The natural environment: a critical missing link in national action plans on antimicrobial resistance

Graziella Iossaa and Piran C. L. Whiteb

a School of Life Sciences, Joseph Banks Laboratories, University of Lincoln, Lincoln, LN6 7TS, UK

b Environment Department, University of York, Wentworth Way, York, YO10 5NG, UK

\*Corresponding author: giossa@lincoln.ac.uk

Antimicrobial resistance (AMR), the ability of a micro-organism to stop an antimicrobial from working against it, is one the greatest global health challenges. It is projected to be the leading cause of death worldwide, claiming an estimated 10 million lives a year, by 2050, primarily in low- and middle-income countries (1). In 2015, the World Health Assembly (WHA) adopted a global action plan on AMR underscored by the One Health approach (2). One Health seeks to improve health and well-being through the integrative management of disease risks at the interface between humans, animals and the natural environment, based on closer collaboration among individual disciplines and an integrated, cross-sectoral approach to research, surveillance, and response (3). The natural or biophysical environment here includes all living (biotic) and non-living (abiotic) factors affecting the survival of all organisms (including humans) at the individual, population, community or ecosystem level. In this context, an ecosystem refers to a community of plants, animals and microorganisms that live, feed, reproduce and interact in the same area or environment. AMR connects human health to the health of ecosystems and the natural environment, in terms of both drivers and consequences. Concurrently with the WHA action in 2015, member states agreed to publish individual national action plans (NAPs) on AMR by May 2017 (2), (4). Here we present the first analysis of the extent to which these post-2015 NAPs have been successful in integrating the natural environment within a One Health approach. We found that NAPs feature human and animal health prominently but that most do not specifically incorporate the natural environment, and hence fall short of achieving a genuine One Health approach. Given the key role of the natural environment in contributing to AMR, we call for greater integration of the natural environment in existing and new NAPs, so that we can maximise our chances of finding holistic and sustainable solutions to this global health threat.

**AMR at the human-animal-environment interface**

Antimicrobial resistance develops in, and is maintained and transmitted across, humans, animals and the natural environment. Resistance is an ancient and naturally-occurring phenomenon, but anthropogenic antibiotic use since the 1930s has been linked to the increasing occurrence of antimicrobial-resistant microorganisms, and in particular, bacteria (5);(6). AMR continues to develop across human-animal-environment systems. The natural environment presents a transmission route and a reservoir for resistant microorganisms and plays a significant role in the development of, and response to, AMR (7). Antimicrobial use in the livestock industry is driving the selection of resistant bacteria in farm animals, and whilst the causal link between antimicrobial use in farm animals and the selection of resistance in humans is difficult to establish, there is widespread evidence of an association (8). Resistant bacteria of animal origin can be transmitted to humans directly (farm workers), via food or indirectly via the natural environment (animal faeces). Moreover, waste-water treatment plants, manure from farm animals, and spill-over from the pharmaceutical production industry, contribute to an environmental reservoir of resistance (7). The natural environment should therefore be a key consideration in understanding and developing strategies to control AMR, as acknowledged through the One Health approach (9).

**The national action plans**

In response to the public health risk posed by AMR, at the Sixty-eighth WHA in May 2015, member states adopted a resolution implementing the global action plan on AMR and agreed to publish NAPs aligned to the global action plan by May 2017 (4). Among the key guiding principles in the drafting of NAPs on AMR is to use a One Health approach and multisectoral coordination that gives the various collaborating organisations equal status and emphasises a sense of ownership of the plan (4). As of May 2018, 56 member states (29.0%, 56/194) have published NAPs, of which 21 have been published since 2015.

We analysed all NAPs published in English after 2015 and up to October 2017 (18, Table 1) to determine the extent to which the NAPs integrated the natural environment within a One Health approach. We used content analysis (10) by constructing a set of categories: i) One Health (inclusion of the term itself, related terms, or no reference); ii) Human-animal-agriculture (agriculture appeared to be used as synonymous for natural environment; inclusion of these keywords as linked to One Health but with no specific mention of One Health, related terms, or no reference); iii) Environment (inclusion of the term itself, related terms, or no reference); and iv) Human-animal health (inclusion of the term itself, related terms, or no reference). The categories also identified the broader context in which those terms were used: in the introduction or problem definition of AMR; in the plans’ strategic objectives; in the implementation; and/or in the evaluation process. As we were particularly interested in multisectoral approaches to tackling AMR, we also looked for evidence of their presence or absence in the NAPs.

Ten out of 18 action plans followed the WHO guidelines and identified five objectives in line with the global action plan on AMR: 1, Improve awareness and understanding of AMR 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; and 5, Develop the economic case for sustainable investment that takes account of the needs of all countries, and increase investment in new medicines, diagnostic tools, vaccines and other interventions; (2),(4). The eight remaining action plans identified further country-specific objectives. Encouragingly, a further objective was to establish governance and a multisectoral approach to combat AMR (6/8).

The most frequent term across all NAPs was that of human-animal health (on average 14.1% of the text contained a reference to human-animal health), followed by human-animal-agriculture (5.1%) and the environment (2.6%, Fig.1). No plans included the words ecology/ecologist/ecosystem (ecosystem was mentioned in five plans but the context –e.g. “clinical settings represent an ecosystem of high antimicrobial usage” or “the entire ecosystem of AMR” - suggests a non-ecological meaning). The term One Health was included in 1.3% of the text of the plans and multisectoral coordination in 3.0% (Fig.1). Across all plans, with regards to the context, a One Health approach was occasionally referenced in the introductory section and in the definition of AMR as a challenge. Twelve of the 18 plans also mentioned a One Health approach in their strategic objectives. However, this was mainly restricted to the need for an integrated surveillance system (Objective 2) with the acknowledgement of a current focus on human and animal health and an intention to integrate the natural environment in the future. Reference to a One Health approach was related mainly to multi-sectoral collaboration and to a ‘whole-of-society’ engagement. In contrast, there was frequent reference to human-animal-agriculture terms in the strategic objectives but these were not specifically linked to One Health.

Although most plans have been drafted by multisectoral coordination teams who acknowledge that One Health underlines their approach, the predominance of topics around human-animal health and the sparsity of topics around the natural environment, suggests a predominance of representatives of the former over the latter on the coordination teams. The reason for this could be two-fold. First, we have an increasing understanding of resistance mechanisms in human-animal systems alongside better developed surveillance methods, and longer-term collaborations among key agencies, such as WHO, FAO and OIE (7),(9). On the other hand, the recent history of the One Health approach has stemmed from confronting emerging infectious diseases outbreaks and its development so far has been primarily embraced by veterinarians and, to an extent, physicians (3). Currently, two of greatest challenges to ensure that One Health becomes embedded in governance are i) ensuring that greater emphasis is placed on the key role of the natural environment and ecosystems in contributing to AMR risk and management (11), and ii) working to break down disciplinary and policy silos and embrace the changes needed to implement a genuinely interdisciplinary and cross-sectoral approach (12).

**Concluding observations**

AMR is a complex multisectoral challenge. Some progress is being made towards embedding a One Health approach in NAPs on AMR. For example, the Sri Lankan NAP provides an example of a cross-sectoral approach including expertise from rural economy, fisheries, aquatic sciences, veterinarians and public health, and the Indian NAP includes an objective on reducing the environmental spread of AMR. However, our analysis suggests that the first set of NAPs have not been wholly successful in instigating a One Health approach. The NAPs have prompted the establishment of multisectoral committees and, in some cases, governance. Yet, whilst human and animal health feature prominently, the natural environment has yet to be fully integrated into these plans. Since the natural environment is a key source and driver of AMR, as highlighted by the WHO/OIE/FAO Tripartite and by the global action plan on AMR (2), this represents an important omission. There is an urgent need for more research into the ecology of AMR in the natural environment, for example the population dynamics of AMR genes and resistant microorganisms, the transmission dynamics of resistance including the role of wildlife (13), the role of biodiversity in enhancing or regulating resistance, the selection pressures operating on resistance, and the role of co-selective factors such as biocides and metals. Without the more specific integration of the natural environment into NAPs and future strategies, we risk jeopardising many of our efforts to tackle the increasing threat posed by AMR (7).

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Competing Interest

None declared.

Figure 1. Content analysis (average term frequency) of the search terms around One Health, human-animal health, human-animal-agriculture, environment and multisectoral engagement for 18 national action plans on antimicrobial resistance published after 2015. Member states are arranged geographically according to the WHO regional classification (African Region (1), Region of Americas (2), Eastern Mediterranean Region (1), European Region (2), South-East Asia Region (8), Western Pacific Region (4)).

Table 1. The geographical spread of the national action plans on antimicrobial resistance considered in our analysis. In brackets is the publication year.

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| WHO geographic classification | National action plan on AMR |
| African Region | Tanzania (2017) |
| Region of Americas | Barbados (2017), Canada (2017) |
| Eastern Mediterranean Region | Oman (2017) |
| European Region | Sweden (2016), Denmark (2017) |
| South-East Asia Region | Maldives (2017), India (2017), Indonesia (2017), Timor-Leste (2017), Nepal (2016), Sri Lanka (2017), Thailand (2016), Bangladesh (2017) |
| Western Pacific Region | Japan (2016), Mongolia (2017), China (2016), New Zealand (2017) |

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