

## From Drug to Ecosystem: Why Pharmacology and Toxicology Matter in One Health

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### Introduction: One health beyond a buzzword

The One Health concept-recognizing the intrinsic interconnectedness of human, animal, and environmental health-has evolved from an academic framework into a global public-health imperative. Emerging zoonoses, antimicrobial resistance (AMR), environmental contamination, food-safety crises, and climate-driven disease shifts have exposed the limitations of silo-based health systems. While clinicians, epidemiologists, microbiologists, and ecologists are often foregrounded in One Health discussions, the role of pharmacologists and toxicologists remains critically under-acknowledged, despite being central to risk mitigation, therapeutic optimization, and preventive governance.

Pharmacologists and toxicologists operate at the intersection of drug-host-pathogen-environment interactions, making them uniquely positioned to translate One Health principles into safe, effective, and sustainable practice. Their expertise is not merely supportive but foundational-bridging molecular science, clinical outcomes, regulatory policy, and environmental stewardship.

### Pharmacology and toxicology: The integrative sciences of One Health

At its core, One Health demands integration-across species, systems, and scales. Pharmacology and toxicology are inherently integrative disciplines, encompassing:

- Comparative biology across animal species and humans.
- Exposure science linking environment, food, and therapeutics.
- Risk-benefit evaluation balancing efficacy with safety.
- Translational science connecting laboratory findings to field realities.

In veterinary contexts especially, drugs administered to animals have downstream consequences for human consumers and ecosystems, making pharmacological decision-making a One Health act by default.

### Antimicrobial stewardship and AMR: A pharmacologist's mandate

Antimicrobial resistance represents perhaps the most visible One Health crisis of the 21<sup>st</sup> century. The irrational use of antimicrobials in food animals-wrong dose, duration, indication, or drug-has contributed significantly to resistant zoonotic pathogens and commensals entering the human population via food chains and the environment.

Here, pharmacologists play a decisive role by:

- Designing species-specific dosing regimens based on pharmacokinetics (PK) and pharmacodynamics (PD).
- Promoting PK-PD-guided antimicrobial therapy to minimize selection pressure.
- Advising on drug rotation, combination therapy, and withdrawal periods.
- Supporting antibiotic alternatives (nutraceuticals, immunomodulators, phytochemicals).

Toxicologists complement this by assessing sub-therapeutic exposure risks, ecological dissemination of resistant genes, and long-term population-level consequences.

Global AMR strategies promoted by organizations such as World Health Organization, Food and Agriculture Organization, and World Organisation for Animal Health rely heavily on pharmacological evidence-underscoring that AMR containment is impossible without pharmacologists at the table.

### Drug residues, food safety, and public trust

Veterinary pharmacologists and toxicologists are the unseen custodians of food safety. Drugs administered to food-producing animals-antibiotics, antiparasitics, NSAIDs, hormones-can persist as residues in meat, milk, eggs, and honey if not properly regulated.

Key one health contributions include:

- Establishment of maximum residue limits (MRLs).
- Withdrawal period determination based on residue depletion kinetics.
- Development and validation of analytical methods (HPLC, LC-MS/MS).
- Risk assessment of chronic low-dose human exposure.

Food safety is not merely a regulatory requirement; it is a cornerstone of consumer confidence and nutritional security. Toxicologists further evaluate cumulative exposure, vulnerable populations (children, pregnant women), and long-term carcinogenic or endocrine effects-dimensions often invisible in routine clinical practice.

### Environmental toxicology: The forgotten arm of One Health

A defining feature of One Health is the environment, yet it remains the least protected domain. Veterinary pharmaceuticals excreted by animals-antibiotics, antiparasitics, hormones-enter soil and water systems, affecting:

- Aquatic organisms and biodiversity.
- Soil microbiota and nutrient cycling.
- Wildlife health and reproductive fitness.

Pharmacologists and toxicologists assess:

- Environmental fate and ecotoxicity of veterinary drugs.
- Bioaccumulation and biomagnification risks.
- Impacts of pesticides, heavy metals, and industrial contaminants on animals and humans.

Without toxicological surveillance, environmental health becomes an afterthought, undermining the very foundation of One Health.

### Clinical toxicology and disaster preparedness

From pesticide poisoning in pets and livestock to industrial chemical spills and mycotoxin outbreaks, toxicologists provide rapid risk assessment, diagnosis, and mitigation strategies. In rural and agricultural settings, veterinarians trained in toxicology often serve as the first responders to environmental and occupational health emergencies.

Their role extends to:

- Development of antidotal therapies and treatment protocols.
- Training farmers and para-veterinary staff in safe chemical handling.
- Advising policymakers on chemical regulation and ban decisions.

These contributions directly protect animal welfare, farmer livelihoods, and human health-epitomizing One Health in action.

### Policy, regulation, and evidence-based governance

One Health cannot succeed without sound policy, and policy without science is fragile. Pharmacologists and toxicologists provide the evidence backbone for:

- National drug approval and scheduling.
- Ban or restriction of hazardous molecules.
- Guidelines for rational drug use.
- Surveillance programs for residues and toxicity.

Their participation ensures that regulations are scientifically defensible, practically implementable, and ethically grounded.

### Education, capacity building, and the future workforce

Perhaps the most enduring One Health contribution of pharmacologists and toxicologists lies in education. By training veterinarians, pharmacists, medical professionals, and researchers to think beyond single-species outcomes, they cultivate a workforce capable of systems thinking.

Incorporating One Health perspectives into pharmacology and toxicology curricula-through case-based learning, residue analytics, environmental risk assessment, and AMR stewardship-ensures that future professionals are not merely drug users but health guardians.

### Conclusion: From Supportive Role to Strategic Leadership

The One Health movement will falter if pharmacologists and toxicologists remain peripheral contributors. Their expertise sits at the confluence of therapy, safety, environment, and policy-precisely where One Health decisions are made.

Recognizing and institutionalizing their leadership role is not optional; it is essential. As the world confronts pandemics, resistance, pollution, and food insecurity, pharmacologists and toxicologists must be acknowledged not as background scientists, but as strategic architects of One Health solutions.

“One Health is not only about treating disease-it is about preventing harm. And prevention begins with understanding what we administer, what we expose, and what we leave behind”.

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