.org/10.1016/j.ijid.2020.12.087

[53] Badulla, W.F.S., Alshakka, M. and Mohamed Ibrahim, M.I. (2020) Antimicrobial Resistance Profiles for Different Isolates in Aden, Yemen: A Cross-Sectional Study in a Resource-Poor Setting. *BioMed Research International*, **2020**, Article ID: 1810290. https://doi.org/10.1155/2020/1810290

[54] Gajdács, M., Urbán, E., Stájer, A. and Baráth, Z. (2021) Antimicrobial Resistance in the Context of the Sustainable Development Goals: A Brief Review. *European Journal of Investigation in Health, Psychology and Education*, **11**, 71-82. https://doi.org/10.3390/ejihpe11010006

[55] Bogdanić, N., Močibob, L., Vidović, T., Soldo, A. and Begovać, J. (2022) Azithromycin Consumption during the COVID-19 Pandemic in Croatia, 2020. *PLOS ONE*, **17**, e0263437. https://doi.org/10.1371/journal.pone.0263437

[56] Murillo-Zamora, E., Trujillo, X., Huerta, M., Mendoza-Cano, O., Guzmán-Esquivel, J., Guzmán-Solórzano, J.A., *et al.* (2022) Empirical Antibiotic Prescribing in Adult COVID-19 Inpatients over Two Years in Mexico. *Antibiotics*, **11**, Article No. 764. https://doi.org/10.3390/antibiotics11060764

[57] Chitungo, I., Dzinamarira, T., Nyazika, T.K., Herrera, H., Musuka, G. and Murewanhema, G. (2022) Inappropriate Antibiotic Use in Zimbabwe in the COVID-19 Era: A Perfect Recipe for Antimicrobial Resistance. *Antibiotics*, **11**, Article No. 244. https://doi.org/10.3390/antibiotics11020244

[58] Muloi, D., Ward, M.J., Pedersen, A.B., Fèvre, E.M., Woolhouse, M.E.J. and Van Bunnik, B.A.D. (2018) Are Food Animals Responsible for Transfer of Antimicrobial-Resistant *Escherichia coli* or Their Resistance Determinants to Human Populations? A Systematic Review. *Foodborne Pathogens and Disease*, **15**, 467-474. https://doi.org/10.1089/fpd.2017.2411

[59] Lepper, H.C., Woolhouse, M.E.J. and van Bunnik, B.A.D. (2022) The Role of the Environment in Dynamics of Antibiotic Resistance in Humans and Animals: A Modelling Study. *Antibiotics*, **11**, Article No. 1361. https://doi.org/10.3390/antibiotics11101361

[60] Parkhill, J. (2022) Antimicrobial Resistance Exchange Between Humans and Animals: Why We Need to Know More. *Engineering*, **15**, 11-12. https://doi.org/10.1016/j.eng.2022.04.007

[61] Ikhimiukor, O.O., Odih, E.E., Donado-Godoy, P. and Okeke, I.N. (2022) A Bottom-Up View of Antimicrobial Resistance Transmission in Developing Countries. *Nature Microbiology*, **7**, 757-765. https://doi.org/10.1038/s41564-022-01124-w

[62] Koutsoumanis, K., Allende, A., Álvarez-Ordóñez, A., Bolton, D., Bover-Cid, S., Chemaly, M., *et al.* (2022) Transmission of Antimicrobial Resistance (AMR) during Animal Transport. *EFSA Journal*, **20**, Article No. 7586. https://doi.org/10.2903/j.efsa.2022.7586

[63] Godman, B., Egwuenu, A., Haque, M., Malande, O.O., Schellack, N., Kumar, S., *et al.* (2021) Strategies to Improve Antimicrobial Utilization with a Special Focus on Developing Countries. *Life* (*Basel*), **11**, Artice No. 528. https://doi.org/10.3390/life11060528

[64] Saleem, Z., Godman, B., Cook, A., Khan, M.A., Campbell, S.M., Seaton, R.A., *et al.* (2022) Ongoing Efforts to Improve Antimicrobial Utilization in Hospitals among African Countries and Implications for the Future. *Antibiotics*, **11**, Artice No. 1824. https://doi.org/10.3390/antibiotics11121824

[65] Kariuki, S., Kering, K., Wairimu, C., Onsare, R. and Mbae, C. (2022) Antimicrobial Resistance Rates and Surveillance in Sub-Saharan Africa: Where Are We Now? *In-*

fection and Drug Resistance, **15**, 3589-3609. https://doi.org/10.2147/IDR.S342753

[66] Laxminarayan, R., Duse, A., Wattal, C., Zaidi, A.K.M., Wertheim, H.F.L., Sumpradit, N., *et al.* (2013) Antibiotic Resistance—The Need for Global Solutions. *The Lancet Infectious Diseases*, **13**, 1057-1098. https://doi.org/10.1016/S1473-3099(13)70318-9

[67] O'Neill, J. (2016) Tackling Drug-Resistant Infections Globally: Final Report and Recommendations. The Review on Antimicrobial Resistance. 1-84. https://amr-review.org/sites/default/files/160518_Final paper_with cover.pdf

[68] Piddock, L.J.V. (2016) Reflecting on the Final Report of the O'Neill Review on Antimicrobial Resistance. *The Lancet Infectious Diseases*, **16**, 767-768. https://doi.org/10.1016/S1473-3099(16)30127-X

[69] Piddock, L.J.V. (2019) The Global Antibiotic Research and Development Partnership (GARDP): Researching and Developing New Antibiotics to Meet Global Public Health Needs. *MedChemComm*, **10**, 1227-1230. https://doi.org/10.1039/C9MD90010A

[70] Lee, C.R., Cho, I.H., Jeong, B.C. and Lee, S.H. (2013) Strategies to Minimize Antibiotic Resistance. *International Journal of Environmental Research and Public Health*, **10**, 4274-4305. https://doi.org/10.3390/ijerph10094274

[71] Uddin, T.M., Chakraborty, A.J., Khusro, A., Zidan, B.R.M., Mitra, S., Emran, T., *et al.* (2021) Antibiotic Resistance in Microbes: History, Mechanisms, Therapeutic Strategies and Future Prospects. *Journal of Infection and Public Health*, **14**, 1750-1766. https://doi.org/10.1016/j.jiph.2021.10.020

[72] World Health Organization (2015) Global Action Plan on Antimicrobial Resistance. World Health Organization, Geneva, 1-28. https://apps.who.int/iris/handle/10665/193736

[73] World Health Organization (2019) Antimicrobial Stewardship Programmes in Health-Care Facilities in Low- and Middle-Income Countries. A WHO Practical Toolkit. https://apps.who.int/iris/bitstream/handle/10665/329404/9789241515481-eng.pdf

[74] Queenan, K., Häsler, B. and Rushton, J. (2016) A One Health Approach to Antimicrobial Resistance Surveillance: Is There a Business Case for It? *The International Journal of Antimicrobial Agents*, **48**, 422-427. https://doi.org/10.1016/j.ijantimicag.2016.06.014

[75] McEwen, S.A. and Collignon, P.J. (2018) Antimicrobial Resistance: A One Health Perspective. *Microbiology Spectrum*, **6**, ARBA-0009-2017. https://doi.org/10.1128/microbiolspec.ARBA-0009-2017

[76] Mackenzie, J.S. and Jeggo, M. (2019) The One Health Approach—Why Is It So Important? *Tropical Medicine and Infectious Disease*, **4**, Article No. 88. https://doi.org/10.3390/tropicalmed4020088

[77] Aslam, B., Khurshid, M., Arshad, M.I., Muzammil, S., Rasool, M., Yasmeen, N., *et al.* (2021) Antibiotic Resistance: One Health One World Outlook. *Frontiers in Cellular and Infection Microbiology*, **11**, Article ID: 771510. https://doi.org/10.3389/fcimb.2021.771510

[78] Guardabassi, L., Butaye, P., Dockrell, D.H., Fitzgerald, J.R. and Kuijper, E.J. (2020) One Health: A Multifaceted Concept Combining Diverse Approaches to Prevent and Control Antimicrobial Resistance. *Clinical Microbiology and Infection*, **26**, 1604-1605. https://doi.org/10.1016/j.cmi.2020.07.012

[79] Earnshaw, S., Mendez, A., Monnet, D.L., Hicks, L., Cruickshank, M., Weekes, L., *et al.* (2013) Global Collaboration to Encourage Prudent Antibiotic Use. *The Lancet*

Infectious Diseases, **13**, 1003-1004. https://doi.org/10.1016/S1473-3099(13)70315-3

[80] Howard, S.J., Catchpole, M., Watson, J. and Davies, S.C. (2013) Antibiotic Resistance: Global Response Needed. *The Lancet Infectious Diseases*, **13**, 1001-1003. https://doi.org/10.1016/S1473-3099(13)70195-6

[81] Stewart, Williams, J. and Wall, S. (2019) The AMR Emergency: Multi-Sector Collaboration and Collective Global Policy Action Is Needed Now. *Global Health Action*, **12**, Article ID: 1855831. https://doi.org/10.1080/16549716.2019.1855831

[82] Iwu, C.D. and Patrick, S.M. (2021) An Insight into the Implementation of the Global Action Plan on Antimicrobial Resistance in the WHO African Region: A Roadmap for Action. *The International Journal of Antimicrobial Agents*, **58**, Article ID: 106411. https://doi.org/10.1016/j.ijantimicag.2021.106411

[83] Sandberg, M., Hesp, A., Aenishaenslin, C., Bordier, M., Bennani, H., Bergwerff, U., *et al.* (2021) Assessment of Evaluation Tools for Integrated Surveillance of Antimicrobial Use and Resistance Based on Selected Case Studies. *Frontiers in Veterinary Science*, **8**, Article No. 663. https://doi.org/10.3389/fvets.2021.620998

[84] Seale, A.C., Gordon, N.C., Islam, J., Peacock, S.J. and Scott, J.A.G. (2017) AMR Surveillance in Low and Middle-Income Settings—A Roadmap for Participation in the Global Antimicrobial Surveillance System (GLASS). *Wellcome Open Research*, **2**, Article No. 92. https://doi.org/10.12688/wellcomeopenres.12527.1

[85] Harbarth, S., Balkhy, H.H., Goossens, H., Jarlier, V., Kluytmans, J., Laxminarayan, R., *et al.* (2015) Antimicrobial Resistance: One World, One Fight! *Antimicrobial Resistance & Infection Control*, **4**, Article No. 49. https://doi.org/10.1186/s13756-015-0091-2

[86] Badau, E. (2021) A One Health Perspective on the Issue of the Antibiotic Resistance. *Parasite*, **28**, Article No. 16. https://doi.org/10.1051/parasite/2021006

[87] Velazquez-Meza, M.E., Galarde-López, M., Carrillo-Quiróz, B. and Alpuche-Aranda, C.M. (2022) Antimicrobial Resistance: One Health Approach. *Veterinary World*, **15**, 743-749. https://doi.org/10.14202/vetworld.2022.743-749

[88] Page, M.J., McKenzie, J.E., Bossuyt, P.M., Boutron, I., Hoffmann, T.C., Mulrow, C.D., *et al.* (2021) The PRISMA 2020 Statement: An Updated Guideline for Reporting Systematic Reviews. *BMJ*, **372**, n71. https://doi.org/10.1136/bmj.n71

[89] Lota, M.M.M., Chua, A.Q., Azupardo, K., Lumangaya, C., Reyes, K., Villanueva, S., *et al.* (2022) A Qualitative Study on the Design and Implementation of the National Action Plan on Antimicrobial Resistance in the Philippines. *Antibiotics*, **11**, Article No. 820. https://doi.org/10.3390/antibiotics11060820

[90] Boon, D.L.C. (2017) National Action Plan on Antimicrobial Resistance in Singapore. *The International Journal of Antimicrobial Agents*, **50**, S21-S22.

[91] Karp, B.E., Tate, H., Plumblee, J.R., Dessai, U., Whichard, J.M., Thacker, E.L., *et al.* (2017) National Antimicrobial Resistance Monitoring System: Two Decades of Advancing Public Health through Integrated Surveillance of Antimicrobial Resistance. *Foodborne Pathogens and Disease*, **10**, 545-557. https://doi.org/10.1089/fpd.2017.2283

[92] Republic of Zambia NAP on AMR (2017) Multi-Sectoral National Action Plan on Antimicrobial Resistance. Government of the Republic of Zambia [Internet]. 1-79. https://www.afro.who.int/publications/multi-sectoral-national-action-plan-antimicrobial-resistance-2017-2027

[93] Chua, A.Q., Verma, M., Hsu, L.Y. and Legido-Quigley, H. (2021) An Analysis of National Action Plans on Antimicrobial Resistance in Southeast Asia Using a Governance Framework Approach. *The Lancet Regional Health—Western Pacific*, **7**,

Article ID: 100084. https://doi.org/10.1016/j.lanwpc.2020.100084

[94] Willemsen, A., Reid, S. and Assefa, Y. (2022) A Review of National Action Plans on Antimicrobial Resistance: Strengths and Weaknesses. *Antimicrobial Resistance and Infection Control*, **11**, Article No. 90. https://doi.org/10.1186/s13756-022-01130-x

[95] Saleem, Z., Hassali, M. and Hashmi, F. (2018) Pakistan's National Action Plan for Antimicrobial Resistance: Translating Ideas into Reality. *The Lancet Infectious Diseases*, **18**, 1066-1067. https://doi.org/10.1016/S1473-3099(18)30516-4

[96] Shabangu, K., Essack, S.Y. and Duma, S.E. (2023) Barriers to Implementing National Action Plans on Antimicrobial Resistance Using a One Health Approach: Policy-Makers' Perspectives from South Africa and Eswatini. *Journal of Global Antimicrobial Resistance*, **33**, 130-136. https://doi.org/10.1016/j.jgar.2023.02.007

[97] From the Federal Task Force on Combating Antibiotic-Resistant Bacteria (2020) National Action Plan for Combating Antibiotic-Resistant Bacteria, 2020-2025. Centers for Disease Control and Prevention, Atlanta. https://www.hhs.gov/sites/default/files/carb-national-action-plan-2020-2025.pdf

[98] Siachalinga, L., Mufwambi, W. and Lee, L.H. (2022) Impact of Antimicrobial Stewardship Interventions to Improve Antibiotic Prescribing for Hospital Inpatients in Africa: A Systematic Review and Meta-Analysis. *Journal of Hospital Infection*, **129**, 124-143. https://doi.org/10.1016/j.jhin.2022.07.031

[99] Verma, M., Shafiq, N., Tripathy, J.P., Nagaraja, S.B., Kathirvel, S., Chouhan, D.K., *et al.* (2019) Antimicrobial Stewardship Programme in a Trauma Centre of a Tertiary Care Hospital in North India: Effects and Implementation Challenges. *Journal of Global Antimicrobial Resistance*, **17**, 283-290. https://doi.org/10.1016/j.jgar.2019.02.020

[100] Doron, S. and Davidson, L.E. (2011) Antimicrobial Stewardship. *Mayo Clinic Proceedings*, **86**, 1113-1123. https://doi.org/10.4065/mcp.2011.0358

[101] Dyar, O.J., Huttner, B., Schouten, J. and Pulcini, C. (2017) What Is Antimicrobial Stewardship? *Clinical Microbiology and Infection*, **23**, 793-798. https://doi.org/10.1016/j.cmi.2017.08.026

[102] Weston, A., Epstein, L., Davidson, L.E., DeMaria, A. and Doron, S. (2013) The Impact of a Massachusetts State-Sponsored Educational Program on Antimicrobial Stewardship in Acute Care Hospitals. *Infection Control & Hospital Epidemiology*, **34**, 437-439. https://doi.org/10.1086/669861

[103] Lakoh, S., Bawoh, M., Lewis, H., Jalloh, I., Thomas, C., Barlatt, S., *et al.* (2023) Establishing an Antimicrobial Stewardship Program in Sierra Leone: A Report of the Experience of a Low-Income Country in West Africa. *Antibiotics*, **12**, Article No. 424. https://doi.org/10.3390/antibiotics12030424

[104] Kotwani, A. and Gandra, S. (2023) Strengthening Antimicrobial Stewardship Activities in Secondary and Primary Public Healthcare Facilities in India: Insights from a Qualitative Study with Stakeholders. *Indian Journal of Medical Microbiology*, **41**, 59-63. https://doi.org/10.1016/j.ijmmb.2022.12.011

[105] Aiesh, B.M., Nazzal, M.A., Abdelhaq, A.I., Abutaha, S.A., Zyoud, S.H. and Sabateen, A. (2023) Impact of an Antibiotic Stewardship Program on Antibiotic Utilization, Bacterial Susceptibilities, and Cost of Antibiotics. *Scientific Reports*, **13**, Article No. 5040. https://doi.org/10.1038/s41598-023-32329-6

[106] Silverberg, S.L., Zannella, V.E., Countryman, D., Ayala, A.P., Lenton, E., Friesen, F., *et al.* (2017) A Review of Antimicrobial Stewardship Training in Medical Education. *International Journal of Medical Education*, **8**, 353-374. https://doi.org/10.5116/ijme.59ba.2d47

[107] Al-Omari, A., Al, Mutair, A., Alhumaid, S., Salih, S., Alanazi, A., Albarsan, H., *et al.* (2020) The Impact of Antimicrobial Stewardship Program Implementation at Four Tertiary Private Hospitals: Results of a Five-Years Pre-Post Analysis. *Antimicrobial Resistance & Infection Control*, **9**, Article No. 95. https://doi.org/10.1186/s13756-020-00751-4

[108] Alabi, A.S., Picka, S.W., Sirleaf, R., Ntirenganya, P.R., Ayebare, A., Correa, N., *et al.* (2022) Implementation of an Antimicrobial Stewardship Programme in Three Regional Hospitals in the South-East of Liberia: Lessons Learned. *JAC-Antimicrobal Resistance*, **4**, dlac069. https://doi.org/10.1093/jacamr/dlac069

[109] Shah, N., Joshi, A. and Ganguly, B. (2017) Impact of Antibiotic Stewardship Program on Prescribing Pattern of Antimicrobials in Patients of Medical Intensive Care Unit. *Journal of Clinical and Diagnostic Research*, **11**, FC11-FC15. https://doi.org/10.7860/JCDR/2017/27171.10237

[110] Timbrook, T.T., Hurst, J.M. and Bosso, J.A. (2016) Impact of an Antimicrobial Stewardship Program on Antimicrobial Utilization, Bacterial Susceptibilities, and Financial Expenditures at an Academic Medical Center. *Hospital Pharmacy*, **51**, 703-711. https://doi.org/10.1310/hpj5109-703

[111] Lee, B.R., Goldman, J.L., Yu, D., Myers, A.L., Stach, L.M., Hedican, E., *et al.* (2017) Clinical Impact of an Antibiotic Stewardship Program at a Children's Hospital. *Infectious Diseases & Therapy*, **6**, 103-113. https://doi.org/10.1007/s40121-016-0139-5

[112] Rogers, V., Katwyk, S., Jones, S.L. and Hoffman, S.J. (2018) Mapping Educational Opportunities for Healthcare Workers on Antimicrobial Resistance and Stewardship around the World. *Human Resources for Health*, **16**, Article No. 9. https://doi.org/10.1186/s12960-018-0270-3

[113] Elgendy, M.O. and Abdelrahim, M.E.A. (2021) Public Awareness about Coronavirus Vaccine, Vaccine Acceptance, and Hesitancy. *Journal of Medical Virology*, **93**, 6535-6543. https://doi.org/10.1002/jmv.27199

[114] Cairns, K.A., Roberts, J.A., Cotta, M.O. and Cheng, A.C. (2015) Antimicrobial Stewardship in Australian Hospitals and Other Settings. *Infectious Diseases and Therapy*, **4**, 27-38. https://doi.org/10.1007/s40121-015-0083-9

[115] Gitaka, J., Kamita, M., Mureithi, D., Ndegwa, D., Masika, M., Omuse, G., *et al.* (2020) Combating Antibiotic Resistance Using Guidelines and Enhanced Stewardship in Kenya: A Protocol for an Implementation Science Approach. *BMJ Open*, **10**, e030823. https://doi.org/10.1136/bmjopen-2019-030823

[116] McKenzie, D., Rawlins, M. and Del Mar, C. (2013) Antimicrobial Stewardship: What's It All about? *Australian Prescriber* **36**, 116-120. https://doi.org/10.18773/austprescr.2013.045

[117] Song, M., Deng, Z., Chan, O. and Grépin, K.A. (2022) Understanding the Implementation of Antimicrobial Policies: Lessons from the Hong Kong Strategy and Action Plan. *Antibiotics*, **11**, Article No. 636. https://doi.org/10.3390/antibiotics11050636

[118] Aryee, A. and Price, N. (2015) Antimicrobial Stewardship—Can We Afford to Do without It? *British Journal of Clinical Pharmacology*, **79**, 173-181. https://doi.org/10.1111/bcp.12417

[119] Gyssens, I.C. (2018) Role of Education in Antimicrobial Stewardship. *Medical Clinics of North America*, **102**, 855-871. https://doi.org/10.1016/j.mcna.2018.05.011

[120] Keitoku, K., Nishimura, Y., Hagiya, H., Koyama, T. and Otsuka, F. (2021) Impact of the World Antimicrobial Awareness Week on Public Interest between 2015 and 2020: A Google Trends Analysis. *International Journal of Infectious Diseases*, **111**,

12-20. https://doi.org/10.1016/j.ijid.2021.08.018

[121] Wu, D., Walsh, T.R. and Wu, Y. (2021) World Antimicrobial Awareness Week 2021—Spread Awareness, Stop Resistance. *China CDC Weekly*, **3**, 987-993. https://doi.org/10.46234/ccdcw2021.241

[122] World Health Organization (2021) World Antimicrobial Awareness Week: Campaign Guidance. https://www.who.int/publications/m/item/world-antimicrobial-awareness-week-campaign-guidance

[123] Pinto, Jimenez, C.E., Keestra, S.M., Tandon, P., Pickering, A.J., Moodley, A., Cumming, O., *et al.* (2023) One Health WASH: An AMR-Smart Integrative Approach to Preventing and Controlling Infection in Farming Communities. *BMJ Global Health*, **8**, e011263. https://doi.org/10.1136/bmjgh-2022-011263

[124] World Health Organization (2021) Global Antimicrobial Resistance and Use Surveillance System (GLASS) Report 2021. World Health Organization, Geneva. https://www.who.int/publications/i/item/9789240027336

[125] Pollack, L.A. and Srinivasan, A. (2014) Core Elements of Hospital Antibiotic Stewardship Programs from the Centers for Disease Control and Prevention. *Clinical Infectious Diseases*, **59**, S97-S100. https://doi.org/10.1093/cid/ciu542

[126] Ribero, Pombo, M.H., Gandra, S., Thompson, D., Lamkang, A.S., Pulcini, C. and Laxminarayan, R. (2018) Global Core Standards for Hospital Antimicrobial Stewardship Programs: International Perspectives and Future Directions. World Innovation Summit for Health, Doha, 1-54.

[127] Masetla, M.A., Ntuli, P.N., Abraham, V., Godman, B., Witika, B.A., Mudenda, S., *et al.* (2023) Antimicrobial Stewardship for Outpatients with Chronic Bone and Joint Infections in the Orthopaedic Clinic of an Academic Tertiary Hospital, South Africa. *Antibiotics*, **12**, Article No. 1142. https://doi.org/10.3390/antibiotics12071142

[128] Arieti, F., Göpel, S., Sibani, M., Carrara, E., Pezzani, M.D., Murri, R., *et al.* (2020) White Paper: Bridging the Gap between Surveillance Data and Antimicrobial Stewardship in the Outpatient Sector—Practical Guidance from the JPIAMR ARCH and COMBACTE-MAGNET EPI-Net Networks. *Journal of Antimicrobial Chemotherapy*, **75**, II42-II51. https://doi.org/10.1093/jac/dkaa428

[129] Hermsen, E.D., MacGeorge, E.L. andresen, M.L., Myers, L.M., Lillis, C.J. and Rosof, B.M. (2020) Decreasing the Peril of Antimicrobial Resistance through Enhanced Health Literacy in Outpatient Settings: An Underrecognized Approach to Advance Antimicrobial Stewardship. *Advances in Therapy*, **37**, 918-932. https://doi.org/10.1007/s12325-019-01203-1

[130] Sine, K., Appaneal, H., Dosa, D. and LaPlante, K.L. (2022) Antimicrobial Prescribing in the Telehealth Setting: Framework for Stewardship during a Period of Rapid Acceleration within Primary Care. *Clinical Infectious Diseases*, **75**, 2260-2265. https://doi.org/10.1093/cid/ciac598

[131] Nathwani, D., Varghese, D., Stephens, J., Ansari, W., Martin, S. and Charbonneau, C. (2019) Value of Hospital Antimicrobial Stewardship Programs [ASPs]: A Systematic Review. *Antimicrobial Resistance and Infection Control*, **8**, Article No. 35. https://doi.org/10.1186/s13756-019-0471-0

[132] Van Katwyk, S.R., Hoffman, S.J., Mendelson, M., Taljaard, M. and Grimshaw, J.M. (2020) Strengthening the Science of Addressing Antimicrobial Resistance: A Framework for Planning, Conducting and Disseminating Antimicrobial Resistance Intervention Research. *Health Research Policy and Systems*, **18**, Article No. 60.

[133] Netthong, R., Kane, R. and Ahmadi, K. (2022) Antimicrobial Resistance and Com-

munity Pharmacists' Perspective in Thailand: A Mixed Methods Survey Using Appreciative Inquiry Theory. *Antibiotics*, **11**, Article No. 161. https://doi.org/10.3390/antibiotics11020161

[134] Bishop, C., Yacoob, Z., Knobloch, M.J. and Safdar, N. (2019) Community Pharmacy Interventions to Improve Antibiotic Stewardship and Implications for Pharmacy Education: A Narrative Overview. *Research in Social and Administrative Pharmacy*, **15**, 627-631. https://doi.org/10.1016/j.sapharm.2018.09.017

[135] Lim, K., Broom, A., Olsen, A. and Seale, H. (2023) Community Pharmacists as Antimicrobial Guardians and Gatekeepers—A Qualitative Study of the Perspectives of Pharmacy Sector Stakeholders. *Exploratory Research in Clinical and Social Pharmacy*, **9**, Article ID: 100212. https://doi.org/10.1016/j.rcsop.2022.100212

[136] Hayes, C.V., Parekh, S., Lecky, D.M., Loader, J., Triggs-Hodge, C. and Ashiru-Oredope, D. (2023) The National Implementation of a Community Pharmacy Antimicrobial Stewardship Intervention (PAMSI) through the English Pharmacy Quality Scheme 2020 to 2022. *Antibiotics*, **12**, Article No. 793. https://doi.org/10.3390/antibiotics12040793

[137] Rusic, D., Bukić, J., Seselja, P.A., Leskur, D., Modun, D., Petric, A., *et al.* (2021) Are We Making the Most of Community Pharmacies? Implementation of Antimicrobial Stewardship Measures in Community Pharmacies: A Narrative Review. *Antibiotics*, **10**, Article No. 63. https://doi.org/10.3390/antibiotics10010063

[138] Tebug, S.F., Mouiche, M.M.M., Abia, W.A., Teno, G., Tiambo, C.K., Moffo, F., *et al.* (2021) Antimicrobial Use and Practices by Animal Health Professionals in 20 Sub-Saharan African Countries. *Preventive Veterinary Medicine*, **186**, Article ID: 105212. https://doi.org/10.1016/j.prevetmed.2020.105212

[139] Payumo, J., Alocilja, E., Boodoo, C., Luchini-Colbry, K., Ruegg, P., McLamore, E., *et al.* (2021) Next Generation of AMR Network. *Encyclopedia*, **1**, 871-892. https://doi.org/10.3390/encyclopedia1030067

[140] Talebi, B., Abadi, A., Rizvanov, A.A., Haertlé, T. and Blatt, N.L. (2019) World Health Organization Report: Current Crisis of Antibiotic Resistance. *BioNanoScience*, **9**, 778-788. https://doi.org/10.1007/s12668-019-00658-4

[141] Sarkar, S. and Okafor, C.C. (2022) Effect of Changes in Veterinary Feed Directive Regulations on Violative Antibiotic Residues in the Tissue of Food Animals from the Inspector-Generated Sampling in the United States. *Microorganisms*, **10**, Article No. 2031. https://doi.org/10.3390/microorganisms10102031

[142] Dillon, M.E. and Jackson-Smith, D. (2021) Impact of the Veterinary Feed Directive on Ohio Cattle Operations. *PLOS ONE*, **16**, e0255911. https://doi.org/10.1371/journal.pone.0255911

[143] More, S.J. (2020) European Perspectives on Efforts to Reduce Antimicrobial Usage in Food Animal Production. *Irish Veterinary Journal*, **73**, Article No. 2. https://doi.org/10.1186/s13620-019-0154-4

[144] Doidge, C., Ruston, A., Lovatt, F., Hudson, C., King, L. and Kaler, J. (2020) Farmers' Perceptions of Preventing Antibiotic Resistance on Sheep and Beef Farms: Risk, Responsibility, and Action. *Frontiers in Veterinary Science*, **7**, Article No. 524. https://doi.org/10.3389/fvets.2020.00524

[145] World Health Organization (2022) The WHO AWaRe (Access, Watch, Reserve) Antibiotic Book. Web Annex. Infographics. 1-160. https://www.who.int/publications/i/item/WHO-MHP-HPS-EML-2022.02

[146] World Health Organization (2021) 2021 AWaRe Classification. https://www.who.int/publications/i/item/2021-aware-classification

[147] Mudenda, S., Daka, V. and Matafwali, S.K. (2023) World Health Organization AWaRe Framework for Antibiotic Stewardship: Where Are We Now and Where Do We Need to Go? An Expert Viewpoint. *Antimicrobial Stewardship & Healthcare Epidemiology*, **3**, e84. https://doi.org/10.1017/ash.2023.164

[148] Hsia, Y., Lee, B.R., Versporten, A., Yang, Y., Bielicki, J., Jackson, C., *et al.* (2019) Use of the WHO Access, Watch, and Reserve Classification to Define Patterns of Hospital Antibiotic Use (AWaRe): An Analysis of Paediatric Survey Data from 56 Countries. *The Lancet Global Health*, **7**, e861-e871.

[149] Sharland, M., Pulcini, C., Harbarth, S., Zeng, M., Gandra, S., Mathur, S., *et al.* (2018) Classifying Antibiotics in the WHO Essential Medicines List for Optimal Use—Be AWaRe. *The Lancet Infectious Diseases*, **18**, 18-20. https://doi.org/10.1016/S1473-3099(17)30724-7

[150] Sharland, M., Zanichelli, V., Ombajo, L.A., Bazira, J., Cappello, B., Chitatanga, R., *et al.* (2022) The WHO Essential Medicines List AWaRe Book: From a List to a Quality Improvement System. *Clinical Microbiology and Infection*, **28**, 1533-1535. https://doi.org/10.1016/j.cmi.2022.08.009

[151] Budd, E., Cramp, E., Sharland, M., Hand, K., Howard, P., Wilson, P., *et al.* (2019) Adaptation of the WHO Essential Medicines List for National Antibiotic Stewardship Policy in England: Being AWaRe. *Journal of Antimicrobial Chemotherapy*, **74**, 3384-3389. https://doi.org/10.1093/jac/dkz321

[152] Mudenda, S., Chomba, M., Chabalenge, B., Hikaambo, C.N., Banda, M., Daka, V., *et al.* (2022) Antibiotic Prescribing Patterns in Adult Patients According to the WHO AWaRe Classification: A Multi-Facility Cross-Sectional Study in Primary Healthcare Hospitals in Lusaka, Zambia. *Journal of Pharmacy and Pharmacology*, **13**, 379-392. https://doi.org/10.4236/pp.2022.1310029

[153] Kiggundu, R., Wittenauer, R., Waswa, J.P., Nakambale, H.N., Kitutu, F.E., Murungi, M., *et al.* (2022) Point Prevalence Survey of Antibiotic Use across 13 Hospitals in Uganda. *Antibiotics*, **11**, Article No. 199. https://doi.org/10.3390/antibiotics11020199

[154] Mudenda, S., Mukela, M., Matafwali, S., Banda, M., Mutati, R.K., Muungo, L.T., *et al.* (2022) Knowledge, Attitudes, and Practices towards Antibiotic Use and Antimicrobial Resistance among Pharmacy Students at the University of Zambia: Implications for Antimicrobial Stewardship Programmes. *Scholars Academic Journal of Pharmacy*, **11**, 117-124. https://doi.org/10.36347/sajp.2022.v11i08.002

[155] Hassan, M.M., Kalam, M.A., Alim, M.A., Shano, S., Nayem, M.R.K., Badsha, M.R., *et al.* (2021) Knowledge, Attitude, and Practices on Antimicrobial Use and Antimicrobial Resistance among Commercial Poultry Farmers in Bangladesh. *Antibiotics*, **10**, Article No. 784. https://doi.org/10.3390/antibiotics10070784

[156] Kalam, M.A., Alim, M.A., Shano, S., Nayem, M.R.K., Badsha, M.R., Al, Mamun, M.A., *et al.* (2021) Knowledge, Attitude, and Practices on Antimicrobial Use and Antimicrobial Resistance among Poultry Drug and Feed Sellers in Bangladesh. *Veterinary Sciences*, **8**, Article No. 111. https://doi.org/10.3390/vetsci8060111

[157] Kainga, H., Phonera, M.C., Chikowe, I., Chatanga, E., Nyirongo, H., Luwe, M., *et al.* (2023) Determinants of Knowledge, Attitude, and Practices of Veterinary Drug Dispensers toward Antimicrobial Use and Resistance in Main Cities of Malawi: A Concern on Antibiotic Stewardship. *Antibiotics*, **12**, Article No. 149. https://doi.org/10.3390/antibiotics12010149

[158] Vijay, D., Bedi, J.S., Dhaka, P., Singh, R., Singh, J., Arora, A.K., *et al.* (2021) Knowledge, Attitude, and Practices (KAP) Survey among Veterinarians, and Risk Factors

Relating to Antimicrobial Use and Treatment Failure in Dairy Herds of India. *Antibiotics*, **10**, Article No. 216. https://doi.org/10.3390/antibiotics10020216

[159] Tahoon, M.A., Khalil, M.M., Hammad, E., Morad, W.S., Awad, S.M. and Ezzat, S. (2020) The Effect of Educational Intervention on Healthcare Providers' Knowledge, Attitude, & Practice towards Antimicrobial Stewardship Program at National Liver Institute, Egypt. *Egyptian Liver Journal*, **10**, Article No. 5. https://doi.org/10.1186/s43066-019-0016-5

[160] Mangesho, P.E., Caudell, M.A., Mwakapeje, E.R., Ole-Neselle, M., Kimani, T., Dorado-García, A., *et al.* (2021) Knowing Is Not Enough: A Mixed-Methods Study of Antimicrobial Resistance Knowledge, Attitudes, and Practises among Maasai Pastoralists. *Frontiers in Veterinary Science*, **8**, Article No. 152. https://doi.org/10.3389/fvets.2021.645851

[161] Dopelt, K., Amar, A., Yonatan, N. and Davidovitch, N. (2023) Knowledge, Attitudes, and Practices Regarding Antibiotic Use and Resistance: A Cross-Sectional Study among Students in Israel. *Antibiotics*, **12**, Article No. 1028. https://doi.org/10.3390/antibiotics12061028

[162] Shah, P., Shrestha, R., Mao, Z., Chen, Y., Chen, Y., Koju, P., *et al.* (2019) Knowledge, Attitude, and Practice Associated with Antibiotic Use among University Students: A Survey in Nepal. *International Journal of Environmental Research and Public Health*, **16**, Article No. 3996. https://doi.org/10.3390/ijerph16203996

[163] Jairoun, A., Hassan, N., Ali, A., Jairoun, O., Shahwan, M. and Hassali, M. (2019) University Students' Knowledge, Attitudes, and Practice Regarding Antibiotic Use and Associated Factors: A Cross-Sectional Study in the United Arab Emirates. *International Journal of General Medicine*, **12**, 235-246. https://doi.org/10.2147/IJGM.S200641

[164] Liu, C., Liu, C., Wang, D. and Zhang, X. (2019) Knowledge, Attitudes and Intentions to Prescribe Antibiotics: A Structural Equation Modeling Study of Primary Care Institutions in Hubei, China. *International Journal of Environmental Research and Public Health*, **16**, Article No. 2385. https://doi.org/10.21203/rs.2.10397/v1

[165] Tembo, N., Mudenda, S., Banda, M., Chileshe, M. and Matafwali, S. (2022) Knowledge, Attitudes and Practices on Antimicrobial Resistance among Pharmacy Personnel and Nurses at a Tertiary Hospital in Ndola, Zambia: Implications for Antimicrobial Stewardship Programmes. *JAC-Antimicrobal Resistance*, **4**, dlac107. https://doi.org/10.1093/jacamr/dlac107

[166] Al-Taani, G.M., Al-Azzam, S., Karasneh, R.A., Sadeq, A.S., Mazrouei, N., *et al.* (2022) Pharmacists' Knowledge, Attitudes, Behaviors and Information Sources on Antibiotic Use and Resistance in Jordan. *Antibiotics*, **11**, Article No. 175. https://doi.org/10.3390/antibiotics11020175

[167] Huang, S. and Eze, U.A. (2023) Awareness and Knowledge of Antimicrobial Resistance, Antimicrobial Stewardship and Barriers to Implementing Antimicrobial Susceptibility Testing among Medical Laboratory Scientists in Nigeria: A Cross-Sectional Study. *Antibiotics*, **12**, Article No. 815. https://doi.org/10.3390/antibiotics12050815

[168] Ahmed, R., Bashir, A., Brown, J.E.P., Cox, J.A.G., Hilton, A.C., Jordan, S.L., *et al.* (2020) Aston University's Antimicrobial Resistance (AMR) Roadshow: Raising Awareness and Embedding Knowledge of AMR in Key Stage 4 Learners. *Infection Prevention in Practice*, **2**, Article ID: 100060. https://doi.org/10.1016/j.infpip.2020.100060

[169] Miyano, S., Htoon, T.T., Nozaki, I., Pe, E.H. and Tin, H.H. (2022) Public Knowledge, Practices, and Awareness of Antibiotics and Antibiotic Resistance in Myan-

mar: The First National Mobile Phone Panel Survey. *PLOS ONE*, **17**, e0273380. https://doi.org/10.1371/journal.pone.0273380

[170] Inácio, J., Barnes, L.M., Jeffs, S., Castanheira, P., Wiseman, M., Inácio, S., *et al*. (2017) Master of Pharmacy Students' Knowledge and Awareness of Antibiotic Use, Resistance and Stewardship. *Currents in Pharmacy Teaching and Learning*, **9**, 551-559. https://doi.org/10.1016/j.cptl.2017.03.021

[171] Ashiru-Oredope, D., Hopkins, S., Vasandani, S., Umoh, E., Oloyede, O., Nilsson, A., *et al*. (2021) Healthcare Workers' Knowledge, Attitudes and Behaviours with Respect to Antibiotics, Antibiotic Use and Antibiotic Resistance across 30 EU/EEA Countries in 2019. *Eurosurveillance*, **26**, Article ID: 1900633. https://doi.org/10.2807/1560-7917.ES.2021.26.12.1900633

[172] Kalonga., J., Hangoma., J., Banda., M., Munkombwe., D. and Mudenda, S. (2020) Antibiotic Prescribing Patterns in Paediatric Patients at Levy Mwanawasa University Teaching Hospital in Lusaka, Zambia. *International Journal of Pharmacy and Pharmacology*, **4**, Article No. 138. https://doi.org/10.31531/2581-3080.1000138

[173] Mudenda, S., Bangara, F., Sitali, J. and Banda, M. (2019) Knowledge, Attitude, and Practices on Antibiotic Resistance among Pharmacists at the University Teaching Hospitals in Lusaka, Zambia. *Journal of Harmonized Research in Pharmacy*, **8**, 12-25. https://doi.org/10.30876/JOHR.8.2.2019.12-24

[174] Hussain, I., Yousaf, N., Haider, S., Jalil, P., Saleem, M.U., Imran, I., *et al*. (2021) Assessing Knowledge and Perception Regarding Antimicrobial Stewardship and Antimicrobial Resistance in University Students of Pakistan: Findings and Implications. *Antibiotics*, **10**, Article No. 866. https://doi.org/10.3390/antibiotics10070866

[175] Zulu, A., Matafwali, S.K., Banda, M. and Mudenda, S. (2020) Assessment of Knowledge, Attitude and Practices on Antibiotic Resistance among Undergraduate Medical Students in the School of Medicine at the University of Zambia. *International Journal of Basic & Clinical Pharmacology*, **9**, 263-270. https://doi.org/10.18203/2319-2003.ijbcp20200174

[176] Mudenda, S., Hankombo, M., Saleem, Z., Sadiq, M.J., Banda, M., Munkombwe, D., *et al*. (2021) Knowledge, Attitude, and Practices of Community Pharmacists on Antibiotic Resistance and Antimicrobial Stewardship in Lusaka, Zambia. *Journal of Biomedical Research & Environmental Sciences*, **2**, 1005-1014. https://doi.org/10.37871/jbres1343

[177] Sefah, I.A., Akwaboah, E., Sarkodie, E., Godman, B. and Meyer, J.C. (2022) Evaluation of Healthcare Student's Knowledge on Antibiotic Use, Antimicrobial Resistance and Antimicrobial Stewardship Programs and Associated Factors in a Tertiary University in Ghana: Findings and Implications. *Antibiotics*, **11**, Article No. 1679. https://doi.org/10.3390/antibiotics11121679

[178] Shatla, M., Althobaiti, F.S. and Almqaiti, A. (2022) Public Knowledge, Attitudes, and Practices towards Antibiotic Use and Antimicrobial Resistance in the Western Region of Saudi Arabia. *Cureus*, **14**, e31857. https://doi.org/10.7759/cureus.31857

[179] Chea, B., Kong, S., Thim, S., Ban, N., Seng, S., Fernandez-Colorado, C., *et al*. (2022) Knowledge, Attitudes, and Practices of Antimicrobial Use and Resistance among Livestock Producers in Cambodia. *Open Journal of Animal Sciences*, **12**, 454-466. https://doi.org/10.4236/ojas.2022.123034

[180] Kemp, S.A., Pinchbeck, G.L., Fèvre, E.M. and Williams, N.J. (2021) A Cross- Sectional Survey of the Knowledge, Attitudes, and Practices of Antimicrobial Users and Providers in an Area of High-Density Livestock-Human Population in Western Kenya. *Frontiers in Veterinary Science*, **8**, Article ID: 727365. https://doi.org/10.3389/fvets.2021.727365

[181] Kalam, M.A., Rahman, M.S., Alim, M.A., Shano, S., Afrose, S., Jalal, F.A., *et al.* (2022) Knowledge, Attitudes, and Common Practices of Livestock and Poultry Veterinary Practitioners Regarding the AMU and AMR in Bangladesh. *Antibiotics*, **11**, Article No. 80. https://doi.org/10.3390/antibiotics11010080

[182] IACG (2018) Surveillance and Monitoring for Antimicrobial Use and Resistance.

[183] Klein, E.Y., Van, Boeckel, T.P., Martinez, E.M., Pant, S., Gandra, S., Levin, S.A., *et al.* (2018) Global Increase and Geographic Convergence in Antibiotic Consumption between 2000 and 2015. *Proceedings of the National Academy of Sciences of the United States of America*, **115**, E3463-E3470. https://doi.org/10.1073/pnas.1717295115

[184] Schnall, J., Rajkhowa, A., Ikuta, K., Rao, P. and Moore, C.E. (2019) Surveillance and Monitoring of Antimicrobial Resistance: Limitations and Lessons from the GRAM Project. *BMC Medicine*, **17**, Article No. 176. https://doi.org/10.1186/s12916-019-1412-8

[185] Lim, C., Ashley, E.A., Hamers, R.L., Turner, P., Kesteman, T., Akech, S., *et al.* (2021) Surveillance Strategies Using Routine Microbiology for Antimicrobial Resistance in Low- and Middle-Income Countries. *Clinical Microbiology and Infection*, **27**, 1391-1399. https://doi.org/10.1016/j.cmi.2021.05.037

[186] Acharya, K.P., Subramanya, S.H. and Lopes, B.S. (2019) Combatting Antimicrobial Resistance in Nepal: The Need for Precision Surveillance Programmes and Multi-Sectoral Partnership. *JAC-Antimicrobial Resistance*, **1**, dlz066. https://doi.org/10.1093/jacamr/dlz066

[187] Joshi, M.P., Hafner, T., Twesigye, G., Ndiaye, A., Kiggundu, R., Mekonnen, N., *et al.* (2021) Strengthening Multisectoral Coordination on Antimicrobial Resistance: A Landscape Analysis of Efforts in 11 Countries. *Journal of Pharmaceutical Policy and Practice*, **14**, Article No. 27. https://doi.org/10.1186/s40545-021-00309-8

[188] McKenzie, J.S., Morris, R.S., Midwinter, A., Burgess, S., Amia, W.C., Lopes, H., *et al.* (2019) A Protocol for Active AMR Surveillance in Poultry. Towards a One Health AMR Surveillance System: Protocol for Active AMR Surveillance in Commercial Broiler and Layer Chicken Populations for the Fleming Fund Grants Programme. Version 2. https://www.flemingfund.org/app/uploads/97eb17b6835316221f4818842f0079a9.pdf

[189] Ariyawansa, S., Gunawardana, K.N., Hapudeniya, M.M., Manelgamage, N.J., Karunarathne, C.R., Madalagama, R.P., *et al.* (2023) One Health Surveillance of Antimicrobial Use and Resistance: Challenges and Successes of Implementing Surveillance Programs in Sri Lanka. *Antibiotics*, **12**, Article No. 446. https://doi.org/10.3390/antibiotics12030446

[190] Berman, T.S., Barnett-Itzhaki, Z., Berman, T. and Marom, E. (2023) Antimicrobial Resistance in Food-Producing Animals: Towards Implementing a One Health Based National Action Plan in Israel. *Israel Journal of Health Policy Research*, **12**, Article No. 18. https://doi.org/10.1186/s13584-023-00562-z

[191] Ikhimiukor, O.O. and Okeke, I.N. (2023) A Snapshot Survey of Antimicrobial Resistance in Food-Animals in Low and Middle-Income Countries. *One Health*, **16**, Article ID: 100489. https://doi.org/10.1016/j.onehlt.2023.100489

[192] Kimera, Z.I., Mshana, S.E., Rweyemamu, M.M., Mboera, L.E.G. and Matee, M.I.N. (2020) Antimicrobial Use and Resistance in Food-Producing Animals and the Environment: An African Perspective. *Antimicrobial Resistance and Infection Control*, **9**, Article No. 37. https://doi.org/10.1186/s13756-020-0697-x

[193] Food and Agriculture Organization of the United Nations (2019) Monitoring and Surveillance of Antimicrobial Resistance in Bacteria from Healthy Food Animals Intended for Consumption. Regional Antimicrobial Resistance Monitoring and Surveillance Guidelines. https://www.fao.org/documents/card/en/c/ca6897en

[194] Seo, K.W. and Lee, Y.J. (2019) Detection of Plasmid-Mediated Quinolone Resistance Genes in *β*-Lactamase-Producing *Escherichia coli* Isolates from Layer Hens. *Poultry Science*, **98**, 1480-1487. https://doi.org/10.3382/ps/pey545

[195] Bennani, H., Cornelsen, L., Stärk, K.D.C. and Häsler, B. (2021) Characterisation and Mapping of the Surveillance System for Antimicrobial Resistance and Antimicrobial Use in the United Kingdom. *Veterinary Record*, **188**, e10. https://doi.org/10.1002/vetr.10

[196] Simjee, S., McDermott, P., Trott, D.J. and Chuanchuen, R. (2018) Present and Future Surveillance of Antimicrobial Resistance in Animals: Principles and Practices. *Microbiology Spectrum*, **6**, ARBA-0028-2017. https://doi.org/10.1128/microbiolspec.ARBA-0028-2017

[197] Seo, K.W., Shim, J.B. and Lee, Y.J. (2019) Comparative Genetic Characterization of Third-Generation Cephalosporin-Resistant *Escherichia coli* Isolated from a Layer Operation System in Korea. *Poultry Science*, **98**, 1472-1479. https://doi.org/10.3382/ps/pey513

[198] El-Shazly, D.A., Nasef, S.A., Mahmoud, F.F. and Jonas, D. (2017) Expanded Spectrum *β*-Lactamase Producing *Escherichia coli* Isolated from Chickens with Colibacillosis in Egypt. *Poultry Science*, **96**, 2375-2384. https://doi.org/10.3382/ps/pew493

[199] World Health Organization (2017) Integrated Surveillance of Antimicrobial Resistance in Foodborne Bacteria: Application of a One Health Approach. World Health Organization, Geneva. https://apps.who.int/iris/handle/10665/255747

[200] World Organization for Animal Health (2021) OIE Terrestrial Animal Health Code. https://www.woah.org/en/what-we-do/standards/codes-and-manuals/terrestrial-code-online-access/?id=169&L=0&htmfile=chapitre_antibio_harmonisation.htm

[201] World Health Organization (2015) Global Antimicrobial Resistance Surveillance System. Manual for Early Implementation. http://www.who.int/drugresistance/en

[202] Donado-Godoy, P., Castellanos, R., León, M., Arevalo, A., Clavijo, V., Bernal, J., *et al.* (2015) The Establishment of the Colombian Integrated Program for Antimicrobial Resistance Surveillance (COIPARS): A Pilot Project on Poultry Farms, Slaughterhouses and Retail Market. *Zoonoses Public Health*, **62**, 58-69. https://doi.org/10.1111/zph.12192

[203] Collignon, P.C., Conly, J.M., Andremont, A., McEwen, S.A., Aidara-Kane, A., Griffin, P.M., *et al.* (2016) World Health Organization Ranking of Antimicrobials According to Their Importance in Human Medicine: A Critical Step for Developing Risk Management Strategies to Control Antimicrobial Resistance from Food Animal Production. *Clinical Infectious Diseases*, **63**, 1087-1093. https://doi.org/10.1093/cid/ciw475

[204] Seale, A.C., Hutchison, C., Fernandes, S., Stoesser, N., Kelly, H., Lowe, B., *et al.* (2017) Supporting Surveillance Capacity for Antimicrobial Resistance: Laboratory Capacity Strengthening for Drug Resistant Infections in Low and Middle Income Countries. *Wellcome Open Research*, **2**, Article No. 91. https://doi.org/10.12688/wellcomeopenres.12523.1

[205] Bertagnolio, S., Suthar, A.B., Tosas, O. and Van Weezenbeek, K. (2023) Antimicrobial Resistance: Strengthening Surveillance for Public Health Action. *PLoS Medicine*, **20**, e1004265. https://doi.org/10.1371/journal.pmed.1004265

[206] World Health Organization (2022) Global Antimicrobial Resistance and Use Surveillance System (GLASS) Report: 2022. World Health Organization, Geneva. https://www.who.int/publications/i/item/9789240062702

[207] World Health Organization (2014) Antimicrobial Resistance: Global Report on Surveillance. 1-256.

[208] Tacconelli, E., Carrara, E., Savoldi, A., Harbarth, S., Mendelson, M., Monnet, D.L., *et al.* (2018) Discovery, Research, and Development of New Antibiotics: The WHO Priority List of Antibiotic-Resistant Bacteria and Tuberculosis. *The Lancet Infectious Diseases*, **18**, 318-327. https://doi.org/10.1016/S1473-3099(17)30753-3

[209] Ho, C.W.L. and Lee, T.-L. (2020) Global Governance of Anti-Microbial Resistance: A Legal and Regulatory Toolkit. In: Jamrozik, E. and Selgelid, M., Eds., *Ethics and Drug Resistance: Collective Responsibility for Global Public Health*, Springer, Cham, 401-420. https://doi.org/10.1007/978-3-030-27874-8_25

[210] World Health Organization (2018) Global Antimicrobial Resistance Surveillance System (GLASS) Report: Early Implementation 2017-2018. World Health Organization, Geneva, 1-260.

[211] Iskandar, K., Molinier, L., Hallit, S., Sartelli, M., Hardcastle, T.C., Haque, M., *et al.* (2021) Surveillance of Antimicrobial Resistance in Low- and Middle-Income Countries: A Scattered Picture. *Antimicrobial Resistance and Infection Control*, **10**, Article No. 63. https://doi.org/10.1186/s13756-021-00931-w

[212] Gandra, S., Alvarez-Uria, G., Turner, P., Joshi, J., Limmathurotsakul, D. and van Doorn, H.R. (2020) Antimicrobial Resistance Surveillance in Low- and Middle-Income Countries: Progress and Challenges in Eight South Asian and Southeast Asian Countries. *Clinical Microbiology Reviews*, **33**, e00048-19. https://doi.org/10.1128/CMR.00048-19

[213] Hay, S.I., Rao, P.C., Dolecek, C., Day, N.P.J., Stergachis, A., Lopez, A.D., *et al.* (2018) Measuring and Mapping the Global Burden of Antimicrobial Resistance. *BMC Medicine*, **16**, Article No. 78. https://doi.org/10.1186/s12916-018-1073-z

[214] O'Neil, J. (2014) Review on Antibiotic Resistance. Antimicrobial Resistance: Tackling a Crisis for the Health and Wealth of Nations. The Health and Wealth of Nations. https://wellcomecollection.org/works/rdpck35v

[215] Jonas, O.B., Irwin, A., Berthe, F.C.J., Le, Gall, F.G. and Marquez, P. (2017) Drug-Resistant Infections: A Threat to Our Economic Future. World Bank Report 2, 1-132. https://www.worldbank.org/en/topic/health/publication/drug-resistant-infections-a-threat-to-our-economic-future

[216] Jiang, T.T., Yang, Y.Q., Cao, N.X., Yin, Y.P. and Chen, X.S. (2020) Novel Education-Based Intervention to Reduce Inappropriate Antibiotic Prescribing for Treatment of Gonorrhoea in China: Protocol for a Cluster Randomised Controlled Trial. *BMJ Open*, **10**, e037549. https://doi.org/10.1136/bmjopen-2020-037549

[217] McDonagh, M.S., Peterson, K., Winthrop, K., Cantor, A., Lazur, B.H. and Buckley, D.I. (2018) Interventions to Reduce Inappropriate Prescribing of Antibiotics for Acute Respiratory Tract Infections: Summary and Update of a Systematic Review. *Journal of International Medical Research*, **46**, 3337-3357. https://doi.org/10.1177/0300060518782519

[218] Milani, R.V., Wilt, J.K., Entwisle, J., Hand, J., Cazabon, P. and Bohan, J.G. (2019) Reducing Inappropriate Outpatient Antibiotic Prescribing: Normative Comparison Using Unblinded Provider Reports. *BMJ Open Quality*, **8**, e000351. https://doi.org/10.1136/bmjoq-2018-000351

[219] Yevutsey, S.K., Buabeng, K.O., Aikins, M., Anto, B.P., Biritwum, R.B., Frimodt-Møller, N., *et al.* (2017) Situational Analysis of Antibiotic Use and Resistance in Ghana: Policy and Regulation. *BMC Public Health*, **17**, Article No. 896. https://doi.org/10.1186/s12889-017-4910-7

[220] Kapona, O. (2017) Zambia Successfully Launches the First Multi-Sectoral National Action Plan on Antimicrobial Resistance (AMR). *The Health Press Zambia Bulletin*, 1, 5-7. https://www.flemingfund.org/wp-content/uploads/ec74b8a828168c148bcba3700ace7989.pdf

[221] Mremi, I.R., Rumisha, S.F., Sindato, C., Kimera, S.I. and Mboera, L.E.G. (2022) Comparative Assessment of the Human and animal Health Surveillance Systems in Tanzania: Opportunities for an Integrated One Health Surveillance Platform. *Global Public Health*. https://doi.org/10.1080/17441692.2022.2110921

[222] Nulty, K.M., Soon, J.M., Wallace, C.A. and Nastasijevic, I. (2016) Antimicrobial Resistance Monitoring and Surveillance in the Meat Chain: A Report from Five Countries in the European Union and European Economic Area. *Trends in Food Science and Technology*, **58**, 1-13. https://doi.org/10.1016/j.tifs.2016.09.010

[223] Zhao, C., Wang, Y., Tiseo, K., Pires, J., Criscuolo, N.G. and Van Boeckel, T.P. (2021) Geographically Targeted Surveillance of Livestock Could Help Prioritize Intervention against Antimicrobial Resistance in China. *Nature Food*, **2**, 596-602. https://doi.org/10.1038/s43016-021-00320-x

[224] Schrijver, R., Stijntjes, M., Rodríguez-Baño, J., Tacconelli, E., Babu Rajendran, N. and Voss, A. (2018) Review of Antimicrobial Resistance Surveillance Programmes in Livestock and Meat in EU with Focus on Humans. *Clinical Microbiology and Infection*, **24**, 577-590. https://doi.org/10.1016/j.cmi.2017.09.013

[225] Aidara-Kane, A., Angulo, F.J., Conly, J., Minato, Y., Silbergeld, E.K., McEwen, S.A., *et al.* (2018) World Health Organization (WHO) Guidelines on Use of Medically Important Antimicrobials in Food-Producing Animals. *Antimicrobial Resistance & Infection Control*, **7**, Article No. 7. https://doi.org/10.1186/s13756-017-0294-9

[226] Tang, K.L., Caffrey, N.P., Nóbrega, D.B., Cork, S.C., Ronksley, P.E., Barkema, H.W., *et al.* (2017) Restricting the Use of Antibiotics in Food-Producing Animals and Its Associations with Antibiotic Resistance in Food-Producing Animals and Human Beings: A Systematic Review and Meta-Analysis. *The Lancet Planetary Health*, **1**, e316-e327. https://doi.org/10.1016/S2542-5196(17)30141-9

[227] Maron, D.F., Smith, T.J.S. and Nachman, K.E. (2013) Restrictions on Antimicrobial USe in Food Animal Production: An International Regulatory and Economic Survey. *Globalization and Health*, **9**, Article No. 48. https://doi.org/10.1186/1744-8603-9-48

[228] Cogliani, C., Goossens, H. and Greko, C. (2011) Restricting Antimicrobial Use in Food Animals: Lessons from Europe. *Microbe*, **6**, 274-279. https://doi.org/10.1128/microbe.6.274.1

[229] Schuts, E.C., Boyd, A., Muller, A.E., Mouton, J.W. and Prins, J.M. (2021) The Effect of Antibiotic Restriction Programs on Prevalence of Antimicrobial Resistance: A Systematic Review and Meta-Analysis. *Open Forum Infectious Diseases*, **8**, ofab070. https://doi.org/10.1093/ofid/ofab070

[230] Inthavong, P., Chanthavong, S., Nammanininh, P., Phommachanh, P., Theppangna, W., Agunos, A., *et al.* (2022) Antimicrobial Resistance Surveillance of Pigs and Chickens in the Lao People's Democratic Republic, 2018-2021. *Antibiotics*, **11**, Article No. 177. https://doi.org/10.3390/antibiotics11020177

[231] Buzdugan, S.N., Alarcon, P., Huntington, B., Rushton, J., Blake, D.P. and Guitian, J. (2021) Enhancing the Value of Meat Inspection Records for Broiler Health and Welfare Surveillance: Longitudinal Detection of Relational Patterns. *BMC Veterinary Research*, **17**, Article No. 278. https://doi.org/10.1186/s12917-021-02970-2

[232] Wertheim, H.F.L., Huong, V.T.L. and Kuijper, E.J. (2021) Clinical Microbiology Laboratories in Low-Resource Settings, It Is Not Only about Equipment and Reagents, but Also Good Governance for Sustainability. *Clinical Microbiology and Infection*, **27**, 1389-1390. https://doi.org/10.1016/j.cmi.2021.07.027

[233] Ferguson, J.K., Joseph, J., Kangapu, S., Zoleveke, H., Townell, N., Duke, T., *et al.* (2020) Quality Microbiological Diagnostics and Antimicrobial Susceptibility Testing, an Essential Component of Antimicrobial Resistance Surveillance and Control Efforts in Pacific Island Nations. *Western Pacific Surveillance and Response*, **11**, 41-46. https://doi.org/10.5365/wpsar.2018.9.3.004

[234] Amin, M., Pasha, M.H., Hoque, M.N., Siddiki, A.Z., Saha, S. and Kamal, M.M. (2022) Methodology for Laboratory-Based Antimicrobial Resistance Surveillance in Animals. *Veterinary World*, **15**, 1066-1079. https://doi.org/10.14202/vetworld.2022.1066-1079

[235] Malania, L., Wagenaar, I., Karatuna, O., Tambic Andrasevic, A., Tsereteli, D., Baidauri, M., *et al.* (2021) Setting up Laboratory-Based Antimicrobial Resistance Surveillance in Low- and Middle-Income Countries: Lessons Learned from Georgia. *Clinical Microbiology and Infection*, **27**, 1409-1413. https://doi.org/10.1016/j.cmi.2021.05.027

[236] Musicha, P., Cornick, J.E., Bar-Zeev, N., French, N., Masesa, C., Denis, B., *et al.* (2017) Trends in Antimicrobial Resistance in Bloodstream Infection Isolates at a Large Urban Hospital in Malawi (1998-2016): A Surveillance Study. *The Lancet Infectious Diseases*, **17**, 1042-1052. https://doi.org/10.1016/S1473-3099(17)30394-8

[237] Catalán, P., Wood, E., Blair, J.M.A., Gudelj, I., Iredell, J.R. and Beardmore, R.E. (2022) Seeking Patterns of Antibiotic Resistance in ATLAS, an Open, Raw MIC Database with Patient Metadata. *Nature Communications*, **13**, Article No. 2917. https://doi.org/10.1038/s41467-022-30635-7

[238] Kiggundu, R., Lusaya, E., Seni, J., Waswa, J.P., Kakooza, F., Tjipura, D., *et al.* (2023) Identifying and Addressing Challenges to Antimicrobial Use Surveillance in the Human Health Sector in Low- and Middle-Income Countries: Experiences and Lessons Learned from Tanzania and Uganda. *Antimicrobial Resistance & Infection Control*, **12**, Article No. 9. https://doi.org/10.1186/s13756-023-01213-3

[239] Musicha, P., Feasey, N.A., Cain, A.K., Kallonen, T., Chaguza, C., Peno, C., *et al.* (2017) Genomic Landscape of Extended-Spectrum β-Lactamase Resistance in *Escherichia coli* from an Urban African Setting. *Journal of Antimicrobial Chemotherapy*, **72**, 1602-1609. https://doi.org/10.1093/jac/dkx058

[240] Yamba, K., Lukwesa-Musyani, C., Samutela, M.T., Kapesa, C., Hang'ombe, M.B., Mpabalwani, E., *et al.* (2023) Phenotypic and Genotypic Antibiotic Susceptibility Profiles of Gram-Negative Bacteria Isolated from Bloodstream Infections at a Referral Hospital, Lusaka, Zambia. *PLOS Global Public Health*, **3**, e0001414. https://doi.org/10.1371/journal.pgph.0001414

[241] Phiri, N., Mainda, G., Mukuma, M., Sinyangwe, N.N., Banda, L.J., Kwenda, G., *et al.* (2020) Antibiotic-Resistant Salmonella Species and *Escherichia coli* in Broiler Chickens from Farms, Abattoirs, and Open Markets in Selected Districts of Zambia. *Journal of Epidemiological Research*, **6**, 13-21. https://doi.org/10.5430/jer.v6n1p13

[242] Muligisa-Muonga, E., Mainda, G., Mukuma, M., Kwenda, G., Hang'ombe, B., Flavien, B.N., *et al.* (2021) Antimicrobial Resistance of *Escherichia coli* and Salmo-

nella Isolated from Retail Broiler Chicken Carcasses in Zambia. *Journal of Epidemiological Research*, **6**, 35-43. https://doi.org/10.5430/jer.v6n1p35

[243] Agarwal, A., Kapila, K. and Kumar, S. (2009) WHONET Software for the Surveillance of Antimicrobial Susceptibility. *Medical Journal Armed Forces India*, **65**, 264-266. https://doi.org/10.1016/S0377-1237(09)80020-8

[244] World Health Organization (2022) WHONET Microbiology Laboratory Database Software. World Health Organization (WHO) Collaborating Centre for Surveillance of Antimicrobial Resistance. https://whonet.org

[245] Saeed, N., Zeeshan, M., Farooqi, J., Shakoor, S., Jabeen, K., Malik, F.R., *et al.* (2022) Open Online Courses for Strengthening Laboratory-Based Detection of Antimicrobial Resistance in Pakistan. *Frontiers in Public Health*, **10**, Article ID: 773704. https://doi.org/10.3389/fpubh.2022.773704

[246] Saeed, D.K., Hasan, R., Naim, M., Zafar, A., Khan, E., Jabeen, K., *et al.* (2017) Readiness for Antimicrobial Resistance (AMR) Surveillance in Pakistan; a Model for Laboratory Strengthening. *Antimicrobial Resistance & Infection Control*, **6**, Article No. 101. https://doi.org/10.1186/s13756-017-0260-6

[247] Huber, N. andraud, M., Sassu, E.L., Prigge, C., Zoche-Golob, V., Käsbohrer, A., *et al.* (2022) What Is a Biosecurity Measure? A Definition Proposal for Animal Production and Linked Processing Operations. *One Health*, **15**, Article ID: 100433. https://doi.org/10.1016/j.onehlt.2022.100433

[248] Renault, V., Humblet, M.F. and Saegerman, C. (2022) Biosecurity Concept: Origins, Evolution and Perspectives. *Animals*, **12**, Article No. 63. https://doi.org/10.3390/ani12010063

[249] Toroghi, R., Salamatian, I., Bassami, M.R., Irankhah, N., Emarloo, A., Mahouti, A., *et al.* (2020) Implementation of High-Level Biosecurity Measures Can Reduce the Baseline Antibody Titers of Newcastle Disease in Non-Integrated Layer Flocks in Northeast Iran. *World's Poultry Science Journal*, **76**, 757-766. https://doi.org/10.1080/00439339.2020.1823301

[250] Conan, A., Goutard, F.L., Sorn, S. and Vong, S. (2012) Biosecurity Measures for Backyard Poultry in Developing Countries: A Systematic Review. *BMC Veterinary Research*, **8**, Article No. 240. https://doi.org/10.1186/1746-6148-8-240

[251] Cristalli, A. and Capua, I. (2007) Practical Problems in Controlling H5N1 High Pathogenicity Avian Influenza at Village Level in Vietnam and Introduction of Biosecurity Measures. *Avian Diseases*, **51**, 461-462. https://doi.org/10.1637/7564-033106R.1

[252] Henning, K.A., Henning, J., Morton, J., Long, N.T., Ha, N.T. and Meers, J. (2009) Farm- and Flock-Level Risk Factors Associated with Highly Pathogenic Avian Influenza Outbreaks on Small Holder Duck and Chicken Farms in the Mekong Delta of Viet Nam. *Preventive Veterinary Medicine*, **91**, 179-188. https://doi.org/10.1016/j.prevetmed.2009.05.027

[253] Alhaji, N.B. and Odetokun, I.A. (2011) Assessment of Biosecurity Measures against Highly Pathogenic Avian Influenza Risks in Small-Scale Commercial Farms and Free-Range Poultry Flocks in the Northcentral Nigeria. *Transboundary and Emerging Diseases*, **58**, 157-161. https://doi.org/10.1111/j.1865-1682.2010.01195.x

[254] Crew, C.R., Brennan, M.L. and Ireland, J.L. (2023) Implementation of Biosecurity on Equestrian Premises: A Narrative Overview. *Veterinary Journal*, **292**, Article ID: 105950. https://doi.org/10.1016/j.tvjl.2023.105950

[255] Morley, P.S. (2002) Biosecurity of Veterinary Practices. *Veterinary Clinics of North America: Food Animal Practice*, **18**, 133-155.

https://doi.org/10.1016/S0749-0720(02)00009-9

[256] Rojo-Gimeno, C., Postma, M., Dewulf, J., Hogeveen, H., Lauwers, L. and Wauters, E. (2016) Farm-Economic Analysis of Reducing Antimicrobial Use Whilst Adopting Improved Management Strategies on Farrow-to-Finish Pig Farms. *Preventive Veterinary Medicine*, **129**, 74-87. https://doi.org/10.1016/j.prevetmed.2016.05.001

[257] Postma, M., Vanderhaeghen, W., Sarrazin, S., Maes, D. and Dewulf, J. (2017) Reducing Antimicrobial Usage in Pig Production without Jeopardizing Production Parameters. *Zoonoses Public Health*, **64**, 63-74. https://doi.org/10.1111/zph.12283

[258] Tilli, G., Laconi, A., Galuppo, F., Mughini-Gras, L. and Piccirillo, A. (2022) Assessing Biosecurity Compliance in Poultry Farms: A Survey in a Densely Populated Poultry Area in North East Italy. *Animals*, **12**, Article No. 1409. https://doi.org/10.3390/ani12111409

[259] Scott, A.B., Singh, M., Groves, P., Hernandez-Jover, M., Barnes, B., Glass, K., *et al.* (2018) Biosecurity Practices on Australian Commercial Layer and Meat Chicken Farms: Performance and Perceptions of Farmers. *PLOS ONE*, **13**, e0195582. https://doi.org/10.1371/journal.pone.0195582

[260] Haque, M. (2020) Handwashing in Averting Infectious Diseases: Relevance to COVID-19. *Journal of Population Therapeutics and Clinical Pharmacology*, **27**, e37-e52. https://doi.org/10.15586/jptcp.v27SP1.711

[261] Mathur, P. (2011) Hand Hygiene: Back to the Basics of Infection Control. *Indian Journal of Medical Research*, **134**, 611-620. https://doi.org/10.4103/0971-5916.90985

[262] Ackers, L., Ackers-Johnson, G., Welsh, J., Kibombo, D. and Opio, S. (2020) Infection Prevention Control (IPC) and Antimicrobial Resistance (AMR). In: Ackers, L., *et al.*, Eds., *Anti-Microbial Resistance in Global Perspective*, Springer, Berlin, 53. https://doi.org/10.1007/978-3-030-62662-4_4

[263] Moralejo, D., El, Dib, R., Prata, R.A., Barretti, P. and Corrêa, I. (2018) Improving Adherence to Standard Precautions for the Control of Health Care-Associated Infections. *Cochrane Database of Systematic Reviews*, **2**, CD010768. https://doi.org/10.1002/14651858.CD010768.pub2

[264] Watson, J., D'Mello-Guyett, L., Flynn, E., Falconer, J., Esteves-Mills, J., Prual, A., *et al.* (2019) Interventions to Improve Water Supply and Quality, Sanitation and Handwashing Facilities in Healthcare Facilities, and Their Effect on Healthcare-Associated Infections in Low-Income and Middle-Income Countries: A Systematic Review and Supplementary Scopin. *BMJ Global Health*, **4**, e001632. https://doi.org/10.1136/bmjgh-2019-001632

[265] Ling, M.L., Ching, P., Cheng, J., Lang, L., Liberali, S., Poon, P., *et al.* (2023) APSIC Dental Infection Prevention and Control (IPC) Guidelines. *Antimicrobial Resistance & Infection Control*, **12**, Article No. 53. https://doi.org/10.1186/s13756-023-01252-w

[266] Haque, M., Sartelli, M., McKimm, J. and Bakar, M.A. (2018) Health Care- Associated Infections—An Overview. *Infection and Drug Resistance*, **11**, 2321-2333. https://doi.org/10.2147/IDR.S177247

[267] Haque, M., McKimm, J., Sartelli, M., Dhingra, S., Labricciosa, F.M., Islam, S., *et al.* (2020) Strategies to Prevent Healthcare-Associated Infections: A Narrative Overview. *Risk Management and Healthcare Policy*, **13**, 1765-1780. https://doi.org/10.2147/RMHP.S269315

[268] Mo, Y., Pham, T.M., Lim, C., Horby, P., Stewardson, A.J., Harbarth, S., *et al.* (2022) The Effect of Hand Hygiene Frequency on Reducing Acute Respiratory Infections in the Community: A Meta-Analysis. *Epidemiology and Infection*, **150**, e79.

https://doi.org/10.1017/S0950268822000516

[269] Sangalang, S.O., Lemence, A.L.G., Ottong, Z.J., Valencia, J.C., Olaguera, M., Canja, R.J.F., *et al.* (2022) School Water, Sanitation, and Hygiene (WaSH) Intervention to Improve Malnutrition, Dehydration, Health Literacy, and Handwashing: A Cluster-Randomised Controlled Trial in Metro Manila, Philippines. *BMC Public Health*, **22**, Article No. 2034. https://doi.org/10.1186/s12889-022-14398-w

[270] Gizaw, Z., Addisu, A. and Dagne, H. (2019) Effects of Water, Sanitation and Hygiene (WASH) Education on Childhood Intestinal Parasitic Infections in Rural Dembiya, Northwest Ethiopia: An Uncontrolled Before-and-After Intervention Study. *Environmental Health and Preventive Medicine*, **24**, Article No. 16. https://doi.org/10.1186/s12199-019-0774-z

[271] Sands, M. and Aunger, R. (2020) Determinants of Hand Hygiene Compliance among Nurses in US Hospitals: A Formative Research Study. *PLOS ONE*, **15**, e0230573. https://doi.org/10.1371/journal.pone.0230573

[272] Jeihooni, A.K., Kashfi, S.H., Bahmandost, M. and Harsini, P.A. (2018) Promoting Preventive Behaviors of Nosocomial Infections in Nurses: The Effect of an Educational Program Based on Health Belief Model. *Investigacion y Educacion en Enfermeria*, **36**, e09. https://doi.org/10.17533/udea.iee.v36n1e09

[273] Ravikumar, R., Chan, J. and Prabakaran, M. (2022) Vaccines against Major Poultry Viral Diseases: Strategies to Improve the Breadth and Protective Efficacy. *Viruses*, **14**, Article No. 1195. https://doi.org/10.3390/v14061195

[274] Hoelzer, K., Bielke, L., Blake, D.P., Cox, E., Cutting, S.M., Devriendt, B., *et al.* (2018) Vaccines as Alternatives to Antibiotics for Food Producing Animals. Part 1: Challenges and Needs. *Veterinary Research*, **49**, Article No. 64. https://doi.org/10.1186/s13567-018-0560-8

[275] Micoli, F., Bagnoli, F., Rappuoli, R. and Serruto, D. (2021) The Role of Vaccines in Combatting Antimicrobial Resistance. *Nature Reviews Microbiology*, **19**, 287-302. https://doi.org/10.1038/s41579-020-00506-3

[276] Buchy, P., Ascioglu, S., Buisson, Y., Datta, S., Nissen, M., Tambyah, P.A., *et al.* (2020) Impact of Vaccines on Antimicrobial Resistance. *International Journal of Infectious Diseases*, **90**, 188-196. https://doi.org/10.1016/j.ijid.2019.10.005

[277] Rosini, R., Nicchi, S., Pizza, M. and Rappuoli, R. (2020) Vaccines against Antimicrobial Resistance. *Frontiers in Immunology*, **11**, Article No. 1048. https://doi.org/10.3389/fimmu.2020.01048

[278] Vekemans, J., Hasso-Agopsowicz, M., Kang, G., Hausdorff, W.P., Fiore, A., Tayler, E., *et al.* (2021) Leveraging Vaccines to Reduce Antibiotic Use and Prevent Antimicrobial Resistance: A World Health Organization Action Framework. *Clinical Infectious Diseases*, **73**, e1011-e1017. https://doi.org/10.1093/cid/ciab062

[279] Adisasmito, W.B., Almuhairi, S., Behravesh, C.B., Bilivogui, P., Bukachi, S.A., Casas, N., *et al.* (2022) One Health: A New Definition for a Sustainable and Healthy Future. *PLOS Pathogens*, **18**, e1010537. https://doi.org/10.1371/journal.ppat.1010537

[280] World Health Organization (2021) Antimicrobial Resistance and the United Nations Sustainable Development Cooperation Framework. World Health Organization Report, 1-24. https://www.who.int/publications/i/item/9789240036024

[281] de Mesquita, S., Saraiva, M., Lim, K., do, Monte, D.F.M., Givisiez, P.E.N., Alves, L.B.R., de Freitas, N.O.C., *et al.* (2022) Antimicrobial Resistance in the Globalized Food Chain: A One Health Perspective Applied to the Poultry Industry. *Brazilian Journal of Microbiology*, **53**, 465-486. https://doi.org/10.1007/s42770-021-00635-8

[282] Kahn, L.H. (2017) Antimicrobial Resistance: A One Health Perspective. *Transac-*

tions of the Royal Society of Tropical Medicine and Hygiene, **111**, 255-260. https://doi.org/10.1093/trstmh/trx050

[283] Musoke, D., Kitutu, F.E., Mugisha, L., Amir, S., Brandish, C., Ikhile, D., *et al.* (2020) A One Health Approach to Strengthening Antimicrobial Stewardship in Wakiso District, Uganda. *Antibiotics*, **9**, Article No. 764. https://doi.org/10.3390/antibiotics9110764

[284] Aenishaenslin, C., Häsler, B., Ravel, A., Parmley, E.J., Mediouni, S., Bennani, H., *et al.* (2021) Evaluating the Integration of One Health in Surveillance Systems for Antimicrobial Use and Resistance: A Conceptual Framework. *Frontiers in Veterinary Science*, **8**, Article ID: 611931. https://doi.org/10.3389/fvets.2021.611931

[285] Wu, D., Elliott, C. and Wu, Y. (2021) Food Safety Strategies: The One Health Approach to Global Challenges and China's Actions. *China CDC Weekly*, **3**, 507-513. https://doi.org/10.46234/ccdcw2021.131

[286] Ma, F., Xu, S., Tang, Z., Li, Z. and Zhang, L. (2021) Use of Antimicrobials in Food Animals and Impact of Transmission of Antimicrobial Resistance on Humans. *Biosafety and Health*, **3**, 32-38. https://doi.org/10.1016/j.bsheal.2020.09.004

[287] Dalton, K.R., Rock, C., Carroll, K.C. and Davis, M.F. (2020) One Health in Hospitals: How Understanding the Dynamics of People, Animals, and the Hospital Built-Environment Can Be Used to Better Inform Interventions for Antimicrobial-Resistant Gram-Positive Infections. *Antimicrobial Resistance and Infection Control*, **9**, Article No. 78. https://doi.org/10.1186/s13756-020-00737-2

[288] Babu Rajendran, N., Arieti, F., Mena-Benítez, C.A., Galia, L., Tebon, M., Alvarez, J., *et al.* (2022) EPI-Net One Health Reporting Guideline for Antimicrobial Consumption and Resistance Surveillance Data: A Delphi Approach. *The Lancet Regional Health—Europe*, **26**, Article ID: 100563. https://doi.org/10.1016/j.lanepe.2022.100563

[289] Ventola, C.L. (2015) The Antibiotic Resistance Crisis: Part 1: Causes and Threats. *Pharmacology & Therapeutics*, **40**, 277-283.

[290] Selaledi, L.A., Hassan, Z.M., Manyelo, T.G. and Mabelebele, M. (2020) The Current Status of the Alternative Use to Antibiotics in Poultry Production: An African Perspective. *Antibiotics*, 1-18.

[291] Ghosh, C., Sarkar, P., Issa, R. and Haldar, J. (2019) Alternatives to Conventional Antibiotics in the Era of Antimicrobial Resistance. *Trends in Microbiology*, **27**, 323-338. https://doi.org/10.1016/j.tim.2018.12.010

[292] Cheng, G., Hao, H., Xie, S., Wang, X., Dai, M., Huang, L., *et al.* (2014) Antibiotic Alternatives: The Substitution of Antibiotics in Animal Husbandry? *Frontiers in Microbiology*, **5**, Article No. 217. https://doi.org/10.3389/fmicb.2014.00217

[293] Lin, D.M., Koskella, B. and Lin, H.C. (2017) Phage Therapy: An Alternative to Antibiotics in the Age of Multi-Drug Resistance. *World Journal of Gastrointestinal Pharmacology and Therapeutics*, **8**, 162-173. https://doi.org/10.4292/wjgpt.v8.i3.162

[294] Moghadam, M.T., Khoshbayan, A., Chegini, Z., Farahani, I. and Shariati, A. (2020) Bacteriophages, a New Therapeutic Solution for Inhibiting Multidrug-Resistant Bacteria Causing Wound Infection: Lesson from Animal Models and Clinical Trials. *Drug Design, Development and Therapy*, **14**, 1867-1883. https://doi.org/10.2147/DDDT.S251171

[295] Chegini, Z., Khoshbayan, A., Vesal, S., Moradabadi, A., Hashemi, A. and Shariati, A. (2021) Bacteriophage Therapy for Inhibition of Multi Drug-Resistant Uropathogenic Bacteria: A Narrative Review. *Annals of Clinical Microbiology and Antimicrobials*, **20**, Article No. 30. https://doi.org/10.1186/s12941-021-00433-y

[296] Pires, D.P., Costa, A.R., Pinto, G., Meneses, L. and Azeredo, J. (2020) Current Challenges and Future Opportunities of Phage Therapy. *FEMS Microbiology Reviews*, **44**, 684-700. https://doi.org/10.1093/femsre/fuaa017

[297] Balcázar, J.L., Blas, I., Ruiz-Zarzuela, I., Cunningham, D., Vendrell, D. and Múzquiz, J.L. (2006) The Role of Probiotics in Aquaculture. *Veterinary Microbiology*, **114**, 173-186. https://doi.org/10.1016/j.vetmic.2006.01.009

[298] Callaway, T.R., Lillehoj, H., Chuanchuen, R. and Gay, C.G. (2021) Alternatives to Antibiotics: A Symposium on the Challenges and Solutions for Animal Health and Production. *Antibiotics*, **10**, Article No. 471. https://doi.org/10.3390/antibiotics10050471

[299] Wall, S. (2019) Prevention of Antibiotic Resistance—An Epidemiological Scoping Review to Identify Research Categories and Knowledge Gaps. *Global Health Action*, **12**, Article ID: 1756191. https://doi.org/10.1080/16549716.2020.1756191

[300] Toroitich, A.M., Dunford, L., Armitage, R. and Tanna, S. (2022) Patients Access to Medicines—A Critical Review of the Healthcare System in Kenya. *Risk Management and Healthcare Policy*, **15**, 361-374. https://doi.org/10.2147/RMHP.S348816

[301] Shafiq, N., Pandey, A.K., Malhotra, S., Holmes, A., Mendelson, M., Malpani, R., *et al.* (2021) Shortage of Essential Antimicrobials: A Major Challenge to Global Health Security. *BMJ Global Health*, **6**, e006961. https://doi.org/10.1136/bmjgh-2021-006961

[302] Nwokike, J., Clark, A. and Nguyen, P.P. (2018) Medicines Quality Assurance to Fight Antimicrobial Resistance. *Bulletin of the World Health Organization*, **96**, 135-137. https://doi.org/10.2471/BLT.17.199562

[303] Shrestha, P., Cooper, B.S., Coast, J., Oppong, R., Do Thi Thuy, N., Phodha, T., *et al.* (2018) Enumerating the Economic Cost of Antimicrobial Resistance per Antibiotic Consumed to Inform the Evaluation of Interventions Affecting Their Use. *Antimicrobial Resistance & Infection Control*, **7**, Article No. 98. https://doi.org/10.1186/s13756-018-0384-3

[304] Zabala, G.A., Bellingham, K., Vidhamaly, V., Boupha, P., Boutsamay, K., Newton, P.N., *et al.* (2022) Substandard and Falsified Antibiotics: Neglected Drivers of Antimicrobial Resistance? *BMJ Global Health*, **7**, e008587. https://doi.org/10.1136/bmjgh-2022-008587

[305] Ching, C. and Zaman, M.H. (2020) Development and Selection of Low-Level Multi-Drug Resistance over an Extended Range of Sub-Inhibitory Ciprofloxacin Concentrations in *Escherichia coli*. *Scientific Reports*, **10**, Article No. 8754. https://doi.org/10.1038/s41598-020-65602-z

[306] World Health Organization (2017) WHO Global Surveillance and Monitoring System for Substandard and Falsified Medical Products. https://apps.who.int/iris/handle/10665/326708

[307] Ozawai, S., Higgins, C.R., Yemeke, T.T., Nwokike, J.I., Evans, L., Hajjou, M., *et al.* (2020) Importance of Medicine Quality in Achieving Universal Health Coverage. *PLOS ONE*, **15**, e0232966. https://doi.org/10.1371/journal.pone.0232966

[308] Shukar, S., Zahoor, F., Hayat, K., Saeed, A., Gillani, A.H., Omer, S., *et al.* (2021) Drug Shortage: Causes, Impact, and Mitigation Strategies. *Frontiers in Pharmacology*, **12**, Article ID: 693426. https://doi.org/10.3389/fphar.2021.693426

[309] Anderson, M., Schulze, K., Cassini, A., Plachouras, D. and Mossialos, E. (2019) A Governance Framework for Development and Assessment of National Action Plans on Antimicrobial Resistance. *The Lancet Infectious Diseases*, **19**, e371-e384. https://doi.org/10.1016/S1473-3099(19)30415-3

[310] Kimura, S. and Nakamura, Y. (2020) Global Circulation of Imitated Products, Poor Quality Pharmaceuticals, Fake Products, and Health Problems. In: Kimura, S. and Nakamura, Y., Eds., *Poor Quality Pharmaceuticals in Global Public Health*, Springer, Singapore, 27-61. https://doi.org/10.1007/978-981-15-2089-1_2

[311] Kimura, S. and Nakamura, Y. (2020) Poor Quality Pharmaceuticals in Global Public Health. Springer, Singapore. https://doi.org/10.1007/978-981-15-2089-1

[312] Majumder, M.A.A., Rahman, S., Cohall, D., Bharatha, A., Singh, K., Haque, M., *et al.* (2020) Antimicrobial Stewardship: Fighting Antimicrobial Resistance and Protecting Global Public Health. *Infection and Drug Resistance*, **13**, 4713-4738. https://doi.org/10.2147/IDR.S290835

[313] Sharma, A., Singh, A., Dar, M.A., Kaur, R.J., Charan, J., Iskandar, K., *et al.* (2022) Menace of Antimicrobial Resistance in LMICs: Current Surveillance Practices and Control Measures to Tackle Hostility. *Journal of Infection and Public Health*, **15**, 172-181. https://doi.org/10.1016/j.jiph.2021.12.008

[314] Wu, S., Tannous, E., Haldane, V., Ellen, M.E. and Wei, X. (2022) Barriers and Facilitators of Implementing Interventions to Improve Appropriate Antibiotic Use in Low- and Middle-Income Countries: A Systematic Review Based on the Consolidated Framework for Implementation Research. *Implementation Science*, **17**, Article No. 30. https://doi.org/10.1186/s13012-022-01209-4

[315] Ohashi, T., Nagashima, M., Kawai, N., Ohmagari, N. and Tateda, K. (2022) A Narrative Review on Drug Development for the Management of Antimicrobial-Resistant Infection Crisis in Japan: The Past, Present, and Future. *Expert Review of Anti-Infective Therapy*, **20**, 1603-1614. https://doi.org/10.1080/14787210.2022.2142118

[316] Bergmann, J.N., Killen-Cade, R.R., Parish, L.A., Albrecht, M.T. and Wolfe, D.N. (2022) Partnering on Vaccines to Counter Multi-Drug Resistant Threats: Workshop Proceedings, Biomedical Advanced Research and Development Authority. *Human Vaccines & Immunotherapeutics*, **18**, Article ID: 2058840. https://doi.org/10.1080/21645515.2022.2058840

[317] Dutescu, I.A. and Hillier, S.A. (2021) Encouraging the Development of New Antibiotics: Are Financial Incentives the Right Way forward? A Systematic Review and Case Study. *Infection and Drug Resistance*, **14**, 415-434. https://doi.org/10.2147/IDR.S287792

[318] Wouters, O.J., McKee, M. and Luyten, J. (2020) Estimated Research and Development Investment Needed to Bring a New Medicine to Market, 2009-2018. *JAMA*, **323**, 844-853. https://doi.org/10.1001/jama.2020.1166

[319] Jackson, N., Czaplewski, L. and Piddock, L.J.V. (2018) Discovery and Development of New Antibacterial Drugs: Learning from Experience? *Journal of Antimicrobial Chemotherapy*, **73**, 1452-1459. https://doi.org/10.1093/jac/dky019

[320] Årdal, C., Balasegaram, M., Laxminarayan, R., McAdams, D., Outterson, K., Rex, J.H., *et al.* (2020) Antibiotic Development—Economic, Regulatory and Societal Challenges. *Nature Reviews Microbiology*, **18**, 267-274. https://doi.org/10.1038/s41579-019-0293-3

[321] Todd, M.H., Klug, D.M., Idiris, F.I.M., Blaskovich, M.A.T., von Delft, F., Dowson, C.G., *et al.* (2021) There Is No Market for New Antibiotics: This Allows an Open Approach to Research and Development. *Wellcome Open Research*, **6**, Article No. 146. https://doi.org/10.12688/wellcomeopenres.16847.1

[322] Miethke, M., Pieroni, M., Weber, T., Brönstrup, M., Hammann, P., Halby, L., *et al.* (2021) Towards the Sustainable Discovery and Development of New Antibiotics.

Nature Reviews Chemistry, **5**, 726-749. https://doi.org/10.1038/s41570-021-00313-1

[323] Simpkin, V.L., Renwick, M.J., Kelly, R. and Mossialos, E. (2017) Incentivising Innovation in Antibiotic Drug Discovery and Development: Progress, Challenges and Next Steps. *Journal of Antibiotics* (*Tokyo*), **70**, 1087-1096. https://doi.org/10.1038/ja.2017.124

[324] Årdal, C., Røttingen, J.A., Opalska, A., Van Hengel, A.J. and Larsen, J. (2017) Pull Incentives for Antibacterial Drug Development: An Analysis by the Transatlantic Task Force on Antimicrobial Resistance. *Clinical Infectious Diseases*, **65**, 1378-1382. https://doi.org/10.1093/cid/cix526

[325] Brogan, D.M. and Mossialos, E. (2013) Incentives for New Antibiotics: The Options Market for Antibiotics (OMA) Model. *Globalization and Health*, **9**, Article No. 58. https://doi.org/10.1186/1744-8603-9-58

[326] Gotham, D., Moja, L., van der Heijden, M., Paulin, S., Smith, I. and Beyer, P. (2021) Reimbursement Models to Tackle Market Failures for Antimicrobials: Approaches Taken in France, Germany, Sweden, the United Kingdom, and the United States. *Health Policy* (*New York*), **125**, 296-306. https://doi.org/10.1016/j.healthpol.2020.11.015

[327] León-Buitimea, A., Garza-Cárdenas, C.R., Garza-Cervantes, J.A., Lerma-Escalera, J.A. and Morones-Ramírez, J.R. (2020) The Demand for New Antibiotics: Antimicrobial Peptides, Nanoparticles, and Combinatorial Therapies as Future Strategies in Antibacterial Agent Design. *Frontiers in Microbiology*, **11**, Article No. 1669. https://doi.org/10.3389/fmicb.2020.01669

[328] Mudenda, S., Hikaambo, C.N., Chabalenge, B., Mfune, R.L., Mufwambi, W., Ngazimbi, M., *et al.* (2023) Antibacterial Activities of Honey against *Escherichia coli* and *Staphylococcus aureus*: A Potential Treatment for Bacterial Infections and Alternative to Antibiotics. *Journal of Pharmacognosy and Phytochemistry*, **12**, 6-13. https://doi.org/10.22271/phyto.2023.v12.i3a.14655

[329] Hikaambo, C.N., Chilala, P., Ndubi, F., Mayoka, G., Kampamba, M., Kabuka, R., *et al.* (2023) Antimicrobial Activities of *Solanum aculeastrum* Fruit Extract against *Escherichia coli*, *Staphylococcus aureus* and *Candida albicans*: Significance of African Traditional Medicine in Combating Infections and Attaining Universal Health Coverage. *Journal of Pharmacy and Pharmacology*, **14**, 176-188. https://doi.org/10.4236/pp.2023.145013

[330] Hikaambo, C.N., Kaacha, L., Mudenda, S., Nyambe, M.N., Chabalenge, B., Phiri, M., *et al.* (2022) Phytochemical Analysis and Antibacterial Activity of Azadirachta indica Leaf Extracts against *Escherichia coli*. *Journal of Pharmacy and Pharmacology*, **13**, 1-10. https://doi.org/10.4236/pp.2022.131001

[331] Mutola, S., Pemunta, N.V. and Ngo, N.V. (2021) Utilization of Traditional Medicine and Its Integration into the Healthcare System in Qokolweni, South Africa; Prospects for Enhanced Universal Health Coverage. *Complementary Therapies in Clinical Practice*, **43**, Article ID: 101386. https://doi.org/10.1016/j.ctcp.2021.101386

[332] Keter, L.K. and Mutiso, P.C. (2012) Ethnobotanical Studies of Medicinal Plants Used by Traditional Health Practitioners in the Management of Diabetes in Lower Eastern Province, Kenya. *Journal of Ethnopharmacology*, **139**, 74-80. https://doi.org/10.1016/j.jep.2011.10.014

[333] WHO (2021) Antibacterial Agents in Clinical and Preclinical Development. https://apps.who.int/iris/handle/10665/340694

[334] Wylie, M.R. and Merrell, D.S. (2022) The Antimicrobial Potential of the Neem Tree *Azadirachta indica*. *Frontiers in Pharmacology*, **13**, Article ID: 891535.

https://doi.org/10.3389/fphar.2022.891535

[335] Brown, E., O'Brien, M., Georges, K. and Suepaul, S. (2020) Physical Characteristics and Antimicrobial Properties of *Apis mellifera*, *Frieseomelitta nigra* and *Melipona favosa* Bee Honeys from Apiaries in Trinidad and Tobago. *BMC Complementary Medicine and Therapies*, **20**, Article No. 85. https://doi.org/10.1186/s12906-020-2829-5

[336] Butler, M.S. and Buss, A.D. (2006) Natural Products—The Future Scaffolds for Novel Antibiotics? *Biochemical Pharmacology*, **71**, 919-929. https://doi.org/10.1016/j.bcp.2005.10.012

[337] Mahady, G.B., Huang, Y., Doyle, B.J. and Locklear, T. (2008) Natural Products as Antibacterial Agents. In: *Studies in Natural Products Chemistry*, Vol. 35, Elsevier, Amsterdam, 423-444. https://doi.org/10.1016/S1572-5995(08)80011-7

[338] Sithole, T., Mahlangu, G., Salek, S. and Walker, S. (2020) Evaluating the Success of ZaZiBoNa, the Southern African Development Community Collaborative Medicines Registration Initiative. *Therapeutic Innovation and Regulatory Science*, **54**, 1319-1329. https://doi.org/10.1007/s43441-020-00154-y

[339] Blaschke, T.F., Lumpkin, M. and Hartman, D. (2020) The World Health Organization Prequalification Program and Clinical Pharmacology in 2030. *Clinical Pharmacology & Therapeutics*, **107**, 68-71. https://doi.org/10.1002/cpt.1680

[340] Ncube, B.M., Dube, A. and Ward, K. (2021) Establishment of the African Medicines Agency: Progress, Challenges and Regulatory Readiness. *Journal of Pharmaceutical Policy and Practice*, **14**, Article No. 29. https://doi.org/10.1186/s40545-020-00281-9

[341] Sidibé, M., Dieng, A. and Buse, K. (2023) Advance the African Medicines Agency to Benefit Health And Economic Development. *BMJ* (*Clinical Research ed*.), **380**, 386. https://doi.org/10.1136/bmj.p386

[342] World Health Organization (2019) Turning Plans into Action for Antimicrobial Resistance (AMR) Working Paper 2.0: Implementation and Coordination. World Health Orgaization (WHO/WSI/AMR/2019), Geneva. https://www.who.int/publications/i/item/turning-plans-into-action-for-antimicrobial-resistance-(-amr)-working-paper-2.0-implementation-and-coordination

[343] Jacobs, T.G., Robertson, J., Van Den Ham, H.A., Iwamoto, K., Bak, Pedersen, H. and Mantel-Teeuwisse, A.K. (2019) Assessing the Impact of Law Enforcement to Reduce Over-the-Counter (OTC) Sales of Antibiotics in Low- and Middle-Income Countries; A Systematic Literature Review. *BMC Health Services Research*, **19**, Article No. 536. https://doi.org/10.1186/s12913-019-4359-8

[344] Porter, G., Joshi, J., Bhullar, L. and Kotwani, A. (2020) Using "Smart Regulation" to Tackle Antimicrobial Resistance in Low-Income and Middle-Income Countries. *BMJ Global Health*, **5**, e001864. https://doi.org/10.1136/bmjgh-2019-001864

[345] Dhingra, S., Rahman, N.A.A., Peile, E., Rahman, M., Sartelli, M., Hassali, M.A., *et al*. (2020) Microbial Resistance Movements: An Overview of Global Public Health Threats Posed by Antimicrobial Resistance, and How Best to Counter. *Frontiers in Public Health*, **8**, Article ID: 535668. https://doi.org/10.3389/fpubh.2020.535668

[346] Redding, L.E., Brooks, C., Georgakakos, C.B., Habing, G., Rosenkrantz, L., Dahlstrom, M., *et al*. (2020) Addressing Individual Values to Impact Prudent Antimicrobial Prescribing in Animal Agriculture. *Frontiers in Veterinary Science*, **7**, Article No. 297. https://doi.org/10.3389/fvets.2020.00297

[347] Lee, C.R., Lee, J.H., Kang, L.W., Jeong, B.C. and Lee, S.H. (2015) Educational Effectiveness, Target, and Content for Prudent Antibiotic Use. *BioMed Research International*, **2015**, Article ID: 214021. https://doi.org/10.1155/2015/214021

[348] Mwatondo, A., Rahman-Shepherd, A., Hollmann, L., Chiossi, S., Maina, J., Kurup, K.K., *et al*. (2023) A Global Analysis of One Health Networks and the Proliferation of One Health Collaborations. *The Lancet*, **401**, 605-616. https://doi.org/10.1016/S0140-6736(22)01596-3

[349] Wernli, D., Jørgensen, P.S., Parmley, E.J., Troell, M., Majowicz, S., Harbarth, S., *et al*. (2020) Evidence for Action: A One Health Learning Platform on Interventions to Tackle Antimicrobial Resistance. *The Lancet Infectious Diseases*, **20**, e307-e311. https://doi.org/10.1016/S1473-3099(20)30392-3

[350] Socal, M.P., Sharfstein, J.M. and Greene, J.A. (2021) The Pandemic and the Supply Chain: Gaps in Pharmaceutical Production and Distribution. *American Journal of Public Health*, **111**, 635-639. https://doi.org/10.2105/AJPH.2020.306138

[351] Bown, C.P. (2022) How COVID-19 Medical Supply Shortages Led to Extraordinary Trade and Industrial Policy. *Asian Economic Policy Review*, **17**, 114-135. https://doi.org/10.1111/aepr.12359

[352] Gereffi, G. (2020) What Does the COVID-19 Pandemic Teach Us about Global Value Chains? The Case of Medical Supplies. *Journal of International Business Policy*, **3**, 287-301. https://doi.org/10.1057/s42214-020-00062-w

[353] Jean, S. (2020) How the COVID-19 Pandemic Is Reshaping the Trade Landscape and What to Do about It. *Intereconomics*, **55**, 135-139. https://doi.org/10.1007/s10272-020-0890-4

[354] Chatterjee, P. (2020) Indian Pharma Threatened by COVID-19 Shutdowns in China. *The Lancet*, **395**, 675. https://doi.org/10.1016/S0140-6736(20)30459-1

[355] Banda, G., Mugwagwa, J., Mackintosh, M. and Mkwashi, A. (2022) The Localisation of Medical Manufacturing in Africa. Institute for Economic Justice, Johannesburg. https://www.iej.org.za/localisation-of-medical-manufacturing-in-africa

[356] Berman, D., Chandy, S.J., Cansdell, O., Moodley, K., Veeraraghavan, B. and Essack, S.Y. (2022) Global Access to Existing and Future Antimicrobials and Diagnostics: Antimicrobial Subscription and Pooled Procurement. *The Lancet Global Health*, **10**, e293-e297. https://doi.org/10.1016/S2214-109X(21)00463-0

[357] Okhravi, C., Callegari, S., McKeever, S., Kronlid, C., Baraldi, E., Lindahl, O., *et al*. (2018) Simulating Market Entry Rewards for Antibiotics Development. *Journal of Law, Medicine & Ethics*, **46**, 32-42. https://doi.org/10.1177/1073110518782913

[358] McKellar, M.R. and Fendrick, A.M. (2014) Innovation of Novel Antibiotics: An Economic Perspective. *Clinical Infectious Diseases*, **59**, S104-S107. https://doi.org/10.1093/cid/ciu530

[359] Towse, A., Hoyle, C.K., Goodall, J., Hirsch, M., Mestre-Ferrandiz, J. and Rex, J.H. (2017) Time for a Change in How New Antibiotics Are Reimbursed: Development of an Insurance Framework for Funding New Antibiotics Based on a Policy of Risk Mitigation. *Health Policy* (*New York*), **121**, 1025-1030. https://doi.org/10.1016/j.healthpol.2017.07.011

[360] Veepanattu, P., Singh, S., Mendelson, M., Nampoothiri, V., Edathadatil, F., Surendran, S., *et al*. (2020) Building Resilient and Responsive Research Collaborations to Tackle Antimicrobial Resistance—Lessons Learnt from India, South Africa, and UK. *International Journal of Infectious Diseases*, **100**, 278-282. https://doi.org/10.1016/j.ijid.2020.08.057

[361] Prentiss, T., Weisberg, K. and Zervos, J. (2018) Building Capacity in Infection Prevention and Antimicrobial Stewardship in Low- and Middle-Income Countries: The Role of Partnerships Inter-Countries. *Current Treatment Options in Infectious Dis-*

eases, **10**, 7-16. https://doi.org/10.1007/s40506-018-0140-5

[362] Pierce, J., Apisarnthanarak, A., Schellack, N., Cornistein, W., Maani, A., Al Adnan, S., *et al.* (2020) Global Antimicrobial Stewardship with a Focus on Low- and Middle-Income Countries. *International Journal of Infectious Diseases*, **96**, 621-629. https://doi.org/10.1016/j.ijid.2020.05.126

[363] Alm, R.A. and Gallant, K. (2020) Innovation in Antimicrobial Resistance: The CARB-X Perspective. *ACS Infectious Diseases*, **6**, 1317-1322. https://doi.org/10.1021/acsinfecdis.0c00026

[364] Saha, M. and Sarkar, A. (2021) Review on Multiple Facets of Drug Resistance: A Rising Challenge in the 21st Century. *Journal of Xenobiotics*, **11**, 197-214. https://doi.org/10.3390/jox11040013

[365] Laxminarayan, R., Van, Boeckel, T., Frost, I., Kariuki, S., Khan, E.A., Limmathurotsakul, D., *et al.* (2020) The Lancet Infectious Diseases Commission on Antimicrobial Resistance: 6 Years Later. *The Lancet Infectious Diseases*, **20**, e51-e60. https://doi.org/10.1016/S1473-3099(20)30003-7

[366] Outterson, K., Rex, J.H., Jinks, T., Jackson, P., Hallinan, J., Karp, S., *et al.* (2016) Accelerating Global Innovation to Address Antibacterial Resistance: Introducing CARB-X. *Nature Reviews Drug Discovery*, **15**, 589-590. https://doi.org/10.1038/nrd.2016.155

[367] Villanueva, P., Coffin, S.E., Mekasha, A., McMullan, B., Cotton, M.F. and Bryant, P.A. (2022) Comparison of Antimicrobial Stewardship and Infection Prevention and Control Activities and Resources between Low-/Middle- and High-Income Countries. *The Pediatric Infectious Disease*, **41**, S3-S9. https://doi.org/10.1097/INF.0000000000003318

[368] Mukosha, M., Jacobs, C., Kaonga, P., Musonda, P., Vwalika, B., Lubeya, M.K., *et al.* (2023) Determinants and Outcomes of Low Birth Weight among Newborns at a Tertiary Hospital in Zambia: A Retrospective Cohort Study. *Annals of African Medicine*, **22**, 271-278. https://doi.org/10.4103/aam.aam_22_22

[369] Chizimu, J.Y., Solo, E.S., Bwalya, P., Kapalamula, T.F., Mwale, K.K., Squarre, D., *et al.* (2023) Genomic Analysis of *Mycobacterium tuberculosis* Strains Resistant to Second-Line Anti-Tuberculosis Drugs in Lusaka, Zambia. *Antibiotics*, **12**, Article No. 1126. https://doi.org/10.3390/antibiotics12071126

[370] Boutayeb, A. (2010) The Impact of Infectious Diseases on the Development of Africa. In: Preedy, V.R. and Watson, R.R., Eds., *Handbook of Disease Burdens and Quality of Life Measures*, Springer, Berlin, 1171-1188. https://doi.org/10.1007/978-0-387-78665-0_66

[371] Boutayeb, A. (2006) The Double Burden of Communicable and Non-Communicable Diseases in Developing Countries. *Transactions of the Royal Society of Tropical Medicine and Hygiene*, **100**, 191-199. https://doi.org/10.1016/j.trstmh.2005.07.021

[372] Van Der Ham, M., Bolijn, R., Vries, A., Campos Ponce, M. and Van Valkengoed, I.G.M. (2021) Gender Inequality and the Double Burden of Disease in Low-Income and Middle-Income Countries: An Ecological Study. *BMJ Open*, **11**, e047388. https://doi.org/10.1136/bmjopen-2020-047388

[373] Manderson, L. and Jewett, S. (2023) Risk, Lifestyle and Non-Communicable Diseases of Poverty. *Globalization and Health*, **19**, Article No. 13. https://doi.org/10.1186/s12992-023-00914-z

[374] Ayorinde, A., Ghosh, I., Ali, I., Zahair, I., Olarewaju, O., Singh, M., *et al.* (2023) Health Inequalities in Infectious Diseases: A Systematic Overview of Reviews. *BMJ*

Open, **13**, e067429. https://doi.org/10.1136/bmjopen-2022-067429

[375] Bhutta, Z.A., Sommerfeld, J., Lassi, Z.S., Salam, R.A. and Das, J.K. (2014) Global Burden, Distribution, and Interventions for Infectious Diseases of Poverty. *Infectious Diseases of Poverty*, **3**, Article No. 21. https://doi.org/10.1186/2049-9957-3-21

[376] Pokharel, S., Raut, S. and Adhikari, B. (2019) Tackling Antimicrobial Resistance in Low-Income and Middle-Income Countries. *BMJ Global Health*, **4**, e002104. https://doi.org/10.1136/bmjgh-2019-002104

[377] Dunachie, S.J., Day, N.P. and Dolecek, C. (2020) The Challenges of Estimating the Human Global Burden of Disease of Antimicrobial Resistant Bacteria. *Current Opinion in Microbiology*, **57**, 95-101. https://doi.org/10.1016/j.mib.2020.09.013

[378] Wozniak, T.M., Dyda, A., Merlo, G. and Hall, L. (2022) Disease Burden, Associated Mortality and Economic Impact of Antimicrobial Resistant Infections in Australia. *The Lancet Regional Health—Western Pacific*, **27**, Article ID: 100521. https://doi.org/10.1016/j.lanwpc.2022.100521

[379] Gulumbe, B.H., Haruna, U.A., Almazan, J., Ibrahim, I.H., Faggo, A.A. and Bazata, A.Y. (2022) Combating the Menace of Antimicrobial Resistance in Africa: A Review on Stewardship, Surveillance and Diagnostic Strategies. *Biological Procedures Online*, **22**, Article No. 19. https://doi.org/10.1186/s12575-022-00182-y

[380] Huong, V.T.L., Ngan, T.T.D., Thao, H.P., Quang, L.M., Hanh, T.T.T., Hien, N.T., *et al.* (2021) Assessing Feasibility of Establishing Antimicrobial Stewardship Programmes in Two Provincial-Level Hospitals in Vietnam: An Implementation Research Study. *BMJ Open*, **11**, e053343. https://doi.org/10.1136/bmjopen-2021-053343

[381] Langlois, E.V., McKenzie, A., Schneider, H. and Mecaskey, J.W. (2020) Measures to Strengthen Primary Health-Care Systems in Low- and Middle-Income Countries. *Bulletin of the World Health Organization*, **98**, 781-791. https://doi.org/10.2471/BLT.20.252742

[382] World Health Organization (2019) Health Workers' Education and Training on Antimicrobial Resistance: Curricula Guide.

[383] Kpokiri, E.E., Ladva, M., Dodoo, C.C., Orman, E., Aku, T.A., Mensah, A., *et al.* (2022) Knowledge, Awareness and Practice with Antimicrobial Stewardship Programmes among Healthcare Providers in a Ghanaian Tertiary Hospital. *Antibiotics*, **11**, Article No. 6. https://doi.org/10.3390/antibiotics11010006

[384] Jayatilleke, K. (2020) Challenges in Implementing Surveillance Tools of High- Income Countries (HICs) in Low Middle Income Countries (LMICs). *Current Treatment Options in Infectious Diseases*, **12**, 191-201. https://doi.org/10.1007/s40506-020-00229-2

[385] Mathew, P., Ranjalkar, J. and Chandy, S.J. (2020) Challenges in Implementing Antimicrobial Stewardship Programmes at Secondary Level Hospitals in India: An Exploratory Study. *Frontiers in Public Health*, **8**, Article ID: 493904. https://doi.org/10.3389/fpubh.2020.493904

[386] World Health Organization (2019) Global Spending on Health: A World in Transition. 1-68. https://apps.who.int/iris/handle/10665/330357

[387] Othieno, J.O., Njagi, O. and Azegele, A. (2020) Opportunities and Challenges in Antimicrobial Resistance Behavior Change Communication. *One Health*, **11**, Article ID: 100171. https://doi.org/10.1016/j.onehlt.2020.100171

[388] Cuevas, C., Batura, N., Wulandari, L.P.L., Khan, M. and Wiseman, V. (2021) Improving Antibiotic Use through Behaviour Change: A Systematic Review of Interventions Evaluated in Low- and Middle-Income Countries. *Health Policy and Plan-*

ning, **36**, 754-773. https://doi.org/10.1093/heapol/czab021

[389] Mitchell, J., Cooke, P., Ahorlu, C., Arjyal, A., Baral, S., Carter, L., *et al.* (2022) Community Engagement: The Key to Tackling Antimicrobial Resistance (AMR) across a One Health Context? *Global Public Health*, **17**, 2647-2664. https://doi.org/10.1080/17441692.2021.2003839

[390] Ghiga, I., Sidorchuk, A., Pitchforth, E., Stålsby, Lundborg, C. and Machowska, A. (2023) "If You Want to Go Far, Go Together"—Community-Based Behaviour Change Interventions to Improve Antibiotic Use: A Systematic Review of Quantitative and Qualitative Evidence. *Journal of Antimicrobial Chemotherapy*, **78**, 1344-1353. https://doi.org/10.1093/jac/dkad128

[391] Borek, A.J., Santillo, M., Wanat, M., Butler, C.C. and Tonkin-Crine, S. (2022) How Can Behavioural Science Contribute to Qualitative Research on Antimicrobial Stewardship in Primary Care? *JAC-Antimicrobial Resistance*, **4**, dlac007. https://doi.org/10.1093/jacamr/dlac007

[392] Saleem, Z., Hassali, M.A., Godman, B., Fatima, M., Ahmad, Z., Sajid, A., *et al.* (2020) Sale of WHO AWaRe Groups Antibiotics without a Prescription in Pakistan: A Simulated Client Study. *Journal of Pharmaceutical Policy and Practice*, **13**, Article No. 26. https://doi.org/10.1186/s40545-020-00233-3

[393] Sweileh, W.M. (2021) Global Research Publications on Irrational Use of Antimicrobials: Call for More Research to Contain Antimicrobial Resistance. *Global Health*, **17**, Article No. 94. https://doi.org/10.1186/s12992-021-00754-9

[394] Mudenda, S., Witika, B.A., Sadiq, M.J., Banda, M., Mfune, R.L., Daka, V., *et al.* (2020) Self-Medication and Its Consequences during & after the Coronavirus Disease 2019 (COVID-19) Pandemic: A Global Health Problem. *European Journal of Public Health*, **5**, em0066. https://doi.org/10.29333/ejeph/9308

[395] Petrović, A.T., Pavlović, N., Stilinović, N., Lalović, N., Kusturica, M.P., Dugandžija, T., *et al.* (2022) Self-Medication Perceptions and Practice of Medical and Pharmacy Students in Serbia. *International Journal of Environmental Research and Public Health*, **19**, Article No. 1193. https://doi.org/10.3390/ijerph19031193

[396] Alomaim, L.H.M., Alnefaie, A.F., Alowaymir, N.A., Alahedb, N.A.S., Alomair, H.O.A., Alanazi, R.S.M., *et al.* (2023) Prevalence of Self-Medication among Female University Students During Examinations: A Cross-Sectional Study in Saudi Arabia. *Cureus*, **15**, e37269.

[397] Chuwa, B.B., Njau, L.A., Msigwa, K.I. and Shao, E.R. (2021) Prevalence and Factors Associated with Self Medication with Antibiotics among University Students in Moshi Kilimanjaro Tanzania. *African Health Sciences*, **21**, 633-639. https://doi.org/10.4314/ahs.v21i2.19

[398] Aslam, A., Zin, C.S., Jamshed, S., Ab Rahman, N.S., Ahmed, S.I., Pallós, P., *et al.* (2022) Self-Medication with Antibiotics: Prevalence, Practices and Related Factors among the Pakistani Public. *Antibiotics*, **11**, Article No. 795. https://doi.org/10.3390/antibiotics11060795

[399] Mukokinya, M.M.A., Opanga, S., Oluka, M. and Godman, B. (2018) Dispensing of Antimicrobials in Kenya: A Cross-Sectional Pilot Study and Its Implications. *Journal of Research in Pharmacy Practice*, **7**, 77-82. https://doi.org/10.4103/jrpp.JRPP_17_88

[400] Malik, B. and Bhattacharyya, S. (2019) Antibiotic Drug-Resistance as a Complex System Driven by Socio-Economic Growth and Antibiotic Misuse. *Scientific Reports*, **9**, Article No. 9788. https://doi.org/10.1038/s41598-019-46078-y

[401] Ferdiana, A., Liverani, M., Khan, M., Wulandari, L.P.L., Mashuri, Y.A., Batura, N.,

et al. (2021) Community Pharmacies, Drug Stores, and Antibiotic Dispensing in Indonesia: A Qualitative Study. *BMC Public Health*, **21**, Article No. 1800. https://doi.org/10.1186/s12889-021-11885-4

[402] Aslam, A., Zin, C.S., Ab Rahman, N.S., Gajdács, M., Ahmed, S.I. and Jamshed, S. (2021) Self-Medication Practices with Antibiotics and Associated Factors among the Public of Malaysia: A Cross-Sectional Study. *Drug, Healthcare and Patient Safety*, **13**, 171-181. https://doi.org/10.2147/DHPS.S331427

[403] Zardosht, M., Dastoorpoor, M., Hashemi, F.B., Estebsari, F., Jamshidi, E., Abbasi-Ghahramanloo, A., *et al.* (2016) Prevalence and Causes of Self Medication among Medical Students of Kerman University of Medical Sciences, Kerman, Iran. *Global Journal of Health Sciences*, **8**, 150. https://doi.org/10.5539/gjhs.v8n11p150

[404] Abdelwahed, A.E., Abd-elkader, M.M., Mahfouz, A., Abdelmawla, M.O., Kabeel, M., Elkot, A.G., *et al.* (2023) Prevalence and Influencing Factors of Self-Medication during the COVID-19 Pandemic in the Arab Region: A Multinational Cross- Sectional Study. *BMC Public Health*, **23**, Article No. 180. https://doi.org/10.1186/s12889-023-15025-y

[405] Owusu-Ofori, A.K., Darko, E., Danquah, C.A., Agyarko-Poku, T. and Buabeng, K.O. (2021) Self-Medication and Antimicrobial Resistance: A Survey of Students Studying Healthcare Programmes at a Tertiary Institution in Ghana. *Frontiers in Public Health*, **9**, Article ID: 706290. https://doi.org/10.3389/fpubh.2021.706290

[406] Darko, E. and Owusu-Ofori, A. (2020) Antimicrobial Resistance and Self- Medication: A Survey among First-Year Health Students at a Tertiary Institution in Ghana. *International Journal of Infectious Diseases*, **101**, 43. https://doi.org/10.1016/j.ijid.2020.09.145

[407] Elmahi, O.K.O., Musa, R.A.E., Shareef, A.A.H., Omer, M.E.A., Elmahi, M.A.M., Altamih, R.A.A., *et al.* (2022) Perception and Practice of Self-Medication with Antibiotics among Medical Students in Sudanese Universities: A Cross-Sectional Study. *PLOS ONE*, **17**, e0263067. https://doi.org/10.1371/journal.pone.0263067

[408] Zeb, S., Mushtaq, M., Ahmad, M., Saleem, W., Rabaan, A.A., Naqvi, B.S.Z., *et al.* (2022) Self-Medication as an Important Risk Factor for Antibiotic Resistance: A Multi-Institutional Survey among Students. *Antibiotics*, **11**, Article No. 842. https://doi.org/10.3390/antibiotics11070842

[409] Kelly, M.P. and Barker, M. (2016) Why Is Changing Health-Related Behaviour So Difficult? *Public Health*, **136**, 109-116. https://doi.org/10.1016/j.puhe.2016.03.030

[410] Ombelet, S., Ronat, J.B., Walsh, T., Yansouni, C.P., Cox, J., Vlieghe, E., *et al.* (2018) Clinical Bacteriology in Low-Resource Settings: Today's Solutions. *The Lancet Infectious Diseases*, **18**, e248-e258. https://doi.org/10.1016/S1473-3099(18)30093-8

[411] Moirongo, R.M., Aglanu, L.M., Lamshöft, M., Adero, B.O., Yator, S., Anyona, S., *et al.* (2022) Laboratory-Based Surveillance of Antimicrobial Resistance in Regions of Kenya: An Assessment of Capacities, Practices, and Barriers by Means of Multi-Facility Survey. *Frontiers in Public Health*, **10**, Article ID: 1003178. https://doi.org/10.3389/fpubh.2022.1003178

[412] Browne, A.J., Kashef Hamadani, B.H., Kumaran, E.A.P., Rao, P., Longbottom, J., Harriss, E., *et al.* (2020) Drug-Resistant Enteric Fever Worldwide, 1990 to 2018: A Systematic Review and Meta-Analysis. *BMC Medicine*, **18**, Article No. 1. https://doi.org/10.1186/s12916-019-1443-1

[413] Turner, P., Fox-Lewis, A., Shrestha, P., Dance, D.A.B., Wangrangsimakul, T., Cusack, T.P., *et al.* (2019) Microbiology Investigation Criteria for Reporting Objectively (MICRO): A Framework for the Reporting and Interpretation of Clinical Microbi-

ology Data. *BMC Medicine*, **17**, Article No. 70.
https://doi.org/10.1186/s12916-019-1301-1

[414] Okeke, I.N., Feasey, N., Parkhill, J., Turner, P., Limmathurotsakul, D., Georgiou, P., *et al.* (2020) Leapfrogging Laboratories: The Promise and Pitfalls of High-Tech Solutions for Antimicrobial Resistance Surveillance in Low-Income Settings. *BMJ Global Health*, **5**, e003622. https://doi.org/10.1136/bmjgh-2020-003622

[415] Amir, A. (2023) Challenges and Solutions towards Antimicrobial Stewardship Implementation. *International Journal of Infectious Diseases*, **130**, S39.
https://doi.org/10.1016/j.ijid.2023.04.092

[416] Hazim, C., Abubeker, I.R., Westercamp, M., Belete, G.A., Amare, Kibret, B., Kanter, T., *et al.* (2018) Establishment of a Sentinel Laboratory-Based Antimicrobial Resistance Surveillance Network in Ethiopia. *Health Security*, **16**, S30-S36.
https://doi.org/10.1089/hs.2018.0052

[417] Larsson, D.G.J. and Flach, C.F. (2022) Antibiotic Resistance in the Environment. *Nature Reviews Microbiology*, **20**, 257-269.
https://doi.org/10.1038/s41579-021-00649-x

[418] Annunziato, G. (2019) Strategies to Overcome Antimicrobial Resistance (AMR) Making Use of Non-Essential Target Inhibitors: A Review. *International Journal of Molecular Sciences*, **20**, Article No. 5844. https://doi.org/10.3390/ijms20235844

[419] Terreni, M., Taccani, M. and Pregnolato, M. (2021) New Antibiotics for Multidrug-Resistant Bacterial Strains: Latest Research Developments and Future Perspectives. *Molecules*, **26**, Article No. 2671.
https://doi.org/10.3390/molecules26092671

[420] Algammal, A., Hetta, H.F., Mabrok, M. and Behzadi, P. (2023) Editorial: Emerging Multidrug-Resistant Bacterial Pathogens "Superbugs": A Rising Public Health Threat. *Frontiers in Microbiology*, **14**, Article ID: 1135614.
https://doi.org/10.3389/fmicb.2023.1135614

[421] Almagor, J., Temkin, E., Benenson, I., Fallach, N. and Carmeli, Y. (2018) The Impact of Antibiotic Use on Transmission of Resistant Bacteria in Hospitals: Insights from an Agent-Based Model. *PLOS ONE*, **13**, e0197111.
https://doi.org/10.1371/journal.pone.0197111

[422] Chokshi, A., Sifri, Z., Cennimo, D. and Horng, H. (2019) Global Contributors to Antibiotic Resistance. *Journal of Global Infectious Diseases*, **11**, 36-42.
https://doi.org/10.4103/jgid.jgid_110_18

[423] Sreeja, M.K., Gowrishankar, N.L., Adisha, S. and Divya, K.C. (2017) Antibiotic Resistance-Reasons and the Most Common Resistant Pathogens—A Review. *Research Journal of Pharmacy and Technology*, **10**, 1886-1890.
https://doi.org/10.5958/0974-360X.2017.00331.6

[424] Friedman, N.D., Temkin, E. and Carmeli, Y. (2016) The Negative Impact of Antibiotic Resistance. *Clinical Microbiology and Infection*, **22**, 416-422.
https://doi.org/10.1016/j.cmi.2015.12.002

[425] Sulis, G., Daniels, B., Kwan, A., Gandra, S., Daftary, A., Das, J., *et al.* (2020) Antibiotic Overuse in the Primary Health Care Setting: A Secondary Data Analysis of Standardised Patient Studies from India, China and Kenya. *BMJ Global Health*, **5**, e003393. https://doi.org/10.1136/bmjgh-2020-003393

[426] Sulis, G., Sayood, S. and Gandra, S. (2022) Antimicrobial Resistance in Low- and Middle-Income Countries: Current Status and Future Directions. *Expert Review of Anti-Infective Therapy*, **20**, 147-160.
https://doi.org/10.1080/14787210.2021.1951705

[427] Von Wintersdorff, C.J.H., Penders, J., Van Niekerk, J.M., Mills, N.D., Majumder, S., Van Alphen, L.B., *et al.* (2016) Dissemination of Antimicrobial Resistance in Microbial Ecosystems through Horizontal Gene Transfer. *Frontiers in Microbiology*, **7**, Article No. 173. https://doi.org/10.3389/fmicb.2016.00173

[428] Jordanwood, T., Nakyanzi, A., Pattnaik, A. and Ravishankar, N. (2020) How Primary Health Care Services Are Financed in Uganda: A Review of the Purchasing Landscape. 1-27. https://thinkwell.global/wp-content/uploads/2020/09/Uganda-Policy-Review_Final_21-Sept-2020-Final-.pdf

[429] World Health Organization (2018) WHO Report on Surveillance of Antibiotic Consumption: 2016-2018 Early Implementation. https://apps.who.int/iris/handle/10665/277359

[430] Devriendt, T., Shabani, M. and Borry, P. (2021) Data Sharing in Biomedical Sciences: A Systematic Review of Incentives. *Biopreservation and Biobanking*, **19**, 219-227. https://doi.org/10.1089/bio.2020.0037

[431] Scheepers, L.N., Niesing, C.M. and Bester, P. (2023) Facilitators and Barriers to Implementing Antimicrobial Stewardship Programs in Public South African Hospitals. *Antimicrobial Stewardship & Healthcare Epidemiology*, **3**, e34. https://doi.org/10.1017/ash.2022.355

[432] Lambraki, I.A., Cousins, M., Graells, T., Leger, A., Henriksson, P., Harbarth, S., *et al.* (2022) Factors Influencing Antimicrobial Resistance in the European Food System and Potential Leverage Points for Intervention: A Participatory, One Health Study. *PLOS ONE*, **17**, e0263914. https://doi.org/10.1371/journal.pone.0263914

[433] Tiong, J.J.L., Loo, J.S.E. and Mai, C.W. (2016) Global Antimicrobial Stewardship: A Closer Look at the Formidable Implementation Challenges. *Frontiers in Microbiology*, **7**, Article No. 1860. https://doi.org/10.3389/fmicb.2016.01860

[434] Steinmann, K.E., Lehnick, D., Buettcher, M., Schwendener-Scholl, K., Daetwyler, K., Fontana, M., *et al.* (2018) Impact of Empowering Leadership on Antimicrobial Stewardship: A Single Center Study in a Neonatal and Pediatric Intensive Care Unit and a Literature Review. *Frontiers in Pediatrics*, **6**, Article No. 294. https://doi.org/10.3389/fped.2018.00294

[435] Aika, I.N. and Enato, E. (2022) Health Care Systems Administrators Perspectives on Antimicrobial Stewardship and Infection Prevention and Control Programs across Three Healthcare Levels: A Qualitative Study. *Antimicrobial Resistance & Infection Control*, **11**, Article No. 157. https://doi.org/10.1186/s13756-022-01196-7

[436] Baraka, M.A., Alsultan, H., Alsalman, T., Alaithan, H., Islam, M.A. and Alasseri, A.A. (2019) Health Care Providers' Perceptions Regarding Antimicrobial Stewardship Programs (AMS) Implementation-Facilitators and Challenges: A Cross- Sectional Study in the Eastern Province of Saudi Arabia. *Annals of Clinical Microbiology and Antimicrobials*, **18**, Article No. 26. https://doi.org/10.1186/s12941-019-0325-x

[437] Charani, E., Smith, I., Skodvin, B., Perozziello, A., Lucet, J.C., Lescure, F.X., *et al.* (2019) Investigating the Cultural and Contextual Determinants of Antimicrobial Stewardship Programmes across Low-, Middle- and High-Income Countries—A Qualitative Study. *PLOS ONE*, **14**, e0209847. https://doi.org/10.1371/journal.pone.0209847

[438] Hardefeldt, L.Y., Gilkerson, J.R., Billman-Jacobe, H., Stevenson, M.A., Thursky, K., Bailey, K.E., *et al.* (2018) Barriers to and Enablers of Implementing Antimicrobial Stewardship Programs in Veterinary Practices. *Journal of Veterinary Internal Medi-*

cine, **32**, 1092-1099. https://doi.org/10.1111/jvim.15083

[439] Kiggundu, R., Waswa, J.P., Nakambale, H.N., Kakooza, F., Kassuja, H., Murungi, M., *et al*. (2023) Development and Evaluation of a Continuous Quality Improvement Programme for Antimicrobial Stewardship in Six Hospitals in Uganda. *BMJ Open Quality*, **12**, e002293. https://doi.org/10.1136/bmjoq-2023-002293

[440] Chetty, S., Reddy, M., Ramsamy, Y., Dlamini, V.C., Reddy-Naidoo, R. and Essack, S.Y. (2022) Antimicrobial Stewardship in Public-Sector Hospitals in KwaZulu- Natal, South Africa. *Antibiotics*, **11**, Article No. 881. https://doi.org/10.3390/antibiotics11070881