presents a threat for increased transmission of zoonotic pathogens between animals and humans along the livestock value chain, increasing the likelihood of novel zoonotic pathogens establishing themselves in human populations, the overall endemic burden of common zoonoses, and the threat of infectious disease outbreaks which can threaten global health security.

One Health approach has been defined by the American Veterinary Medical Association as the integrative effort of multiple disciplines working locally, nationally, and globally to attain optimal health for people, animals, and the environment [2]. Globally, the recognition of the threat of emerging and re-emerging zoonoses led to advocacy for the adoption of a One Health approach at country level aimed at strengthening monitoring and response to zoonotic disease risks via a multisectoral, transdisciplinary collaboration [3, 4]. In practice, different countries have approached implementation the principle of One Health variously with varying successes and challenges [5]. In Kenya, creation of a coordination framework between public health and animal (domestic

control endemic zoonotic disease. In Particular a lack of a formal framework for systematic collaboration between government Ministries and among key stakeholders on management of zoonotic disease outbreaks was a critical gap.

DGHP's One Health Program worked with other partners including the US Cooperative Biological Engagement Program of the Department of Defense and Biological Engagement Program of the Department of State, to continually advocate for and provide technical and financial assistance to the establishment of a formal collaborative framework between the public and animal health sectors. These efforts led to the formation of a national One Health coordinating office referred to as Zoonotic Disease Unit (ZDU) in 2012 and the process to do this has been laid out previously [13] (Fig. 1).

The ZDU's key mandate was to act as a focal point of collaboration between the MoH and the MALF with a goal to establish structures and partnerships that promote the One Health approach, to enhance or build zoonotic epidemic and endemic disease surveillance, and to coordinate implementation of control measure and to support public health research in Kenya [13, 14].

In 2013, the governance system in Kenya changed from a centralized to a devolved government of 47 counties; where functions such as public health and animal were undertaken by county governments. This provided an opportunity and need to expand the One Health approach to the subnational (county) level. To cascade the benefits of One Health approach to the county level, the ZDU and its partners have embarked in training and setting up county One Health units supported mainly through CDC Kenya's Global Health Security Agenda (GHSA) implementing partners. County One Health units focus on initiating or enhancing communication platforms between the health and livestock sectors to improve surveillance and reporting of zoonotic diseases, ensuring rapid joint investigation and response to zoonotic disease outbreaks to mitigate disease impact. As of April 2017, there were 31 of 47 Kenya counties with established county One Health units. Through collaborations with other international partners, there will be county One Health units in all 47 counties by 2019. Sharing of disease outbreak information across sectors and rapid joint outbreak response at county level should help reduce the burden of spillover to humans that acquire zoonotic disease infections as illustrated by an example of an anthrax outbreak in Nakuru County (Table 1).

In 2015, a multidisciplinary team of human, animal and wildlife health experts in surveillance, research and laboratory science drawn from the national and county levels conducted prioritization of zoonotic diseases in Kenya [15]. From a list of 35 zoonotic diseases, the top five were anthrax, trypanosomiasis, rabies, brucellosis and Rift Valley Fever. Based on these findings, development and implementation of disease prevention and control plans for these priority zoonoses with greatest public health impact is being undertaken while promoting collaborative research and surveillance for all the diseases to generate national data and for evaluating control strategies.

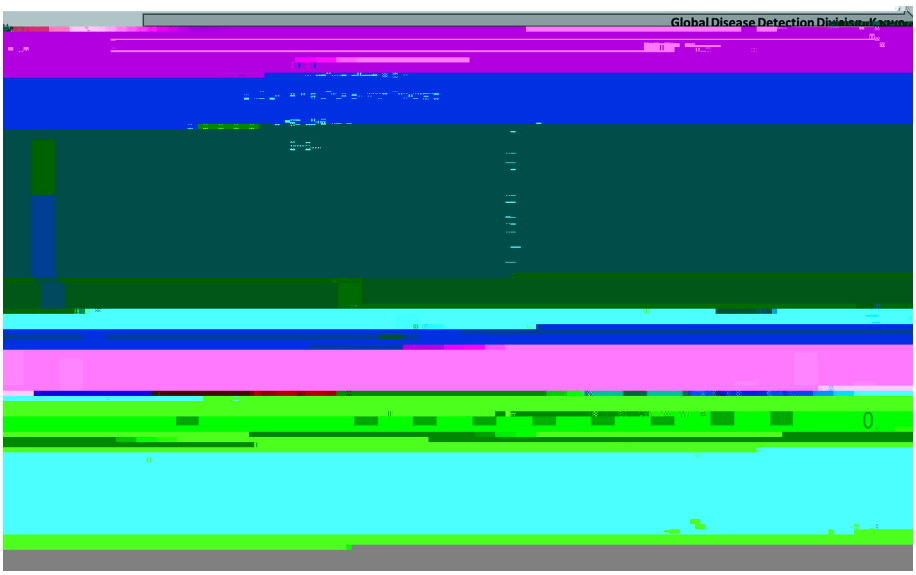

Fig. 1 Major milestones on One Health implementation and publications on zoonoses by year, CDC-Kenya, 2004–2017. Global Disease Detection Division (GDDD) now called the Division of Global Health Protection (DGHP); Field Epidemiology and Laboratory Training program (FELTP); Ministry of Health (MOH)

One Health workforce development

In 2004, the Kenya Ministry of Health, with support from CDC and other partners, launched Kenya's Field Epidemiology and Laboratory Training Program (FELTP). This program provides training in applied epidemiology, resulting in a Master's of Science (MSc), initially offered to medical doctors and laboratory scientists working within government ministries [16]. Since 2006, with increased recognition of the value of One Health, veterinarians have been admitted to the training [16]. By 2017, the Kenya FELTP had 169 medical and 19 veterinary epidemiologists complete the two-year training program. Of these trained veterinarians, all initially returned to government positions, and the majority stayed at national or country level, strengthening collaboration between the human and animal health sector with fellow FELTP graduates participating in joint outbreak response and other activities during their training (Fig. 2).

S r eillance

Surveillance for animal diseases in most developing countries is designed to detect notifiable and trade sensitive diseases (e.g. foot and mouth disease) and to report to the World Organization for Animal Health (OIE). However, these systems are established to detect animal syndromes and generally without consideration of zoonotic aspects of clusters of animal diseases and the risk that infections may spill-over to humans locally and further afield. This calls for establishment of surveillance platforms that can detect and

Zoonotic disease research in Kenya

The burden and transmission dynamics of many zoonotic infections are poorly understood in developing countries, including Kenya, which can challenge the progress of disease control programs to reduce burden and impact. In 2005, KEMRI and the DGHP in Kenya established the Population Based Infectious Disease Surveillance (PBIDS) platforms in a rural site in Western Kenya and an urban site in Nairobi to define the burden, etiologies and risk factors of common infectious disease syndromes (fever, jaundice, diarrhea and respiratory illness) among others [20, 21]. Additionally, in 2008 through collaborative partnerships with the Wellcome Trust, zoonotic disease research was started among farmers and animals within PBIDS. The zoonotic disease research in DGHP has catalyzed additional studies within the PBIDS platform with other partners such as Washington State University and developed further platforms in different sites in the country with the overall focus of generating disease data to inform public health actions (Fig. 1). Some examples of these are outlined below.

Q-fever

Coxiella burnetti is on the US Federal Select Agent list and was first reported in Kenya over half a century ago, but since the late 1970's there had been no further study of this pathogen. In 2009, KEMRI and CDC Kenya carried out retrospective studies on archived human sera collected between 2007 and 2008 in the PBIDS platform and cross-sectional studies carried out in the same site in 2009 among cattle, sheep and goats and the vector ticks to determine the sero-prevalence of the disease [22

Brucellosis

CDC Kenya and the ZDU implemented a study in three counties among humans and their livestock and found a varying (2.4–46.4%) seroprevalence in humans and 1.2–13.5% in livestock among the counties, largely associated with cultural practices around livestock and their products particularly unpasteurized milk and low knowledge levels on brucellosis. This underscored the need for targeted public health messaging, effective diagnostic capacity in local hospitals and systematic control programs for brucellosis in animals [25].

Rift Valley fever

The momentum built around the 2006–2007 RVF outbreak in Kenya progressed to robust research projects by multisectoral collaborative research groups. A key output from learning the lessons on preparedness from the 2006–2007 outbreak is the RVF decision support tool kit for Chief Veterinary officers in the Horn of Africa region to support evidence-based actions to mitigate the impact of RVF outbreaks when they occur [26]. This tool has been adapted into the RVF integrated preparedness and response plan for Kenya and was applied in late 2015 when RVF was predicted in Kenya and the Eastern Africa region as described previously.

Other DGHP- Kenya research work on RVF described climatic, geographic, and geologic predictive factors associated with occurrence of RVF in Kenya [27, 28]. These data taken together with a historical review of RVF out-

these pathogens as etiologies for undifferentiated fever in humans using multi-pathogen detection assay such as the AFI TaqMan array card in several sites including the PBIDs platform in Western Kenya.

Linking animal ownership and health status to human health outcomes

Since 2013, CDC and KEMRI in collaboration with Washington State University have conducted animal (cattle, sheep, goats, and poultry) syndromic surveillance in 1500 households in Western Kenya, a subset of the on-going PBIDS platform [7]. This integrated and unique study design allows for measuring of the impact of livestock diseases on human health and socio-economic status at household level. Preliminary data analysis reported at household level, showed strong association between cumulative human and animal illness though the mechanism for this association was not clear [7]. Further work looking at the linkage of human health and owning livestock through the nutritional pathway as well as assessing the

been the establishment of an effective cross-sectoral coordinating government unit (ZDU), an enhanced surveillance system in domestic and wild animals that meets the needs of animal and human health, a workforce trained in the One Health approach, improved outbreak investigations and a robust and productive public health scientific program including the discovery of zoonotic pathogens new to the world. The adoption of the One Health program and approach in Kenya has led to rapid detection and control of zoonotic disease outbreaks at their source and thereby enhanced global health security. These achievements have allowed for advocacy and informed decisions to be made on the control and prevention of zoonotic pathogens and have identified gaps in diagnosis and surveillance. However, challenges remain in sustainability, veterinary laboratory diagnosis and resources to implement more comprehensive control and prevention measures.

Since zoonotic infections continue to impose a health burden on population, and new zoonoses can emerge in any country and spread globally, the regional and global adoption of the One Health agenda is a key capacity of the global health security agenda. Lessons learnt from Counties in Kenya are applicable to establish One Health programs throughout Kenya, the African region, and beyond.

Abbreviations

CDC: Centers for Disease Control and Prevention; DGHP: Division of Global Health Protection; GDDD: Global Disease Detection Division; HPAI: Highly pathogenic avian influenza; KEMRI: Kenya Medical Research Institute; MERS COV: Middle East Respiratory Syndrome Corona Virus; RVF: Rift Valley Fever; ZDU: Zoonotic Disease Unit

Acknowledgements

Establishment of ZDU and programs: We would like to acknowledge the Directors of Medical Services, Ministry of Health and Director of Veterinary Services, Ministry of Agriculture, Livestock and Fisheries and personnel from the respective ministries and Kenya Wildlife Service for their excellent collaboration and efforts in setting infrastructure and continued facilitation for ZDU operations. We would also like to acknowledge the technical and financial support from Biological Engagement Program of the US Department of State, Defense Threat Reduction Agency of the US Department of Defense, US Agency for International Development (USAID)-Kenya, World Health Organization (WHO), Food and Agriculture Organization of the United Nations – Emergency Center for Transboundary Animal Diseases (ECTAD) Kenya, International Livestock Research Institute (ILRI), Africa Field Epidemiology Network (AFENET) and Kenya Medical Research Institute among other stakeholders. We also would like to acknowledge excellent research collaboration with the Wellcome trust; Washington State University with funding from Paul Allen Foundation; The Global Alliance for Livestock Veterinary Medicines; Defense Threat Reduction Agency of the US Department of Defense; The One Health Office in the National Center for Emerging and Zoonotic Infectious Diseases, and the Center for Global Health, US CDC, Atlanta.

Funding

Publication of this article was funded by US Centers for Disease Control and Prevention, Global Detection Division, Division of Global Health Protection, Kenya.

Availability of data and materials

All data generated or analyzed during this study are included in this published article.

About this supplement

This article has been published as part of *BMC Public Health Volume 19 Supplement 3, 2019: 10th anniversary of the Centers for Disease Control and Prevention - Global Disease Detection program.* The full contents of the supplement are available online at https://bmcpublichealth.biomedcentral.com/articles/supplements/volume-19-supplement-3.

Authors' contributions