JOURNAL OF CLINICAL AND BIOMEDICAL SCIENCES

EDITORIAL

OPEN ACCESS

Received: 04-10-2025
Accepted: 19-11-2025
Published: 19-12-2025

Citation: K Indrani. Circular and Planetary Health in the One Health Paradigm. 2025; 15(4):237-238. https://doi.org/10.58739/jcbs/v15i4.editorial

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Funding: None

Competing Interests: None

Published By Sri Devaraj Urs Academy of Higher Education, Kolar, Karnataka

ISSN
Print: 2231-4180
Electronic: 2319-2453

Circular and Planetary Health in the One Health Paradigm

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Abstract

The recognition of the "One Health" concept—integrating human, animal, plant, and environmental health—has gained momentum, albeit later than ideal. Events such as the COVID-19 pandemic have underscored the interconnectedness of these domains, revealing vulnerabilities in food security and the critical importance of environmental health.

Climate change has further complicated this landscape by altering pathogen dynamics, contributing to the emergence of new strains, and shifting the geographical distribution of diseases affecting humans, animals, and plants. These changes affect the resilience and productivity of ecosystems by influencing host-pathogen interactions, biodiversity, and crop and livestock health.

Armed conflict and environmental degradation also threaten food systems by damaging soil quality, increasing pathogen persistence, and undermining the foundational elements needed for healthy plant and animal development. Moreover, challenges like antimicrobial resistance (AMR), mycotoxin contamination , and marine toxins further emphasize the need for a unified health approach.

As the global population is projected to exceed 9 billion by 2050—primarily in low- and middle-income countries—addressing neo-pandemics, food security, water scarcity, vector borne diseases and pest-related crop losses is more urgent than ever. Promoting plant health is essential not only for food safety and economic development but also for achieving sustainable urban environments. Green infrastructure—such as urban agriculture, integrated pest management, and the strategic design of plant systems—can mitigate urban heat island effects, enhance air quality, promote biodiversity, and contribute to more sustainable and healthier cities. Plants are central to the health of soil, air, and water, and therefore play a crucial role in ecosystem sustainability and health of the human race.

While the "One Health" framework has catalysed collaboration across sectors, it often retains a clinical focus that overlooks broader ecological and societal interactions. The term emerged from the evolution of "One Medicine," initiated by pioneers like William Osler and later revitalized by Schwab, who acknowledged the mutual health dependencies between humans and animals. The One Health approach has driven progress in zoonotic disease surveillance, interdisciplinary research, and international policy-making. Yet, integration across sectors—especially between plant, animal, and human health—remains fragmented due to institutional silos, funding disparities, and methodological differences.

To overcome these limitations, the concept of planetary health has emerged. This broader framework addresses the human impact on Earth's biophysical systems—often referred to as the Anthropocene era—and emphasizes the need for sustainable interactions between civilization and nature. Defined as the health of human civilization and the natural systems on which it depends, planetary health promotes a solution-oriented, interdisciplinary approach to health and sustainability.

In parallel, the circular health paradigm builds upon One Health and Planetary Health by introducing a systems-based perspective. It highlights the role of big data, non-biomedical disciplines, and the interconnectedness of living and non-living systems impacting the environment such as layers of the earth (soil) , air, water, fire etc. Circular health envisions a holistic, adaptive framework to guide interprofessional education and policy-making aimed at building more resilient and equitable ecosystems.

Antimicrobial resistance (AMR), a cross sectoral crisis, is one of the most pressing threats to global health. Its emergence is driven by the misuse and overuse of antimicrobials in humans, animals (terrestrial and aquatic), and agriculture. Mobile genetic elements enable the horizontal transfer of resistance genes across species and ecosystems, necessitating a “One Health” approach to management and mitigation.

Global collaboration is already underway through the quadripartite alliance of FAO, WOAH, WHO, and UNEP, which addresses AMR within this integrative framework. Historically, AMR knowledge has been based on phenotypic studies. However, recent advances in whole genome sequencing (WGS) and metagenomics have opened new avenues for surveillance and resistance gene identification.

Despite these advancements, challenges persist in standardizing antimicrobial susceptibility testing (AST) and interpreting data across different ecosystems. Tools such as EUCAST and CLSI rely on epidemiological cut-off values (ECOFFs) that require global datasets. Capacity building for genomic surveillance and the harmonization of bioinformatics tools are urgently needed to support global AMR strategies.

Highthroughput genomics and omics in AMR surveillance is being increasingly used to study the traceability and spread of genes across sectors. Modern technologies—such as Whole genome sequencing, transcriptomics (e.g., RNA-Seq), and pangenomics—enable deeper insights into resistance mechanisms, gene expression under antibiotic stress, and evolutionary dynamics of pathogens. The notorious ESKAPE pathogens (*Enterococcus faecium, Staphylococcus aureus, Klebsiella pneumoniae, Acinetobacter baumannii, Pseudomonas aeruginosa, Enterobacter spp.)* exemplify the urgency of these efforts due to their adaptability and resistance profiles. Integrated omics approaches—combining genomics, transcriptomics, proteomics, and metabolomics—are essential to understand pathogen behavior, host-pathogen interactions, and resistance pathways. Machine learning and data mining further enhance predictive models for resistance phenotypes and drug targets, contributing to improved diagnostics, treatment strategies, and public health interventions.

The rising complexity of global health threats calls for convergence across disciplines. COVID-19 acted as a catalyst for interdisciplinarity, highlighting the need for integrated education, shared surveillance, and systems thinking. The fusion of One Health, Planetary Health, and Circular Health offers a promising path forward. By prioritizing plant and soil health including all of the environmental health and acknowledging the interconnectedness of all life forms and ecosystems, we can design a healthier, more resilient planet. There is an urgent need towards fostering resilient and integrated health. Embracing this holistic approach is not just a necessity—it is the foundation for global well-being to meet all the UN Sustainable Development Goals.