Research Priorities in One Health

Mala Chhabra[1]*, Ruchita Chhabra[2], Nandini Duggal[1*]

[1]Atal Bihari Vajpayee Institute of Medical Sciences and Dr. Ram Manohar Lohia Hospital, New Delhi,
[2]Institute of Liver & Biliary Sciences, New Delhi

***Corresponding author**
Dr. Mala Chhabra, M.D.
Department of Microbiology, Atal Bihari Vajpayee Institute of Medical Sciences & Dr. Ram Manohar Lohia Hospital, New Delhi
malachhabra@yahoo.co.in

Abstract

One Health is an interdisciplinary approach that recognizes the interconnections between human health, animal health, plant health and environment. It emphasizes collaboration and coordination among multiple sectors to address complex health challenges at the human- animal-environment interface. This article explores various research priorities within the One Health framework, including zoonotic disease surveillance and control, antimicrobial resistance (AMR), food safety, environmental impact on health, and One Health policy and governance. By integrating research outputs from various disciplines, leveraging technology, and fostering collaboration, researchers and policymakers can contribute to better health outcomes for humans, animals, plants and environment. The prime focus is to highlight the significance of the areas of research in advancing One Health research and addressing national and global health challenges.

Keywords: One Health Research, Research Priority, Multidisciplinary Approach, Global Health, Surveillance, Health Outcome

Introduction

The One Health approach has emerged as a powerful framework for addressing complex health challenges by recognizing the interconnectedness of human health, animal health, plant health and environment. By understanding and addressing these interconnections, better health outcomes can be achieved for all. The One Health framework aligns closely with the Sustainable Development Goals (SDGs) set forth by the United Nations, as they share a common objective of promoting health, well-being, and sustainability for all. Out of the 17 SDGs, eight (2,3,6,10, 13,14,15 & 17) are directly related to One Health, highlighting the broad relevance and impact of this approach. (Fig 1). Additionally, SDG 16 and 1 are indirectly related to One Health by focusing on providing environmental justice and overarching goal of "No Poverty". Collectively, these SDGs encompass a wide range of interconnected issues, fostering a comprehensive framework to achieve global health and sustainable development.[1,2,3]

In the face of emerging infectious diseases, antimicrobial resistance, and environmental degradation, it is imperative to identify and prioritize key research areas within the One Health paradigm which involve multiple disciplines. These research priorities aim to enhance our understanding, preparedness, and response to global health threats, while fostering collaboration between diverse disciplines. The priority research areas within One Health are (but not limited to,) (i) Zoonotic disease surveillance and control (ii) Combating antimicrobial resistance (AMR) (iii) Food safety (iv) Environmental impact on health.[4]

The aim of this article is to delve into these research priorities, providing specific examples and references to highlight the significance of these areas of focus in advancing One Health research and addressing national and global health challenges.

Zoonotic Diseases: Emerging and Re-emerging infections

Zoonotic diseases, which originate in animals and can be transmitted to humans, have the potential to cause widespread illness, economic disruptions, and even pandemics. Effective surveillance and control of zoonotic diseases are paramount to prevent and mitigate their impact on human and animal health. Thus, robust research efforts focused on zoonotic disease surveillance and control are critical within the One Health framework.

Surveillance

Surveillance systems play a crucial role in detecting, monitoring and setting up early warning signals for emerging and remerging zoonotic diseases. By actively monitoring animal populations, including wildlife, livestock, and companion animals, the potential reservoirs of zoonotic pathogens can be identified and their transmission dynamics can be tracked. Surveillance data provides valuable insights into the geographical distribution, prevalence, and risk factors associated with zoonotic diseases.

Research in this area aims to enhance surveillance

Figure 1: One Health Approach priorities to improve health outcomes -- Alignment with Sustainable Development Goals

strategies by integrating multiple data sources and developing innovative approaches using IT tools. For example, advancements in remote sensing technologies can contribute to zoonotic disease surveillance by monitoring environmental factors linked to disease transmission, such as vegetation indices, temperature, and water bodies. These data can aid in identifying high-risk areas and predicting outbreaks, enabling targeted surveillance and intervention efforts. In addition, mapping and layering, using Geographic Information System (GIS), data on distribution of human, animal, vector and environmental indices along with the epidemiology of diseases may aid in detection of "hotspots" and generating early warning signals for prevention of disease outbreaks.[5,6]

Moreover, research efforts focus on understanding the drivers of zoonotic disease emergence and transmission. Factors such as land-use changes, climate change, wildlife trade, and human behaviour can significantly impact disease dynamics. Investigating these drivers can provide valuable insights into risk factors and inform preventive measures. For instance, studies have shown that deforestation and habitat fragmentation can increase interactions between humans, wildlife, and domestic animals, thereby elevating the risk of zoonotic disease spill over.[7]

Table 1: Research Priorities for Zoonotic Diseases, Vector Borne Diseases and Plant, Animal & Human Health

Zoonotic Diseases[12]	1. Burden of disease • Measures of mortality, morbidity and health associated life years. • Measure health-adjusted life years (HALYs) for capturing associated duration, suffering and subsequent disability due to disease. The two most common HALYs are quality-adjusted life years (QALYs) and disability-adjusted life years (DALYs). • Measures of mortality and morbidity in animals • Economic (monetary) burden of zoonotic disease 2. Intervention-oriented research issues • Community-led or community-directed interventions • Community-led Total Sanitation 3. Research at the human-animal interface for spill over and disease transmission 4. Chemotherapy and immunization • Mass chemotherapy (mass-targeted, humans-animals) 5. Vector and intermediate host control 6. Vaccination a control option for zoonoses -vaccination coverage, impact and drivers • Animal-targeted immunization • Human-targeted vaccines

Zoonotic Diseases[12]	7. Targeting animal reservoirs to control zoonotic diseases 8. Health education and health literacy 9. Cost–effectiveness analysis 10. Disease-specific research priorities • Studies of disease burden in both humans and animals in both urban and rural settings in a manner that brings the human and veterinary health communities together; • Determination of the economic cost of these diseases for both the human and animal populations involved; • Studies of the efficacy of integrated interventions that address more than one disease and/or agent at the same time; • Determination of the cost-effectiveness of these interventions; • Studies on promotion of health literacy and social mobilization to ensure maximal engagement of the affected populations in the selected interventions.
Vector-Borne Diseases	1. Vector Biology and Ecology: Investigate the biology, behavior, and ecology of vectors for understanding their distribution, abundance, and capacity to transmit diseases. Identify factors influencing vector population dynamics, such as breeding sites, climate change impacts, and vector control strategies. 2. Disease Surveillance: Develop robust surveillance systems to integrate human, animal, environmental and vector surveillance data for setting up early warning signals and rapid response to vector-borne diseases.Methods to enhance the accuracy, timeliness, and spatial resolution of surveillance systems to effectively monitor disease transmission patterns and identify hot spots and high-risk areas. 3. Integrated Vector Management: Develop and evaluate the effectiveness, feasibility, and sustainability of integrated vector management strategies that combine multiple approaches to control vectors such as insecticide-treated bed nets, indoor residual spraying, larval source reduction, biological control, and community engagement. 4. Vector Control Tools and Technologies: Develop novel vector control tools and technologies that are environmentally friendly, cost-effective, and sustainable such as, evaluation of vector trapping systems, new insecticides, vector control products, and genetic control methods (sterile insect technique, gene drive technologies etc). 5. Climate Change and Vector-Borne Diseases: Investigate the impact of climate change on vector-borne diseases such as, how climate variability and environmental factors influence vector distribution, vectorial capacity, and disease transmission dynamics. 6. One Health Approaches in Vector Control: Understand the role of animal reservoirs and wildlife in disease transmission, assessing the impact of vector control interventions on non-target organisms, and evaluating the effectiveness of community-based interventions involving multiple stakeholders. 7. Vector-Borne Disease Vaccines: Research focuses on vaccine development, efficacy, safety, and the impact of vaccination on disease transmission dynamics of vector borne disease such as dengue, malaria, zika and tick-borne diseases 8. Health Education and Behavioral Interventions: Research on studying human behavior, social determinants of health, and community perceptions to design effective interventions that improve vector control practices, use of protective measures, and compliance with treatment and preventive measures.
Plant, Animal and Human Health[18]	• Surveillance, early warning and control systems capable of analysing disease emergence by developing participatory health approaches and collective control; • Biocontrol and antimicrobial resistance; • Phytobiomes, microbiomes, holobiomes and interactions between communities of microorganisms; • Genome editing (resistance, vaccines, vectors, etc); • Big data, particularly text and environmental data and metagenomics; • Modelling, including spatial modelling, studies of human and animal mobility, landscape analysis; • Health economics and public-private sector partnerships; • Analyses of the socioeconomic and cultural factors that determine the behaviour of at-risk social players; • Support of territorial players adopting an integrated health management approach (including farmers, consumers, decision makers, etc); • Contributing to drafting and analyzing health policy.

Prevention and control

This includes evaluation of diagnostic tools, development of vaccines, and assessment of interventions aimed at reducing disease transmission. Research can focus on understanding the effectiveness of vaccination campaigns, investigating the impact of vector control measures, and identifying strategies for promoting responsible pet ownership and animal hygiene practices.[8]

One noteworthy example of research in zoonotic disease surveillance and control is the surveillance of zoonotic viruses in wildlife populations. By studying wildlife species known to harbour zoonotic viruses, such as bats and primates, researchers can detect potential reservoirs and assess the risk of viral spill over to humans. This approach was exemplified during the Ebola and Nipah Virus outbreaks, where surveillance efforts in bat populations helped identify potential sources of the virus.[9,10,11]

The Global Virome Project (GVP) is also an exemplary collaborative scientific initiative to discover zoonotic viral threats. It is aimed to identify unknown viruses and fill the knowledge gap, including their host(s), ecology and drivers and learn where the greatest threats for spillover exist. It will provide new strategies for prevention and development of vaccines and countermeasures.[12]

WHO's Disease Reference Group on Zoonoses and Marginalized Infectious Diseases of Poverty (DRG6), published a report that highlights common research priorities for all zoonoses and disease specific research priorities which will help policy-making decisions for improved surveillance, interaction between the health, livestock, agriculture, natural resources and wildlife sectors in tackling zoonotic diseases, and true assessment of the burden of zoonoses (Table 1). [13]

Vaccine Development

Vaccine development is a crucial research priority for addressing zoonotic diseases and emerging pathogens, protecting both human and animal populations. This can enhance preparedness and response efforts against emerging Zoonotic infections like Ebola, Middle East Respiratory Syndrome (MERS), and emerging coronaviruses like SARS-CoV-2 and ultimately reducing the impact of outbreaks and preventing future pandemics.

Research in vaccine development aims to achieve several key objectives. First, it involves identifying target antigens that can elicit a robust immune response against specific pathogens. This involves studying the characteristics of the pathogen, such as its surface proteins or genetic components, to identify suitable vaccine candidates. Researchers also explore various vaccine platforms and delivery systems to optimize the immune response generated by the vaccine, vaccine safety and efficacy through extensive pre-clinical and clinical trials.

In the context of One Health, vaccine development research often involves collaborations across disciplines. For example, human and veterinary scientists collaborate to understand the transmission dynamics of zoonotic pathogens and identify potential reservoirs in animal populations. This collaboration helps in identifying suitable vaccine targets and evaluating the impact of vaccination on reducing transmission and preventing spill over events.

One notable example of vaccine development research within the One Health framework is the development of vaccines against the H5N1 avian influenza virus. Avian influenza represents a zoonotic threat, with the potential for human-to-human transmission and severe disease outcomes. By understanding the genetic diversity of the virus, conducting surveillance in poultry populations, and assessing vaccine candidates, significant progress has been made in developing effective vaccines to protect both human and animal populations.[14]

Moreover, the ongoing COVID-19 pandemic has highlighted the importance of vaccine development in addressing emerging pathogens.15 The rapid development and deployment of vaccines against SARS-CoV-2 have demonstrated the power of global collaboration and accelerated research efforts. Vaccine development research has not only focused on achieving high efficacy but also on ensuring equitable access, vaccine distribution, and overcoming vaccine hesitancy to control the spread of the virus.

Antimicrobial Resistance (AMR)

Antimicrobial resistance (AMR) is a global health crisis that occurs when microorganisms develop the ability to survive and grow in the presence of antimicrobial drugs, rendering these medications ineffective. AMR poses significant threat to human, animal, plant and environmental health, leading to increased mortality, prolonged illnesses, and higher healthcare costs (use of expensive drugs, greater use of diagnostics etc). The emergence and spread of resistant pathogens have profound implications for public health, food security, and the effectiveness of medical interventions worldwide.[16]

Addressing AMR requires a multi-faceted approach, and research efforts focus on several key priorities within the One Health framework. The policies in this regard are, by and large, in place. The important research

priority is the implementation and responsible use of policies. This involves promoting appropriate prescribing practices in human medicine, reducing unnecessary antimicrobial use in animal and agriculture, and implementing surveillance systems to monitor antimicrobial consumption and resistance patterns. Additionally, research aims to develop strategies to educate healthcare providers, veterinarians, and the general public about the prudent use of antimicrobials and the importance of infection prevention and control measures, biosafety, biosecurity and environmental contamination.

Another research priority is the exploration of alternative antimicrobial strategies. This includes the development of new classes of antimicrobial agents, repurposing of existing drugs, and investigation of novel therapeutic approaches such as bacteriophage therapy or immunotherapies. By diversifying antimicrobial arsenal, resistance mechanisms employed by pathogens can be overcome to ensure effective treatment options.[17]

Infection prevention and control plays a vital role in combating AMR. Research in this area focuses on identifying effective interventions to reduce the transmission of resistant pathogens. This includes improving and monitoring hygiene practices, optimizing sterilization techniques, and implementing surveillance systems to detect outbreaks and monitor healthcare-associated infections. By preventing the spread of infections, the selective pressure on microbes can be reduced, thereby limiting the emergence and dissemination of resistance.

WHO has prioritized 40 research topics for evidence generation to inform the AMR policy. The research findings will be critical in guiding policy-makers, researchers, funders, implementing partners, industry and civil society in generating new evidence to inform antimicrobial resistance policies and interventions as part of collective efforts to address antimicrobial resistance. These research priorities have been categorized under five heads- AMR prevention, diagnostics, treatment and care and cross cutting issues and drug-resistant TB.[18]

FAO-ICAR experts identified about 20 research priority projects in animals and fisheries reflecting antimicrobial usage in India, antimicrobial resistances, links between Antimicrobial use and AMR, direction of transmission of antimicrobial resistance, rate of development of antimicrobial resistance, surveillance and monitoring of counterfeit and fake usage of antibiotics, rapid diagnostic development, alternatives to antibiotics usage and other preventive methods of vaccines and probiotics.[19]

Within the One Health framework, numerous research initiatives have addressed AMR and demonstrated the effectiveness of interdisciplinary collaboration. For instance, studies have investigated the transmission dynamics of resistant bacteria between animals and humans, highlighting the interconnectedness of human and animal health. This knowledge informs strategies to control the spread of AMR and emphasizes the importance of coordinated efforts between healthcare sectors, veterinary medicine, and environmental agencies.

Food Safety

Foodborne zoonoses are diseases that can be transmitted to humans through the consumption of contaminated food of animal origin. These diseases pose significant public health risks and highlight the interconnections between human health, animal health, and the environment. Causative agents of foodborne zoonotic diseases include Salmonella sp, Campylobacter sp, Escherichia coli, Toxoplasma sp, Hepatitis E, Listeria monocytogenes and others. These diseases can be transmitted through direct contact with infected animals, consumption of undercooked or raw meat, eggs, dairy products, contaminated water, or fruits and vegetables contaminated with animal feces.

One of the major issues in food safety has been the lack of cross-sectoral collaboration across the food production chain. Major food safety events have been significantly affected by the lack of collaboration between animal health, food control, and human health sector. The One Health approach emphasizes the need for coordinated actions to prevent, detect, and control foodborne zoonoses. This includes collaboration between human health agencies, veterinary authorities, agriculture departments, food safety agencies, and environmental agencies. By working together, these sectors can implement strategies to ensure the safety of the food from "Farm to Fork" by addressing issues in food production chain, supply chain, protect animal health, and safeguard public health. This includes implementing good agricultural practices on farms to minimize the risk of contamination, ensuring proper animal health and hygiene measures, conducting regular monitoring and surveillance of food products, and promoting safe food handling practices during processing, distribution, and preparation.[19]

One Health research plays a crucial role in understanding the transmission dynamics, risk factors, and control strategies of foodborne zoonoses. Researchers investigate the sources of contamination, the impact of agricultural practices on disease prevalence, and the effectiveness of interventions such as vaccination, improved sanitation, and hygiene practices. This knowledge informs the development of

evidence-based guidelines and policies to mitigate the risk of foodborne zoonoses.

Furthermore, surveillance systems are vital for early detection and response to foodborne zoonotic outbreaks. These systems involve monitoring and analyzing data on human cases, animal diseases, and environmental factors. By integrating data from multiple sources, public health authorities can identify patterns, trace the source of contamination, and implement appropriate control measures to prevent further spread. [20]

The integration of the One Health approach into food safety regulations and policies is crucial. This involves developing and implementing regulations that encompass the entire food production chain, including primary production, processing, transportation, and retail. It also requires collaboration between agencies responsible for human health, animal health, and food safety to ensure effective coordination and enforcement of regulations.

Environmental Impact on Health

Probably the oldest written document about on environmental impact on health is 'On Airs, Waters, and Places', written by Hippocrates which describes how human health is influenced by its interaction with the environment. [21]

Research on the environmental impact on health focuses on studying the effects of various factors, such as climate change, pollution, habitat loss, and biodiversity decline, on disease transmission and overall health outcomes. These factors can directly or indirectly influence the emergence and spread of zoonotic diseases and pose risks to both human and animal populations.

One significant environmental factor of concern is climate change. Rising temperatures, changing precipitation patterns, and extreme weather events associated with climate change have direct and indirect effects on health. For instance, shifts in temperature and rainfall can influence the distribution and abundance of vectors (such as mosquitoes and ticks) and alter the geographical range of infectious diseases. Research in this area aims to understand the specific impacts of climate change on disease transmission and develop strategies to mitigate these risks.

Pollution, both air and water, is another critical environmental factor affecting health. Exposure to pollutants, such as particulate matter, toxic chemicals, and heavy metals, can lead to respiratory diseases and other non-communicable diseases such as cardiovascular problems, and other adverse health outcomes. Research efforts focus on assessing the health impacts of pollution, identifying sources of contamination, and implementing measures to reduce pollution levels and protect human, animal and plant health. [22]

Habitat loss and biodiversity decline are also areas of concern within the One Health framework. Destruction of natural habitats and loss of biodiversity can disrupt ecological balance and increase the risk of disease transmission. Deforestation can lead to increased contact between humans, vectors, wildlife, and domestic animals, facilitating the spillover of zoonotic pathogens. For example, scrub typhus, a disease which was primarily reported from foothills of Himalayas is now being reported from atleast 2/3rds of the country. This may be due to deforestation, urbanization leading to removal of scrub vegetation exposing mite islands and decrease of human-vector interface. Research in this area explores the complex relationships between biodiversity, ecosystem health, and disease dynamics to inform conservation efforts and mitigate disease risks.

Additionally, the impact of environmental degradation on water and food security is a crucial research area within the One Health approach. Contamination of water sources and foodborne illnesses can have severe health consequences. Understanding the sources of contamination, developing effective monitoring systems, and implementing appropriate interventions are vital to ensuring access to safe water and food for both human and animal populations.

One example of research on the environmental impact on health is the study of vector-borne diseases, such as malaria, dengue, Lyme disease, CCHF, KFD etc. Researchers investigate how environmental factors, such as temperature, precipitation, and land use, influence the distribution and abundance of disease-carrying vectors. By understanding these relationships, interventions can be designed to minimize vector populations and reduce disease transmission risks. (Table 1).The integration of environmental considerations in health policies and interventions is essential for fostering resilient and sustainable health systems in the face of global challenges.

The European consortium has identified six overarching research agenda covering 30 specific research priorities under the Health and Environment Research Agenda (HERA) project for the environment, climate & health, 2021–2030. [23]

French Agricultural Research Centre for International Development (CIRAD) works with its partners to build knowledge and solutions and invent resilient farming systems for a more sustainable, inclusive world. In the field of plant, animal and ecosystem health, CIRAD's

research fits into a systemic, integrated approach that addresses the links between agriculture and health. It acts as a leading contact for ministries in charge of health management, international organizations and the French Ministry of Agriculture, on various topics such as epidemiological surveillance and global health monitoring. It is involved in the integrated One Health approach covering a range of disciplines (from biology to the social sciences), sectors (environment, agriculture, public health, etc), and players (political, institutional, research, private, and beneficiaries such as producers and livestock farmers). The One Health research includes several fields that are vital for implementing integrated approaches: entomology, microbiome studies, knowledge of disease-resistant local varieties and races, ecology on every level, epidemiology and modelling, risk analysis and improvement of surveillance systems.[23] (Table 1)

Xenotransplantation and One Health

Xenotransplantation refers to the transplantation of organs, tissues, or cells from one species to another, usually from animals to humans. This emerging field of medical science holds promise for addressing the critical shortage of human organs available for transplantation.

However, xenotransplantation also raises important considerations related to human health, animal welfare, potential zoonotic disease transmission, use of Genetically Engineered Animals, ethical considerations, and ecological implications of using animals as organ donors for humans.[24]

By adopting One Health approach, researchers, clinicians, policymakers, and stakeholders in xenotransplantation can ensure that human health advances are pursued while minimizing risks to animal welfare, environmental sustainability, and zoonotic disease transmission.

Collaborative research, multidisciplinary engagement, and ethical considerations are critical for advancing the field of xenotransplantation.

One Health policy and Governance

One Health policy and governance research is crucial to effectively implement the One Health approach. Evaluating the impact of current policies, identifying gaps and barriers to collaboration within various disciplines, strengthening collaborative national and international networks, developing effective intersectoral and multidisciplinary/transdisciplinary training programmes for capacity building and developing strategies for integrating One Health into national and international health systems are vital for successfully addressing global health challenges within this framework.

The latest definition of One Health by the CDC has expanded the approach from multidisciplinary to transdisciplinary. In a multidisciplinary approach, different disciplines contribute their knowledge and expertise to address a common problem, but they typically remain within their disciplinary boundaries. On the other hand, a transdisciplinary approach involves researchers from various disciplines working together to create new ideas, theories, methodologies, and practical applications that go beyond the limitations of individual disciplines[4,25]

By prioritizing research in these areas, the One Health approach can generate evidence-based strategies and interventions to mitigate the risks of emerging diseases, improve public health outcomes, and promote sustainable and resilient health systems.

Financial support & sponsorship

None.

Conflicts of Interest

None.

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