INTRODUCTION

Prevention is a critical, yet neglected, cornerstone to the response to antimicrobial resistance (AMR). The importance of a multitude of preventative measures is recognised across the One Health spectrum, with attention drawn to the issue by multilateral institutions. The 2022 World Antimicrobial Awareness Week saw the World Health Organization, the Food and Agriculture Organization, the United Nations Environment Programme and the World Organisation for Animal Health focused their campaign on the theme ‘Preventing AMR together’ to improve awareness and understanding of AMR and encourage best practices. While a One Health framework is now promoted for conceptualising the complex problem of AMR, the evidence base of interventions designed within this rubric is thin. Outstanding questions remain, for example, about how best to prevent and control infection across humans, animals, and the environment.

In public health, measures such as hygiene practices, biosecurity, vaccinations and other means to strengthen immunity, are commonly used to prevent and control infections. Highlighting the potential contribution of such measures to reducing AMR, the World Bank introduced the terms ‘AMR-sensitive’ and ‘AMR-specific’ to describe interventions that indirectly or directly contribute to reducing AMR, respectively. For example, measures to reduce the burden of infections in human health, such as water, sanitation, and hygiene (WASH), are recognised as essential to support AMR strategies due to their potential to indirectly combat AMR and produce co-benefits. Thus, investments in these interventions would be ‘AMR-Smart.’

Currently, measures to prevent and control infections in human health are most obvious for infections acquired in healthcare settings. Infection Prevention and Control (IPC) in human health is considered fundamental for AMR, defined as measures ‘that prevent patients and health workers from being harmed by avoidable infections and as a result of AMR.’ In animal health, the prevention and control of infections commonly focus on measures to reduce the risk of introduction and/or spread of diseases between animals on farms and from and to farm workers. While the acronym IPC most commonly refers to healthcare settings in the human health sector, the general principle of infection prevention and control has a wider resonance. The subtle but important differences in the terminology for prevention and control of infections between health sectors have the potential to create misunderstandings across the wider One Health spectrum.

SUMMARY BOX

- While the One Health framework is now widely accepted as a strength in understanding antimicrobial resistance (AMR), its application in intervention design to prevent and control drug-resistant infections across humans, animals, and the environment remains weak.
- The potential for infection prevention and control measures to contribute to the AMR agenda is recognised in rhetoric, but evidence to guide action is patchy and uncoordinated.
- While water, sanitation, and hygiene (WASH) and on-farm biosecurity interventions are key strategies for preventing and controlling infections, they are frequently implemented separately for humans and animals. We argue for integration across these sectors to improve planning for AMR control.


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sphere, with consequences for the design and assumptions embedded in AMR interventions and programmes.

Measures to prevent and control infections at a community level in animal agricultural settings where humans and animals live in close contact is an overlooked area ripe for a One Health approach, especially when a significant proportion of the global population is involved in small-scale, semi-intensive livestock farming. It has been estimated that around 1 billion people (about 12% of the global human population) rely on smallholder livestock production5 and about 60 million on aquaculture for their livelihoods.6 The livestock population slaughtered for meat consumption in 2018 was estimated to be as high as 82 billion animals (69 billion chickens, 1.5 billion pigs, 656 million turkeys, 574 million sheep, 479 million goats and 302 million cattle).7 These figures are especially significant for low- and middle-income countries (LMICs) where animal production systems contribute to nearly 40% of countries’ agricultural gross domestic product and 2–33% of household incomes.5

In this commentary, we propose an integrative approach to infection prevention and control by combining WASH and biosecurity interventions to tackle AMR in human and animal populations beyond healthcare facilities, such as in settings where people and animals interact closely.

WASH AND ON-FARM BIOSECURITY AS INFECTION PREVENTION AND CONTROL MEASURES

WASH comprises a group of measures to provide or improve drinking water supply (water quantity), as well as to remove or inactivate pathogens and chemicals ‘at source’ and/or ‘at point of use’ (water quality), to provide or improve facilities for the disposal of human waste (sanitation), and to promote or implement changes in hygienic practices (hygiene).8 A recent study9 suggests biosecurity measures in animal health to be defined as ‘the implementation of a segregation, hygiene or management procedure (excluding medically effective feed additives and preventive/curative treatment of animals) that specifically aims at reducing the probability of the introduction, establishment, survival or spread of any potential pathogen to, within or from a farm, a linked processing operation or a geographical area’.

Further breaking down the concept of biosecurity involves subdividing it into measures covering the areas of bioexclusion (the practices which together prevent the introduction of new pathogens), biocontainment (the escape of pathogens to neighbouring farms/animal facilities), and biomanagement (the control and management of pathogens already present in farms/animal facilities).10 Both WASH and biosecurity measures overlap in many areas as both aim to reduce health risks and exposure to hazardous microorganisms in humans and animals, respectively. Yet, they are commonly implemented in different ways, with significant conceptual differences.

Despite WASH in healthcare settings starting to gain attention in recent years,11 most WASH interventions are implemented in ‘open’ systems at a community level and focus on providing infrastructure for clean water and sanitation or changing hygiene practices by humans, primarily aiming to reduce enteric infections.
by preventing faecal-oral transmission of pathogens between humans and decreasing human exposure to human faeces. These interventions do not commonly recognize the added benefit of WASH to reduce exposure to pathogens coming from/to animals other than those associated with diarrhoea, despite being implemented in agricultural communities mainly composed of smallholders and subsistence farmers in close contact with animals. They often do not measure animals’ negative or positive contributions to the outcomes of the implemented measures.

By contrast, biosecurity interventions frequently operate in ‘closed’ systems (at a farm level) and focus on avoiding or managing the introduction of various pathogens of significance to animal health and diverse transmission pathways. Compared with WASH, the concept of biosecurity takes a broader approach to improve the farm environment. For example, managing air quality—not just water quality or hygienic practices—is often considered crucial for reducing the risk of infections on farms. Although some on-farm biosecurity interventions account for the potential risk of introduction of infections for animals by farmworkers, this is frequently associated with known animal pathogens important for international trade, whereas the presence of opportunistic bacteria in humans that are not considered highly infectious but could carry antimicrobial resistance genes (ARGs) is not commonly assessed, despite evidence of transmissions such as methicillin-resistant *Staphylococcus aureus* between farmworkers and animals and vice versa.12 13 While biosecurity interventions can effectively prevent and control infections in animal production systems, their ability to contribute to better health outside of farms has been less investigated. As well, there has been a disproportionate placement of responsibility to implement biosecurity measures on farmers, with little education and training for farm workers, no opportunities for knowledge co-creation with other stakeholders,
nor engagement from industry and government, leading to challenges with compliance.14

While the biological differences between humans and non-human animals mean that microorganisms can affect them differently, causing disease in humans but not in other animals and vice versa, the potential for acquiring and disseminating ARGs, supporting the perpetuation of AMR in both pathogenic and non-pathogenic bacteria is very high.15 Furthermore, the lack of knowledge on the directionality of microbial spread between humans and animals and the potential for ARGs dissemination between animals and humans16–20 highlights the importance of integrative approaches to AMR prevention and control, especially when most deaths associated with AMR in 2019 were linked to Escherichia coli, Staphylococcus aureus, Klebsiella pneumoniae, Streptococcus pneumoniae, Acinetobacter baumannii and Pseudomonas aeruginosa,21 which can be both pathogenic and opportunistic bacteria for both humans and animals.

**BEYOND WASH AND ON-FARM BIOSECURITY TOWARDS AMR-SMART ONE HEALTH WASH**

The potential for WASH interventions to support AMR control strategies in communities, healthcare facilities, and animal and plant production is recognised.22 However, implementing this in animal agricultural communities is not straightforward. In current practice, WASH and on-farm biosecurity interventions are not interconnected and are implemented and assessed separately. However, both can be applied in integrated approaches to prevent and control infections and complement each other to reduce burden of infections and AMR in humans and animals in settings where humans and animals interact closely. Furthermore, both WASH and biosecurity interventions can positively contribute to preventing environmental contamination as some of these measures focus on the safe disposal of human and animal waste.

To illustrate the interconnections and the relevance of WASH and biosecurity measures to the AMR agenda,
we developed a One Health framework by reviewing relevant research literature guided by a grounded theory approach. Drafts of the graphic were shared and improved through an iterative process between our interdisciplinary team which included expertise from veterinary medicine, medical anthropology, microbiology, environmental engineering, WASH and One Health. We proposed several pathways to conceptualise how poor WASH and lack of biosecurity measures in animal agricultural settings could contribute to infection prevention and control at different levels of the One Health triad. As both WASH and biosecurity share the goal of reducing exposure of people or animals to infectious agents to preserve health, the absence of such measures increases the likelihood of interactions between microbes-host and microbe-microbe. The absence of WASH and biosecurity may therefore increase microbial multiplication and spread, contributing to the emergence and dissemination of ARGs between humans, animals, and the environment. In this scenario, the development of AMR not only has health consequences but also affects the economy of farmers and increases healthcare expenditure, which is especially important in LMICs (figure 1).

We also explored a range of WASH and biosecurity interventions commonly implemented in LMICs and animal production settings. Through content analysis, we identified commonalities, interconnections, and potential gaps (figure 2) and proposed new definitions and examples of interventions from these commonly separated fields (table 1). Although the new proposed definition of biosecurity measures\(^8\) proposes to exclude some veterinary medical interventions, in the typology presented here, we still include interventions traditionally considered part of biosecurity measures that are available in the current literature.

**CONCLUSIONS**

While WASH and on-farm biosecurity traditionally operate in open and closed systems, respectively, their potential to jointly contribute to the prevention and control of infections and AMR in farming communities beyond their traditional operating frameworks is significant, especially in communities where humans and animals interact closely and where the boundaries between them are not necessarily defined by infrastructure. As previously suggested,\(^23\)\(^24\) it is crucial to also address the animal and environmental components within a One Health approach to AMR, and also to ensure air quality for human health within WASH interventions, especially in view of the current COVID-19 pandemic, which exposed our vulnerability to airborne pathogens and the risks of close interactions between humans and animals.

We suggest several pathways to illustrate WASH and biosecurity overlaps and their potential to impact AMR directly or indirectly in the human-animal-environmental interface. We propose integrating these two fields for the prevention and control of infections and AMR, which will improve not only human but also animal and environmental health, leveraging the synergies and differences of these two traditionally separated fields, and recognising their potential to complement each other when addressing health issues in the One Health triad.

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