European Journal of Science, Innovation and Technology

Vol. 1 No. 1 (2021)

One Health Approach in Combating Antimicrobial Resistance in Sub-Saharan Countries: Regulatory Perspective: Comprehensive Literature Review

Yesuneh Tefera Mekasha[1]*, Gemmechu Hasen Godena[2]

[1]College of Veterinary Medicine and Animal Sciences, Department of Veterinary Pharmacy, University of Gondar, Gondar, Ethiopia

[2]Jimma University Laboratory of Drug Quality (JuLaDQ), Jimma University, Jimma, Ethiopia

Abstract. Antimicrobial resistance is the ability of a microorganism to tolerate antimicrobial treatments. It is a problem in Africa, due to the very fact that folks are susceptible to infections and that they have an enormous appetite for antibiotics because they believe it is a robust medicine that results in high consumption rates. Knowledge of local and regional antimicrobial resistance is vital for deciding. However, surveillance capacity for antimicrobial resistance is lacking throughout sub-Saharan countries and current antimicrobial resistance data are sparse. This review sought to deal with this gap by summarizing, assessing, and documenting all available data on this public issue within the sub-Saharan countries for the reader. Data for this review were collected from an on-line database. Searches were conducted using one health, antibacterial, policies, regulation, antimicrobial resistance, and sub-Saharan countries as a keyword by inserting into search engines. One health approach collaborating with other stakeholders, and regulatory agents working together to optimize the health of animals, humans, foodstuffs, and the environment by combating antimicrobial resistance.

Thus, the implementation of one health approach, and regulatory perspective in combating antimicrobial resistance should be critically recognized as a framework for addressing this global issue. Therefore, the target of the present seminar was to review the one health approach, and regulatory perspective in combating antimicrobial resistance in sub-Saharan countries.

Keywords: antimicrobial resistance, Sub-Saharan countries, One Health approach, Regulatory perspective, surveillance

*Corresponding Author

Introduction

Background

Internationally, there is a growing concern over antimicrobial resistance (AMR) which is currently estimated to account for quite 700,000 deaths per annum worldwide. If no appropriate measures are taken to halt its progress, AMR will cost approximately 10 million lives and about US$100 trillion per annum by 2050 (O'Neill, 2016). In contrast to another health issues, AM may be a problem that concerns every country regardless of its level of income and development as resistant pathogens do not respect borders (O'Neill, 2016; WHO, 2014). The threat of antimicrobial resistance (AMR) is growing at an alarming rate and therefore the situation is probably aggravated in developing countries thanks to gross abuse within the use of antimicrobials (Byarugaba, 2004).

Antimicrobial resistance is one among the main global public health problems facing Africa. The matter is becoming serious since most of the antimicrobials are already the last line of defense. Various studies reviewed the difficulty of antimicrobial resistance in Africa. Drugs are known to enhance the standard of lives and ensure increase in lifetime of patients which suggests got to address antimicrobial resistance in healthcare cannot be overemphasized. With AMR, there is a rise in death rate thanks to the very fact that microbes are developing resistance to the drug which has once been proven to point out therapeutic actions. Inappropriate use of antibiotics among the population and livestock by the farmers, circulation of counterfeit drugs and substandard prescriptions along-side poor diagnosis, or lack of it are adding fuel to the already fired path of microbial resistance. In most regions of Africa, antibiotics are often purchased over the counter with little or no medical advice by most of medicine dealer basically due to the lack of the data. It is important for healthcare provider to know mechanism of antibiotic resistance, associated problems and therefore the possible solutions (Sageman, 2015).

It is documented that any use of antimicrobials however appropriate and justified, contributes to the event of resistance, but widespread unnecessary and excessive use makes things worse (Laxminarayan et al., 2013). Misuse of antimicrobials is facilitated in developing countries by their availability over the counter, without prescription and through unregulated supply chains (Okeke et al., 2005).

A number of recent reviews summarized AMR data in Africa, which focused on sub-Saharan African countries. A high level of resistance to the commonly used antibiotics within the sub-Saharan African region was reported. For instance, 90% of Gram negatives were immune to chloramphenicol, commonly used antibiotic. In contrast, resistance to 3rd generation cephalosporins (like ceftriaxone) was less common, recommending this group to be used (Leopold et al., 2014).

In order to strengthen the global control and prevention of emerging diseases, the "One Health" approach should be implemented into public health practice. Recognized since the 1800s, yet more recently coined the term, the "One Health" concept links human health, animal health, and the environment (Keusch et al., 2009; Rabozzi et al., 2012). Since complex epide miology describes pathogen transmission in the human, animal interface, which challenges the formal assessment of AMR (Wegener, 2012).

Regulations and their enforcement are very important if any headway is to be made in the fight to control the AMR threats. The importation through unapproved routes makes regulation difficult. The sale of antimicrobials on the open markets, vehicles and unapproved locations is also a source of concern (Bekoe & Ahiabu, 2014).

Antimicrobial resistance may be a major public ill health in sub-Saharan countries, thanks to lack of regulation and strict collaboration of one health approach. This review plan to share information about the present status of this public ill health within the African Region supported published literature and lift awareness on the necessity to strengthen one health

approach AMR surveillance and regulatory actions for monitoring this phenomenon through documentation of evidences.

Objectives

General objective:

- To assess the one health approach and regulatory perspective to combat antimicrobial resistance in sub-Saharan countries.

Specific objectives:

- To assess issues and challenges related to antimicrobial resistance in sub-Saharan countries and to spot opportunities for further action and key obstacles that require to be overcome.
- To critically assess how One Health strategies, training, research deal with antimicrobial resistance in sub-Saharan region.
- To review the role of regulatory action in combating of antimicrobial resistance.
- To spot and evaluate the previous studies, then synthesize available data on AMR in sub-Saharan countries for the longer-term article review.

Overview of the Literature

Antimicrobial Resistance

Antimicrobial agents are often divided into groups that supported the mechanism of antimicrobial activity. The most groups are agents that inhibit cell membrane synthesis, depolarize the cell wall, inhibit protein synthesis, inhibit nuclei acid synthesis, and inhibit metabolic pathways in bacteria. It might seem that with such a good range of mechanisms; we might have better control over the organisms. Unfortunately, improper stewardship of antimicrobial agents has helped cause the tremendous resistance issue that we now face. Factors that have contributed to the growing resistance problem include; increased consumption of antimicrobial drugs, both by humans and animals; and improper prescribing of antimicrobial therapy. Overuse of the many common antimicrobials agents by physicians may occur because the selection of drug is predicated on a mixture of low cost and low toxicity (Griffith, Postelnick, & Scheetz, 2012).

The 2014 WHO report identified Africa and South East Asia as the regions without established AMR surveillance systems (WHO, 2014). This lack of quality data is problematic often resulting in treatment guidelines that are not adequate for the local situation. The gap publicly health capacity is additionally a problem given the changing resistance mechanisms, and therefore the emergence of multidrug resistant bacteria which will only be detected through systematic screening in quality assured Microbiology laboratories (Liu et al., 2016; Xavier et al., 2016).

The antimicrobial resistance patterns seen in the animals reflect the types and amounts of antibiotics given to the animals. The transmission of antimicrobial resistance from the animals to humans may occur in various ways, with the direct oral route being the most common (includes eating meat plus ingestion of feces in contaminated food or water). Another common route is from direct contact with the animals by humans (Wegener, 2012). The spread of resistant globally between regions (including between continents) is well documented and presumably thanks to migration of hosts or contaminated goods and products (Kimang'a, 2012).

Mechanism of Antimicrobial Resistance

Inactivating a drug; (4) active drug efflux. Intrinsic resistance may make use of limiting uptake, drug inactivation, and drug efflux; acquired resistance mechanisms used could also be drug target modification, drug inactivation, and drug efflux. Due to differences in structure, etc., there is variation within the sorts of mechanisms employed by gram negative bacteria versus gram positive bacteria. Gram negative bacteria make use of all four main mechanisms, whereas gram positive bacteria less commonly use limiting the uptake of a drug (do not have an LPS outer membrane), and do not have the capacity surely sorts of drug efflux mechanisms (Chancey, Zähner, & Stephens, 2012; Mahon, Lehman, & Manuselis, 2014).

Cause of Antimicrobial Resistance

To better appreciate the causes of AMR, we would like to know the varied sequential steps involved for a drug to urge to a patient, and therefore the eventual use, which include; production, distribution, prescription, dispensing, and eventually consumption of the drug by the patient or use in animal production. Consequently, any imprudent practice along this flow may end in the emergence of resistance (Quick & Bremer, 1997). Factors and stakeholders contributing to the matter of antimicrobial resistance were explained below (Ayukekbong, Ntemgwa, & Atabe, 2017). The subsequent table indicates various factors and stakeholders contributing for the issues of AM.

Table 1: Factors and stakeholders contributing to the problem of antimicrobial resistance

Factors	Contribution	Example
Poor drug quality	Sales of counterfeit, adulterated and poor quality antibiotics	These poor-quality antibiotics can produce sub inhibitory concentration in vivo, which increases the selection of resistant strains
Regulators	While most developed countries have developed AMR action plans, this is still lacking in many developing countries especially in Africa	Most countries lack the resources to enforce policies regarding the manufacture and distribution of substandard drugs
Prescribers	Excessive clinical use and misuse is partially responsible for increase rate of resistance	Variation in prescription practice among health care provider. Sometimes there is prescription of a wrong drug, wrong doses, or antimicrobial not necessary at all
Dispensers	Drug vendors usually have little or no knowledge of the required dosage regimen, indication, or contraindications	Medications are usually purchased in small aliquots from roadside stall and storage and distribution is usually done under inadequate conditions
Users (patients)	High rate of self-medication and lack of treatment compliance	Patients fail to adhere to dosage regimens and discontinue treatment when symptoms subside before pathogen is eliminate
Animal industry	The use of antimicrobial drugs in agriculture or industrial settings, exerts a selection pressure which can favor the survival of resistant strains (or genes) over susceptible ones	Resistant bacteria in animals can be transferred to humans through the consumption of food or through direct contact with food producing animals or through environmental spread

Issues and Challenges Associated with AMR in Sub-Saharan Region

Drugs are poisons. The statement seems to not scare many people to stick to drug regimen, and therefore the use of drug prescribed or recommended by qualified medical personnel. Antibiotics play a big role in reducing the challenges of communicable diseases (CDs). Everywhere the planet including Africa, we will ask the utilization of medicine and its efficacy in curative power is infinite. The threats of antimicrobial resistance have significant effect in reduction of the effectiveness of medicine within the treatment and mitigation of infections which may be public health issues with national health dimension. Antimicrobial resistance is a problem in Africa thanks to the very fact that folks are susceptible to infections and that they have an enormous appetite for antibiotics because they believe it is a robust medicine which results in high consumption rates (Sprenger, 2012).

Lack of comprehensive burden data on antimicrobial resistance is one the main barrier in recognition of drug resistance in various regions of Africa because the information illustrates the particular prevalence of resistant infections and the way it affects the overall health and also the economic costs (Nugent, Back, & Beith, 2010).

Table 2: The difficulties associated with antimicrobial resistance in sub-Saharan region

Challenges of antimicrobial resistance	References
Little or no plan to address antimicrobial resistance (AMR) due to lack of comprehensive policy, Weakness of medicines regulatory and increase in circulation of fake antimicrobial drugs is common	Ndihokubwayo (2013)
Lack of antimicrobial resistance surveillance strategies, Substandard laboratory capacity on Antimicrobial resistance testing and reporting, Lack of essential laboratory reagents and consumables, Limited and substandard quality assurance and control formalities	
Poor investment in research work	Okeke et al. (2007)
Health systems lack money	Ndihokubwayo (2013)

One Health Approach

One Health refers to the collaboration of multiple disciplines, sectors and groups working locally, nationally and globally to achieve optimal health for people, animals and therefore the environment (Association AVM, 2008). AMR has been reported in emerging infectious diseases, emphasizing this intimate connection to the "One Health" concept and human, animal and environmental health (Robinson et al., 2016).

The necessity to enhance human health, animal health and agricultural productivity in low and middle-income countries has led to the extensive use of antimicrobials without respecting therapy guidelines. However, farmers' ignorance of the hazards associated with antibiotic therapy and therefore the widespread use of antimicrobials in food producing animals has escalated the emergence of antimicrobial resistance (AMR) (González & Dittrich, 2017). Thus, the worldwide public health concerns with reference to the antibiotics utilized in food producing animals is due to the very fact that they're closely associated with those utilized in human medicine and choose for resistance (Tang et al., 2017).

One Health is extremely broad in its scope, encompassing many zoonotic diseases and environmental health problems. Because the risks related to the AMR crisis are so profound, many of the foremost prominent supporters of a one Health approach have increasingly focused on applications and approaches to addressing bacterial resistance. Global bodies like the planet Health Organization (WHO), the planet Organization for Animal Health (OIE), the United Nations Food and Agriculture Organization, alongside governments, nongovernmental organizations and public private partnerships, like the One Health Initiative[1], the One Health Commission, and therefore the One Health Platform[2], among others, have added recommendations, reports, activities, meetings and academic resources targeting AMR.

One World, One Health – Veterinary Perspectives

One Health requires multidisciplinary efforts at global, national and native levels, for the sake of our planet, mankind and animals. It had been initiated at the American Veterinary Medical Association (AVMA) Annual Convention (2007) as launched by the American Medical Association alongside AVMA, and therefore the Centers for Disease Control and Prevention (CDC). One health concept is governed by an excellent deal of interest also as resources. To a particular level it is thanks to the greater popularity attained by the term population health. Successes up to a particular extent to supply understanding of socioeconomic gradients in health status at depth although achieved, has not led to sufficient development of corresponding policies which will effectively reduce the inequalities in health (Glouberman & Millar, 2003).

Increase in international trade and travel, global climate change, habitat destruction, ecotourism, changes in ecosystem and biodiversity have resulted in exposure of humans as well as animals to new pathogens to which they were never exposed, requiring proper veterinary attention (Morse, 1995). The animal and human health are often improved and enhanced within 'One Health' concept using innovative partnerships, collaborations, and research/surveillance/ control programs. The novel advances in diagnostics and therapeutics got to be explored to their full potentials to safeguard health of humans also as their companion animals (Schmitt & Henderson, 2005). The concept of 'One World One Health, suggests during a conference of the Wildlife Conservation Society, 2004, helps in building the cooperative momentum to regulate and defeat emerging and reemerging diseases at the interface between man, animal and ecosystem (Ahmed et al., 2012).

[1]One Health Initiative. One Health Initiative will unite human and veterinary medicine. Retrieved March 10, 2017, from www.onehealthinitiative.com/index.php

[2]One Health Platform. The Public One Health Agenda. Retrieved March 10, 2017, from www.onehealthplatform.com/what-we-do/public-one-health-agenda

Putting National Multi-Sectoral, One Health Processes and Activities

International, regional, and national organizations, agencies and institutions have developed preprocess and activities to sustain the expansion of the multisectoral, One Health approach. Regions and countries are successfully using these One Health processes and activities. Accordingly, the TZG includes accounts of how regions and countries have successfully implemented elements of the multisectoral, one health approach. In an attempt to assist regions and countries determine the resources available, and a sequence of elements that might add their setting, this section uses the metaphor of growing a tree to explain "Growing with the One Health approach. A critical concept is that how each region or country can best grow with the One Health approach depends on their context and priorities. Additionally, regions and countries could also be conscious of other multisectoral, One Health processes and actions that would successfully promote growth of the One Health approach (WHO, 2019). The subsequent figure shows the essential elements growing with one health approach.

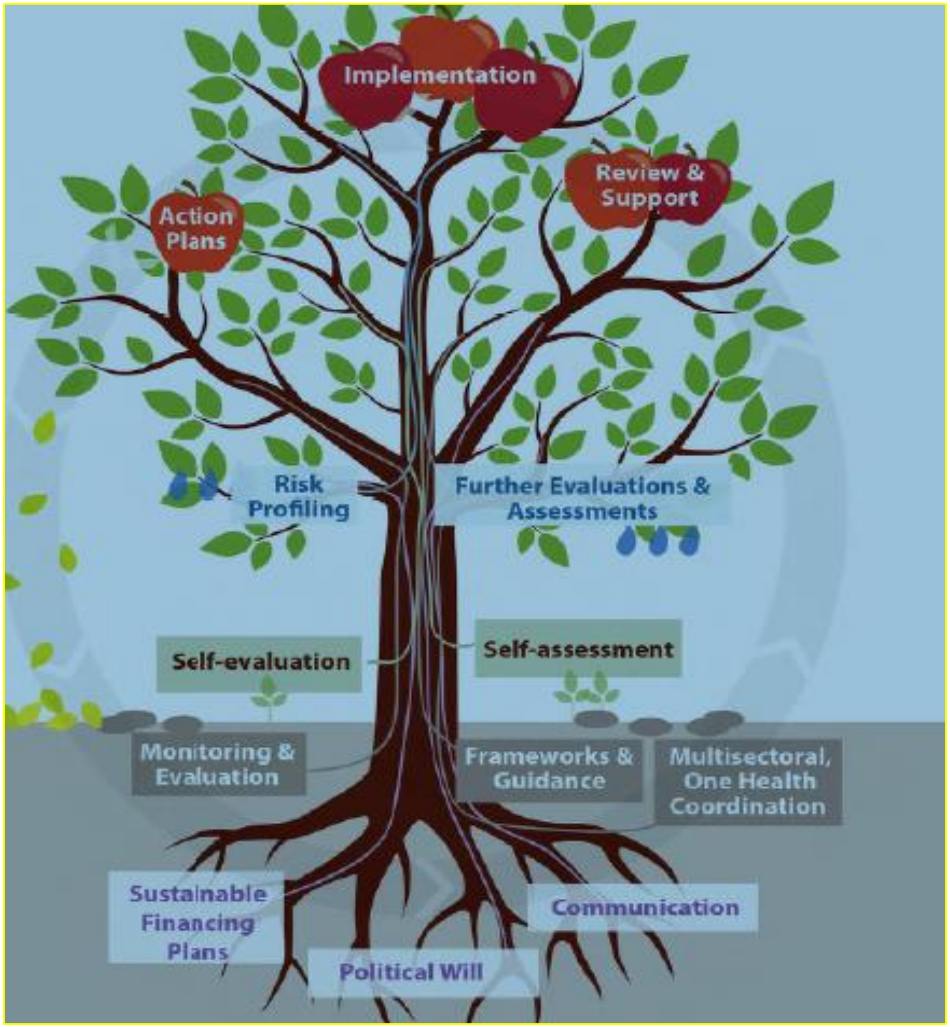

Figure 1: Essential elements growing with one health approach

One Health Strategies to Address Antimicrobial Resistance

WHO and other international agencies (e.g., Food and Agriculture Organization (FAO), world organization for Animal Health (OIE)), alongside many individual countries, have developed comprehensive action plans to deal with the antimicrobial resistance crisis (WHO, 2015a). The WHO Plan embraces a one health approach to deal with antimicrobial resistance, and it calls on member countries to try to an equivalent when developing their own action

plans. The WHO Global Action Plan seeks to deal with five major objectives that comprise the subtitles of the subsequent sections.

Table 3: One Health strategies to address antimicrobial resistance

There are five main pillars to the WHO Global Plan for addressing AMR in Africa:	Murph et al. (2017)
1. Improve Awareness and Understanding of Antimicrobial Resistance through Effective Communication, Education and Training	
2. Strengthen the Knowledge and Evidence Base through Surveillance and Research	
3. Reduce the Incidence of Infection through Effective Sanitation, Hygiene and Infection Prevention Measures	
4. Optimize the Use of Antimicrobial Medicines in Human and Animal Health	
5. Develop the Economic Case tor Sustainable Investment	

Regulator Perspectives in Combating Antimicrobial Resistance

Enforcement of laws regulating drug distribution, and use within the country is significant in achieving the target of the world (Regulatory Body Act, 2013). The straightforward access to restricted drugs depicted within the results will encourage inappropriate use of antibiotics. This phenomenon has the tendency to encourage overuse of antibiotics, and therefore the development of resistant bacterial strains. Things where antibiotics are prescribed and dispensed by unauthorized persons within the health system is discrepant to the Health Professions Regulation (Iuga & McGuire, 2014). Containment of AMR provide disturbing scenarios for the fight against AMR within the country. There have been no shared efforts among users of antibiotics by policy directions in addressing the problems of AMR under the one health concept. Several African countries have national action plan on the containment of AMR (Gelband & Delahoy, 2014).

Africa CDC's Response to AMR

In accordance with the worldwide Action Plan and to satisfy needs specific to Africa, Africa CDC will establish the Antimicrobial Resistance Surveillance Network AMRSNET may be a network of public health institutions and leaders from human and animal health sectors who will collaborate to live, prevent, and alleviate harm from AMR organisms. Core members of AMRSNET are going to be derived from African National Public Health Institutes (NPHI). The four goals of AMRSNET are:

- Improve surveillance of AMR organisms among humans and animals;
- Delay emergence of AMR;
- Limit transmission of AMR;
- Mitigate harm among patients infected with AMR organisms (WHO, 2015b).

Overuse and misuse resulting from poor prescribing and dispensing behavior, uninformed patient demand and lack of adherence to treatment regimen prescribed, low-quality drug formulations, inadequate dosage regimens, and insufficient duration of therapy also are important contributors to AMR (WHO, 2010). Animal husbandry is proliferating in our country and hence there is a possible rise in irrational use of AMs as this sector expands. Achieving this strategy involves the strengthening of technical and regulatory requirements alongside bringing a few changes within the behavior of the prescribers, dispensers and users. Policies and regulations that encourage more appropriate and rational use of AMs are key long-term interventions for the containment of AMR (Tollefson, 2004).

The Role of Government Regulatory Agencies

With the new and emergent issue regarding the event of AMR, government agencies globally have engaged in new action plans so as to combat the AMR (Government of the United

States, 2015). However, actions toward this has been severely lacking in developing countries especially those in Africa where top-quality regulatory agencies are lacking. While many developed countries have developed such AMR, action plans either nationally or at the regional level like the ecu Union and Asia Pacific region, this is often still lacking in many developing countries especially in Africa (Government of the United Kingdom, 2013). a couple of African countries are identified as being involved within the Global Antibiotic Resistance Partnership (GARP), established in 2009 to make a platform for developing actionable policy proposals on antibiotic resistance in low income and middle-income countries (Dua, Kunin, & White, 1994).

What most developing countries especially those in Africa lack is not the legislation prohibiting the manufacture, and distribution of substandard drugs but resources to enforce these policies and to impose penalties to defaulters. There is also lack of resources to spot counterfeit drugs or verify the standard of locally manufactured or imported drugs (WHO, 2015c). Additionally, governments got to address the sale of antimicrobials without prescription and illegalize the dispensing of medicine by unauthorized and unqualified persons. There is also need for the population to be sensitized on the general public health risks of AMR. A recent WHO survey revealed that while much activity is underway and lots of governments are committed to addressing the AMR problem, there are major gaps in Actions needed across all 6 WHO regions to stop the misuse of antibiotics and reduce spread of AMR (Coll-Seck et al., 2017).

Methodology

Description of the Review

This review was conducted in Sub-Saharan region, with supported published articles that dedicated in cross sectional study, work shop, research, survey, reporting on one health approach, and regulatory perspective combating AMR. The review was conducted from January to February, 2020.

Search Strategy

Relevant literature was identified from the PubMed, BMC, and Elsevier and google scholar. Each search was performed on only English articles using terms like:

- bacterial resistance;
- antibiotic use, cause, mechanism of resistance, antimicrobial resistance;
- one health approach and regulation, policies, surveillance and sub-Saharan countries.

Only publications listing original data on one health approach, and regulatory perspective combating AMR in sub-Saharan countries in humans, and animals were included. The coverage included research articles concerning one health approach, regulatory perspective, policies academic institutions to combat antimicrobial resistance involving subjects of a sub-Saharan countries.

Literature Search Results

Antimicrobial Resistance in Sub-Saharan Countries

Resistance to common antimicrobials affects diseases that have not received dedicated increases in funding over the past decade. Examples include pathogens like Shigella and Vibrio cholerae and Streptococcus pneumoniae. These diseases are major causes of childhood death in Sub-Saharan Africa (Mason et al., 1997).

Evidently, antibiotics are widely and inappropriately utilized in Africa resulting to antibiotic resistance. this example interrupts on the standard of patient care through its associated mortality, morbidity, and significant economic consequences (Mandomando et al., 2010). Since antibiotics are the foremost commonly prescription drugs in hospitals and their use are one among the important factors for the event and spread of resistance within the hospitals, an audit of their susceptibility patterns is vital in implementation of rational empirical antibiotic strategy. The detailed percentage of AMR in sub-Saharan countries were shown in Table 4.

Table 4: Percentage of AMR reported in sub-Saharan region

Countries	Bacteria sp.	Percentage of drug resistance	Ref.
S. Africa	*N. gonorrhoeae*	Increases from 0% to 16% from 1984 to 2004 to penicillin, 7% Cipro, 36% TTC	Mac-Arthur et al. (2001)
	S. aureus	Methicillin-resistant (80%)	
Zimbabuwe	Gram(-) Bacilli	Amp (80%), COT (68.5%)	Ferreira, Costa, and Vaz Pato (1992)
	Gram (+) Cocci	Nalidixic acid (81%) and COT (69%) with *E. coli* showing as high as 84% resistance to ampicillin and 68% to Cotrimoxazole. Over 90% of isolates are resistant to Trimethoprim/Sulfamethoxazole and 16% are resistant to Tetracycline.	Ceccarelli et al. (2006)
Mozambique and Angola	-	Increasing resistance to Ampicillin, Streptomycin, Spectinomycin, Trimethoprime Sulfisoxazole, Kanamycin, Chloramphenicol, Tetracycline and Gentamycin has been observed. In patients with no history of prior tuberculosis treatment, the multidrug resistance rate is 3.4 and resistance to isoniazid and Streptomycin (HS) is 5.2%. Drug resistance is significantly more common among those with a history of prior treatment.	Ombui, Kimotho, and Nduhiu (2000); Anguzu and Olila (2007); Messele and Alebachew (1980); Asrat (2008)
Kenya	*S. aureus*	71% MDR	Kibret and Abera (2011)
Uganda	*Staphylococcus aureus Pseudomonas aeruginosa, Proteus mirabilis*	Resistance to Ampicillin, Amoxicillin and Chloramphenicol has been documented and are reportedly multidrug resistant; but the percentage of this drug was not reported	Andargachew, Afework, and Belay (2005)
Ethiopia	*Gonococcal strains*	Multidrug resistant; Elevated resistance among gastrointestinal pathogens as well as increased and multiple resistance rates to Erythromycin (89.4%), Amoxicillin (86.0%) and Tetracycline (72.6%) have been documented in isolates from urine, ear discharge, pus swab from wounds, and eye discharge. Isolates from the cerebrospinal fluids (CSF) as well as urinary pathogens have demonstrated multidrug resistance.	Getenet and Wondewosen (2011); Okesola and Oni (2009); Iheanyi et al. (2009); Iwalokun et al. (2001); Clarence, Helen, and Nosakhare (2007)
Nigerian	High resistance in	Examination of antimicrobial susceptibility of *Shigella* spp. And *Escherichia coli*, isolates from	Wernli, Haustein, and Conyl (2011);

	both Gram (+), and Gram (-) isolates	diarrheal patients in Nigeria indicate that over 70% of the *Shigella* isolates are resistant to two or more drugs. During 1990-2000, resistance to Ampicillin reportedly increasing from 70% to 90%, Co-trimoxazole from 77% to 85%, Chloramphenicol from 71% to 77%, Streptomycin from 71% to 79%, and Nalidixic acid from 0% to 11.3%.	United Nations Statistics Division (n.d.); Vlieghe et al. (2009); USAID (2003)
Central Africa (Cameroon, Gaboon, chad, Sao tome principble, CAR, C.brazzaville, Democratic Republic of the Congo, Angola and Equatorial Guinea) countries	*Shigella, salmonella sp*ecies and MRSA	Significant findings included multidrug resistance in *Shigella* and *Salmonella* spp. And the emergence of Methicillin-resistant *Staphylococcus aureus*, high-level Penicillin-resistant *Streptococcus pneumoniae* and extended-spectrum beta-lactamases among Gram-negative pathogens. Clearly, Central African region shares the worldwide trend of increasing antimicrobial resistance	Petti, Polage, and Quinn (2006); Gray and Carter (1997)

The following table (5) shows the common antibiotics that induce resistance in sub-Saharan regional countries.

Table 5: Antibiotic resistance reported in sub-Saharan African countries

Sub-Saharan regions	Antibiotics Resistance Reported	Ref.
Southern Africa especially Angola, Zimbabwe and Mozambique	Ciprofloxacin, Ampicillin, Clotrimoxazole, Nalidixic acid, Tetracycline, Trimethoprim/Sulfamethoxazole, Spectinomycin, Streptomycin, Kanamycin, Chloramphenicol and Gentamycin	Wiersinga et al. (2004)
East Africa especially Kenya, Uganda and Ethiopia	Ampicillin, Amoxycillin, Chloramphenicol, Erythromycin and Tetracycline	
Western and Northern Africa	Ampicillin, Clotrimoxazole, Nalidixic acid, Tetracycline, Streptomycin and Chloramphenicol	

One Health Capacity Building in Sub-Saharan African Countries

One Health is one among the concepts suitable for Africa's current challenges. Closer cooperation between different sectors and disciplines has never been more important than within the past few years. Many authors have indicated the importance of one Health in Africa starting from advocating for work and research among pastoralist communities in Sub-Saharan Africa to tackling zoonotic diseases like Ebola, to putting together capacity in health professionals and examining One Health policy, especially, for the control of endemic and neglected zoonotic diseases (UON, 2016; Thomas et al., 2015; National Action Plan on Antimicrobial Resistance, 2017).

The main objectives of the One Health field attachments are to coach students to deal with complex health challenges within the community. This is often done through developing One Health teams that are ready to conduct holistic community assessment at the human, animal and environment interface, develop community-based interventions, and work closely with communities to gauge interventions using available resources (ReAct, 2017).

Some of the institutions are arising with degree programs that check out One Health. The sustainability of funding for such programs is at stake given the limited pool of funders. In some instances, One Health is more focused on zoonotic diseases. With the growing interest in One Health, focus should move faraway from just infectious diseases to other issues like AMR. The challenge of the 21st century is antimicrobial resistance (AMR) (Antimicrobial Resistance

National Action Plan, 2018). The succeeding table describe that the tutorial institutions and networks conducting One Health training and research activities.

Table 6: Academic One Health training, research and outreach activities

Country	Academic institutions	One Health activities
Senegal	Ecole Inter-state sciences and veterinary medicine	EISVM is a member of Afrique One and OHCEA. It serves as a regional veterinary school for most Francophone countries in Africa.
Ethiopia	Jimma University	As a member of OHCEA, it has been training students and staff on one Health, and conducting One Health student club debates. Both schools of veterinary medicine and public health are members
	Mekelle University	It is one of the OHCEA institutions that hold multidisciplinary One Health field attachments, e-Learning, training of community members on infectious diseases by both college of veterinary medicine and public health
	University of Addis Ababa	This university is the newest member of OHCEA admitted into the network in October 2016. It has had collaborations with US universities to conduct One Health Summer Institutes
Uganda	Makerere University	It is a member of Afrique One and OHCEA. The headquarters for OHCEA is situated at this institution at the School of Public health. In addition, Makerere University hosts infectious disease institute and RUFORUM that conduct multidisciplinary training and research for graduate students.
Kenya	Moi University	Moi University is a member of OHCEA. It currently runs a Field Epidemiology program in Collaboration with Kenta Ministry of Health. It also has a vibrant One Health student club that promotes one Health through awareness campaign and social media discussions (such as Twitter and Facebook) and participation in field attachments
	University of Nairobi	Both the School of Veterinary Medicine and Public Health are members of OHCEA and they have One Health activities. University of Nairobi, both Faculty of Veterinary medicine and School of Public health are Members of OHCEA. They both collaboratively, together with Moi University, participate in One Health field attachments, One Health student clubs, support for student research
Tanzania	Muhimbili University of Health and Allied Sciences	It is a member of Afrique One, SACIDS, and OHCEA
	Sokoine University of Agriculture	It is the headquarters for SACIDs and is also sponsored by Predict and OHCEA. It is a member of Afrique One, SACIDS, and OHCEA.
Republic of South Africa	Stellenbosch University	Its medical school is a member of SACIDs
	University of Pretoria	It is member of SACIDs with an institutional One health platform, a partner of One health program at the South Africa Regional Global Disease Detection Center. It is one of the partners for the Ecohealth Alliance that promotes multidisciplinary research
Cameroon	Universite des Montagnes	Member of OHCEA. It is the only private university member of the OHCEA network promoting student multidisciplinary field attachments and One Health student clubs
	University of Buea	The Faculty of Health Sciences and Faculty of Agriculture and Veterinary Sciences are members of OHCEA and they teach health sciences
Co te d'Ivoire	University Nangui Abrogoua	It is a member of Afrique One.
DRC	University of Kinshasa	The Faculty of Public Health is a member of OHCEA and participates in OHCEA activities.
	University of Lubumbashi	The Faculty of Veterinary medicine is a founding member of both OHCEA and SACIDS

Rwanda	University of Rwanda	University of Rwanda One Health student club members participate in community awareness on sanitation, Rabies, and have One Health field attachments
Zambia	University of Zambia	School of Medicine and School of Veterinary Medicine are both members of SACIDs. It has a Masters of One health in analytical epidemiology.

National Action Plan of Selected African Countries to Combat AMR

Preventing antimicrobial resistance is must be tackled with cross sectional collaboration all levels of the whole society Prevention concerns humans, animals, foodstuffs and therefore the environment. Attention is to be paid, both in human and medicine, to the detection and control of spreading of resistance, prevention of infections and antimicrobial stewardship. Antimicrobial resistance may be a global cross border health threat that needs continuous preparedness. The worldwide community must promptly react against new threats. This new National Action Plan on Antimicrobial Resistance describes present control measures of antimicrobial resistance (WHO, 2015d). The following table shows that national action plan on AMR during a selected sub-Saharan region.

Table 7: Antimicrobial resistance NAP development for implementation

Countries	**NAP on AMR**	**Role and Responsibilities**	**Challenges**	**WHO (2013)**
Ethiopia	MOH	Conducted its AMR Situational Analysis in 2008/9 and developed the AMR Prevention and Containment Strategies in 2011	Finance, Human resource capacity, Inadequate national surveillance systems and the influx of poor and sub-standard medicines	
Zambia	National Public Health Institute	Identifying the major AMR and discussion	Lack of dedicated staff to spearhead AMR activities across the sectors, limited access to funding, inadequate enforcement of current regulations around the use of antimicrobials.	
Malawi	MOH	Coordination of AMR activities will be Done by the Multi sectoral AMR Coordinating Unit which will oversee the implementation of NAP	Financial resources.	
Ghana	MOH, Food and Agriculture, Environment, Science and Technology, Fisheries.	Ghana's AMR NAP provides the road map and the requisite strategies to contain the menace of AMR. The NAP Formulated on the One Health Concept	Enactment of appropriate laws and instruments to support the implementation of NAP & the AMR Policy	
Kenya	MOH	The policy provides a framework for NAP implementation and development of its AMR	Limited resources: Sustaining the one-health approach moving forward, Sustainability of the policies outcomes, Devolved government and decentralized government challenges	

Zimbabuwe	MOH	Following a One Health Approach Zimbabwe conducted its Situational Analysis of AMR in 2016 and embarked on the process of developing the NAP and emphasize the joint commitment in addressing AMR	Policy development, staff, availability of antimicrobial resistance data to guide clinical practice and policymaking	
Nigeria	Nigeria Centre for Disease Control	Enrolled in the Global Antimicrobial Resistance Surveillance System	Costing of activities and prioritization, Governance issues and involvement of colleagues across sectors, Actualizing surveillance systems: implementing to scale, funding	
South Africa	MOH	Environmental services/ hand hygiene, Quality and Prioritization of activities for AMR	Costing of the NAP is challenging, an intensive exercise and difficulty, however very important.	
Uganda	MOH and NAMRSC	To create awareness, understanding and improving education on AM use, resistance prevention and containment in humans, animals and the environment	Financial resources and lack of awareness (EFSA, 2011)	

Comparison of Strategies and Policies on Combatting AMR

Overview of the Responses to the Questionnaire

The European Commission sent out questionnaires to 128 EU delegations and received a solution from 77 countries. It should be noted that some countries did not answer every question or relevant sub question within the questionnaire, then the individual response rates to every question varied accordingly (i.e., there have been but 77 responses to many questions). Responses to the questionnaire were received between January and August 2017. Therefore, it is going to be possible that there is more updated information in reference to certain questions as compared with the info cited during this report, as long as numerous responding countries stated that they were working actively during 2017 to develop national policies or action plans on AMR in line with relevant WHO guidance (WHO, 2013).

Table 8: Overview of the responses to the questionnaire

Overview of the responses			
World Bank geographic region	**No of answers**	**World Bank income group**	**No of answers**
East Asia & Pacific	13	High income	12
Europe & Central Asia	13	Low income	14
Latin America & Caribbean	19	Lower middle income	22
Middle East & North Africa	7	Upper middle income	29
North America	1		
South Asia	2		
Sub-Saharan Africa	22		
Total No of answers: 77			

Source: http://www.who.int/antimicrobial-resistance/en/

Strategies and Policies on Combatting AMR

Antimicrobial resistance (AMR) is often defined because the ability of a microorganism to face up to antimicrobial treatments (EFSA, 2011). Combatting the threat posed by AMR

may be a priority for the economic commission and for several countries and international organizations round the world. To tackle AMR, steps should be taken in the least levels of society, with governments often expected to supply leadership. the planet Health Organization (WHO) member countries' national authorities are expected to deliver comprehensive action plans and guidelines, and make them in line with a one Health approach (EFSA, 2011; WHO, 2016).

The WHO, the planet Organization for Animal Health (OIE) and therefore the Food and Agriculture Organization (FAO) have jointly collected information from countries round the world on their progress in implementing the worldwide action plan on AMR and actions to deal with AMR across all sectors, via a self-assessment questionnaire distributed to countries in November 2016 (EFSA, 2011; WHO, 2016).

National action plans, strategies, policies and guidelines are usually wont to help tackle effectively the event and spread of AMR. Out of 77 respondent countries, 29 stated that they had developed a relevant specific national action plan or policy/strategy while 48 stated that they had not. Rock bottom proportion of respondent countries with established policies comes from Latin America & Caribbean (11 %) and Sub-Saharan Africa (27 %). The relatively high number of respondent countries that have relevant policies comes from East Asia &Pacific (8 out of 13) and Europe & Central Asia (7 out of 13) (WHO, 2016). The following figure seemed to suggest that, compared to other regions, there has been less progress within the Latin American & Caribbean and Sub-Saharan Africa regions in developing national action plans or policies/strategies to deal with AMR.

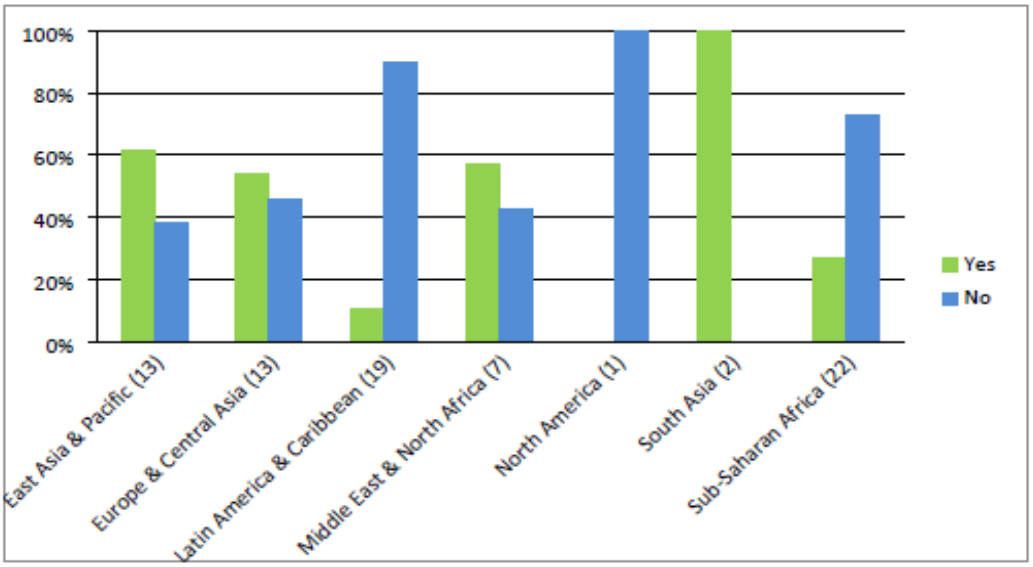

Figure 2: National action plans and strategies on AMR
Source: http://www.who.int/antimicrobial-resistance/en/

Discussion

This review indicated that the role of one health approach and regulatory perspective to combat AMR in Sub-Saharan countries. A serious portion of the population of sub-Saharan region most of them are suffering from AMR. Lack of oversight of antibiotic prescription, and therefore the scarcity of relevant local data on AMR, weak collaboration between one health approach, policies and regulatory agent due to resource constraints, lack of well-trained profession, poor diagnosis was adding fuel to the already fired path of microbial resistance.

The Review on one health approach and regulatory perspective on resistance in sub-Saharan countries comes at a crucial time and has little question already been influential in bringing this critical topic into stage of worldwide debate different stakeholders, who would normally have not paid attention to the present problem. The assessment measured the most factors contributing to the event of antibiotic resistance, and therefore the consequences for human health that specialize in the impact of resistance in species commonly related to infection (i.e. Staphylococcus aureus, Klebsiella pneumoniae, vibro cholera) were a serious explanation for childhood death in Sub-Saharan countries (Mason et al., 1997).

The evidence presented here indicates that AMR, especially to the widely used antibiotics (ampicillin, tetracycline's and trimethoprim sulfamethoxazole), is prevalent and customary in sub-Saharan countries especially East Africa and should be a growing problem, exclusively among hospitalized and postoperative patients. However, resistance is probably going underreported during this region as noted by the WHO Global Report on AMR; thanks to limited availability of diagnostic testing, microbiology support and limited comparability of laboratory standards. Many of an equivalent factor resulting in the lack to check clinical isolates for antimicrobial susceptibility contribute to antibiotic overuse and misuse when laboratory data are lacking and may contribute to exacerbation of AMR (WHO, 2014).

The problem of AMR is particularly urgent regarding antibiotic resistance in bacteria. Over several decades, to varying degrees, bacteria causing common or severe infections have developed resistance to every new antibiotic coming to plug. Faced with this reality, the necessity for action to avert a developing global crisis in health care is imperative. To deal with this urgent public issue, WHO embraces the one health approach to combat antimicrobial resistance across the planet (Murph et al., 2017).

While most developed countries have developed AMR regulatory action this is often still lacking in many developing countries particularly in sub-Saharan countries. Most countries lack the resources to enforce policies regarding the manufacture and distribution of substandard Drugs (Ayukekbong, Ntemgwa, & Atabe, 2017). National action plans, strategies, policies and guidelines are usually wont to help tackle effectively the event and spread of AMR. This review designates that sub-Saharan countries has less progress in developing national action plans, policies and strategy; this report accepts as true with compared to Europe, east Asia and pacific countries (WHO, 2016).

Limitation: One key limitation of this review, lack of comprehensive burden data on antimicrobial resistance is one the main barrier in recognition of drug resistance in various regions of sub-Saharan countries; because the info illustrates the particular prevalence of resistant infections, and the way it affects the overall health and also the economic costs. There are many literatures regarding one health approach collaborating with different regulation and policy to deal with antimicrobial resistance, however most of them are done outside of African countries. This limit further and detail review of the literature. There are more organizations, universities, and agencies performing on One Health approach to combat AMR in Africa that have not been included during this article review.

Strength: The review appreciates the readers who provide more of data about; one health approach, regulation, policies and action plan in sub-Saharan countries in combating AMR and to enhance future review articles.

Conclusion

Antimicrobial resistance (AMR) is widely acknowledged as a worldwide ill health, yet in many parts of African countries its magnitude is not well elucidated. With the growing interest in One Health, focus should move faraway from just infectious diseases to AMR. This review also coined that the need of state structure within the prevention of AMR through evaluation of existing and relevant governance model from others. Lack of one health approach collaboration, resources, research, knowledge, weak regulatory, education about AMR in sub-Saharan countries were challenged issue and expose the population to ADR and depression. Hence implementation of one health approach and regulatory perspective in combating AMR were one among the flinch observed at the days of review.

Based on the above conclusion the subsequent recommendations were forwarded:

- One Health approach should be increasingly recognized as a critical framework for addressing antimicrobial resistance.
- Training, education and awareness creation about AMR are highly recommended.
- Research should be encouraged among the sub-Saharan country.
- Prescribers should update his or her knowledge so on ensure proper prescription of antimicrobial drugs.
- Government should invest more in research and antimicrobial stewardship program.
- Regulatory framework should need further assessments, and documentation as evidence of review and research for the longer term.

Acknowledgments

I would like to acknowledge postgraduate library employer and library officer of Jimma University. The author also would like to thank instructor, Gemmechu Hasen for his supervision, encouragement, and provision of reference materials for an achievement of the actual comprehensive review.

Abbreviation

AMR: Antimicrobial Resistance; AMRSNET: Antimicrobial Resistance Surveillance Network; CDC: Center for Disease Control; FAO: Food and Agriculture Organization; GARP: Global Antibiotic Resistance Partnership; GLASS: Global Antimicrobial Resistance Surveillance System; IHR: International Health Regulation; NPHI: National Public Health Institution; OHCEA: One health Central East Africa; OIE: World Organization for Animal Health; SACIDS: Southern African Centre for Infectious Disease Surveillance

Authors' Contribution

YT and GH; writing the review, editing, reading and approved the final manuscript.

Conflict of Interest

There is no conflict regarding the publication.

References

Adebayo, O. & Johnson, L. (2006). Antimicrobial susceptibility patterns and characterization of clinical isolates of *Staphylococcus aureus* in KwaZulu-Natal province, South Africa. *BMC Infectious Diseases, 6*, 125.

Ahmed, S.S., Ersbøll, A.K., Biswas, P.K., Christensen, J.P., Hannan, A.S., & Toft, N. (2012). Ecological determinants of highly pathogenic avian influenza (H5N1) outbreaks in Bangladesh. *PLoS One, 7*(3), e33938.

Andargachew, M., Afework, K., & Belay, T. (2005). Bacterial isolates from cerebrospinal fluids and their antibiotic susceptibility patterns in Gondar University Teaching Hospital, Northwest Ethiopia. *Ethiop. J. Health Dev., 19*(2), 160-164.

Anguzu, J.R., & Olila, D. (2007). Drug sensitivity patterns of bacterial isolates from septic post-operative wounds in a regional referral hospital in Uganda. *African Health Sciences, 7*(1), 148-154.

Antimicrobial Resistance National Action Plan 2018-2023.

Asrat, D. (2008). *Shigella* and *Salmonella* serogroups and their antibiotic susceptibility patterns in Ethiopia. *La Revue de Sante de la Mediterranee orientale, 14*(4), 760-767.

Association AVM (2008). One Health: a new professional imperative, One Health Initiative Task Force: Final Report. Schaumburg, IL, USA: American Veterinary Medical Association. https://www.avma.org/sites/default/files/resources/onehealth_final.pdf

Ayukekbong, J. A., Ntemgwa, M., & Atabe, A. N. (2017). The threat of antimicrobial resistance in developing countries: causes and control strategies. *Antimicrobial Resistance & Infection Control, 6*, 47. DOI 10.1186/s13756-017-0208.

Bekoe, S. & Ahiabu. (2014). *Quality and Use of Antibacterial agents purchased from formal and informal medicine suppliers in Ghana*. Presentation.

Byarugaba, D. K. (2004). A view on antimicrobial resistance in developing countries and responsible risk factors. *Int J Antimicrob Agents, 24*, 105–10.

Ceccarelli, D., Salvia, A. M., Sami, J., Cappuccinelli, P., & Colombo, M. M. (2006). New cluster of plasmid-located class 1 integrons in Vibrio cholerae O1 and a dfrA15 cassette-containing integron in Vibrio parahaemolyticus isolated in Angola. *Antimicrobial Agents and Chemotherapy, 50*(7), 2493-2499.

Chancey, S.T., Zähner, D., & Stephens, D.S. (2012). Acquired inducible antimicrobial resistance in Gram-positive bacteria. *Future Microbiol, 7*, 959–978.

Clarence, S., Helen, U., & Nosakhare, O. (2007). Multi-antibiotics-resistance plasmid profile of enteric pathogens in pediatric patients from Nigeria. *Biokemistri, 19*(1), 35-42.

Coll-Seck, A. M. et al. (2017). Governance against antimicrobial resistance in Africa: confronting AMR when resources are limited – the example of Senegal. AMR Control, Jul 26, 2.

Dua, V., Kunin, C.M., & White, L.V. (1994). The use of antimicrobial drugs in Nagpur, India. A window on medical care in a developing country. *Soc Sci Med, 38*, 717–24.

EFSA (2011). Antimicrobial resistance. Retrieved from https://www.efsa.europa.eu/en/topics/topic/antimicrobial-resistance

Ferreira, E., Costa, M., & Vaz Pato, M.V. (1992). Resistance to antibiotics of *Vibrio cholerae* strains isolated in Angola. *Pathol Biol (Paris), 40*(5), 561-5. MID:1495844.

Gelband, H. & Delahoy, M. (2014). *Policies to address antibiotic resistance in low-and middle-income countries.* Retrieved May 15, 2017, from https://www.cddep.org/wp-content/uploads/2017/06/abrinlmics_cddep_gelband and_delahoy_9-14.pdf

Getenet, B. & Wondewosen, T. (2011). Bacterial Uropathogens in Urinary Tract Infection and Antibiotic Susceptibility Pattern in Jimma University Specialized Hospital, Southwest Ethiopia. *Ethiop J Health Sci*, *21*(2), 141-146.

Glouberman, S. & Millar, J. (2003). Evolution of the determinants of health, health policy, and health information systems in Canada. *Am. J. Pub. Health, 93*(3), 388-392.

González, J.I. & Dittrich, S. (2017). Antimicrobial resistance in Africa: a systematic review. *BMC Infect Dis, 17*, 616. https://doi.org/10.1186/s12879–1201 7–12713-12871.

Government of the United Kingdom (2013). UK Five Year Antimicrobial Resistance Strategy 2013 to 2018. Retrieved January 4, 2017, from https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/244058/20130902_UK_5_year_AMR_strategy.pdf.

Government of the United States (2015). National strategy for combating antibiotic-resistant bacteria. Retrieved January 4, 2017, from https://www.cdc.gov/drugresistance/pdf/national_action_plan_for_combating_antibotic-resistant_bacteria.pdf

Gray, I.P. & Carter, J.Y. (1997). An evaluation of clinical laboratory services in sub-saharan Africa: Ex africa semper aliquid novi? *Clinica Chimica Acta, 267*(1), 103–128.

Griffith, M., Postelnick, M., & Scheetz, M. (2012). Antimicrobial stewardship programs: methods of operation and suggested outcomes. *Expert Rev Anti-Infe, 10*, 63–73.

Iheanyi, O., Femi, A., Timothy, A., Amusan, A., Tolulope, A., & Ejembi, J. (2009). Incidence of Multi-Drug Resistance (MDR) Organisms in Abeokuta, Southwestern Nigeria. *Global Journal of Pharmacology, 3*(2), 69-80.

Iuga, A.O. & McGuire, M.J. (2014). Adherence and health care costs. *Risk Manag Healthc Policy, 7*, 35-44. Retrieved May 15, 2017, from http://www.ncbi.nlm.nih.gov/pubmed/24591853

Iwalokun, B., Gbenle, G., Smith, S., Ogunledun, A., Akinsinde, K., & Omonigbehin, E.A. (2001). Epidemiology of Shigellosis in Lagos, Nigeria: Trends in Antimicrobial Resistance. *J Health Popul Nutr, 19*(3), 183-190.

Keusch, G.T., Pappaioanou, M., Gonzalez, M.C., Xcott, K.A., & Tsai, P. (Eds.) (2009). *Committee on Achieving Sustainable Global Capacity for Surveillance and Response to Emerging Diseases of Zoonotic Origin*. Washington DC: National Academies Press.

Kibret, M. & Abera, B. (2011). Antimicrobial susceptibility patterns of *E. coli* from clinical sources in northeast Ethiopia. *African Health Sciences, 11*(S1), S40-S45.

Kimang'a, A. N. (2012). A Situational Analysis of Antimicrobial Drug Resistance in Africa; Are We Losing the Battle? *Ethiopian Journal of Health Sciences, 22*(2), 135-143.

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. *Lancet Infect Dis, 13*, 1057–98.

Leopold, S. J., van Leth, F., Tarekegn, H., & Schultsz, C. (2014). Antimicrobial drug resistance among clinically relevant bacterial isolates in sub-Saharan Africa: a systematic review. *Journal of Antimicrobial Chemotherapy, 69*(9), 2337-2353.

Liu, Y.Y., Wang, Y., Walsh, T.R., Yi, L.X., Zhang, R., Spencer, J., Doi, Y., Tian, G., Dong, B., Huang, X. et al. (2016). Emergence of plasmid-mediated colistin resistance mechanism MCR-1 in animals and human beings in China: a microbiological and molecular biological study. *Lancet Infect Dis, 16*(2), 161–8.

Mac-Arthur, A., Gloyd, S., Perdigão, P., Noya, A., Sacarlal, J., & Kreiss, J. (2001). Characteristics of drug resistance and HIV among tuberculosis patients in Mozambique. *Int J Tuberc Lung Dis, 5*(10), 894-902.

Mahon, C.R., Lehman, D.C., & Manuselis, G. (2014). Antimicrobial agent mechanisms of action and resistance. In *Textbook of Diagnostic Microbiology* (pp. 254–273). St. Louis: Saunders.

Mandomando, I., Sigaúque, B., Morais, L., et al. (2010). Antimicrobial drug resistance trends of bacteremia isolates in a rural hospital in southern Mozambique. *Am J Trop Med Hyg, 83*(1), 152-7.

Mason, P.R., Gwanzura, L., Latif, A.S., Marowa, E., Ray, S., & Katzenstein, D.A. (1997). Antimicrobial resistance in gonococci isolated from patients and from commercial sex workers in Harare, Zimbabwe. *Int J Antimicrob Agents, 9*(3), 175-9.

Mbanga, J., Dube, S., & Munyanduki, H. (2010). Prevalence and drug resistance in bacteria of the urinary tract infections in Bulawayo province, Zimbabwe. *East Afr J Public Health, 7*(3), 229-32.

Messele, G. & Alebachew, T. (1980). *Neisseria gonorrhoeae* isolates from Ethiopia: 2 Pair correlations between minimal inhibitory concentration values of five antibiotics and frequency of multiple antibiotic resistance. *Bulletin of the World Health Organization, 58*(1), 73-79.

Morse, S.S. (1995). Factors in the emergence of infectious diseases. *Emerg. Infect. Dis., 1*(1), 7.

Murph, D., Ricci, A., Auce, Z., Beechinor, J.G, Bergendahl, H, Breathnach, R, Bures, J., Pedro, J., da Silva, D., Hederová, J., et al. (2017). EMA and EFSA Joint Scientific Opinion on Measures to Reduce the Need to Use Antimicrobial Agents in Animal Husbandry in the European Union, and the Resulting Impacts on Food Safety (RONAFA). *EFSA J., 15*, 4666.

National Action Plan on Antimicrobial Resistance 2017–2021.

Ndihokubwayo, J. B., Yahaya, A. A., Desta, A. T. et al. (2013). *Antimicrobial Resistance in the Africa Region: Issues, Challenges and Action Proposed.* Retrieved March 24, 2017, from http://www.aho.afro.who.int/en/ahm/issue/16/report/antimicrobial-resistance-african-region-issues-challenges-and-actions-proposed/

Nugent, R., Back, E., & Beith, A. (2010). *The race against drug resistance*. Retrieved December 5, 2017, from https://www.cgdev.org/files/1424207_file_CGD_DRWG_FINAL.pdf

O'Neill, J. (2016). *Tackling Drug Resistant Infections Globally: Final Report and Recommendations*. Review on Antimicrobial Resistance, May 2016.

Okeke, I.N., Aboderin, O.A., Byarugaba, D.K., Ojos, K., & Opintan, J. (2007). Growing problem of multidrug-resistant enteric pathogens in Africa. *Emerg Infect Dis, 13*(114), 1640.1646. http://dx.doi.org/10.3201/eid1311.07067.

Okeke, I.N., Klugman, K.P., Bhutta, Z.A., Duse, A.G., Jenkins, P., O'Brien, T.F., et al. (2005). Antimicrobial resistance in developing countries. Part II: strategies for containment. *Lancet Infect Dis, 5*, 568–80.

Okesola, A.O. & Oni, A.A. (2009). Antimicrobial Resistance among Common Bacterial Pathogens in South Western Nigeria. *American-Eurasian J. Agric. and Environ. Sci., 5*(3), 327-330.

Ombui, J.N., Kimotho, A.M., & Nduhiu, J.G. (2000). Antimicrobial Resistance Patterns and Plasmid Profiles of Staphylococcus aureus Isolated from Milk and Meat. *East African Medical Journal, 77*(9), 463-467.

Petti, C.A., Polage, C.R., & Quinn, T. (2006). Laboratory medicine in Africa: barrier to effective health care. *Clin Infect Dis, 42*, 377-382.

Quick, J., & Bremer, K. (1997). Quality control of essential drugs. *Lancet Lond Engl, 350*, 1106.

Rabozzi, G., Bonizzi, L., Crespi, E., Somaruga, C., Sokooti, M., Tabibi, R., Vellere, F., Brambilla, G., & Colosio, C. (2012). Emerging zoonoses: The "One Health approach". *Saf Health Work, 3*(1), 77-83.

ReAct (2017). Action on Antibiotic Resistance (ReAct), Africa Annual Conference 2017.

Regulatory Body Act (2013). Health Professions Regulatory Body Act, 857. Ghana: Ghana Publishing Corporation.

Robinson, T.P., Bu, D.P., Carrique-Mas, J., Fèvre, E.M., Gilbert, M., Grace, D., et al. (2016). Antibiotic resistance is the quintessential One Health issue. *Trans R Soc Trop Med Hyg, 110*(7), 377-380.

Sageman, A. (2015). *Antibiotic Resistance Mechanisms, Problems and Solutions*. Honors Projects. 416. Retrieved March 18, 2017, from http://scholarworks.gvsu.edu/honorsprojects/416

Schmitt, B. & Henderson, L. (2005). Diagnostic tools for animal diseases. *Rev. Sci. Tech. Off. Int. Epiz., 24*(1), 243-250.

Sprenger, M. (2012). WHO AMR Secretariat Director: Health systems lack money – African region total per capital expenditure 171 USD.

Tang, L.K., Caffrey, P.N., Nóbrega, B.D., Cork, C.S., Ronksley, E.P., Barkema, W.H., Polachek, J.A., Ganshorn, H., Sharma, N., Kellner, D.J., 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. *Lancet Planet Health, 1*, 316–27.

Thomas, M.R., Smith, G., Ferreira, F.H.G., Evans, D., Maliszewska, M., Cruz, M., et al. (2015). *The economic impact of Ebola on sub-Saharan Africa: updated estimates for 2015*. Washington, DC: World Bank Group; 2015. Retrieved from http://documents.wo

rldbank.org/curated/en/541991468001792719/The-economic-impactof-Ebola-on-sub-Saharan-Africa-updated-estimates-for-2015

Tollefson, L. (2004). Developing new regulatory approaches to antimicrobial safety. *J Vet Med B Infect Dis Vet Public Health, 51,* 415–8.

United Nations Statistics Division (n.d.). Standard country and area codes classification (M49). http://unstats.un.org/unsd/methods/m49/m49regin.htm

UON (2016). One Health Club of the University of Nairobi; The One Health outreach and collaborative activities of the club. Nairobi, Kenya: University of Nairobi. Retrieved October 26, 2016, from http://studentorganisations.uonbi.ac.ke/ohsa-uon/about-us/

USAID (2003). United States Agency for International Development. Bureau for Africa, Office of Sustainable Development. The Health Sector Human Resource Crisis in Africa: An Issues Paper.

Vlieghe, E., Phoba, M.F., Tamfun, J.M., & Jacobs, J. (2009). Antibiotic resistance among bacterial pathogens in Central Africa: a review of the published literature between 1955 and 2008. *International Journal of Antimicrobial Agents*, *34*(4), 295-303.

Wegener, H.C. (2012). Antibiotic resistance – linking human and animal health. In E.R. Choffnes, D.A. Relman, L. Olsen, R. Hutton, & A. Mack (Eds.), *Improving food safety through a One Health approach: A workshop summary* (pp. 331-349). Washington (DC): National Academies Press.

Wernli, D., Haustein, T., & Conyl, J. (2011). The application of the international health regulations to the global threat of antimicrobial resistance. *PLOS Med, 8*(4), e1001022.

WHO (2010). Regional Strategy on Prevention and Containment of Antimicrobial Resistance 2010-2015, WHO Regional Office for South-East Asia.

WHO (2013). Antimicrobial resistance. Retrieved from http://www.who.int/antimicrobial-resistance/en/

WHO (2014). Antimicrobial Resistance. In Global Report on Surveillance. Geneva, Switzerland.

WHO (2015a). Global Action Plan on Antimicrobial Resistance. Geneva, Switzerland: WHO. Retrieved January 15, 2019, from http://www.wpro.who.int/entity/drug_resistance/resources/global_action_plan_eng.pdf

WHO (2015b). Global Action Plan on Antimicrobial Resistance. Available online from: http://apps.who.int/iris/bitstream/10665/193736/1/9789241509763_eng.pdf.

WHO (2015c). WHO report finds systems to combat antibiotic resistance lacking. Retrieved January 4, 2017, from http://www.who.int/mediacentre/news/releases/2015/antibiotic-resistance-lacking/en/

WHO (2015d). Antimicrobial resistance. Global Action Plan. Retrieved from http://www.who.int/antimicrobial-resistance/global-action-plan/database/en/

WHO (2016). Global monitoring of country progress on addressing antimicrobial resistance: Self-assessment questionnaire 2016-17. Retrieved from http://www.who.int/antimicrobial-resistance/global-action plan/AMR-self-assessment-2016/en/.

WHO (2019). World Health Organization, Food and Agriculture Organization of the United Nations & World Organisation for Animal Health. Taking a multisectoral, one health approach: a tripartite guide to addressing zoonotic diseases in countries. World Health Organization. https://apps.who.int/iris/handle/10665/325620

Wiersinga, W.J., Dellen, Q.M., Spanjaard, L., Kan, H.J., Groen, A.L., & Wetsteyn, J.C. (2004). High mortality among patients with bacterial meningitis in a rural hospital in Tanzania. *Ann Trop Med Parasitol, 98*(3), 271-8.

Xavier, B.B., Lammens, C., Ruhal, R., Kumar-Singh, S., Butaye, P., Goossens, H., & Malhotra-Kumar, S. (2016). Identification of a novel plasmid-mediated colistinresistance gene, mcr-2, in Escherichia Coli, Belgium, June 2016. *Euro Surveill, 21*(27).