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Chapter

Tackling COVID-19 through the One Health Approach

Ayodele Oluwaseun Ajayi, Olawale Peter Odeleye and Oluwabukola Atinuke Popoola

Abstract

The Covid-19 pandemic is currently ravaging the globe with enormous morbidity and mortality. This pandemic, caused by the SARS-CoV-2 started from China and has spread across the globe. Initial reports indicated that the SARS-CoV-2 initially emerged among animals from where they transfer to humans. Different strategies deployed to curtail the pandemic have yielded little result. Therefore, the One-Health concept may compliment existing strategies. The One Health places emphasis on the between the animal-human-ecosystem interface and how this can be used to tackle public health problems, including the COVID-19 pandemic. One Health Surveillance will involve tracking viral pathogens in animals to access risk of transfer to humans. It will also stimulate targeted approaches for prevention and treatment of viral zoonotic infections. There should be an integrated and interdisciplinary One-Health surveillance that should incorporate veterinary, medical or public health and environmental scientists to synergise surveillance effort to track emergence of infectious diseases in the future.

Keywords: Surveillance, One-Health, COVID-19, SARS-CoV-2

1. Introduction

The One Health is an interdisciplinary concept that encompasses animal health, human health and the ecosystem with huge emphasis on how public health problems can be solved at the interface between these entities [1–3]. The interface between humans, animals and the ecosystem are intricately interconnected to the extent that whatever happens in any of these entities most likely affects others [4]. Therefore, the concept of One Health relies on the understanding that human health, animal health and the environment are intricately linked together and they can be affected simultaneously [5]. Historically, the nature of the intricate interactions between animals, humans and the ecosystem have continued to shape human events and local or global public health [6].

There has been a historical consensus that some factors that affect human health can be traced to animal factors and origins [7]. Humans have coexisted with animals and this has formed the basis for studying the human-animal interface [8, 9]. For example, it has been confirmed that close to 70% of all infectious diseases have zoonotic origins [10–12]. It has also been implied in some scientific contexts that the control of aetiological agents in animals could prove effective in controlling such agents within the human population to improve public health [13, 14].

Another imperative of the One Health is the growing interconnectedness between the ecosystems of humans, animals and the environment, which may include wildlife, urban areas and farming systems [15, 16]. The increasing anthropological activities of humans have diminished the delineation between these ecosystems and have increased the frequency of contact between animals and humans [17]. Humans now stand at increased risk of having contact with animals that have been displaced from their original ecosystems. This has further increased the risks of emerging and re-emerging infectious diseases and their attendant burdens on humans and global economy ([18]. Some infectious diseases that were hitherto absent in human populations are now common due to the increased contact of humans with animals [19].

It has also been noted that some environmental factors affect the health of humans and animals [20]. The increasing anthropogenic activities have led to a distortion of the delicate natural environmental balance [21]. Intense industrial activities release greenhouse gases into the environment, leading to climate change and increased risk of respiratory problems among humans and animals. The activities of chemical and pharmaceutical industries have also been linked with the release of chemicals into the environment, particularly soil and water; and they can be absorbed by humans, animal and plants [22]. For instance, some studies have confirmed the residual amounts of antibiotics found in urine of animals are partly due to the release of pharmaceutical wastes into the environment [23]. Several pathogens, particularly viruses and bacteria, have been confirmed to be carried by environmental reservoirs and matrixes from where they can be transmitted to humans and animals to cause diseases [24]. One of the fallouts of globalization is the increased speed and frequency of travels by different channels of transportation, namely air, sea and land. This has facilitated the massive movement of humans and animals across transcontinental boundaries [25]. Unfortunately, humans that carry active infectious diseases serve as reservoir through which infectious pathogens can be transmitted or transferred across international boundaries [26, 27]. In addition, massive demand for protein and animal products increases the number of animals that are transported across international borders with increased risk of transfer of resident zoonotic flora and pathogens across international boundaries [28]. This factor has contributed to the increased interface between animals and humans.

It is within this context that different countries and international organizations, particularly the World Health Organization, (WHO), Organization for Animal Health (OIE) and Food and Agricultural Organization (FAO) agreed on a global consensus that some problems of global importance can be tackled through the One Health approach [29]. It places emphasis on multi-sectoral collaborations and frameworks to solve pertinent global health problems, both nationally and internationally. They also encourage different countries to come up with their One Health policies with a view to enhance the quality of their public health. Many countries across the globe have responded to this challenge and institutionalized One Health into their surveillance systems to improve public health. For instance, the African Center for Disease Control has incorporated the One Health framework into its activities with a view to tackle the periodic problem of emerging infectious diseases within the continent.

2. Brief review of zoonotic viruses and their epidemiology

Zoonotic infections are those infections that originate from animals and are transmitted through the agency of animals or insects to humans [30, 31]. It has since been on record that the vast majority of emerging infectious diseases have zoonotic origins [32, 33]. It has also been established that many viruses have animals as their reservoirs and some even exist as part of the natural flora of the animals. Many animals that have served as proven reservoirs of viruses include bats, dogs, primates, and many other exotic species of animals [34]. It has been recognized that the knowledge of viruses and their natural hosts or ecosystems is important to effectively recognize measures to combat zoonotic infections, including those caused by viruses [35]. Such knowledge will enable scientists determine the possible viral flora of such animals, detect any seasonal changes in the carriage of such viruses that may negatively impact public health and allow medical practitioners, veterinary physicians and epidemiologists to predict possible emergence of viral infections, risks and threats to humans and public health [36–38].

A vast majority of infectious diseases that have significant toll on public health, in terms of mortality and morbidity, have zoonotic origins [39]. Similarly, viral zoonoses contribute a significant proportion of infectious diseases across the globe with significant economic burden running to billions of US dollars annually [37]. Furthermore, Africa and other developing countries appear to have the highest burden of viral zoonotic infections, with significant mortality and morbidity [40, 41]. The diminishing demarcation between the animal wildlife and human ecosystems increases the risk of contact and interaction between humans and animals with consequent increase in the surge of emerging and re-emerging infectious diseases in Africa and across the globe [42]. As stated above, Africa has its fair share of zoonotic viral diseases with well documented mortality and morbidity attributed to them. The following are examples of past or recent wave of zoonotic viral diseases in Africa.

i. **Ebola virus disease:** This is a usually fatal disease caused by the Ebola virus. It has been established that this disease is usually transmitted through contact of apparently healthy individuals with the body fluids of individuals infected with the virus [43, 44]. Earlier and recent reports suggest that the virus was originally found in primates and bats in wildlife from where they were transmitted to humans that came in contact with them [45, 46]. It can also be transmitted from wild animals such as fruit bats and porcupines [47]. The earliest reported case of the diseases was in 1976 in the Democratic republic of Congo [48]. The most pronounced outbreak of this disease was reported in 2014 in Liberia, Sierra Leone and Guinea with combined mortality of approximately 11,000 deaths [49]. The fatal nature and the huge mortality reported in the recent outbreaks draws attention to the zoonotic origin of the disease and how it can be tackled through one health.

ii. **Lassa fever:** This disease is caused by the Lassa fever virus and is endemic mostly in Nigeria and other neighboring countries, including Cote d'Ivoire, Guinea, Central African Republic, Mali, Senegal and Congo [50]. The natural host of the virus is the rodent *Mastomys natalensis,* which is mostly found in tropical environments in West Africa [51]. This rodent is originally resident in the bushes and tropical rainforest but the increasing and massive urbanization in most parts of Nigeria and West Africa dislodge these rodents from their natural habitat, increasing the risk of transmission of this virus to humans [42]. Epidemiologically, the annual incidence of this disease in Africa is estimated at 200,000, with estimated mortality of 500 with 60 million people at risk of contracting the disease [52, 53].

iii. **Rabies**: This disease is caused by the Rabies virus and it is found mostly in Africa and Asia [54]. It is a fatal disease with high mortality in endemic regions where the disease is common. Relative to the high mortality associated with this disease, it is estimated that 99% of close to 59000 deaths caused by this disease are originated from dogs [55]. The virus also circulates in wildlife, especially wild bats and racoons where they can also be transmitted to domestic animals that come in contact with them [55]. The strong knowledge of the transmission link of the virus between dogs and humans led the effective control of the disease through vaccination of dogs and this has proven effective till date ([56–58].

iv. **Human Arbovirus infections:** This represents the categories of infections that are caused by mosquitoes and ticks that feed on blood and transmit viruses to susceptible hosts during the process [59]. These Arboviruses still present a huge threat to public health especially in developing countries [60]. The morbidity and mortality associated with diseases caused by arboviruses is significant [61]. However, the increasing rate of urbanization and other related anthropogenic forces increase the chance of transmission of arboviruses to humans [62]. The most prominent arboviral infection among humans is the Dengue fever caused by the Dengue virus which accounts for more than 40.000 deaths per annum [63]. Around 2015, the Zika virus infection caused some morbidities and mortalities in Brazil and neighboring countries and still a threat till date [64].

It has been noted that the zoonotic origins, epidemiological burden and transmission cycles of the viral infections emphasize the need for effective control of zoonotic viral infections through the One Health approach, especially in the paradigm of other measures that have been adopted and have not effectively controlled the diseases.

3. Brief review of the COVID-19 pandemic

A new viral disease emerged in China and has since spread to different parts of the world with more than 145 million people infected and more than 3 million deaths. After extensive molecular studies, the etiology of the virus was identified as SARS-COV-2 with innate ability to spread rapidly among humans [65–68]. Furthermore, new variants of the virus were later identified in different countries with enhanced abilities to spread faster than the previous wild types discovered. This implies that more people will be infected and more may likely die of this disease. These new variants therefore appear to have altered the epidemiology of the disease in some parts of the world [69–72].

Different countries, international and scientific organizations responded swiftly to the spread of the pandemic with an array of measures to limit the spread of the disease across national and international boundaries [73, 74]. Such measures included isolation and quarantine, restriction of international flights, social distancing and personal hygiene, which include hand washing and use of nose masks [74–78]. Following global agreement that vaccines may likely end the pandemic, different companies and research organisations have developed vaccines and the largest and unprecedented vaccination drive have since commenced in different countries and millions more people have been projected to be vaccinated over time [79, 80].

However, the different initiatives intended to control the spread of the disease shortly before the vaccines were discovered appeared to have limited effects in controlling the spread of the disease. For instance, strict hand washing remains a challenge in many poor and developing countries due to lack of adequate water supply [78]. Furthermore, the screening measures at international airports only captures symptomatic carriers while asymptomatic carriers can escape the screening routines [77]. Also, most of these measures appear short term and may not be sustained on these long run [81]. Inadequate logistics for distribution of masks and other sanitary materials limit access by people in remote areas. The limited success achieved in limiting the spread of the disease calls for more deliberate and innovative approaches towards controlling the spread and even eliminating the disease.

4. Zoonotic origin of *COVID-19*

The preliminary investigations in China that followed the onset of the pandemic revealed that bats and exotic animals at a popular market are the initial sources of the organisms [82, 83]. It was also hypothesized that the humans that initially came into contact with the animals may have triggered the pandemic [84]. The coronaviruses are a large family of viruses that has been found to be common among animals and wildlife, including bats [82]. The initial strains of the virus were genomically correlated with that of bats. This implies that the virus may have originated from bats, although the exact transmission to animals remains relatively unknown [84]. The extensive zoonotic origin of these types of viruses heightens the risk of their transfer from the wildlife to the human population [85]. The growing urbanization, anthropogenic pressure and climate change encroaches the original wildlife, resulting in the spillover of the viruses as the animals migrate to areas inhabited by humans [86].

5. The imperative of one health surveillance

The initial transfer pattern of the virus from animals and wild life to the environment and humans confirms that the One Health approach can be applied to tackle the spread of the diseases, in view of the outright failure or limited success achieved with other preliminary methods deployed to control the transmission of the disease [81, 87]. Animals serve as the reservoir of the virus from where they can be shed into the environment. Such animals, usually in wildlife, frequently come into contact with humans and they transmit the virus in the process. Furthermore, humans can serve as conduit to transfer to other humans and this scenario is particularly problematic in the case of the SARS-CoV-2 [88]. In addition, humans can also transmit the virus asymptomatically to other humans and the environment [89]. The virus has been found on surfaces, foods and sewages [90].

There is a strong consensus in the global scientific arena that the One Health concept provides a stronger approach to tackle the spread of infectious diseases including those caused by zoonotic viruses. In response, different international organizations have put up strong statements in support of the One Health approach to tackle the current surge of infectious diseases. They further encourage different countries to prioritize this concept and come up with policies to tackle the spread of infectious diseases, which can be extended to the current COVID-19 pandemic.

In major effort to solidify the One Health footprint on global public health, three major international organizations, namely the World Health Organization (WHO), Food and Agricultural Organization (FAO) and the Organization for Animal Health (OIE) produced a joint and strategic framework aimed at reducing infectious diseases at the animal-humans-ecosystem interface. With strong link of the coronavirus with wild life and the environment, viral diseases of zoonotic origins also fall with the scope of infectious diseases that can be tackled through the One-Health policy [91].

Several countries have since keyed into the strategic initiatives and have recognized it as an important approach to tackle the surge of emerging infectious diseases, including the current COVID-19 pandemic. For instance, the African Center for Disease Control has incorporated it into its public health programmes in the continent [29]. The European Union (EU) have since produced its own One Health action plan to tackle different public health problems most especially antibiotic resistance and zoonoses [92]. Similarly, the Asia continent has the One Health Tripartite frame work the comprises of the Asia region of the WHO, FAO and OIE to give full attention to One Heal issues with a view to tackle public health challenges that most especially antibiotic resistance and zoonoses [93].

However, it appears there is no standard approach for tackling COVID-19 as a means to prevent further spread of the pandemic. This can be viewed from the fact that the pandemic is relatively new and it may take some time to design One health policies that will specifically suit the pandemic. One of the key peculiarities of the current pandemic is the easy spread of the COVID-19, compared with the other public health threats that are currently being addressed by One Health. Also, the massive mortality and morbidity of the current pandemic is another peculiarity for which custom made One Health policies should be designed to tackle the current pandemic. Generally, the One Health approach recognizes that scientific expertise should be drawn from disciplines, most especially, medicine, veterinary science and environmental science in order to public health threats including the current COVID-19.

6. Surveillance for infectious diseases

The surveillance for infectious diseases is a very crucial epidemiological tool that serves different purposes in public health. More specifically, infectious diseases surveillance can be used to determine the current prevalence of infectious diseases at a given time. It also assists in the monitoring of changes in infectious diseases trend over time. It helps to determine or reveal risks of emergence of infectious diseases and how such risks can be mitigated. More importantly, infectious diseases surveillance allows targeted policies for prevention and control of infectious diseases within particular groups within a population [94].

Within the COVID-19 pandemic, the extensive surveillance capacities and protocols developed over the years have assisted in tracking the spread of the pandemic and helped to determine the massive threat it has posed in terms of morbidity and mortality [95, 96]. The massive surveillance efforts put forward, most especially by developed countries and China has enhanced targeted policies to tackle the spread of the disease and treatment. For instance, the United Kingdom recently announced massive vaccinations for the entire country. China was able to track sporadic emergence of the diseases and targeted quarantine followed such efforts. In contrast, African countries seem to have limited capacities for surveillance of infectious diseases and this may partly explain the low prevalence of the diseases in Africa.

7. One health surveillance

The paradigm of surveillance for the COVID-19 pandemic within the one health concept is somewhat different. Due to the interdisciplinary nature of one health, surveillance efforts and policies should be designed to encompass human health or population, animal health and the ecosystem. In fact, this surveillance approach has been recognized as a crucial component of One Health and this integrated approach can be used to track emerging and re-emerging diseases. Surveillance efforts targeted at animals and wild life has revealed that coronaviruses, including the SARS-CoV-2 constitute part of the flora of such animals. Although the immediate animal to human transmission of the SARS-CoV-2 could not be established, direct human to human transmission has been established and this has been attributed to the vast majority of the transmission of the virus. The virus has also been found in solid household waste, sewage and hospital droplets and these carry the risk of transmitting the virus to susceptible individuals [97].

8. Conclusion

The One Health concept is a relatively new approach being promoted as a strategy to tackle some public health problems at the human-animal-ecosystem interface. Consequently, its application is gradually gaining traction and some time is needed to really access its benefits. Currently, there are few evidence of the potential and practical benefits of this approach to tackle public health challenges on the scale of those posed by the COVID-19 pandemic.

That notwithstanding, few instances of the immediate, potential and practical benefit of using the One Health approach have emerged. The United States Agency for International development recently developed a PREDICT One Health surveillance system to track potential emergence of pathogenic viruses and their possible spill-over to the human population. The successful application of this project has led to the improvement of our understanding of evolution of viruses on a global scale [98]. Furthermore, another coordinated One Health simulation study using the Rift Valley virus was used to demonstrate the potential applicability and success of this approach. The study concluded that a multidisciplinary investigation using this approach can yield a higher statistical power and reveal complex relationships between regarding the epidemiology of the virus in animal and environmental settings [99].

It is evident from the foregoing that the One Health surveillance initiative can be applied at the human-animal-ecosystem interface to track any emerging infectious diseases. The incorporation of molecular techniques can be used to establish the clonality between the viral strains among animals, humans and the ecosystem. Due to the massive and devastating nature of the COVID-19 pandemic, the One Health surveillance must be globally envisioned in order to effectively track and control the spread of the disease [100].

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References

[1] Davis MF, Rankin SC, Schurer JM, Cole S, Conti L, Rabinowitz P. Checklist for one health epidemiological reporting of evidence (COHERE). One Health 2017; 4:14-21. doi: 10.1016/j.onehlt.2017.07.001.

[2] Mackenzie JS, Jeggo M. The One Health Approach-Why Is It So Important?. Trop Med Infect Dis. 2019; 4(2):88. doi:10.3390/tropicalmed 4020088

[3] Chiesa F, Tomassone L, Savic S. A Survey on One Health Perception and Experiences in Europe and Neighboring Areas. Front Public Health. 2021; 9:609949. doi:10.3389/fpubh.2021.609949.

[4] Rabinowitz P, Conti L. Links among human health, animal health, and ecosystem health. Annu Rev Public Health. 2013;34:189-204. doi: 10.1146/annurev-publhealth-031912-114426. Epub 2013 Jan 16. PMID: 23330700.

[5] Trinh P, Zaneveld JR, Safranek S, Rabinowitz PM. One Health Relationships Between Human, Animal, and Environmental Microbiomes: A Mini-Review. Front Public Health. 2018;6:235. doi:10.3389/fpubh.2018.00235

[6] Evans BR, Leighton FA. A history of One Health. Rev Sci Tech. 2014;33(2):413-20. doi: 10.20506/rst.33.2.2298. PMID: 25707172.

[7] Reperant L.A., Cornaglia G., Osterhaus A.D.M.E. The Importance of Understanding the Human–Animal Interface. In: Mackenzie J., Jeggo M., Daszak P., Richt J. (eds) One Health: The Human-Animal-Environment Interfaces in Emerging Infectious Diseases. Current Topics in Microbiology and Immunology, 2012; 365. Springer, Berlin, Heidelberg. https://doi.org/10.1007/82_2012_269

[8] Carter NH, Shrestha BK, Karki JB, Pradhan NM, Liu J. Coexistence between wildlife and humans at fine spatial scales. Proc Natl Acad Sci U S A. 2012;109(38):15360-15365. doi:10.1073/pnas.1210490109

[9] Mekonen, S. Coexistence between human and wildlife: the nature, causes and mitigations of human wildlife conflict around Bale Mountains National Park, Southeast Ethiopia. BMC Ecol 2020;**20:** 51. https://doi.org/10.1186/s12898-020-00319-1

[10] Kruse H, kirkemo AM, Handeland K. Wildlife as source of zoonotic infections. Emerg Infect Dis. 2004;10(12):2067-2072. doi:10.3201/eid1012.040707

[11] Serge Morand, K. Marie McIntyre, Matthew Baylis, Domesticated animals and human infectious diseases of zoonotic origins: Domestication time matters, Infection, Genetics and Evolution, 2014; 24: 76-81, ISSN 1567-1348, https://doi.org/10.1016/j.meegid.2014.02.013.

[12] Haider N, Rothman-Ostrow P, Osman AY. COVID-19-Zoonosis or Emerging Infectious Disease?. Front Public Health. 2020;8:596944. doi:10.3389/fpubh.2020.596944

[13] Rabinowitz PM, Kock R, Kachani M. Toward proof of concept of a one health approach to disease prediction and control. Emerg Infect Dis. 2013;19(12):e130265. doi:10.3201/eid1912.130265

[14] Degeling, C., Johnson, J., Kerridge, I. Implementing a One Health approach to emerging infectious disease: reflections on the socio-political, ethical and legal dimensions. BMC Public Health . 2015;**15:** 1307. https://doi.org/10.1186/s12889-015-2617-1

[15] Milner-Gulland EJ. Interactions between human behaviour and

ecological systems. Philos Trans R Soc Lond B Biol Sci. 2012;367(1586):270-278. doi:10.1098/rstb.2011.0175

[16] Zulkifli I. Review of human-animal interactions and their impact on animal productivity and welfare. J Anim Sci Biotechnol. 2013;4(1):25. doi:10.1186/2049-1891-4-25

[17] Hendry AP, Gotanda KM, Svensson EI. Human influences on evolution, and the ecological and societal consequences. Philos Trans R Soc Lond B Biol Sci. 2017;372(1712): 20160028. doi:10.1098/rstb.2016.0028

[18] National Research Council (US) Committee on Achieving Sustainable Global Capacity for Surveillance and Response to Emerging Diseases of Zoonotic Origin; Keusch GT, Pappaioanou M, Gonzalez MC. (ed). Sustaining Global Surveillance and Response to Emerging Zoonotic Diseases. Washington (DC): National Academies Press (US); 2009. 3p, Drivers of Zoonotic Diseases. Available from: https://www.ncbi.nlm.nih.gov/books/NBK215318/

[19] Cristiano Salata, Arianna Calistri, Cristina Parolin, Giorgio Palù. Coronaviruses: a paradigm of new emerging zoonotic diseases. *Pathogens and Disease*.2019; 77(9): ftaa006. https://doi.org/10.1093/femspd/ftaa006

[20] Acevedo-Whitehouse K, Duffus AL. Effects of environmental change on wildlife health. Philos Trans R Soc Lond B Biol Sci. 2009;364(1534):3429-3438. doi:10.1098/rstb.2009.0128

[21] Rhind SM. Anthropogenic pollutants: a threat to ecosystem sustainability?. Philos Trans R Soc Lond B Biol Sci. 2009;364(1534):3391-3401. doi:10.1098/rstb.2009.0122

[22] Khatri N, Tyagi S. Influences of natural and anthropogenic factors on surface and groundwater quality in rural and urban areas, Frontiers in Life Science. 2015;8:1, 23-39, DOI: 10.1080/21553769.2014.933716

[23] Polianciuc SI, Gurzău AE, Kiss B, Ştefan MG, Loghin F. Antibiotics in the environment: causes and consequences. Med Pharm Rep. 2020;93(3):231-240. doi:10.15386/mpr-1742

[24] Gerba CP. Environmentally Transmitted Pathogens. Environmental Microbiology. 2015;509-550. doi:10.1016/B978-0-12-394626-3.00022-3

[25] Goetz AR, Graham B. Air transport globalization, liberalization and sustainability: post-2001 policy dynamics in the United States and Europe. J Transp Geogr. 2004;12(4):265-276. doi:10.1016/j.jtrangeo.2004.08.007

[26] Mangili A, Gendreau MA. Transmission of infectious diseases during commercial air travel. Lancet. 2005;365(9463):989-996. doi:10.1016/S0140-6736(05)71089-8

[27] Hertzberg VS, Weiss H, Elon L, Si W, Norris SL; FlyHealthy Research Team. Behaviors, movements, and transmission of droplet-mediated respiratory diseases during transcontinental airline flights. Proc Natl Acad Sci U S A. 2018;115(14):3623-3627. doi:10.1073/pnas.1711611115

[28] Goodwin R, Schley D, Lai KM, Ceddia GM, Barnett J, Cook N. Interdisciplinary approaches to zoonotic disease. Infect Dis Rep. 2012;4(2):e37. doi:10.4081/idr.2012.e37

[29] AfricaCDC. One Health [Internet]. 2021. Available from: https://africacdc.org/programme/surveillance-disease-intelligence/one-health/.

[30] Asante J, Noreddin A, El Zowalaty ME. Systematic Review of Important Bacterial Zoonoses in Africa in the Last Decade in Light of the 'One

Health' Concept. Pathogens. 2019;8(2): 50. doi:10.3390/pathogens8020050

[31] Simpson GJG, Quan V, Frean J, Knobel DL, Rossouw J, Weyer J, Marcotty T, Godfroid J, Blumberg LH. Prevalence of Selected Zoonotic Diseases and Risk Factors at a Human-Wildlife-Livestock Interface in Mpumalanga Province, South Africa. Vector Borne Zoonotic Dis. 2018;18(6):303-310. doi: 10.1089/vbz.2017.2158. PMID: 29664701.

[32] Cutler SJ, Fooks AR, van der Poel WH. Public health threat of new, reemerging, and neglected zoonoses in the industrialized world. Emerg Infect Dis. 2010;16(1):1-7. doi:10.3201/eid1601.081467

[33] Belay ED, Kile JC, Hall AJ. Zoonotic Disease Programs for Enhancing Global Health Security. Emerg Infect Dis. 2017;23(13):S65-S70. doi:10.3201/eid2313.170544

[34] Shi Z, Hu Z. A review of studies on animal reservoirs of the SARS coronavirus. Virus Res. 2008;133(1):74-87. doi:10.1016/j.virusres.2007.03.012

[35] One Health Commission, "What is one health?" [Internet]. 2019. Available from:https://www.onehealthcommission.org/en/why_one_health/what_is_one_health/.

[36] G. Venkatesan, V. Balamurugan, P.N. Gandhale, R.K. Singh, V. Bhanuprakash. Viral Zoonosis: A Comprehensive Review. Asian Journal of Animal and Veterinary Advances. 2010; 5: 77-92.

[37] Karesh WB, Dobson A, Lloyd-Smith JO. Ecology of zoonoses: natural and unnatural histories. Lancet. 2012;380(9857):1936-1945. doi:10.1016/S0140-6736(12)61678-X

[38] Everard M, Johnston P, Santillo D, Staddon C. The role of ecosystems in mitigation and management of Covid-19 and other zoonoses. Environ Sci Policy. 2020;111:7-17. doi:10.1016/j.envsci.2020.05.017

[39] Kemunto, N., Mogoa, E., Osoro, E. Zoonotic disease research in East Africa. BMC Infect Dis. 2018;**18:**545. https://doi.org/10.1186/s12879-018-3443-8

[40] Meslin, F.X. Impact of zoonoses on human health. Vet. Ital. **2006**;42: 369-379.

[41] Fenollar F, Mediannikov O. Emerging infectious diseases in Africa in the 21st century. New Microbes New Infect. 2018;26:S10-S18. doi:10.1016/j.nmni.2018.09.004

[42] Rahman MT, Sobur MA, Islam MS. Zoonotic Diseases: Etiology, Impact, and Control. Microorganisms. 2020;8(9):1405.doi:10.3390/microorganisms8091405

[43] Park DJ, Dudas G, Wohl S, Goba A, Whitmer SL. Ebola Virus Epidemiology, Transmission, and Evolution during Seven Months in Sierra Leone. Cell. 2015;18;161(7):1516-26. doi: 10.1016/j.cell.2015.06.007. PMID: 26091036; PMCID: PMC4503805.

[44] Reichler MR, Bangura J, Bruden D, Keimbe C, Duffy N, Thomas H, Knust B, Farmar I, Nichols E, Jambai A, Morgan O, Hennessy T; Household Transmission Investigative Team. Household Transmission of Ebola Virus: Risks and Preventive Factors, Freetown, Sierra Leone. J Infect Dis. 2018;24; 218(5):757-767. doi: 10.1093/infdis/jiy204. PMID: 29659910; PMCID: PMC6508068.

[45] Marí Saéz A, Weiss S, Nowak K. Investigating the zoonotic origin of the West African Ebola epidemic. EMBO Mol Med. 2015;7(1):17-23. doi:10.15252/emmm.201404792

[46] Alexander KA, Sanderson CE, Marathe M, et al. What factors might

have led to the emergence of Ebola in West Africa?. PLoS Negl Trop Dis. 2015;9(6):e0003652. doi:10.1371/journal.pntd.0003652

[47] Fan Y, Zhao K, Shi ZL, Zhou P. Bat Coronaviruses in China. Viruses. 2019;11(3):210. doi:10.3390/v11030210

[48] Kadanali A, Karagoz G. An overview of Ebola virus disease. North Clin Istanb. 2015;2(1):81-86. doi:10.14744/nci.2015.97269

[49] Center for Disease Control. 2014-2016 Ebola outbreak in West Africa [Internet]. 2019. Available from: https://www.cdc.gov/vhf/ebola/history/2014-2016-outbreak/index.html.

[50] Richmond JK, Baglole DJ. Lassa fever: epidemiology, clinical features, and social consequences. BMJ. 2003;327:1271-1275. https://dx.doi.org/10.1136%2Fbmj.327.7426.1271.

[51] Bonwitt J, Mari Saez A., Joseph L, Rashid A., Dawson M., Buanie J., Lamin J., Diana S., Borchert M., Foday, Fichet-Calvet E.,Bronw H. At home with mastomys and Rattus: Human-rodent interactions and potential for primary transmission of Lassa virus in domestic spaces. The Americal Journal of Tropical Medicine and Hygiene. 2017; 96 (4): 935-43. https://doi.org/10.4269/ajtmh.16-0675 PMID:28167603

[52] Centers for Disease Control (CDC). Lassa fever. Centre for Disease Control [Internet]. 2019. Available from:www.cdc.gov/vhf/lassa.

[53] Yaro, C.A., Kogi, E., Opara, K.N. Infection pattern, case fatality rate and spread of Lassa virus in Nigeria. BMC Infect Dis. 2021;**21:** 149. https://doi.org/10.1186/s12879-021-05837-

[54] Knobel DL, Cleaveland S, Coleman PG. Re-evaluating the burden of rabies in Africa and Asia. Bull World Health Organ. 2005;83(5):360-368.

[55] Pieracci EG, Pearson CM, Wallace RM. Vital Signs: Trends in Human Rabies Deaths and Exposures - United States, 1938-2018. MMWR Morb Mortal Wkly Rep. 2019;68(23): 524-528. doi:10.15585/mmwr.mm6823e1

[56] Aréchiga Ceballos N, Karunaratna D, Aguilar Setién A. Control of canine rabies in developing countries: key features and animal welfare implications. Rev Sci Tech. 2014;33(1):311-21. doi: 10.20506/rst.33.1.2278. PMID: 25000804.

[57] Sabeta C, Ngoepe EC. Controlling dog rabies in Africa: successes, failures and prospects for the future. Rev Sci Tech. 2018;37(2):439-449. English. doi: 10.20506/rst.37.2.2813. PMID: 30747136.

[58] Cleaveland S, Thumbi SM, Sambo M, Lugelo A, Lushasi K, Hampson K, Lankester F. Proof of concept of mass dog vaccination for thecontrol and elimination of canine rabies. Rev Sci Tech. 2018;37(2):559-568. English. doi: 10.20506/rst.37.2.2824. PMID: 30747125.

[59] Gubler DJ. Human arbovirus infections worldwide. Ann N Y Acad Sci. 2001;951:13-24. doi: 10.1111/j.1749-6632.2001.tb02681.x. PMID: 11797771.

[60] Girard M, Nelson CB, Picot V, Gubler DJ. Arboviruses: A global public health threat. Vaccine. 2020 May 19;38(24):3989-3994. doi: 10.1016/j.vaccine.2020.04.011. Epub 2020 Apr 24. PMID: 32336601; PMCID: PMC7180381.

[61] Labeaud AD, Bashir F, King CH. Measuring the burden of arboviral diseases: the spectrum of morbidity and mortality from four prevalent infections. Popul Health Metr. 2011;10;9(1):1. doi: 10.1186/1478-7954-9-1. PMID: 21219615; PMCID: PMC3024945.

[62] Whitehorn J, Yacoub S. Global warming and arboviral infections. Clin

Med (Lond). 2019;19(2):149-152. doi:10.7861/clinmedicine.19-2-149

[63] Kading RC, Brault AC, Beckham JD. Global Perspectives on Arbovirus Outbreaks: A 2020 Snapshot. Trop Med Infect Dis. 2020;5(3):142. doi:10.3390/tropicalmed5030142

[64] Rawal G, Yadav S, Kumar R. Zika virus: An overview. J Family Med Prim Care. 2016;5(3):523-527. doi:10.4103/2249-4863.197256

[65] Zhou P. A. Pneumonia outbreak associated with a new coronavirus of probable bat origin. Nature. 2020;579:270-273. doi: 10.1038/s41586-020-2012-7.

[66] Verity R., Okell L.C., Dorigatti I., Winskill P., Whittaker C., Imai N., Cuomo-Dannenburg G., Thompson H., Walker P.G.T., Fu H., Dighe A., Griffin J.T., Baguelin M., Bhatia S., Boonyasiri A., Cori A., Cucunubá Z., FitzJohn R., Gaythorpe K., Green W., Hamlet A., Hinsley W., Laydon D., Nedjati-Gilani G., Riley S., van Elsland S., Volz E., Wang H., Wang Y., Xi X., Donnelly C.A., Ghani A.C., Ferguson N.M. Estimates of the severity of coronavirus disease 2019: a model-based analysis. Lancet Infect. Dis. 2020;S1473-3099(20):30243-7. doi: 10.1016/S1473-3099(20)30243-7. PMID: 32240634; PMCID: PMC7158570.

[67] World Health Organization. Mission summary: WHO Field Visit to Wuhan, China [Internet]. 2020. Available from: https://www.who.int/china/news/detail/22-01-2020-field-visit-wuhan-china-jan-2020 20-21 January

[68] Johns Hopkins Coronavirus Resource Center [Internet]. 2021. Available from: https://coronavirus.jhu.edu/.

[69] Urhan, A., Abeel, T. Emergence of novel SARS-CoV-2 variants in the Netherlands. Sci Rep. 2021;**11:** 6625. https://doi.org/10.1038/s41598-021-85363-7

[70] Awadasseid A, Wu Y, Tanaka Y, Zhang W. SARS-CoV-2 variants evolved during the early stage of the pandemic and effects of mutations on adaptation in Wuhan populations. Int J Biol Sci. 2021;17(1):97-106. doi:10.7150/ijbs.47827

[71] Happi, A.N., Ugwu, C.A. & Happi, C.T. Tracking the emergence of new SARS-CoV-2 variants in South Africa. Nat Med. 2021;**27:** 372-373.

[72] Gómez CE, Perdiguero B, Esteban M. Emerging SARS-CoV-2 Variants and Impact in Global Vaccination Programs against SARS-CoV-2/COVID-19. Vaccines (Basel). 2021;9(3):243. doi:10.3390/vaccines9030243

[73] Ajayi A O. The COVID-19 pandemic: critical issues and perspectives for infectious disease prevention in Africa, Infection Ecology & Epidemiology. 2020;10:1. DOI: 10.1080/20008686.2020.1798073

[74] Güner R, Hasanoğlu I, Aktaş F. COVID-19: Prevention and control measures in community. Turk J Med Sci. 2020;50(SI-1):571-577. doi:10.3906/sag-2004-146

[75] Patel A, Patel S, Fulzele P, Mohod S, Chhabra KG. Quarantine an effective mode for control of the spread of COVID19? A review. J Family Med Prim Care. 2020;9(8):3867-3871. doi:10.4103/jfmpc.jfmpc_785_20

[76] Bielecki M, Patel D, Hinkelbein J. Air travel and COVID-19 prevention in the pandemic and peri-pandemic period: A narrative review. Travel Med Infect Dis. 2021;39:101915. doi:10.1016/j.tmaid.2020.101915

[77] Sharun K, Tiwari R, Natesan S, Yatoo MI, Malik YS, Dhama K.

International travel during the COVID-19 pandemic: implications and risks associated with 'travel bubbles'. J Travel Med. 2020;27(8):taaa184. doi:10.1093/jtm/taaa184

[78] Donde OO, Atoni E, Muia AW, Yillia PT. COVID-19 pandemic: Water, sanitation and hygiene (WASH) as a critical control measure remains a major challenge in low-income countries. Water Res. 2021;191:116793. doi:10.1016/j.watres.2020.116793

[79] World Health Organisation. WHO lists two additional COVID-19 vaccines for emergency use and COVAX roll-out [Internet]. 2021. Available from:https://www.who.int/news/item/15-02-2021-who-lists-two-additional-covid-19-vaccines-for-emergency-use-and-covax-roll-out

[80] CDC. Different COVID-19 Vaccines[Internet]. 2021. Available from:https://www.cdc.gov/coronavirus/2019-ncov/vaccines/different-vaccines.html

[81] Jorwal P, Bharadwaj S, Jorwal P. One health approach and COVID-19: A perspective. J Family Med Prim Care. 2020;9(12):5888-5891. doi:10.4103/jfmpc.jfmpc_1058_20

[82] Mackenzie JS, Smith DW. COVID-19: a novel zoonotic disease caused by a coronavirus from China: what we know and what we don't. Microbiol Aust. 2020;MA20013. doi:10.1071/MA20013

[83] Aguirre AA, Catherina R, Frye H, Shelley L. Illicit Wildlife Trade, Wet Markets, and COVID-19: Preventing Future Pandemics. World Med Health Policy. 2020;10:1002/wmh3.348. doi:10.1002/wmh3.348

[84] Shereen MA, Khan S, Kazmi A, Bashir N, Siddique R. COVID-19 infection: Origin, transmission, and characteristics of human coronaviruses. J Adv Res. 2020;24:91-98. doi:10.1016/j.jare.2020.03.005

[85] Cui J, Han N, Streicker D. Evolutionary relationships between bat coronaviruses and their hosts. Emerg Infect Dis. 2007;13(10):1526-1532. doi:10.3201/eid1310.070448

[86] Neiderud CJ. How urbanization affects the epidemiology of emerging infectious diseases. Infect Ecol Epidemiol. 2015;5:27060. doi:10.3402/iee.v5.27060

[87] Arne Ruckert 1 & Kate Zinszer2 & Christina Zarowsky2 & Ronald Labonté1 & Hélène Carabin. What role for One Health in the COVID-19 pandemic? Canadian Journal of Public Health. 2020;111:641-644.

[88] Han D, Li R, Han Y, Zhang R, Li J. COVID-19: Insight into the asymptomatic SARS-COV-2 infection and transmission. Int J Biol Sci. 2020;16(15):2803-2811. doi:10.7150/ijbs.48991

[89] Carraturo F, Del Giudice C, Morelli M. Persistence of SARS-CoV-2 in the environment and COVID-19 transmission risk from environmental matrices and surfaces. Environ Pollut. 2020;265(Pt B):115010. doi:10.1016/j.envpol.2020.115010

[90] Eslami H, Jalili M. The role of environmental factors to transmission of SARS-CoV-2 (COVID-19). AMB Express. 2020;10(1):92. doi: 10.1186/s13568-020-01028-0. PMID: 32415548; PMCID: PMC7226715.

[91] OIE. One World, One Health Summary of the FAO/OIE/WHO[Internet]. 2009. Available from:https://www.oie.int/doc/ged/D6296.PDF

[92] European commision. A European One Health Action Plan against Antimicrobial Resistance (AMR) [Internet]. 2021. Available from:. https://ec.europa.eu/health/sites/health/files/antimicrobial_resistance/docs/amr_2017_action-plan.pdf.

[93] The FAO, OIE and WHO in Asia and the Pacific (Asia Pacific Tripartite) [Internet]. 2021. Available from:https://rr-asia.oie.int/wp-content/uploads/2020/03/one-health-leaflet.pdf.

[94] Murray J, Cohen AL. Infectious Disease Surveillance. International Encyclopedia of Public Health. 2017;222-229. doi:10.1016/B978-0-12-803678-5.00517-8

[95] Ibrahim NK. Epidemiologic surveillance for controlling Covid-19 pandemic: types, challenges and implications. J Infect Public Health. 2020;13(11):1630-1638. doi:10.1016/j.jiph.2020.07.019

[96] Luo H, Lie Y, Prinzen FW. Surveillance of COVID-19 in the General Population Using an Online Questionnaire: Report From 18,161 Respondents in China. JMIR Public Health Surveill. 2020;6(2):e18576. doi:10.2196/18576

[97] Al Huraimel K, Alhosani M, Kunhabdulla S, Stietiya MH. SARS-CoV-2 in the environment: Modes of transmission, early detection and potential role of pollutions. Sci Total Environ. 2020;744:140946. doi:10.1016/j.scitotenv.2020.140946.

[98] Kelly TR, Karesh WB, Johnson CK, et al. One Health proof of concept: Bringing a transdisciplinary approach to surveillance for zoonotic viruses at the human-wild animal interface. *Prev Vet Med*. 2017;137(Pt B):112-118. doi:10.1016/j.prevetmed.2016.11.023

[99] Rostal MK, Ross N, Machalaba C, Cordel C, Paweska JT, Karesh WB. Benefits of a one health approach: An example using Rift Valley fever. *One Health*. 2018;5:34-36. Published 2018 Jan 11. doi:10.1016/j.onehlt.2018.01.001

[100] Bordier M, Uea-Anuwong T, Binot A, Hendrikx P, Goutard FL. Characteristics of One Health surveillance systems: A systematic literature review. Prev Vet Med. 2020;181:104560. doi: 10.1016/j.prevetmed.2018.10.005. Epub 2018 Oct 13. PMID: 30528937.