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Impacts of antimicrobial resistance: examining the animal and human health, economic and environmental consequences

U. Magnusson* [(1)] & G. Ström Hallenberg [(2)]

(1) Department of Clinical Sciences, Swedish University of Agricultural Sciences, Ulls väg 26, 756 51 Uppsala, Sweden

(2) Department of Animal Health and Welfare, Swedish Board of Agriculture, Skeppsbrogatan 2, 553 29 Jönköping, Sweden

*Corresponding author: ulf.magnusson@slu.se

Summary

This article examines current options and data availability for estimating impact of antimicrobial resistance (AMR) from a One Health perspective. Microbes resistant to antimicrobials are transmitted among all One Health compartments, but the weights of the different transmission routes are under-studied. The environment serves as a reservoir and vehicle for transmission of resistant bacteria, and antimicrobial pollution can contribute to evolution of AMR.

Therapeutic failures are well known to impact AMR in the livestock sector but are seldom translated into economic metrics. Detailed and harmonised global data on antimicrobial use and resistance is lacking, and there is no universally recognised system for estimating costs for animal morbidity and mortality, production loss and health expenditure.

Estimates of the impact of AMR in the human health sector have better geographical coverage and are more detailed than in the livestock sector. Still, there is a scarcity of data from some parts of the world. Impacts in this sector include a substantial burden on healthcare systems due to slower recovery and increased risk of complications from infectious diseases.

For both the livestock sector and the human health sector, impact and mitigation opportunities for AMR as well as data availability differ between economic settings, with more severe consequences and fewer mitigation opportunities in low- and middle-income countries than in high-income countries. The economic impact on the livestock

sector in particular remains under-reported. Calculating such costs may motivate farmers to adopt a more restrictive and medically rational use of antimicrobials and mitigate the potential for divergence between the livestock sector perspective and public health perspective on antimicrobial use.

Keywords

Animal health – Antimicrobial resistance – Antimicrobial use – Environment – Health economics – Human health – Impact assessment – One Health.

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Introduction

A recent report by the Global Leaders Group on Antimicrobial Resistance identified severe impacts of antimicrobial resistance (AMR) on several sectors in society [1]. These findings in turn call for analyses and actions from a One Health perspective, as resistant microbes and resistance genes may move between humans, animals and the environment [2]. This article focuses on the impact of AMR on the livestock sector, but with an outlook spanning human health and the environment, and the interlinkages between these three sectors.

The livestock sector is the largest global user of antimicrobial agents, specifically antibiotics, and is thus a major driver for the emergence of AMR [3]. The interlinkages between human and animal health in the context of AMR are accentuated by the facts that humans and animals share several pathogenic microbes, i.e. zoonoses, and that the same kinds of antimicrobials, specifically antibiotics, are used to fight these microbes [4,5]. Several case reports highlight how bacteria resistant to antibiotics can be transmitted from animals to humans via direct contact or via the food chain, while a lesser number of reports address transmission in the other direction [6]. Still, the magnitude of transmission from the livestock sector to humans is largely unknown, and the impact on the general human population is also unclear [6,7]. Even so, these findings call for restrictive and medically rational use of antimicrobials in the livestock sector, to protect both public health and animal health.

Resistant microbes from both livestock and humans may also end up in the environment, which thus becomes a reservoir for AMR, with possible public health implications [8] (Fig. 1). In addition, antimicrobials present in the environment as pollutants from healthcare units, livestock farms, drug manufacturing, etc., may contribute to the propagation of AMR.

The impact of AMR on the human health, animal health and environmental sectors varies – and, consequently, so do mitigation opportunities – between low-, middle- and high-income countries. There are several factors at play, such as available technical resources in the three sectors, professional capacity, public awareness, maturity in governance and policies related to AMR, as well as ability to monitor compliance with relevant regulations and to enforce them. Generally, the impact of AMR in all three sectors is regarded to be higher in low- and middle-income countries (LMICs), where mitigation opportunities are fewer, such that AMR disproportionately affects underprivileged populations [8-10].

Impacts on animal health and economic consequences for the livestock sector

Assessment of impact on the livestock sector, and ensuing counteractions, requires several kinds of data: firstly, data about antimicrobial use; secondly, data on resistance rates among the pathogens of concern; and finally, the impact in terms of mortality and morbidity and lowered productivity (Fig. 2). The following sections review the access to data within these three domains.

Data on antimicrobial use in livestock

The World Organisation for Animal Health (WOAH) publishes an annual overview of antimicrobial use in animals [11]. This report is extensive in coverage: the 95 WOAH

Members that report antimicrobials normalised by animal biomass represent 65% of the global animal biomass (terrestrial and aquatic food-producing animals). However, the data are presented per WOAH region (Africa, the Americas, the Middle East, Asia and the Pacific, and Europe), making them less suitable for granular analysis of the causality between antimicrobial use and resistance.

A higher degree of resolution is found in the annual reporting on antimicrobial sales for food-producing animals from 31 European countries by the European Medicines Agency [12]. These reports show several national datasets, including sales by antibiotic class. If matched by solid data on resistance prevalence, these data may be used to analyse the association between use and resistance at national level. This in turn might provide feasible stewardship actions, as countries are generally more homogeneous than regions with respect to regulations, traditions and culture. In the human health sector, such aspects, including socio-economic ones, have been shown to be associated with antibiotic resistance [13].

There are also research data on the global use of antimicrobials. One inclusive study is based on usage reporting from 42 countries and extrapolation by a five-step statistical procedure to the remaining 145 countries in the world [3]. With the caveat that parts of these data are generated by extrapolation, they may be used to assess the association between use and resistance at national levels where resistance rates are available. In addition to these data, available comprehensive reviews of the literature on antimicrobial use in food-producing animals in LMICs might be used for the same purposes as above [14,15].

Data on antimicrobial resistance among livestock

Currently, there is no systematic global reporting on AMR in livestock. In 2024, the Food and Agriculture Organization of the United Nations introduced the InFARM programme, with the goal to support countries in developing and strengthening surveillance of AMR in animals and food [16]. When fully implemented, this programme might serve as a source for national resistance data.

On the regional level, the European Union (EU) compiles a summary report on harmonised AMR monitoring in 32 countries involving three kinds of zoonotic pathogens and commensal indicator bacteria from food-producing animals and meat thereof and from humans [17]. Besides regionally aggregated data, this reporting provides data stratified by country, microbe, source and antibiotic class. Hence, these data are very suitable for assessing the association between antimicrobial use and resistance at national as well as regional level.

In the EU there are also national surveillance programmes [18]. For instance, German and Swedish programmes include a range of pathogens in clinical isolates from animals, and these resistance data are presented in national annual reporting, GERM-Vet and Swedres-Svarm, respectively [19]. These data may be used to analyse the association between antibiotic use and resistance nationally, keeping in mind the sampling frame.

The scientific literature contains several reports from studies performed in countries from most regions in the world where antimicrobial use and resistance in pathogenic as well as commensal indicator bacteria have been sampled from livestock. Other studies systematically compile resistance data from such studies in LMICs and globally [20,21]. The authors collected data from point prevalence surveys and created a geospatial model that displayed the resistance to various antibiotics in both commensal and pathogenic bacteria. In addition, they identified a lack of surveys from several LMICs that are large livestock producers and calculated resistance hotspots. Even though this approach cannot fully substitute surveillance information, it provides a valuable source of data for investigating the relationship between antimicrobial use and resistance.

Assessment of impact on livestock health and productivity

It is well known among farmers and veterinarians that antibiotic resistance may cause therapeutic failures if there is a disadvantageous match between the antibiotic and the resistant pathogen. This may be mitigated by the veterinarian's experience with the disease and resistance situation at the particular farm, or it can be avoided by a proper microbiological susceptibility testing before treatment [22]. The latter is unfortunately not always available and may also delay adequate treatment. Infections with resistant pathogens may thus delay effective treatment, or, if multi-resistant, make treatment difficult or even impossible [23]. The clinical effects on the farm are prolonged treatment periods and increased morbidity or even mortality. For the farmer, this leads to lowered productivity and economic loss, including animal health expenditures. Highlighting this causal chain of events could serve as a powerful argument for a more restrictive and medically rational use of antibiotics among individual farmers as well as in the entire livestock sector. This will also mitigate the potential for diverging perspectives on antimicrobial use between the livestock sector and the public health sector.

However, to make such an argument effective, the impact of AMR should ideally be translated into a monetary metric that can be applied across different scales, e.g. at farm level and national level, in different farming systems, and in all economic settings and geographies. The Global Burden of Animal Diseases programme has introduced a promising system that appears to fulfil these requirements [24,25]. Still, several challenges remain before the AMR impact on the livestock sector can be estimated with more detail and precision than the aggregated estimates made by the World Bank. These estimates indicate a decline in livestock production in 2050 ranging from about 10% in low-income countries in a high-AMR scenario to 2% in high-income countries in a low-AMR scenario [10]. Firstly, as shown above, reliable and detailed data on resistance among animal pathogens that are needed for systematic impact estimates are not globally available. Secondly, and obviously, all the data needed for the very impact assessment relating to livestock mortality and morbidity, productivity loss and health expenditures may be difficult to collect across farming systems. Still, while estimates with imperfect data will inevitably generate imperfect results, they will provide feedback loops about where data collection systems should be improved to collect missing elements [25].

Thus, data paucity is the main hurdle for estimating the impact of AMR on the livestock sector. In addition, one rarely discussed AMR impact pathway that may affect the livestock sector is that consumer trust in animal-source food may be jeopardised in settings where livestock production relies on excessive use of antibiotics (as reflected by high AMR prevalence). The fear of losing consumers' trust was the catalyst for Swedish farmers' demand to their government to ban antibiotics as feed additives in the mid-1980s [26]. The farmers, in close cooperation with academia and government agencies, then enhanced the development and implementation of disease preventive measures. This has resulted in the lowest use of antimicrobials per food-producing animal biomass in the EU, combined with a very high productivity per animal. This path, to reduce the need for antimicrobials by investing in good animal husbandry, effective biosecurity and relevant vaccination programmes, has been followed by other countries and is now the recommended global approach [27].

Impacts on human health and related consequences

Bacteria resistant to antibiotics are judged to be a human health concern comparable to HIV and malaria combined [28], affecting all regions of the world. Notably, the emerging resistance to antibiotics is jeopardising the attainment of several of the United Nations

Sustainable Development Goals (SDGs) – not only those targets relating to health (SDG 3), but also poverty eradication (SDG 1), for example [29].

A recent and thorough systematic analysis of the global burden of bacterial AMR, including data from 204 countries and territories, estimates that in 2021, 1.14 million deaths were attributable to bacterial AMR and 4.71 million were associated with bacterial AMR [9]. Notably, during the period 1990–2021, deaths from AMR decreased by 50% among children younger than 5 years old but increased by 80% among persons older than 70. In 2021, the rates of deaths attributable to AMR were highest in sub-Saharan Africa and South Asia. A forecast in the same report indicates that 1.91 million deaths attributable to AMR will occur in 2050, with the highest rates occurring in South Asia, Latin America and the Caribbean. The increase in deaths is forecasted to be largest among those older than 70.

In the human health sector, one commonly used method to assess the economic impact of diseases is the calculation of disability-adjusted life years (DALYs) [30]. In short, the DALY is a measure that combines premature death and years of healthy life lost due to disability. In 2021, the global DALYs attributable to bacterial AMR were calculated to be more than 42 million [9]. However, the forecasted increase in DALYs to 2050 was less than that for attributable mortality (9.4% *versus* 69.6%). This lower increase in DALYs is due to improved health among the younger population compared to those over 70. It should be noted that the DALY varies by disease, and thus also by which microbe has become resistant. In turn, the underlying data for such calculations must have a high degree of resolution, and the scarcity of data from some LMICs limits the precision in modelling of the AMR impact [9].

Besides the direct impact on human health, another AMR impact is the increased burden on healthcare systems. This includes longer hospital stays caused by slower recovery and increased risk of complications from infectious diseases. As an example, it has been calculated that by 2050 there will be 569 million extra hospital days annually in the EU and the European Economic Area because of AMR [31].

The assessment of the impact of AMR has a far better geographical coverage and is far more detailed in the human health sector than in the livestock sector. Still, there is a geographically uneven distribution of reliable data: in general, there are better data from high-income countries than from LMICs. As in the livestock sector, this underlines the need for improved monitoring and reporting globally.

The role of the environment sector in the antimicrobial resistance–One Health context

The environment compartment undoubtedly plays a role in the emergence of the AMR crises. However, language concerning the environment in international and regional One Health/AMR policy documents is confusing, as previously reported [32]. Statements such as 'AMR is threatening the health of the environment' are misleading, as AMR is a matter of therapeutic failure and the environment is rarely, if ever, treated with antimicrobials. There is a danger that such misleading statements about the impact of AMR will challenge the justified commitments and actions related to the environment sector in the work against AMR.

Instead, the environment may play a role in the transmission of resistant bacteria, most commonly by faecal contamination, among humans, among livestock or between humans and livestock. More rarely, resistance factors from the environmental biota may be picked up by bacteria that are then transmitted to humans or livestock [8].

In addition, antimicrobial pollution, via excretion from humans and animals into the environment, could contribute to the evolution of resistant microbes. However, these concentrations are most often below those that drive selection of resistant bacterial clones [30]. Still, there are reports of concentrations in the environment that reach those that select for resistance or even exceed minimum inhibitory concentrations – the latter in untreated hospital effluents and industrial surface water [33]. Antimicrobial pollution from drug industries is a particular concern as the drugs have not been metabolised in humans or animals and thus maintain their full potency.

In short, AMR may emerge from the environment and then be transmitted to humans and animals, resulting in an impact on public and animal health.

Conclusions

The AMR-related interlinkages between humans, animals and the environment are well established. However, more research is needed to quantify the magnitude of the various transmission routes. The environment may serve as a reservoir or vehicle for AMR genes and microbes as well as, in some cases, being a compartment where resistant microbes are selected due to antibiotic pollution.

The impact of AMR on human health nationally and globally is immense and is estimated in a harmonised way, by combining the effects of premature death and years of healthy life lost due to disability. The reporting of this impact has good resolution and geographic coverage, with the exception of some LMICs. Expenditures by healthcare systems due to AMR have not been estimated in an equally internationally harmonised way but are substantial where such estimations have been made. Notably, AMR also has impacts on other aspects of society and the SDGs that have not yet been properly priced.

The impact of AMR on the livestock sector is well known but rarely translated into economic metrics. This is due to scattered data on antimicrobial use and, in particular, AMR and the lack of application of a harmonised system for estimating the costs of animal morbidity and mortality, production loss and health expenditure. Generating solid data on these costs, both at the farm level and on an aggregated national or global level, is of the utmost importance. This will motivate farmers to apply a more restrictive and medically rational use of antimicrobials and support policies that foster sound interventions.

Impacts de la résistance aux agents antimicrobiens : examiner les conséquences sur la santé animale, la santé humaine, l'économie et l'environnement

U. Magnusson & G. Ström Hallenberg

Résumé

Cet article examine les solutions appliquées actuellement pour évaluer l'impact de la résistance aux agents antimicrobiens (RAM) dans une perspective « Une seule santé », ainsi que les données disponibles à cette fin. Si la transmission de microorganismes résistants aux agents antimicrobiens a lieu dans tous les compartiments « Une seule santé », l'importance relative des différentes routes de transmission reste insuffisamment étudiée. L'environnement faisant office de réservoir et de vecteur de transmission des bactéries résistantes, la pollution antimicrobienne contribue aux évolutions de la RAM.

Dans le secteur de l'élevage, les échecs thérapeutiques jouent un rôle bien connu dans le développement de résistances aux antimicrobiens, mais ils sont rarement traduits sous forme d'indicateurs économiques. Nous manquons de données détaillées et harmonisées sur l'utilisation des agents antimicrobiens et sur la résistance aux antimicrobiens à l'échelle mondiale ; de même, il n'existe pas de système universellement reconnu pour estimer les coûts induits par la morbidité et la mortalité des animaux d'élevage, les pertes de production et les dépenses vétérinaires.

Dans le secteur de la santé humaine, les estimations relatives à l'impact de la RAM sont à la fois plus complètes dans leur couverture géographique et plus précises que dans le domaine de la production animale. Les données de santé publique restent malgré tout lacunaires dans certaines régions du monde. L'impact dans ce secteur est surtout imputable à la charge importante supportée par les systèmes de santé, du fait du rétablissement plus lent des patients et du risque accru de complications chez les personnes atteintes de maladies infectieuses.

L’impact de la RAM, les perspectives d’atténuation et la disponibilité de données varient significativement suivant les contextes économiques, avec des conséquences plus graves et moins de perspectives d’atténuation dans les pays à revenu faible et intermédiaire que dans ceux à revenu élevé, et ce aussi bien en santé animale qu’en santé humaine. En particulier, l’impact économique sur le secteur de l’élevage reste insuffisamment documenté. Le fait de pouvoir évaluer ces coûts pourrait inciter les éleveurs à adopter un usage plus restrictif des antimicrobiens en s’appuyant davantage sur la rationalité médicale et permettrait d’atténuer les éventuelles divergences de vues entre le secteur de l’élevage et celui de la santé publique concernant l’utilisation des agents antimicrobiens.

Mots-clés

Économie de la santé – Environnement – Évaluation d’impact – Résistance aux agents antimicrobiens – Santé animale – Santé humaine – Une seule santé – Utilisation des agents antimicrobiens.

Repercusiones de la resistencia a los antimicrobianos: análisis de las consecuencias para la sanidad animal, la salud humana, la economía y el medio ambiente

U. Magnusson & G. Ström Hallenberg

Resumen

La presente publicación analiza las opciones actuales y la disponibilidad de datos para evaluar las repercusiones de la resistencia a los antimicrobianos (RAM) desde la perspectiva del enfoque «Una sola salud». Si bien los microbios resistentes a los antimicrobianos se transmiten entre todos los compartimentos del enfoque «Una sola salud», aún no se ha estudiado lo suficiente la importancia de las diferentes vías de transmisión. El medio ambiente actúa a la vez como reservorio y vehículo para la transmisión de bacterias resistentes, y la contaminación por antimicrobianos puede ser un factor de evolución de la RAM.

Aunque es bien sabido que los fracasos terapéuticos repercuten en la RAM en el sector ganadero, rara vez se traducen en parámetros económicos. No se dispone de suficientes datos detallados y armonizados sobre el uso y la resistencia a los antimicrobianos a nivel mundial, y no existe un sistema universalmente reconocido para estimar los costos de la morbilidad y mortalidad animal, la pérdida de producción y los gastos sanitarios.

Las estimaciones de las repercusiones de la RAM en el sector de la salud humana tienen una mejor cobertura geográfica y son más detalladas que en el sector ganadero. Sin embargo, los datos de algunas partes del mundo son muy escasos. Algunas de las repercusiones en este sector son: una carga sustancial para los sistemas de salud, debido a una recuperación más lenta, y un aumento del riesgo de complicaciones por enfermedades infecciosas.

Las repercusiones y las oportunidades de mitigación de la RAM, así como la disponibilidad de datos, tanto para el sector ganadero como para la salud humana, difieren entre entornos económicos, con consecuencias más graves y menos oportunidades de mitigación en los países de ingresos bajos y medios que en los de ingresos altos. Aún no hay suficiente información sobre las repercusiones económicas en el sector ganadero en particular. Calcular estos costos puede incitar a los ganaderos a adoptar un uso más restrictivo y racional, desde el punto de vista médico, de los antimicrobianos y reducir la posible divergencia entre la perspectiva del sector ganadero y la perspectiva de la salud pública con respecto al uso de antimicrobianos.

Palabras clave

Economía de la sanidad – Evaluación de las repercusiones – Medio ambiente – Resistencia a los antimicrobianos – Salud humana – Sanidad animal – Una sola salud – Uso de antimicrobianos.

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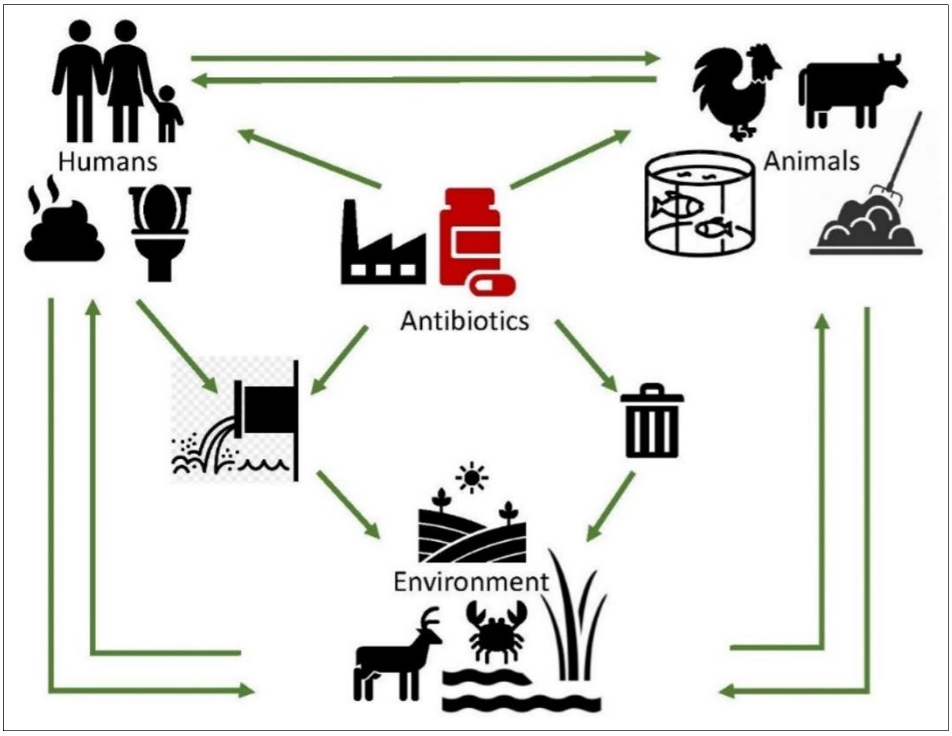
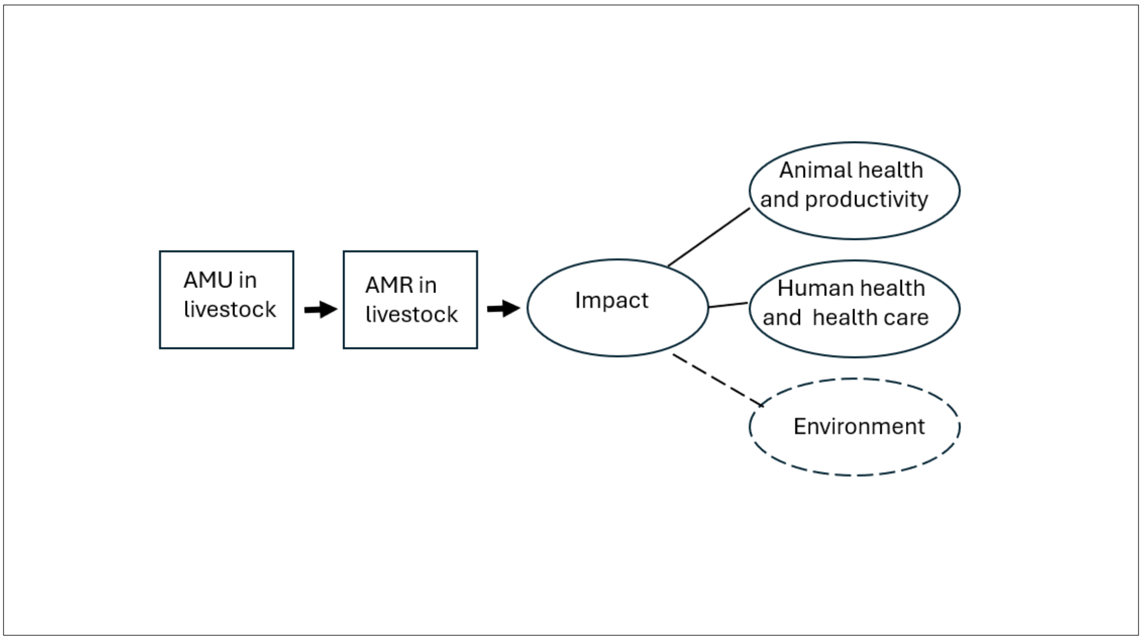


Figure 1

The interlinkage and possible transmission routes of antibiotic resistance among the three One Health compartments: humans, animals and the environment

Adopted from: Swedish International Development Cooperation Agency (Sida). Addressing antimicrobial resistance to support sustainable development. Sundbyberg (Sweden): Sida; 2022. Available at: https://cdn.sida.se/app/uploads/2022/03/31121910/10206070_Sida_Brief_Antimicrobial_resistance_webb.pdf (accessed on 19 December 2025).



AMU: antimicrobial use
AMR: antimicrobial resistance

Figure 2

The impact pathway from use of antibiotics in the livestock sector, via emergence of antimicrobial resistance, to the three One Health compartments