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# Advancing One Human-Environmental-Animal Health for Global Health Security: What does the evidence say?


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The ongoing COVID-19 pandemic vividly illustrates that the emergence of a new lethal pathogen of probable animal origin in one part of the world affects public health everywhere. In this article, we review the contributions of human-animal-environmental (ONE-HEALTH [OH]) approaches to improving global health security (GHS) across a range of health hazards and summarise contemporary evidence of incremental benefits of an OH approach. We assess how OH approaches were reported to FAO, OIE and WHO, within the respective monitoring and evaluation frameworks of the International Health Regulations (IHR, 2005) and the Performance of Veterinary Services (PVS). We reviewed OH theoretical foundations and methods, case studies and a narrative literature review including IHR (2005) andPVS reports to assess progress of inter-sectoral OH approaches to build human capacity, bridges between stakeholders and institutional adaptation at national and international levels to contribute to global health security (GHS) across a range of health hazards. Examples from joint health services and infrastructure, surveillance-response, antimicrobial resistance (AMR) surveillance, food safety and food security, environmental hazards, water and sanitation, and zoonoses control clearly show incremental benefits of OH approaches. OH approaches appear to be most effective and sustainable in the prevention, preparedness and early detection of evolving risks/hazards and the evidence base for their application is strongest in the control of endemic and neglected tropical diseases. Significant gaps remain at the OH interface to rapidly detect and reduce the risk of widespread community transmission of new and re-emerging infections. For benefits to be maximised and extended, improved One Health Operationalisation (OHO) is needed with strengthening of multisectoral coordination mechanisms, for example by fostering a closer interaction between the IHR (2005) and OIE PVS Pathways and the United Nations Environmental Programme (UNEP). OH approaches show quantitative incremental benefits for health services and infrastructure, surveillance-response systems, AMR, food safety and nutrition security, environmental sanitation and zoonoses control for GHS, but gaps in the realisation of OH to covers all species of interest remain. Case studies show evidence for OHO at the institutional and community level. The FAO, OIE and WHO currently play pivotal roles in stimulating OHO at the national and regional levels but will need increased support and allies to both strengthen current activities as well as address a wider set of health hazards across the Socio Ecological System. Progress in sustained OHO should be urgently prioritised at global, regional and national levels by building on, and inclusively broadening existing institutional collaborations at the wildlife-domestic animal-environmental-human interface to better reflect evolving risks and hazards across the Socio-Ecological System in view of a global pandemic treaty.

**Keywords:** One Health, Global Health Security, International Health Regulations, Performance of Veterinary Services Pathway

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**Key messages:**

1. **One Health means that cooperation between human, animal, environmental health and related disciplines leads to benefits that could not be achieved if the different sectors work alone. There is clear evidence for benefits in terms of saved lives of humans and animals and financial savings from a closer cooperation between the sectors across a range of hazards and operational functions. Our analysis indicates greater investment should be directed towards prevention and preparedness interventions across the Socio Ecological System (SES) where the evidence base is most firmly established. This represents a shift of the disease control paradigm upstream, away from an overwhelming focus on surveillance and response in humans which currently predominates, to greater and more pro-active investment in preventive interventions, surveillance in environmental and animal systems and integrated response across all sectors.**
2. **One Health has a high potential to sustainably improve GHS for all by first prioritising national and local capacity building across One Health sectors and disciplines. This horizontal approach should first focus on endemic One Health issues across the ecosystem including those with implications for food security, local community health needs and hazards where the evidence base is most strongly established before considering emergent risks of more global concern.**
3. **There is still a daunting gap to fully operationalize One Health for optimal GHS. As the evidence for its effectiveness broadens, current and future OH approaches should more fully integrate environmental, wildlife and wildlife farming issues across the (SES) to better address contemporary challenges like pandemic threats.**
4. **Many national governments have started operationalizing One Health in their governance and programmes, which are increasingly reflected in reporting to the International Health Regulations (IHR 2005). The IHR, although not explicity mentioning OH, have been an effective catalyst to embed cross sectoral, whole system approaches to public health emergency prevention, preparedness and response but an evidence-led acceleration of implementation and expansion across a wider spectrum of SES hazards is now needed.**
5. **The international organizations World Health Organization (WHO), World Organization for Animal Health (OIE) and the Food and Agricultural Organization of the United Nations (FAO) spearhead One Health technical cooperation at the global level. The addition of United Nations Environmental Program (UNEP) to that collaboration represents an opportunity to more holistically provide technical support to national governments in building their One Health related health security capacities. In 2021 a global One Health High Level Expert Panel (OHLEP) came into operation.**
6. **Further primary research and systematic reviews are needed to evaluate the effectiveness of One Health approaches for specific hazards categories across the SES. These should include analyses on cost effectiveness, comparisons of uni-sectoral versus multisectoral approaches and include relevant outcome measures relating to animal and environmental health, in addition to the primary concerns around human health security.**

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## INTRODUCTION

Human development, expansion of domestic animal populations and transformed landscapes engineered for human populations are having profound effects on the evolution and epidemiology of infectious and non-communicable diseases of all species. Intimate and rapid global interconnections mean that uncontrolled infectious diseases in one part of the world threaten plant, animal (wildlife and domestic) and public health everywhere. Whilst technological advances are making public health services better equipped for detecting, preventing and controlling new infectious diseases and other health hazards, as the current COVID-19 pandemic highlights, major gaps exist in conversion of these advances into effective actions and policies at the animal-human-environment interface[1]. National institutions addressing these challenges worldwide are most often not able to adequately address the myriad array of interconnected risks. There have been numerous human-animal-environmental health approaches to improving global health security (GHS) across a range of health hazards. The ongoing COVID-19 pandemic vividly illustrates, that the emergence of a lethal pathogen of probable animal origin in one part of the world affects public health and almost every sector everywhere.

The extraordinary World Health Assembly in 2001 decided that WHO will work with its member states to towards preparedness and response to pandemics. The Food and Agriculture Organization (FAO), World Health Organization (WHO) and the World Organisation for Animal Health (OIE), support countries to implement international standards and frameworks, such as the International Health Regulations (IHR, 2005), the Terrestrial and Aquatic Codes and Manuals[2] and the Codex Alimentarius (food safety law)[3]. The revised IHR came into force in June 2007 and required all countries to develop core capacities for preventing, detecting and responding to public health emergencies including for infectious agents that can impact the public health of people across countries and adversely affect travel and trade. The IHR promoted building robust public health and animal health systems based on good governance and implementation of internationally accepted standards.

In 2010, a Tripartite concept note between WHO, OIE and FAO recognised a shared responsibility in addressing health risks at the human-animal (wildlife and domestic)-environment interface, with avian influenza, rabies and antimicrobial resistance (AMR) as priorities. The shared views of these international organizations contributed strongly to mainstreaming integrative approaches like One Health (OH) (**Box 1**) that contribute towards GHS, taking advantage of the legal mandate of the IHR (2005) as a driving force[4,5]. To support countries in developing regulations, assessing their capacities to prevent, detect and rapidly respond to public health risks, WHO developed the IHR Monitoring and Evaluation Framework (IHR MEF)[6], which includes inter alia the i) State parties reporting tool for the mandatory annual reporting of level of compliance to the IHR, and ii) the Joint External Evaluation (JEE) for voluntary reviews with peers. The OIE developed the Performance of Veterinary Services (PVS) monitoring and evaluation framework. However, the IHR and PVS mechanisms were not

sufficiently operational to respond in an internationally coordinated way and adequately to theCOVID-19 pandemic. The ongoing COVID-19 pandemic is thus an extraordinary reality check for GHS and calls for a review of the effectiveness of these instruments and other tools for assessing national capacities as well as challenging the assumptions around the operational value of integrated approaches like One Health. [7].

In this article, we review the contributions of human-animal-environmental (ONE-HEALTH [OH]) approaches to improving GHS across a range of health hazards. We summarise contemporary evidence assessing the incremental benefits of an OH approach and how this evidence is reflected in reporting to FAO, OIE and WHO. We identify gaps which remain at the OH interface to rapidly detect and respond to the risk of widespread community transmission of new and re-emerging infections and other health hazards. Through examples from the field we build the case for One Health Operationalisation (OHO) and strengthened multi-sectoral coordination mechanisms. As the IHR adopts an all-hazards approach to GHS, our paper reviews the literature to determine which of the WHO's priority threats to global health[8] would benefit from an OH approach using the classification of hazards outlined in the WHO Health Emergency and Disaster Risk Management Framework[9]. We performed an analysis of the contributions of OH approaches to GHS using a variety of methods detailed in online supplement 1 (S1).

**Historical aspects of OH (723 words)**

OH appeared for the first time in the medical literature in 2005 to emphasize its potential to strengthen health systems[10] by demonstrating value added from a closer cooperation between human and animal health that could not be achieved by the disciplinary approaches alone[11]. This point however revealed the fragmentation of the health communities and differing agendas and much of the ensuing years have been fraught with debate and discussion about what exactly OH is about. **Box 1** summarises current OH theoretical foundations and applied methods for demonstrating the incremental benefits of the approach are outlined in **Boxes 2 and 3.** [12] The first paper to use the term OH in 2005 stated, with regard to avian influenza, that: "research for vaccines should urgently be complemented by modifications to smallholder livestock systems and live-animal markets to prevent or reduce interactions between [wildlife, wildlife farming] and [livestock], which might be reservoirs for future human pandemics"[10]. "However, these implementations should be handled carefully to avoid impending poverty…". This warning, published 15 years ago in *The Lancet*, sounds like a forecast in the face of the current COVID-19 pandemic, but remained largely unheard with a limited global response to preparedness. This may still be a narrow view on how these emergent pathogens are established. Certainly it is not just the transmission and interface which matters but also the socioecological and economic context in which these occurrences happen, enabling expansion and establishment of pathogens across species, much of which happens in the domestic and peri-domestic landscape[13,14].

## Conceptual relationship of OH, EcoHealth and PH

As such there remains an acute need for a proper framing of integrative concepts like OH, EcoHealth or Planetary Health (PH) to promote a better integration across sectors[15] including, importantly, wildlife health which often necessitates being distinguished from animal health where the focus is almost entirely on domestic animals, both legally, economically and practically[12]. OH's conceptual relationship to related ecosystem approaches to health (EcoHealth) and PH are explained in **Figure 1.** In Figure 1, OH is in the first place at the intersection of human (red ellipse) and animal (currently primarily domestic) health (green ellipse), aiming to demonstrate a benefit from a closer cooperation of human and veterinary medicine. Clearly, there are large sections of separated human and animal health not requiring an OH approach. Broader approaches, considering interactions of health and the environment, within social-ecological systems (SES)[17], black ellipse, incorporate OH. OH is thus embedded within ecosystem approaches to health, for which a newer term "Health in Social-Ecological Systems" (HSES) has been coined[18]. OH, by the definition of this paper, includes social and environmental (ecological) factors, which are depicted by the yellow gradient circle, reaching beyond the limits of public and (domestic) animal health.

Planetary Health (PH) sets the ambitious task of understanding the dynamic and systemic relationships between global environmental changes and health including climate change, transboundary fire emissions, persistent organic pollutants and other changes[22] (blue ellipse). PH conceptual thinking aims to identify co-benefits across targets, but remains centred on human health and does not explicitly include animal health[20,22].

Thus OH should be still in the centre of interest, building inter-sectoral cooperation from the inside and gradually expanding it to more complex issues and health security hazards across the whole of the SES, as the evidence base for its effectiveness matures [16,23].

## Evidence for the benefit of OH

While there is consensus that the OH approach is crucial for tackling challenging global health security threats, it is not yet clear that evidence of its effectiveness has been reliably demonstrated. OH characterises the logical view that by coordinating the people and systems working to improve the health of humans, animals and the environment, any associated health threats can be identified as early as possible. This results in reduction or even prevention of harm to health and fewer resources required to deal with the long-term repercussions. There is evidence of benefits of OH across a range of health hazards[9] for health services, newly emerging and endemic zoonoses control in the domestic animal environment, food safety and food/nutrition security, integrated disease and antimicrobial resistance (AMR) surveillance-response systems, water security and sanitation, infrastructure sharing

and communication[21]. For example, joint human and animal routine vaccination services for mobile pastoralists in Chad provide access to health care for populations which would otherwise be excluded and save financial resources by sharing cold chain and transport[24]. Mass vaccination of livestock against brucellosis in Mongolia is not cost effective for public health alone, but when benefits for livestock production and nutrition security are also included it is financially three times more profitable[25] (Formula 3, Box 2). Combining dog vaccination with human post-exposure prophylaxis in an African city is less costly than human post-exposure prophylaxis alone after ten years [26,27] and may lead to the elimination of rabies (Formula 4, Box 2).

The Institute of Medicine (IOM) in 2009[28], and later the World Bank, conceptualized integrated surveillance response in a visionary way, as a time sequence of detection in the environment, wildlife, domestic animals and humans (**Figure 2a**)[29]. The model shows ever increasing costs the later a new emerging pathogen is detected[21,30]. The current COVID-19 pandemic could not be a better example of the urgent need for the kinds of integrated environment-entomological-wildlife-domestic animal-human surveillance and response systems that the World Bank proposes, and the catastrophic socio-economic consequences of failure to implement such systems. There are several examples of the potential benefit of more targeted surveillance of vector borne zoonoses. The integrated surveillance and response of West Nile Virus in mosquitos, wild birds, horses and humans in Emilia Romagna region (Italy), saved more than one million Euros between 2009-2015 compared to separate human and animal surveillance[31]. Wielinga et al. similarly argue that inter-sectoral surveillance has had a significant impact on reducing human salmonellosis through lowering *Salmonella* prevalence in animals[32] citing research which described how disease control was achieved in Denmark through integration of control measures in farms and food processing plants, saving 25.5 million USD [33].

The Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS) saves financial and infrastructural resources and reduces time to detection of newly emerging AMR[18,34]. The CIPARS was able to demonstrate the impact of regulating antimicrobial use on the number of resistant salmonella isolates identified in humans and chickens[35]. A decrease in the number of *Salmonella heidelberg* isolates coincided with the introduction of a voluntary ban on the use of ceftiofur in Quebec, with a subsequent increase when the antibiotic was partially returned to use. Without such integrated surveillance systems, it would not have been possible to determine the impact and cost effectiveness of interventions designed to reduce AMR in human and livestock populations.

The World Bank estimates a saving of 26% of the operations cost of the Canadian Science Centre in Winnipeg, which hosts laboratories for human and animal highly contagious diseases under one roof, when compared to running two separate laboratories for human and animal diseases[36]. The outbreak of Q-fever in the Netherlands (2007-2009) with several thousand human cases could probably have been largely avoided if the veterinary and public health authorities had maintained continuous communication[37] (**Figure 2a**), or if joint human and animal studies had been done, as they were in the

case of brucellosis in Kyrgyzstan[38] (**Box 2**). These examples demonstrate that where capacity exists in both animal (domestic) and human health to address these issues, progress is made. The under-resourced wildlife environment interface remains a major challenge to applied One Health approaches.

As food safety and nutrition security cuts across human, animal and environmental concerns, OH is similarly considered key to multi-sector coordinated progress[39]. The limited research in this area reinforces the importance of coordinated responses but only seldom supports the benefit of OH with consistent evidence of effectiveness, whether in terms of directly attributable improvement to health outcomes or financial savings. Meanwhile the burden of food borne disease (FBD) is well established: according to the WHO Foodborne Disease Burden Epidemiology Reference Group (FERG), 31 foodborne hazards were estimated to have caused more than 600 million illness cases and 420,000 deaths globally in 2010.[40,41]. The World Bank describes an example of 'applying One Health' to FBD in the European Union's coordination of control programs for salmonellosis. The evidence provided is a reduction in reports of human salmonellosis cases from over 200,000 before 2004 in 14 member states to under 90,000 cases in 2014. Integration is described as the involvement of member states and four major institutions (the European Commission, the European Parliament, the European Food Safety Authority, and the European Centre for Disease Prevention and Control), while methods highlighted as key to success range from target reductions to salmonella in livestock to the imposition of trade restrictions[42].

The direct impact of funding provided to integrated systems was assessed by the World Bank using data from FERG. This compared the 'adequacy' of operational funding for veterinary services, based on OIE Performance of Veterinary Services Pathway (PVS) reports, and found that the burden of foodborne disease caused by Animal Source Foods (ASF) was lower in sub-Saharan African countries with adequate funding, with 208 disability adjusted life years (DALYs) per 100,000 population vs. 569 DALYs per 100,000 population in countries with inadequate funding[42].

In the same report, the World Bank identified only seven countries from low or lower-middle income countries with adequate operational funding for their veterinary services (based on PVS reports). The burden of FBD in these countries was 192 DALYs per 100,000 people, compared to 407 per 100,000 in the 48 other low and lower-middle income countries observed[42]. These findings were translated into productivity losses of approximately 95 billion USD (based on their assessment of 2016 income data) due to illness, disability, and premature deaths related to unsafe food[42]. Despite these published examples emphasising improvements to food safety/security as a result of an applied OH approach, the evidence, or lack of evidence, does not allow improvements to be directly attributed to any particular measure. This is unsurprising given the multi-sector, systems-based nature of OH which cannot be studied in isolation and therefore cannot easily adjust for the impact of confounding factors.

Emerging evidence from sewage analysis in the UK and elsewhere suggests that a One Health approach to COVID-19 transmission risk at the human/environmental interface could inform both case detection efforts as well as measures to prevent potential transmission via wastewater[43]. Given suggestions that the COVID-19 pandemic will result in annual UK borrowing this year at five times the amount borrowed in the previous financial year[44], One Health measures which work to identify and control potential sources of infection would prove to be cost-effective.

These examples across the spectrum of disease control from prevention to preparedness, detection and response clearly show the benefits of OH approaches across a range of health hazards. In order for such benefits to be maximised and extended, we need a better and more sustained OHO. The United Nations Environment Program (UNEP) recently joined the Tripartite to address the wildlife environment interface, which is a strong signal for a stronger integration of the environmental dimension of health. This opportunity to integrate the environmental sector more fully opens up an exciting new array of potential partnerships and interventions to improve GHS. For example, the piloting and scaling up of biological control programmes for emerging and endemic infectious diseases has the potential to add new tools to the GHS armoury[45,46]. Already in use widely to support vector borne disease control in malaria programmes, the use of biological controls can be further expanded to help control endemic neglected diseases such as schistosomiasis, through the introduction of cercariae devouring river prawn species[47], to the use of larvivorous fish species and predatory copepods to reduce and prevent dengue transmission as demonstrated successfully in Vietnam[48]. Here in particular, OH approaches across the SES are necessary to test these types of interventions and help describe the complex interplay between host-pathogen -vector-natural predator and their impact on other species within the ecosystem. Environmental science can also help support the control of invasive plant species such as mesquite (*Prosopis juliflora*), which are implicated in maintaining mosquito populations in the dry season[49] and driving malaria, rift valley fever and dengue transmission, while also taking over vast areas of grazing and farmland, outcompeting native vegetation preferred by livestock resulting in large numbers of poisoned cattle and goats, and ultimately depleting water sources[50]. Ironically, the plant was introduced for supporting livestock agriculture by international development agencies,with the particular focus on forage for small ruminants. This produced sectoral benefits but without consideration of the wider ecological impacts – underscoring the need for wider environmental expertise when testing interventions. With COVID-19 highlighting the intimate links between populations density, urban health and pandemic spread, air quality management for the control of respiratory illness and co-morbid conditions has become a priority for policy makers[51]. Here too, environmental science along with urban planners can play an important role in advancing a OH approach with the introduction of plant and tree species that specifically reduce air pollution[52]. This way, strategies and plans can be aligned, for example, towards a global solidarity for the control of zoonoses and other diseases across the human-animal-environment interface (**Figure 2b**), analogous to the Global Fund to Fight AIDS, Tuberculosis and

Malaria[5]. There is no reason why the Global Fund should only concentrate on three most killing diseases. A global consensus to add other diseases of global public interest like selected zoonoses has been proposed already in 2007[53]. The current Covid-19 pandemic has shown that global solidarity for disease control is feasible and requires pragmatic institutional arrangements at international and national levels to handle future pandemic risks effectively.

**Relevance of OH for IHR (2005) and OIE PVS**

Our analyses, based on methods detailed in S1, of WHO IHR MEF and OIE PVS reports show: 1) further appropriation of the use of the term OH in the global evaluation tools and reporting in relation to IHR and PVS, which can be linked to 2) an increased awareness of the relevance of OH for global health security and the use of this terminology or its essence in the language of national leaders and politicians, 3) that despite the progress made in integrating OH for GHS, the IHR MEF would benefit from a separate category in which the operationalisation of OH is systematically evaluated, 4) a certain vagueness of the commonly used definition that allows for mobilising global and local stakeholders from different sectors, but may render the evaluation of its operationalisation more challenging. This is particularly relevant in the definitions of Animal Health which currently in practice excludes non-domestic animals to a large degree.

In the implementation of the IHR MEF, WHO puts forward their collaboration with FAO and OIE in order to support bridging the human-animal interface for the implementation of the IHR for global health security. Tools such as the IHR-PVS National Bridging Workshop have been developed in order to support this joint review[54].

Many of the WHO members state identified gaps with regard to their OHO, also with reference to the recommendations by the team of experts in the JEE reports. The narratives of some of the countries point to their limitations in their current *ad hoc* collaborations based on emergencies or their focus on multi-sectoral approaches with regard to a particular disease. These are aspects that WHO describes as "vertical" approaches, and the aim would be to achieve more "horizontal" and sustainable solutions[55] for disease surveillance and global health security. In order to make progress within the policy cycle, partnership between public institutions and a myriad of private sector actors is required, to establish robust health systems which meet the needs of society. For example, the integration of emerging infections and health impact assessment into the environmental impact assessment process for large scale industrial and land transformation projects could be one area where public-private sector collaboration could be key in mitigating the risk of emerging infectious diseases while also helping companies manage their business continuity risk. Struggles to provide (human) resources for establishing sustainable mechanisms for multi-sectoral collaboration were mentioned at several stages in the available reports, while external long-term funding enabled particularly successful foundation

for some of the national OH mechanisms mentioned in the reports (see, for example, the case study on Côte d'Ivoire in S2).

While OH in forms of multi-sectoral collaboration or external coordination found its way into the discourse of the policy documents evaluating countries' IHR implementation, our analysis also reveals some vagueness in the definition of the term OH. As mentioned earlier, such a "productive vagueness" is not necessarily considered as a disadvantage as it may facilitate communication among different social contexts[56,57]. At the same time, however, it may prevent active engagement if global as well as local actors interpret their existing activities as already within the scope of OH. One Health, in this capacity may also be described as a "soft global health governance"[58], dependent on peer influence of global and local actors rather than the pressure of law[59]. Governance issues are discussed in greater detail in paper four of this series.

Multisectoralism is highly promoted and clearly advocated in the JEE tool and the voluntary request by countries may already reveal a certain commitment to OH, transparency, multisectoral engagement and responsibility to take a systems approach to building the core capacities required under IHR (2005). The available data from the JEE reports therefore also have to be read in this light, and it is noticeable that a high proportion of completed JEE missions have been conducted in African countries (total number 44), revealing particular priorities and aspects linked to donor funding of such missions. In addition, it is important to take into account the different methodologies and the variable quality control that is inherent to the different reporting tools.

The JEE could be advantageously complemented with a tool rating the level of a country's OHO, such as network for evaluation of OH (NEOH), keeping in mind that other tools such as the IHR-PVS National Bridging Workshops (NBW) can complement by helping countries developing concrete roadmaps to improve performance at the human-animal interface[4]. An additional category in the SPAR reporting could be advantageous as this compulsory evaluation is performed annually by all member states and could therefore provide a global overview of countries' self-assessments of their OH-systems and capacity on a regular basis.
The newest development of the current COVID-19 pandemic shows that a global technical (WHO-FAO-OIE-UNEP) and political coordination (United Nations) of pandemics is crucial, especially when taking into account the current global context with multiple actors and interests involved on different scales (**Box 4**).

Certainly, the JEE and the other elements of the IHR MEF, along with other existing tools such as the Global Health Security Index, require improvements to adequately assess country preparedness and response capacity to all public health hazards – by adoption of a broader vision of OH more in keeping with a holistic HSES framework. As such, the IHR MEF will likely need to be revisited if OH is to be firmly embedded in the future and the gaps in the all-hazard approach can be closed as far as possible.

## DISCUSSION

### Evidence of OH for Global Health Security

Considering the above examples of the benefit of OH and the analysis of the relevance of OH for IHR (2005) we can summarize the evidence that OH approaches work for tackling GHS risks and hazards as follows (Table 1): For emerging infections and novel pathogens there are OH institutional (governance) arrangements and engagements, but only episodic effective integrated wildlife-domestic animal- human surveillance and response programs[31,60]. There is an appalling weakness and much need for improvement of OHO, as shown in the current COVID-19 pandemic. Most of the current research reactively focuses on vaccines and drugs with very little on how to prevent future pandemics. A One Health approach proposing integrated wildlife-domestic animal-humand disease surveillance-response systems combined with a better biosecurity and animal welfare at the animal-human interfaces has a realistic potential to contribute to future pandemic prevention[29]. For AMR there are important institutional efforts and engagement and more and more nations implement integrated AMR surveillance programs analogous to the Canadian CIPARS. One Health oriented AMR control programmes have certainly benefitted from greatly increased levels of funding despite the evidence base for these approaches being relatively weak[61]. For endemic infections and Neglected Tropical Diseases (NTD), there is a strong evidence base for OHO, including control programs and proof of economic benefits. Institutions and engagement are well established, but still require a stronger political will for example for rabies[62] or brucellosis elimination[63]. OHO for food safety and nutrition security, institutions and engagement are well established. Surprisingly there is little formal analysis of incremental economic benefits of OHO for food safety and nutrition security, requiring more research. There is a clear shortfall of evidence of OHO for extreme weather, water security and environmental degradation despite the wide array of expertise, experience and insight the environmental sciences have to offer. The recent joining of United Nations Environment Program (UNEP) of the Tripartite FAO/WHO/OIE, becoming a quadripartite engagement is a most welcome extension towards environmental and ecological sectors and actors. The same applies also for the prevention of emerging infections and novel pathogens (see below). Across all the hazard groups, the evidence base was most strongly established for prevention and preparedness interventions using a One Health approach versus those relating specifically to response. **Table 1**, summarises the strength of the current evidence base of applied One Health approaches across a range of health security hazards based on the reviewed literature and JEE/PVS reports analysed in this paper.

### Outlook on future OHO

The conclusions of the current state of OHO are mixed. Although excellent in themselves, institutions, laws and capacities even if intending to do otherwise, globally fail to integrate environmental risk factors of all types and or consider the role of the natural systems (wildlife) in both preventing and promoting microbial evolution and pathogen emergence. For further institutional and legal aspects of OH, we refer to paper 4 of this Lancet series (add Reference to paper 4). There are significant efforts to operationalize OH by many countries, as the case studies suggest (S2) however, there is still a long way to go towards mainstreaming of OHO[64] with sustainable (programmed) budgetary implications to make it effective in the immediate and long term. This is of concern in the face of the current COVID-19 pandemic, which outweighs by a factor of several tens of thousands the cost of the preventive effect of effective OHO. To demonstrate this conceptually, we use the World Bank [30] framework of **Figure 2a** as a starting point. We modified it to include environmental risk [21] as a vision for OH in Global Health Security (**Figure 2a-c**) and its longer term effects (DALYs) to society and households. In essence, the figure shows how the cumulative societal cost increases from earliest detection of emerging pathogens of zoonotic origin from both wildlife and domestic animals until it reaches human populations. The earlier a novel pathogen, food security risk or other SES-relevant hazard (e.g. impending drought/natural hazard) can be detected (reduced time to detection) and the faster information is communicated between animal and human health sectors, the earlier an effective response, preventing exposure and reducing risk of transmission, can be organized and the lesser are the cumulative societal costs of the outbreak or emergency (**Figure 2b-c**). **Figure 2c** would be the final desirable expected stage of global health security through an OH approach. Despite existing environmental threats and some animal exposure, fewer human cases would be observed and cost could be kept at a minimum[65]. This is in keeping with our analysis of hazards across the GHS spectrum (Table 1) which indicate that the evidence base favours shifting the paradigm of disease control upstream from the current focus on detection and response in humans, to prevention and preparedness across the SES. This is the avenue where global OHO can lead in the prevention of future pandemics and other health emergencies[29].

This "early detection-early response (EDER)" framework can be used as a backbone for the OHO within the IHR (2005) and can be evaluated by the four instruments of a revised IHR MEF.

Within GHS, not all global health threats [8,66] can be analysed by this EDER framework alone when grouped into hazard categories. Some of these hazards and risks are more amenable or relevant to being addressed through an OH approach than others and any linked investment should be based on evidence of effectiveness. Advancing OHO would also require the use of different methodological approaches in specific Animal-Human Interfaces (AHI)[11],[67]. AHI can use linear[38] or non-linear models[26,68] and different types of cross-sector economic analyses[25,69]. Case examples like the above mentioned West Nile Virus Surveillance in Italy, can be generalized, paving the way to OH economics of integrated disease surveillance-response systems[31,60]. Novel evaluation frameworks[23,70], like the Network for Evaluation of One Health (NEOH)[71],will need to be included and tested for

complementary usefulness to the IHR MEF. The effective implementation of multisectoral OH approach as part of the core indicators of the IHRMEF, the four C's Communication, Coordination, Collaboration and Capactiy building proposed by the One Health High Level Expert Panel (OHHLEP)[72], functional regional platforms, multi-hazard national public health preparedness, epidemiology training programs and disease specific targets could be assessed as a proxy for the current status of national OHO coordination[73],[65] Where proxy indicators are lacking for more holistic OH-based assessments of the health of the whole SES, these should be developed, and agreed to ensure that the IHR and other GHS initiatives are truly all-hazards in their approach. These considerations around improved monitoring and indicators are further explored in paper three of this Lancet series.

## Towards policies and implementation of OHO

OHO at the national level requires regulations for the prevention, preparedness and response to epidemics and other health emergencies and hazards that are written into environmental standards and public health, animal (domestic and wild) health law[74]. This includes the preparation for an early response to crises through mechanisms that engage all relevant government institutions (whole-of-government emergency management), as well as private sector and civil society organizations. OH and its operationalisation should be specifically defined and expanded based on available scientific evidence. A clear purpose of OHO should be expressed with regard to its relationship towards ministries and government. The legal basis of OHO tasks should be specified with regard to community participation, technical support, multi-sectoral coordination, communication, and scientific exchange. The composition of organisational structures for OHO surely includes representatives of community organisations, public (IHR National Focal Points) and animal (domestic and wild) health, environment (e.g. UNEP National Focal Points), industry, city and town planning (e.g. UN HABITAT, UNIDO National Focal Points), agriculture, nutrition and defence at national and provincial level. The involvement of non-governmental organisation, educators and academia (which are often drivers of OH approaches) and the private sector should be specified. The organisation and leadership, for example, in rotation between sectors, should be clarified. Schedules of meetings and standing committees and taskforces are needed. Procedures for coordination, joint prioritization and agenda setting, decision making, implementation and evaluation / feedback are required. Communication and information channels should be clarified between sectors.

Most importantly the funding of OHO has to be negotiated between the different government sectors, along with the potential of cost sharing[25]. Both donor and national OHO funding should be focused sustainably on those hazards where clear benefits of OH approaches have been demonstrated, and which are initially framed around local and endemic hazards where the evidence base on effectiveness is most firmly established and where the various sectoral interests are equitably met. It should also provide necessary flexibility to address a wider schope where it can be of practical value.

This horizontal approach to OHO at the national and sub-national level is essential for implementation of GHS on the ground. This should be reflected by increasingly harmonised and further developed reporting mechanisms on OHO implementation within the IHR (2005) and PVS Pathways (**Figure 2c**) and more comprehensive surveillance and monitoring using indicators of relevance across the spectrum of hazards in the SES, combining for example surveillance data on West Nile Virus in mosquitoes, wild birds, horses and humans[31] . The COVID-19 outbreak clearly shows that besides a global technical leadership, political coordination mechanisms are needed to achieve GHS at national and international levels.

## CONCLUSIONS

OH approaches show quantitative incremental benefits for health services and infrastructure, surveillance-response systems, AMR, food safety and nutrition security, environmental sanitation and zoonoses control for GHS, but gaps in the realisation of OH to covers all species of interest remain. The evidence base is generally strongest for those OH interventions focused on prevention and preparedness across the spectrum of GHS hazards. In order for such benefits to be maximised and extended for GHS, a wider, global operationalisation of OH is needed, which must be budgeted in multiannual national plans and include a larger allocation of resource towards prevention and preparedness in complement to response. The existing tools of IHR and PVS reporting are working in principle, but they remain insufficient, as the current COVID-19 pandemic shows, and should be further developed to be more effective in future GHS incidents. Specific OH categories in the IHR MEF should contribute to increased fostering of OHO. Certain vagueness of commonly used definitions across the spectrum of hazards and risks, such as zoonoses, require further efforts to better frame integrative health concepts and promote understanding across sectors. The Tripartite international organizations FAO, OIE and WHO play a pivotal role for the expansion, implementation and guidance of OHO at the international and regional level and can encourage and support implementation at national and local levels, although this is ultimately the responsibility of national governments. Further research is needed to demonstrate financial savings associated with OHO similar to the examples mentioned in this paper (S2) and systematic evidence reviews are required of the effectiveness of OH approaches within specific GHS hazard groups. The recent inclusion of UNEP to the Tripartite and the establishment of a One Health high level expert panel[75] is most welcome and would further benefit from the contributions of other institutions such as UN HABITAT, UNIDO to broaden the understanding of ecosystem health and ecosystem services, industrial, rural and urban development and their impact on human and animal agriculture, wellbeing, and welfare. OH has a high potential to sustainably improve GHS for all by first prioritising national capacity building and focusing on local community health needs and hazards before considering those risks of more global concern.

## AUTHOR ROLES AND CONTRIBUTIONS:

OD, DH, RK and AZ ideated the Lancet Theme Series on ONE-HEALTH and GLOBAL HEALTH SECURITY and developed the outline articles and selected lead authors. JZ developed the first and subsequent drafts and led the writing of this article. AKG, BB, ED, FC, HB, JH, JL, KHT, LC, OD, RS, SdR, SS, VRV contributed to the content and planning. AKG, FC, JZ, KHT, SdR, VRV contributed to the data collection and analysis; AKG, DM, ED, JZ, KHT, OD contributed to the cases studies; All authors contributed to the writing of the manuscript; AKG, FC, HB, JH, JL, JZ, KHT, LC, OD, SdR, VRV, AZ, RK, DH contributed to the article revision and pre-final editing.

## Declaration of interests

All authors have an interest in ONE-HEALTH. All authors declare no conflicts of interest. The views and opinions expressed in this article are those of the authors and not of their institutions.


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## LEGENDS

**Legends to figures**:

**Figure 1**: Venn diagram Boolean conceptual relationships of OH, EcoHealth, Health in Social-Ecological Systems and Planetary health.

**Figure 2:** Vision of One Health governance (OHG) in Global Health Security:
**2a)** Status quo with very limited collaboration between animal and public health and separated surveillance and response systems.
**2b)** OHG supported closer collaboration between animal and public health; onset of integrated human-animal-environment surveillance and response systems
**2c)** Full One Health status with closest possible collaboration between animal and public health and integrated human -animal-environment surveillance and response systems.

**Legends to boxes**

Box 1. OH background and contemporary theory
Box 2: Quantitative OH methods
Box 3: Qualitative OH methods
Box 4: COVID-19 and OHO

**Legend to table**:

Table 1, Summary of the evidence that One Health approaches work when tackling critical Global Health Security risks and hazards

**WEB APPENDIX**

S1 Analysis method of One Health governance
S2 Case studies of One Health governance
ST1 Table One Health Governance appearing in JEE reports
ST2 Table One Health Governance appearing in PVS Pathway reports

**Figure 1: Venn diagram Boolean conceptual relationships of OH, EcoHealth, Health in Social-Ecological Systems and Planetary health.**

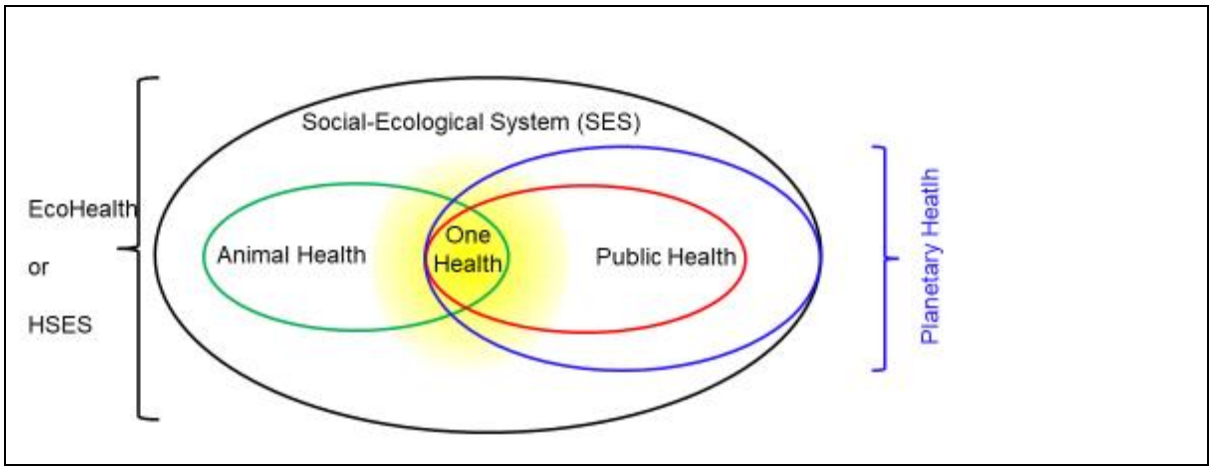
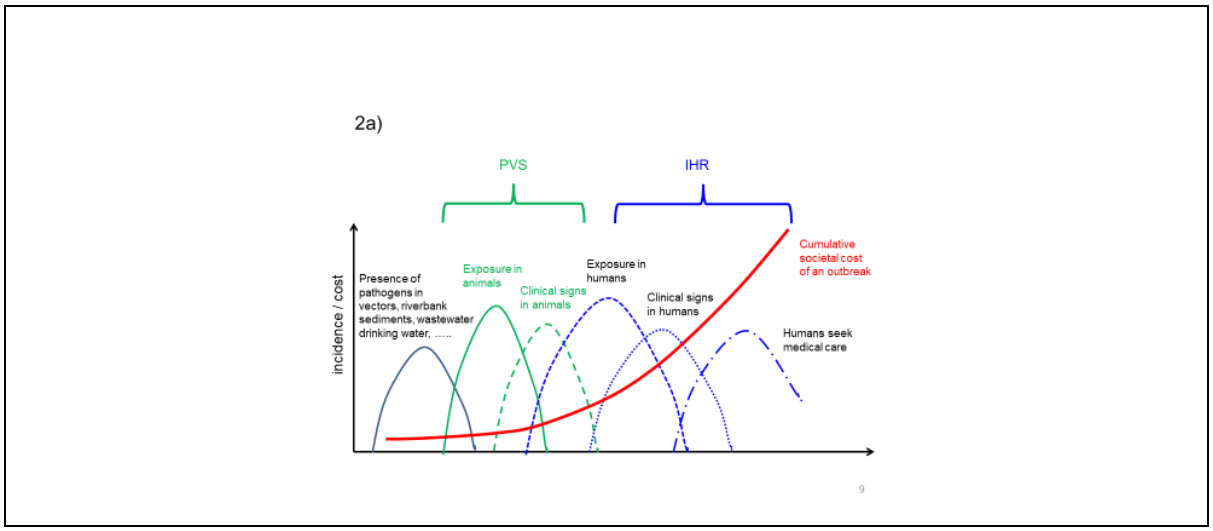
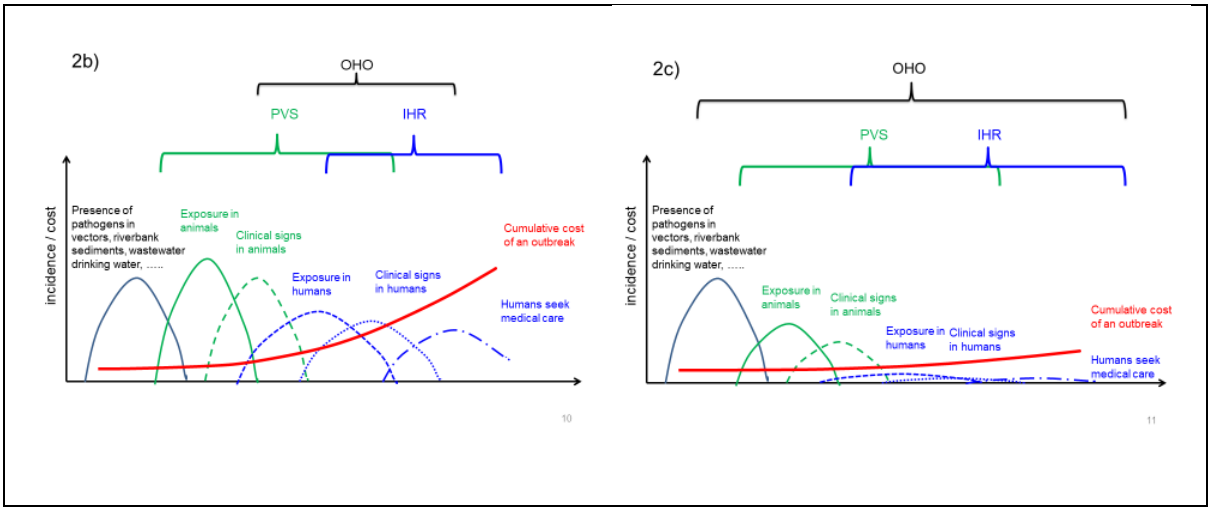



**Figure 2: Vision of One Health governance (OHG) in Global Health Security:**

2a) Status quo with very limited collaboration between animal and public health and separated surveillance and response systems.
2b) OHG supported closer collaboration between animal and public health; onset of integrated human-animal-environment surveillance and response systems
2c) Full One Health status with closest possible collaboration between animal and public health and integrated human - animal-environment surveillance and response systems.



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827 **Box 1. OH background and contemporary theory**

In the 1960s, the veterinary epidemiologist Calvin Schwabe coined the term "One medicine" to focus attention on the commonality of human and animal health interests[76]. Historically, such unifying views are much older[77]. For example, institutional developments such as Veterinary Public Health emerged as a contribution of veterinary medicine to public health in the 1950s[78]. More recently, growing interest in sustainable development has pointed towards the inextricable linkage of human, animal and ecosystem dimensions of health[79-81]. In 2004, the Wildlife Conservation Society (WCS) coined the phrase "One World, One Health™" to underscore the importance of securing human and animal health, ecosystem integrity and the protection of conservation areas under the manifesto of the "Manhattan principles" [82] which were renewed by the "Berlin principles on One Health" in 2019[20].

There has been a range of different adoptions of OH approaches. All of them incorporate human and animal health (although infrequently wildlife), and some also involve contributions from natural and social sciences and the humanities. At its best, OH as a societal problem solving approach, which engages with non-academic actors in the co-production of transformational knowledge for societal problem solving[83,84]. Cooperating partners and stakeholders seek a benefit of working together. A *necessary but not sufficient requirement* for OH is to fully understand systemically, how humans and animals (wildlife and domestic) and their environment are interrelated over all time and space scales. While several definitions of OH have been proposed[12,65], we consider as a *sufficient requirement* for achieving OH to demonstrate benefits resulting from the crosstalk and closer cooperation between human and animal health (domestic and wild) and all related disciplines and stakeholders. This can be expressed as any *added value in terms of health of humans, wildlife, domestic animals and their ecosystems, financial savings, social resilience and environmental sustainability achievable by the*

*cooperation between individuals and institutions working in human and animal health and including other disciplines when compared to the two medicines and other disciplines working separately*[11].

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839 **Box 2: Quantitative OH methods**

*Quantitative and qualitative OH methods*

Demonstrating incremental benefits of OH requires an understanding of the human / animal health interface. Box 2 describes both linear and dynamic quantitative approaches that have been used to develop the evidence base and demonstrate these incremental benefits in terms of OH (Box 1). Human health H and animal health A can be related as linear regression (Equation 1):

$$H_i = \alpha + \beta_k A_{jk} + e_{jk} \quad (1)$$

Whereby $H_i$ is, for example, the brucellosis seroprevalence status of the i-th human community, related to the brucellosis seroprevalence status $A_{jk}$ of the j-th animal of the k-th species in close spatio-temporal relationship, say a household or a village. The term $\alpha$ is the intercept and $e_{jk}$ the residual in the notation of linear regression. In this way, we could show that human brucellosis seroprevalence in Kyrgyz villages most strongly depended on the brucellosis seroprevalence of sheep and not of goats or cattle in this setting, with behavioural risk factors captured in the residual[38]. The relative importance of sheep for the transmission of brucellosis was confirmed by molecular typing of brucellosis strains[85]. The method is interchangeable in that animal health can also be the dependent on a human health indicator.

For dynamic relationships like the transmission of directly transmitted zoonotic diseases (stage 2[86]), the animal-human interface can be expressed as coupled differential equations in a simplified way, ignoring demographic processes, as Equation 2 for newly infected humans:

$$\frac{dI_h}{dt} = \beta I_a S_h \quad (2)$$

Whereby the instantaneous change of newly infected humans $I_h$ is equal to an animal-human transmission constant β times the number of infectious animals $I_a$ and the number of susceptible humans $S_h$. Such models allow assessing, for example, the effect of animal mass vaccination on the number of human exposures for brucellosis[87] or rabies[88]. Such models can be expanded to meta-population or contact network models[89,90]. Similarly, such models can also describe the dynamics of human to animal transmission in an interchangeable way.

Cross sector economic analyses show that Benefit-Cost Ratios (BCR) including benefits to humans and animal health are greater than BCR including human health benefits only (Formula 3)[25].

$$\frac{\textbf{Public health and animal benefits}}{\textbf{Intervention cost in livestock}} \quad >> \quad \frac{\textbf{Public health benefits}}{\textbf{Intervention cost in livestock}} \qquad (3)$$

Similarly, the Cost-Effectiveness (CE), expressed as cost per disability adjusted life year (DALY) averted, of interventions in animals and humans is higher (i.e. requires less cost per disability adjusted life year (DALY) averted) than the CE of interventions in humans only, if transmission between animals, and consequently transmission from animals to humans, can be interrupted.[25] In the case of directly transmitted stage 2 zoonoses, it can be shown that the societal cumulative cost of interventions in animals and humans are lower than interventions in humans only (Formula 4).

$$\textbf{Cumulative cost}_{\textbf{(animals and humans)}} < \textbf{Cumulative cost}_{\textbf{(humans)}} \qquad (4)$$

This is because, in the case of directly transmitted zoonoses, interventions in animals interrupt transmission between animals and consequently from animals to humans, while interventions in humans alone do not interrupt transmission from the animal reservoir. This has been demonstrated for the example of rabies control by dog rabies mass vaccination in N'Djaména, Chad[27,91]. Such analyses should be context specific to assure local validity. If cross-species transmission is rare, human health benefits may be too low to justify intervention costs in animals[92].

The systemic understanding of human and animal health would benefit from expansions to include parameters of the ecosystems (EcoHealth)[79,80] (**Figure 1**). Dynamic changes of human health, animal health and environmental determinants can again be expressed as coupled differential equations, as in Equation 5.

$$\frac{dI_h}{dt} = \beta I_a S_h + \gamma E S_h + \varepsilon E S_a \qquad (5)$$

Newly infected humans $I_h$ depend on the transmission from infected animals $I_a$ and exposure to the environment E (environment-human transmission constant γ) and indirectly from E and susceptible animals $S_a$ (environment – animal transmission constant ε). Equation 5 is applicable for example to the transmission dynamics of human exposure to anthrax *(Bacillus anthracis)* from animals (food), water and other environmental sources. Expansions to ecological determinants are more complex and data variability increases. In a recent study on the dependence of human vitamin A status in pastoralists in Chad, we could demonstrate a link between human serum retinol status and

consumed milk, but not between cow milk retinol levels and the level of beta-carotene in the pasture grass[93]. The variability of beta-carotene in the grass was too high to find a significant relationship with cow milk retinol levels. This example shows that ecological studies of human and animal health including environmental parameters have the potential for a broader understanding but are more difficult to prove due to the high variability of environmental factors.

**Box 3: Qualitative OH methods**

*There are other benefits from OH cooperation that can be difficult to quantify, such as improved insights into complex and context-specific systems, capacity development of institutions and practitioners, or better designed regulatory and non-regulatory interventions generating confidence and resulting social cohesion. By expanding the integration of health towards broad social-ecological issues like antimicrobial resistance or deforestation, complex interactions can become "wicked" and untractable. Rüegg et al. state: "There is a need to provide evidence on the added value of these integrated and transdisciplinary approaches to governments, researchers, funding bodies and stakeholders"[16,23]. The network for evaluation of OH (NEOH) proposes a qualitative and semi-quantitative evaluation and knowledge framework addressing OH operations and infrastructure like Thinking, Planning, Working, Sharing, Learning and Systemic organization within a policy and intervention cycle[16]. This involves a number of components. A OH index is proposed as a spider diagram, whose surface can be calculated and expressed as the so called "One Health-ness" of a program or health system. NEOH has further developed an OH knowledge integration approach to support international health governance[70] (see also below Relevance of OH for IHR). The OH index has been applied to West Nile virus surveillance in Italy[60]. An OH policy cycle analysis allows the assessment of different stages of OH policy development and governance by reviewing systemic thinking and transdisciplinary processes developing target and transformation knowledge for policy development. This is the basis for OH agenda setting, policy formulation and decision making which leads to implementation and evaluation as an iterative process[16,23,70]. It is postulated that a truly One Health integrative approach, not yet achieved in any health sector, will reduce the*

*risk of the global community suffering further pandemics and health crises that cripple the world's economies and cause hardship to rich and poor communities and considerable loss of life.*

**Box 4: COVID-19 and OHO**

The COVID-19 pandemic clearly shows that GHS cannot be disconnected from socio-economic wellbeing, whether poor or rich, and consequently public health and economic imperatives have to be balanced against the detrimental socioeconomic impact of pandemic prevention measures at local, national and global levels[84,94]. Vulnerabilities to infectious disease emergence and pandemics like COVID-19 exist at all scales from local to global with implications for all sectors of business and society. There appears to be a paradox between health and wellbeing related development goals and a consumption driven economic model purporting to help achieve these through ever increasing intensification and efficiency of production. Ultimately, more research is needed on how we can adapt the largely consumption driven economy towards a more ecologically and socially sound economy, reducing the risk of new pandemics of zoonotic origin while maintaining essential livelihoods.[84]

**Table 1, Summary of the evidence that One Health approaches work when tackling critical Global Health Security risks and hazards *(based on consensus view of the authors)* .**

| | | Strength of evidence | | | | |
|---|---|---|---|---|---|---|
| | | No evidence/little evidence | Limited | Medium | Strong | Very strong |
| Health security risks/ hazards | Emerging infections and novel pathogens including AMR | | | | | |
| | Endemic Infections and Neglected Tropical Diseases | | | | | |
| | Food safety and food/nutrition security | | | | | |
| | Extreme weather, water security and environmental degradation | | | | | |

Colour coding for boxes in table:
blue (prevention/preparedness measures) green (detection/surveillance measures) yellow (response/service delivery)

**Advancing One Human-Environmental-Animal Health for Global Health Security: What does the evidence say?**

Zinsstag et al.

## Online Supplements (S1-2)

### S1 METHODS, CASE STUDIES AND LITERATURE REVIEW

We performed an analysis of the contributions of OH approaches to GHS by:

*First* analysing current OH theoretical foundations (**Box 1**) and methods (**Boxes 2 and 3**), including their tentativeness[1] and their conceptual relationship to related ecosystem approaches to health (EcoHealth) and planetary health (PH) (**Figure 1**).

*Second*, drawing on selected case studies, we present contemporary evidence on the advantages of an OH approach in a few well known disease contexts and its capacity to at least deliver added value in terms of human and animal health, financial savings and sustained environmental services through a closer cooperation of human and animal health and related sectors that could not be achieved from sectors working in isolation.

*Third*, analysing annual country self-reporting to the World Health Assembly via the States Parties Self-Assessment Annual Reporting (SPAR)[2] on their implementation of the IHR (2005) and voluntary JEE[3] and on the PVS Pathway[4] to the OIE. We identify and discuss the gaps revealed in the current OH approach and assess the progress of more comprehensive inter-sectoral OH approaches to build human capacity, bridges between actors/stakeholders and robust adaptations of institutions at national and international levels to contribute in future to an improved GHS. Through the IHR (2005), countries engaged in a mutual commitment to develop national capacities to detect, assess, notify and report public health events that could be of international concern. How countries monitor and control diseases depends to a great extent on their capacity and cooperation between sectors[5]. Within these policy cycles from recommendation and obligation to local implementation of OH, concepts and operationalisation of OH move as 'traveling blueprints'[6], shaped by a range of actors who "claim the right to manage interventions, monitor spending and determine beneficiaries"[7,8]. Against the background of these complex policy cycles in diverse political, global and local contexts, our document analysis, based on a content analysis of the reports[9], takes into account the current reporting tools of WHO under the IHR MEF and the PVS reports of the OIE, as well as the existing handbooks that facilitate the assessment of the contribution of the veterinary sector in each of the indicators of the JEE and SPAR[10] tools.

We also searched all published JEE reports [2016-2019] and a random selection of PVS Pathway reports, available online or made accessible by OIE, for the term OH and analysed the technical areas for which OH was considered relevant (Table ST2). In the annual SPAR reports, we not only explored the use of the term OH but also analysed comments in relation to the implementation of OH in the narrative sections of the reports. Apart from the content analysis with regard to the use of the term OH, we furthermore took into consideration the actors involved in the reporting as well as the social and political context, in which the reports where produced[11]. We provide a detailed description of our approach to the document analysis in the online supplement (S1).

*Fourth*, we conducted five case-studies to provide a comprehensive picture about OHO and its benefits, based on expert knowledge and information from institutions leading on OH activities in Côte d'Ivoire, Kenya, Bangladesh, the United Kingdom and Switzerland. These case studies are presented in the online supplement (S2). The analysis of the available reports and case studies allowed us to assess institutional and operational? aspects in relation to multisectoral collaboration: To what extent is OH reflected in the IHR MEF and PVS reports? To what extent do the different reporting tools give information on how countries implemented OH institutionally (with regard to learning, sharing and systemic organisation) and operationally (with regard to OH planning, OH thinking, OH working) for example by systemic multi-sector intervention planning, as put forward by the NEOH evaluation framework (see Box 3: Qualitative OH methods)?[12] We finally attempted to summarize the strength of the evidence of OH approaches for GHS by considering the updated reference lists in the latest comprehensive OH textbook[13] followed by two rounds of adapted delphi consultations with authors to reach a consensus view on table 1.

**Analysis method of One Health Operationalisation (OHO)**

To assess the relevance of One Health for IHR and GHSA, we conducted a document analysis of three different reports, namely SPAR, JEE and PVS reports, that were identified as the relevant documents by FAO, OIE and WHO experts. While the SPAR and JEE reporting tools are part of the IHR Monitoring and Evaluation strategy of WHO, the PVS reports are part of the OIE PVS Pathway. Our analysis was inspired by the semi-quantitative OH evaluation framework by Rüegg et al. Based on NEOH, in their contribution Rüegg et al propose four elements that need to be considered for an evaluation of One Health (1. definition of the OH initiative and its context; 2. description of its theory of change with an assessment of expected and unexpected outcomes; 3. process evaluation of operational and supporting infrastructures (what can be called the "OH-ness"); 4. assessment of the association(s) between the process evaluation and the outcomes produced).[14] In line with element 3 of Rüegg et al's framework, our analysis focused on multisectoral cooperations based on SPAR, JEE and PVS. In order to be able to evaluate an added value, as brought forward in element 2 of the framework, as well as to assess sustainability, we also conducted country case studies including OH initiatives (such as for example, the HAIRS in UK). The case studies have been put together

as an additional methodological strategy to provide more contextual data and up-to-date information unavailable in the mentioned reports. The purpose of the case studies is not to describe the best existing One Health operationalisation models. Countries and initiatives were selected based on authors' professional / research experience in One Health that allowed to get access to additional information and insights.

In the following section we will describe the different reports (SPAR, JEE and PVS) and show how we analysed them. Our method for the analysis of the reports comes close to what can be described as a content analysis, where we basically counted the numbers of instances our established categories were used in the reports (see table in S 2).[9] Nevertheless, in a second step it was also important for our analysis to keep in mind that documents "must be studied as socially situated products",[15] hence it is important to consider the actors involved in its compilation as well as the social context in which the documents were produced.

The "State Parties Self-Assessment Annual Reporting Tool" (SPAR)[16] is used in order to assist state parties of the IHR to meet their duty to report on an annual basis to the World Health Assembly on the progress of their IHR implementation.[17] The SPAR reports are thus mandatory annual self-assessments of WHO State Parties capacities required under the IHR (2005) and to enable reporting annually to the WHA under Art. 54. Member States have implemented this since 2008. SPAR reports are conducted by the member states themselves without the involvement of external experts, which is likely to lead to some bias.[18] The most recent data available for this paper was from 2018, when 191 countries reported their implementation status; of which, 183 used the WHO SPAR questionnaire while 5 countries did not submit a report. We searched the SPAR for on the term One Health and found it exclusively mentioned in the capacity "C3 Zoonotic events and the human-animal interface". In addition, the Tripartite Zoonoses Guide (TZG)[19] also points to the indicator "C2.2 multi-sectoral IHR coordination mechanisms" as part of the capacity "C2. IHR coordination and national IHR focal point functions" as important for multi-sectoral collaboration. The SPAR tool allows for narrative comments in each capacity in order provide a rationale for choosing a particular level. We incorporated the narratives available in English and French with regards to capacities C2 and C3 in our document analysis by using the qualitative data analysis software MAXQDA. Although there is limited representativeness due to the small selection of available narratives and a particular focus on the technical areas concerned with IHR Coordination and zoonotic disease, they revealed some challenges countries face with regard to implementing IHR in general and OHO in particular, such as limited human resources in particular sectors (mainly animal sector) or an ad hoc functioning of multisectoral mechanisms in emergencies as a well as rather vertical approaches, focusing on a particular disease.

The "Joint External Evaluation" (JEE)[20], on the contrary is a voluntary external evaluation by global experts that are conducted upon request by a Member State. The first edition of the JEE tool was available in 2016, currently the second revised (2018) edition is in use. The JEE can be described as a collaborative and multisectoral effort that aims at evaluating the countries capacities "to prevent, detect and rapidly respond to public health threats independently of whether they are naturally occurring, deliberate or accidental".[20] In the JEE a team of external and national experts evaluates jointly national capacity across 19 technical areas.[20] For our analysis we had 96 JEE mission reports at hand. A quantitative content analysis of a few reports revealed that the term One Health was mentioned either to describe existing mechanisms or to highlight that policies and procedures had to be improved based

on a One Health approach. From this first level of analysis, we concluded that whenever the term One Health is mentioned, the concept is considered relevant - either by the country reviewed or the external experts. As a second step and drawing on methods of quantitative content analysis, we searched all 19 technical areas and the executive summary for the term One Health (ST1) The analysis revealed that One Health was considered relevant for 18 out of 19 technical areas with highest relevance for zoonoses and AMR. Other technical areas that had at least 60 hits of One Health mentions are: Workforce development, National Legislation, Policy and Financing, IHR Coordination, Communication and Advocacy; National laboratory system; Real-time surveillance (S2). Considering that One Health was mentioned in every single JEE report confirms that One Health is considered highly relevant for GHS. However, information about a countries' progress of operationalizing OH remains scattered throughout the reports.

The "Performance of Veterinary Services (PVS) Pathway"[21] is described as OIE's flagship programme in order to support stronger national Veterinary Services. By using a set of complementary tools, it "allows national Veterinary Services to identify weaknesses, strengths, and develops strategies to address existing gaps".[22] The PVS reporting was initiated in 2007 and has engaged over 140 countries on a voluntary basis. The PVS Pathway consists of a cycle with four stages: Orientation, Evaluation, Planning and Targeted Support. As described in the PVS tool, the OIE has a OH partnership with WHO "integrating the OIE PVS Pathway with the WHO International Health Regulations (IHR) Monitoring and Evaluation Framework in addressing global health security".[23]
A document analysis of the PVS documents showed that One Health rarely figured in reports before 2016, but that search hits significantly increased in more recent reports (ST2). Part of this change can be attributed to the revision of the PVS tools. Whereas in the 6th edition of the PVS Tool (2013), One Health was only mentioned in the introduction, the concept has become more central in the revision for the most recent edition in 2019. In this seventh edition, One Health is mainly understood and evaluated as "external coordination" of the veterinary services and also figures prominently in the competence of AMR and AMU. It is noteworthy that in the sense of external coordination, One Health has been evaluated in the PVS process for about a decade (OIE, PVS tool 5$^{th}$ edition).

The fact that some of the reports are conducted on a voluntary basis by a mixed evaluation team of national and external experts (JEE, PVS), while others are compulsory self-assessments for each member state as part of the annual IHR reporting (SPAR) has an impact on the completeness and reliability of data. For instance, circumstances that may lead countries to conduct the voluntary JEE or PVS assessments might not be perceptible, when only looking at the reports. Apart from aspects linked to donors' funding priorities (note that most JEE missions were conducted in African countries), regional disease threats, too, may have an impact on which countries undergo an evaluation. In South America, for example, countries have recently conducted assessments of their national capacities due to the Zika virus outbreak, which has given them a good overview of existing gaps making it unnecessary to undergo additional evaluations at this point in time. Hence, the political, social as well as economic contexts of the countries participating in JEE missions may be important to consider, when analysing the state of global health security or One Health in our case. Furthermore, to compare the final scores of member states and produce a ranking would be misleading. The reason is that the evaluations have been conducted by different teams of experts and the strictness by which the scores have been applied may slightly differ from one case to the other.

The primary aim as described for the PVS Pathway is “to assist Member Countries to improve their own systems, and not necessarily to ‘score’ themselves relative to other countries”.[23] (p. vi) Hence, it remains difficult to assess the One Healthness of different countries on the basis of the JEE, PVS and SPAR reports. As a consequence, we rather focused on the qualitative description of gaps and recommendations, as can be seen from the case studies below.

## S2 Case studies of One Health Operationalization

### Côte d’Ivoire

For Côte d’Ivoire, we have a PVS report from 2012 and a JEE report from 2016. In the PVS report from 2012, there is no mention of OH or multisectoral collaboration. The country was in a post-conflict context at that time and the damage and reconstruction of the veterinary services was the focus of the report. In the JEE report, the level of OH operationalization was evaluated. The external experts concluded that a lot remained to be done in terms of actual implementation. They also noted that the country benefitted from capacity strengthening programmes of the Global Health Security Agenda. Right after the completion of the JEE report, between 2016 and 2018 an USAID sponsored project engaged in a multisectoral participatory approach to develop a strategy and operational plan for the operationalization of One Health. These efforts culminated in a government decree that formally established the One Health platform in 2019. With the end of external funding and the frequent reshuffle of government, progress made in OH operationalization at the national level have come to a halt. To date, the government has neither provided the platform with the political support nor the financial mechanism necessary to assure its functioning. When the coronavirus pandemic began at the beginning of 2020, the platform was still not officially launched. As a consequence, the platform has remained inactive throughout the pandemic. Hence, the potential for a coordinated multi-sectoral response was not taken advantage of. The following case shows the relevance of an intersectoral approach.

Members of a household in Abidjan were tested positive for Covid-19. This family had a dog that was very close to the owners. Therefore, the veterinary services advised to investigate on the dog. The contact dog revealed an epidemiological link between the dog and the family members. The dog trainer who visited the family has not been considered or identified by the public health services task personnel. The Covid-19 PCR test of the dog was negative. However, in view of the dog trainer's contact with the family, the veterinary services advised the health services to take a sample from the dog trainer. Surprisingly, that dog trainer's results were positive and he represented a major risk of propagation because he visited several dog owners in the course of his work. As a result of the risks associated with the dog trainer's activities, he was placed in an isolation centre for treatment based on the national protocol. This experience shows the contribution of the veterinary services in the search for contact cases that is one of the weak aspects of the current Covid-19 crisis management. The implementation of the intersectoral approach in case investigations will allow a better identification of contact cases and could contribute to the control of the spread of COVID-19.

Local ownership of the OH approach can be found in the country’s rabies control program, which has benefited from the pan-African research programme Afrique One that has provided capacity building in One Health since 2009. Furthermore, thanks to a collaborative project co-funded by GAVI, the National Institute for Public Health and the Directorate for Veterinary

Services engage in an intersectoral collaboration to advance the rabies elimination strategy for the country. To date, Côte d'Ivoire has developed intersectoral collaboration between human and animal health sectors that collaborate closely in the case of animal bite victims at local and national levels focusing on local OH concerns rather than theoretical or emerging risks that are of bigger interest to global actors and donors.

**United Kingdom**

PVS and JEE reports for the UK are lacking. Nevertheless, the country engaged in a voluntary external evaluation of the Global Health Security Agenda capabilities in 2015. The tool was under development at the time and covered 11 action packages that covered a big part of the JEE tool. The UK's One Health approach to preventing, detecting and responding to infectious disease threats was highlighted as a "best practice" example[24]. The evaluation commented on outstanding collaboration between public health and veterinary officials, recognised by formalised multiagency groups such as the Human Animal Infections and Risk Surveillance Group (HAIRS). It was suggested that such collaborations, which also include wildlife and other specialists, should be used as a best practice example in other countries as they help to move the idea of "One Health" from concept to reality.

HAIRS is a multi-agency and cross-disciplinary horizon scanning group which presents the main forum for member organizations to identify and discuss infections with potential for interspecies transfer[25]. The group meets monthly to identify emerging and potentially zoonotic infections which may pose a threat to UK public health. The group's functions involve 1) identification of hazards 2) risk assessment 3) risk management 4) risk communication.
Potential hazards to the UK population, such as a novel infectious agent or a new disease observed in animals, are identified by HAIRS members through horizon scanning activities or from laboratory reports. The HAIRS group then undertakes formal risk assessments using either a "Zoonotic potential risk assessment" or an "Emerging Infections Risk Assessment tool", in consultation with recognized experts. The probability and impact of the hazard identified is rated as either very low, low, moderate, high or very high. Risk management then involves identifying, selecting, advising or implementing measures to reduce risk, either by using expertise within the HAIRS group, through network contacts or by referral to appropriate groups for risk management. If infections are thought to be of potential significance, the implications are communicated via a publicly available 'Summary of notable events/incidents of public health significance'.

Whilst not defined, the cost saving of regular and proactive inter-disciplinary disease surveillance is likely to be substantial considering, for example, that £1.5 billion was spent on schemes responding to the bovine spongiform encephalopathy (BSE) crisis in the UK between 1996-97[26]. Both the subsequent BSE inquiry[27] and the CMO's annual report of 2002[28] emphasized the need for a mechanism to identify and assess the threat from new and emerging infectious diseases, which has since been met with the formation of HAIRS, in 2004. The HAIRS experience crucially allows for inter-disciplinary relationships to develop ahead of a crisis and brings together those who are senior enough to represent the key organizations involved. Other key components of the HAIRS model include senior level buy-in and support across relevant institutions, systematic record keeping with terms of reference, transparent risk assessment processes and regular communication with meetings scheduled whether

there are incidents to discuss or not. Strategic needs include maintaining members with a depth of experience and knowledge in their field as well close liaison with specialist contacts.

Since 2013, the HAIRS group has published 12 risk assessments of diseases ranging from West Nile virus to tick-borne encephalitis[29] and has most recently assessed the risk of SARS-CoV-2 in companion animals and transmission to humans[30].
Additionally, a summary annual HAIRS report details the emerging issues affecting human and animal health and the outcome of the group's assessment of these issues. The group published discussion of seven issues in 2017, including UK detections of Aedes albopictu, Thelazia callipaeda (Oriental eye worm) and Brucella canis[31]. The latter resulted in facilitation of a rapid response to reports of five canine cases of Brucella canis in dogs imported from eastern Europe, recognizing that animals with asymptomatic infection posed a potential threat to public health. The Animal and Plant Health Agency, Public Health England and the Brucella reference laboratories subsequently collaborated to develop public health guidance for laboratories and veterinarians, highlighting the risk assessment processes for laboratory exposures and advising the veterinary community to consider Brucella canis as a differential diagnosis in dogs assessed with relevant symptoms.

The key resource required for HAIRS activities is regular and ongoing voluntary commitment from members which include senior epidemiologists, public health physicians, scientists, veterinary advisers, veterinary epidemiologists, veterinary investigation officers as well as senior representatives from a range of government and public health agencies. These have included Public Health England, the Department for Environment, Food and Rural Affairs, the Animal Health and Veterinary Laboratories Agency, the Food Standards Agency, the Department of Health, Public Health Wales, the Welsh Government, Public Health Agency Northern Ireland, the Department of Agriculture and Rural Development Northern Ireland, Health Protection Scotland and the Scottish Government. A cost effectiveness analysis of the HAIRS network has not been undertaken and such an initiative would considerably support the growing evidence base on added value of One Health approaches.

**Bangladesh**

In 2011, an OIE PVS evaluation team conducted an Evaluation Mission in Bangladesh and recommended that Veterinary services in Bangladesh faced several challenges including inadequate infrastructure, limited trained personnel, insufficient budget, and sub-optimal operational management.[32] Based on initial evaluation of the PVS evaluation team, in 2015, PVS Gap Analysis Mission worked with Bangladesh and identified key national priorities including livestock development, veterinary public health, animal health and management and organization of the veterinary services. The national core competencies were assessed against the 47 key indicators of the OIE PVS Tool and a five-year action plan was developed. JEE report for Bangladesh published in 2016 highlighted that the country has made substantial progress in complying with the IHR, however it still faces major challenges in some key areas.[33] While staff working within and across different relevant ministries have excellent working relationship, there are no formal agreements and policies on specific roles and responsibilities of the key organizations and senior staff. Such agreements enable rapid decision-making during emergencies. There also exists lack of coordination across JEE elements and many organizations performs as silos which hinder the opportunity to leverage

skills and capacities across organizations. Lastly documentation of plans and procedures needs to be strengthened to prevent loss of local context-specific knowledge and expertise.

One Health Bangladesh[34] is a community led think tank organization for physicians, veterinarian wildlife health experts, social scientists, environmental activists working together to combat the challenges of emerging infectious diseases and other health issues arising at the human-animal interface in a complex ecosystem. The organization is run by a constitution where a National Coordination committee (NCC) from Government, development partners and other organization is considered as highest governing body. The NCC is led by a National Coordinator (Prof Nitish Debnath). The committee is elected every two years. OH Bangladesh has a Strategic Framework and Action Plan in place jointly developed by Government partners, UN agencies which helped in institutionalization of OH approach and targeted activities within the government systems. With funding from the Government of Bangladesh and international partners, there is a functioning OH Secretariat located at Institute of Epidemiology and Disease Control Research (IEDCR).

The organization has around 1000 registered members. The members pay an annual membership fee which supports the organization's ongoing activities. One Health Bangladesh organizes bi-annual conferences to bring all stakeholders together. Additionally, the platform also organizes extended meetings to discuss immediate issues. So far it has organized 10 conferences and 47 meetings.

One Health Bangladesh in collaboration with its local partners has been contributing in capacity building initiatives including OH training by FAO, the Field Epidemiology Training programs jointly organized by the IEDCR and Centers for Disease Control and Prevention (CDC), USA and OH Postgraduate training by Massey University.
During the COVID-19 pandemic, One Health Bangladesh, in partnership with Global Health Development (GHD), has been organizing a series of webinars in response to the COVID-19 pandemic. The discussions from the webinars are influencing policy decisions and collaborative initiatives in dealing with human animal interface issues. The organization is also giving technical support in responding to the current COVID-19 pandemic response and it's members are actively involved in laboratory investigation and epidemiological activities related to the pandemic response. Involving animal health laboratories and universities for diagnosis of COVID-19 could be cited as a successful example of One Health in action in Bangladesh though this has not been formally evaluated in terms of costs saved or timeliness and quality of testing.

Case Study also based on correspondences with One health BD representative (by Nusrat) →maybe add name to acknowledgements?

**Kenya**

Kenya is well documented in the SPAR (2010, 2011, 2012, 2013 and 2018, 2019), JEE (2017) and PVS (last follow up from 2017) reports.

In the executive summary of the Joint External Evaluation report (JEE), the following existing formal mechanisms for intersectoral coordination between human and animal health are

mentioned: The IHR national focal point (NFP), the Zoonotic Disease Unit (ZDU) as well as the National Task Force Committee. Furthermore, the report points to additional rather informal exchanges of information, that exist between different ministries. These exchanges are described to be based on "personal contacts and good will".[35] It is mentioned that multisectoral human resources for human and animal health are available in Kenya, at the national level and that there are multidisciplinary teams available at the national level, however not in the same extent at county or sub-county level. The same applies for One Health coordination, that exists at national level, but would need to be better structured at subnational levels.[35] Although there is a desire to have an integrated surveillance programme including the Ministry of Health, the Ministry of Livestock and the wildlife sector, currently each ministry has its own surveillance and reporting system. Nevertheless, some level of data sharing is available between the ministries and the wildlife agency.

As described in the JEE report, Kenya has disease-specific plans for risk communication, however, there is no comprehensive multisectoral plan.[35] For Rift Valley Fever, Kenya uses a joint risk assessment (JRA).[19] The country furthermore established an integrated approach to develop a surveillance strategy for AMR.[35] This process however, has only started in 2019 and is planned to be further expanded to the subnational level in future.

Kenya's One Health office, the Zoonotic Disease Unit was established through a Memorandum of Understanding between the Ministry of Health and the Ministry of Agriculture, Livestock and Fisheries in 2012. Before the establishment of the Unit, in 2006 a Zoonotic Technical Working Group had been put into place. This working group now serves as an advisory committee that provides technical advice to the ZDU in quarterly meetings. The ZDU supports the coordination at the national level and in 32 of the 47 counties formal training on OH has taken place.[35] There are further activities related to OH in other counties although they did not (yet) undergo the same formal training. According the the JEE report, ZDU's mission is to "establish and maintain active collaboration at the animal–human–ecosystem interface to prevent and control zoonotic diseases".[35] In its 5-year strategic plan (2012-2017) three objectives are mentioned: to strengthen surveillance, prevention and control of zoonoses in both humans and animals; to establish structures and partnerships to promote a One Health approach; to conduct applied research at the human–animal–ecosystem interface.[35] The Unit brings together experts from the field of human health and animal health, it employs one medical and one veterinarian senior epidemiologist. In their commentary, Mbabu et al further more mention the plans to employ an ecologist.[36] Also in the PVS follow up report the ZDU is mentioned. In the PVS report, the dependence on donors is mentioned as a concern, as the ZDU states in their strategic planning from 2012-2017 that "There is a high level of dependence on partner organizations for funding One Health (OH) activities and arrangements in place".[37] In recent years, donor and partners' support for the unit has been on the decline, which may lead to some challenges therefore in adequately addressing the priority issues (as mentioned for example in the SPAR reports) as planned. The Unit is described in the JEE report from 2017 to be "well-functioning with clear terms of reference to support IHR (2005) implementation".[35] As examples, the multisectoral response of the ZDU to disease outbreaks of Human African Trypanosomisasis (April 2012), Rabies (March 2012) and anthrax (October 2012) are mentioned[38] – all local and national disease priorities. It is noticeable, however, that these examples all originate from the year 2012. Apart from avian influenza, Rift Valley fever and rabies belong to the country's priority diseases and the risk mapping of these diseases is one of the activities of the Unit. The Unit established a One Health response team at county level and conducted trainings (Field Epidemiology and Laboratory Training Programme, FELTP). To conclude, in the JEE report of 2017 Kenya's Unit

is praised as a “best practice” model that could serve other Member States in the development of “shared leadership between human and animal sectors”.[35] Nevertheless, more critical voices also emphasize the fact that these aspects would have to be explored more in-depth when it comes to actual practices on the ground. Furthermore, given the narrow focus of the ZDU on zoonoses, other health risks and hazards amenable to a One Health approach such as water security/drought or the current locust plague emergency devastating agricultural production are beyond the scope of activities of the ZDU and seldom figure in the discussions of the One Health advisory group.

Switzerland

According to the OIE, Switzerland has not conducted any activities with the PVS tools, neither as an external evaluation mission nor as a self-assessment. However, there is a JEE report from 2017. The executive summary highlights that Switzerland has “strong capacity for preventing, detecting and responding to zoonotic diseases of public health significance “ based on a One Health approach.[39]

A first analysis of the potential of One Health in Switzerland was done by Meisser et al. in 2011[40]. Interviewed experts confirmed the potential of the One Health concept for Switzerland. Barriers such as differences in professional cultures, the absence of evidence of the added value of OH, federal structures and a relatively low burden of disease were identified. Moreover, a road map for advancing One Health was established, including research activities, capacity-building and a stakeholder approach to joint preparation and tailored implementation of the One Health concept in Switzerland. A detailed description of potential barriers and a clear guide for a step-by-step action plan makes suggestions for a realistic way forward. The cantons of Basel-Stadt[41] and Ticino were early adopters and implemented resources in the planning of a closer cooperation between the different sectors.

The Swiss federal government established a legal sub-structure/subsidiary body for One Health (Unterorgan One Health) in 2017, based on the law on epidemics (Epidemiengesetz). The JEE report positively mentions that the subsidiary body is chaired by the Swiss Federal Food Safety and Veterinary Office, which is also the “IHR contact point for zoonosis and food safety within the Swiss IHR network”.[39]

The body’s regulations define One Health as an integrative approach of cooperation of human- and veterinary medicine. One Health creates an added value in terms of better health of humans and animals, saving of resources and a positive impact on the environment. The purpose of the sub-structure OH is to provide support to the relevant federal offices on the detection, surveillance, prevention and control of zoonoses and vectors and in other tasks in cross-sectoral areas. It further strengthens the collaboration between the federal and the cantonal (provincial) governments. It includes representatives of the federal offices of public health, environment, food safety and veterinary affairs and agriculture. Furthermore, the chief army veterinarian, and representatives of the cantonal public health, animal health, chemistry and pharmacy are represented.

The sub-structures meet regularly and can also meet *ad hoc* on request. Resources are covered by the respective ministries and cantonal governments. The JEE report made recommendations to strengthen One Health training for public health professionals[39] and to use the approach to improve real-time surveillance.[39] Recent key activities are the

development of an integrative strategy on antimicrobial resistance surveillance (STAR), the surveillance of zoonoses and the follow up of porcine influenza.

For the control of COVID-19, the Institut für Viruskrankheiten und Immunprophylaxe (IVI), Swiss institute for highly pathogenic animal diseases is actively involved and a veterinary virologist is a member of the Swiss COVID-19 science task force.[42]

While the IHR document (2005) does not explicitly mention the term “One Health”, we observe a change over time since the beginning of the reporting in the terminology when it comes to the use of the OH concept in the reporting tools. With reference to the PVS reports organized by OIE, our document analysis reveals that the cooperation between public and animal health has been evaluated as “external coordination” of the veterinary services for many years of the studied period of reporting, without explicit mention of the term OH. Whereas in the 6th edition of the PVS Tool (2013), OH was only mentioned in the introduction, the concept has become more central in the revision for the most recent edition in 2019, still referring mostly to external coordination but also relating to AMR and antimicrobial use (AMU). This increased awareness of the benefits of an OH approach is reflected in an increase of OH mentions in recent reports (Table ST2). The PVS reports show that OH is a topic that appears primarily/exclusively in sections on collaboration and AMR.

A need for a multisectoral OH coordination mechanism (MCM) for addressing zoonotic diseases as proposed by the Tripartite Zoonoses Guide (TZG) (FAO, OIE, WHO)[43] can be identified in the SPAR reports, as well as through external assessment in the JEE reports. In the JEE tool, adopting an OH approach is defined as follows: “including, from all relevant sectors, national information, expertise, perspectives and experience necessary to conduct assessments, evaluations and reporting for the implementation of the IHR”[3]. The SPAR tool uses the same definition [2]. A document analysis revealed that the concept of OH is mentioned in all 96 existing JEE reports (Online Supplementary Table ST1), two thirds even mention OH in their executive summary. Depending on the state of OH implementation in a particular country, the external experts either highlighted the strengths of the country’s OH approach or made recommendations for more multisectoral collaboration as a priority action in the report. Furthermore, OH is mentioned in 18 out of the 19 technical areas (ST1) evaluated, particularly for zoonoses and AMR[44]. This means that OH is considered as highly relevant for the IHR process by experts around the world, which could be interpreted as a “collective global commitment” [43]. Given their importance as zoonoses reservoirs, environmental and wildlife issues are absent from much of the text and, even if there is implicit understanding by some of the breadth of wildlife ecology, in practice this is not addressed.

In the State Party Self-Assessment reports, the multisectoral coordination is evaluated amongst others in their technical category “C2.2 Multisectoral IHR coordination mechanisms”[2] while the term OH is exclusively mentioned in the capacity “C3 Zoonotic events and the human-animal interface”.

Within the comment section that allows for narratives in the otherwise quantitatively oriented SPAR reports that are conducted by the countries themselves, the idea of OH is mentioned with regards to current attempts and intentions to either strengthen, further develop, or establish a multi-sectoral collaboration in the respective countries.

In many countries, the veterinary sector is already actively involved in COVID-19 control (see, for example, the Switzerland case study in S2) and though the OIE and FAO are providing a support role to the WHO lead, thewildlife and environment sectors are largely extraneous to the core activities currently involved in the pandemic.

As stated by Hitziger et al., at present, only a limited number of texts focused on “epistemological, institutional, political and social factors are associated with the implementation of a OH approach”[45]. OH governance is a complex process in itself and in recent years, apart from key actors, such as FAO, OIE and WHO, more global players, e.g. key research institutions, philanthropic initiatives by private companies and individuals, are becoming important[5,46]. OH has thus become a complex field of multiple actors, hierarchies and interests[47]. In order to explore these complex local and global contexts of OHO, case studies or best practice examples may provide important insights into the benefits of OHO in institutions and operations. It is noted that the country rankings in the available reports do not reveal their functioning OH mechanisms. Within WHO’s Monitoring and Evaluation Framework two more operational components are mentioned here that can be more suitable to assess the functionality of national systems and the synergies between stakeholders. The After Action Reviews (AAR) and the Simulation Exercises (SIMEX) can test the functionality either following real or during simulated events. These too, however, are often limited by a global and donor focus on security and human diseases of pandemic potential which limit the relevance, utility and sustainability of these tools for national and sub-national non-human health stakeholders who often have more pressing priorities tackling endemic diseases and other local emergencies.

Ongoing self-reporting, joint external evaluation reports, after action reviews, simulation exercises and national policy and planning (NAPHS, IHR-PVS bridging workshop roadmaps, Health Sector plans, disease specific OH plans) can be scrutinized for their adequacy and effectiveness of improved OHO[48]. This can be expressed as reduced time to detection of new hazards, outbreaks and sustained improvements in the control of endemic disease, the incremental number of cases (incidence), and cumulative societal cost in relation to the level of integration of human and animal health sectors (**Figures 3a-c**)[49,50].

## Conclusions

The case studies have provided more detailed insights into the state of One Health operationalization and governance in specific countries. Furthermore, it shows that initiatives at subnational level and in the field of research and capacity strengthening are only partially captured in the SPAR, JEE and PVS reports. In relation to managing the COVID-19 crisis, the potential of One Health collaborations has not been fully utilized.

A more comparative country analysis remains difficult due to the lack of a common mechanism to evaluate different approaches and operationalisations. Furthermore, information on the added value of One Health is difficult to access, as assessments are rare. Hence, a comparative country analysis remains difficult with the patchy information at hand and the lack of a standard evaluation framework or metric.

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