Food and Agriculture Organization
of the United Nations

Antimicrobial Resistance in the Environment

Summary Report of an FAO Meeting of Experts

FAO Antimicrobial Resistance Working Group

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Abstract

In environments affected by anthropogenic activities, antimicrobial residues and antimicrobial resistant (AMR) bacteria are found in surface waters, soils, animal and human waste streams, and foods of plant origin. Surveillance and further testing are needed for comprehensive risk assessments, and to monitor progress in reducing environmental contamination. Filling critical research gaps will enable the development of new treatment technologies and mitigation strategies to limit environmental contamination by antimicrobial residues and AMR organisms. There is increasing recognition that protecting the environment is the responsibility of a wide and diverse group of stakeholders. In countries with developed economies and in resource-limited countries alike, raising awareness about the negative consequences of overusing antimicrobials and the need for effective waste management strategies; the presence of strong land and water protection guidelines and legislation; and the promotion and adoption of best management practices to limit a environmental contamination with antimicrobials should be a high priority across all sectors.

Introduction

Antimicrobial resistance (AMR) is a serious threat to human and animal health, livelihoods, and food security, raising important questions about the role our environment plays in the selection and spread of resistant organisms. Microorganisms naturally produce antimicrobials to outcompete one another for limited resources. AMR is a natural phenomenon in this struggle for survival, which started long before we discovered that antimicrobials could be harnessed to treat infections caused by bacteria, viruses, fungi, and some parasites. The development of AMR (and its spread to other organisms via mobile genetic elements such as plasmids and transposons) has been sped up and amplified by industrial discharges (primarily from pharmaceutical manufacturing), agricultural activities, and human wastes contaminating the environment.

Antimicrobials are widely used for people, livestock, poultry, aquaculture, apiculture, pets, and plants, not only for treatment of infections, but also for disease control, prophylaxis, and to promote growth in food-producing animals. Depending on the species treated and the particular drug used, the percentage of the dosage that is absorbed or metabolized by an individual animal or person, ranges from as little as 10% to over 80%, with the remainder excreted as active compounds through urine and feces into the environment. Soils are contaminated by antimicrobial treatments used for disease control in plant production, and by residues in manures and wastes applied as crop fertilizers. Waste streams from humans and animals treated with antimicrobials are also enriched with resistant microorganisms and antimicrobial resistance genes (ARGs).

Persistence dynamics of antimicrobial residues, ARGs, and the survival of resistant organisms in the environment are complex. A number of biotic and abiotic factors including temperature, solar radiation exposure, pH, soil type, and microbial biocomplexity influence how long residues remain in the environment, and at what rate bacteria proliferate, die off, exchange resistance genes, and are dispersed. Of growing concern are the effects that low concentrations of antimicrobials (lower than minimal inhibitory concentrations of antimicrobials) have as a selective force in AMR emergence. Compounding this problem, processes of cross-resistance and co-selection can further contribute to the multi-drug resistance. Thus, resistance that develops in the environment may be clinically relevant across all sectors.

Many studies have documented antimicrobial residues in ecosystems influenced by both urban and agricultural activities. Likewise, ARGs and bacteria (notably zoonotic organisms) with resistance to one or more antibiotics can be detected in surface waters, in soils, in animal feeds and on edible plants around the globe. In some regions, guidelines and regulations have been introduced to limit environmental contamination by industrial, human and animal wastes. However, there are still many gaps in knowledge about the ecology of AMR when it comes to environmental contamination with antimicrobial residues, resistant bacteria, and ARGs. For example, the magnitude of the public health threat posed by AMR organisms (and ARGs) in the environment, and the effects of antimicrobial residues on soil ecosystem services, such as biogeochemical cycles, are still unknown.

What can be done to minimize antimicrobial residues and AMR in the environment?

There are multiple potential sources of antimicrobials entering the environment. Among the most important contributors to environmental pollution by antimicrobials are waste from pharmaceutical manufacturing plants, hospitals, wastewater treatment plants, untreated human wastes, waste and runoff from aquaculture, livestock, and plant-based food production and processing facilities. However, the attributable fraction of each source, and factors governing abundance and distribution of AMR organisms, ARGs, and residues in the environment from agricultural sources are unclear. Despite current knowledge gaps, there are several practical actions that can be taken to minimize environmental contamination with antimicrobial residues, AMR, and ARGs.

(1) **Protecting water from contamination with residues** is the first step in reducing their impact on the environment. This may be achieved by regulating and enforcing the amount of antimicrobial residues discharged into the environment.
(2) **With respect to agricultural sources, reducing the need for antimicrobial use through improved animal health and hygiene practices** is the single most effective way to proactively reduce the contamination of animal wastes with antimicrobial residues and AMR bacteria.
(3) Subsequently, **effective treatment of wastes to reduce and eliminate residual antimicrobials** will reduce environmental contamination. Since most waste treatment protocols were not designed specifically to address antimicrobial residues, their efficacy to mitigate these residues is highly variable depending on the treatment process and the specific antimicrobial in question. A more effective approach will need to overcome challenges of limited or absent waste treatment facilities and standard operating procedures, limited awareness, resources and infrastructure, and weak or poorly enforced regulations. These challenges are especially pronounced in low- and middle-income countries (LMICs) and require urgent attention.

While many developed countries are aware of and practice some level of environmental protection, more widespread and rigorous implementation of these practices specifically aimed at reducing antimicrobial residue pollution in the environment will go a long way towards slowing the development of AMR – a priority for all countries in the context of the Global Action Plan on AMR.

Innovation needs for environmental protection

Additional information, tools, and activities are urgently needed to better characterize and mitigate the risks associated with antimicrobial residues and AMR bacteria from agronomic sources in the environment, particularly in LMICs. Paramount among research priorities is determining the magnitude of the direct and indirect public health costs posed by environmental contamination with antimicrobial residues, AMR organisms, and ARGs. Of comparable urgency is the need to determine the relative fraction of contamination attributable to the various potential sources of environmental antimicrobial residues so that interventions and resource allocation can be prioritized for maximum impact and return on investment.

Additional information is also needed to better understand the impact, effectiveness, costs and benefits of different waste treatment practices, such as composting and manure storage, biochar formation, anaerobic digestion, ozone and ultra-violet light treatment, among others. The role of wildlife as reservoirs in disseminating AMR and ARGs across sectors warrants study as well. Key variables to measure in future studies include: the interactive effects of the environmental matrix and conditions; the specific microorganisms of interest for the antimicrobial under study; persistence of antimicrobial residues, AMR organisms, ARGs, and the impact of soil resistome (*i.e*. collection of ARGs) composition and diversity on ecosystem services in general. The latter may be especially relevant for food productivity and safety.

Programmes and tools to systematically measure and record antimicrobial contamination and AMR bacteria in the environment at national levels are virtually absent. Environmental AMR surveillance systems need to be integrated and harmonized with surveillance in the human, animal, and food sectors to track the spread of antimicrobial residues, AMR organisms and ARGs to better assess the risks and priority areas for intervention. Development of rapid and inexpensive tests to characterize the resistome of microbe populations in the environment would also help in the selection of more appropriate AMR surveillance and mitigation strategies. A key challenge in this work will be determining an appropriate standard denominator when expressing the magnitude of changes in environmental contamination so that progress within and across countries can be monitored in kind.

Increasing awareness of the issue of antimicrobial residues and AMR contamination in the environment is vital to drive changes in stakeholder practices. Requiring increased transparency on environmental aspects of waste management in food production, processing, and pharmaceutical production may further empower consumers to demand products produced by companies that prioritize environmental protection.

Endnote

This overview of AMR and the environment is based on the discussions of a technical meeting of experts on these issues that was convened by FAO in November 2017. A more detailed technical paper is forthcoming.

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