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Message from the Editor-in-Chief

I welcome all our readers to this issue of the GET Journal of Biosecurity and One Health. In this issue, we are proud to present to our readers six new articles from our international and national contributors who have generously shared their research findings on various aspects of Biosecurity and One Health. The journal of Biosecurity and One Health is a journal devoted exclusively to the publication of high-quality research papers that covers transdisciplinary fields of Biosecurity and One Health. The journal aims to publish high quality varied article types such as Research papers, Reviews, Short Communications and Case studies.

This issue of the GET journal include papers on biosecurity policy and planning in Nigeria, public health risk assessment, modeling of Covid-19 cases in Nigeria; and papers on emerging infectious diseases such as Covid-19, Ebola and Monkey Pox. Also included in this issue is the communique of the 8th African Conference on One Health and Biosecurity.

In spite of our best efforts, due to the decision of our reviewers and the editorial board, we could not include some of the submitted manuscripts in the present issue. However, his should not discourage authors from sending their original research papers, case studies or short communications for publication in our journal in the future.

Finally, I thank our esteemed authors for submitting their original and quality manuscripts for publication in the GET journal, and to our reviewers and editorial board members, thank you for your hard work in ensuring the high quality of the GET journal is maintained. We hope everyone, from authors to reviewers, will continue to give their strong support to this journal.

Prof. Akin Abayomi
Editor-in-Chief
GET Journal of Biosecurity and One Health

ABOUT GET JOURNAL

GET Journal of Biosecurity and One Health is an international scholarly peer reviewed Open Access journal that aims to promote research in all the related fields of Biosecurity and One Health. The United Nations Food and Agriculture Organisation defines biosecurity in the context of a strategic and integrated approach that encompasses the policy, regulatory frameworks, instruments, and activities for analysing and managing relevant risks to human, animal and plant health, and associated risks to the environment. Biosecurity covers food safety, zoonoses, the introduction of animal and plant diseases and pests, the introduction and release of living modified organisms (LMOs) and their products (genetically modified organisms or GMOs), and the introduction and management of invasive alien species. The GET Journal of Biosecurity and One Health is devoted exclusively to the publication of high-quality research papers that covers multidisciplinary fields of Biosecurity and One Health. The journal aims to publish high quality varied article types such as Research, Reviews, Short Communications, Case Reports, Perspectives (Editorials), Clinical Images.

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EDITORIAL BOARD

Prof. Akin Abayomi is the Honourable Commissioner for Health, Lagos State, an experienced and versatile Medical Doctor who has served as a lecturer and practitioner in Africa as well as the West Indies and has written numerous research publications on Cancer, Diabetes and Sickle Cell Anaemia. He obtained an MBBS degree from the University of London, United Kingdom and a Master of Philosophy (M.Phil) in Ecology and Environmental Health Management from the University of Pretoria, South Africa. He was a Consultant Haematologist and Lecturer at the University of Zimbabwe Medical School and Harare Group of Teaching Hospitals, Zimbabwe, between 1994 and 1998. He was also Chief Physician at the Princess Marina Hospital, Gabarone, Botswana in 1998.

He is a Fellow of the Royal College of Physicians of Edinburgh (2010) and the Royal College of Pathologists of the United Kingdom (2013), He was the Consultant Haematologist, Faculty of Medicine & Research, Queen Elizabeth Hospital, University of West Indies, Bridgetown, Barbados from 1998-2006. He was a Bone Marrow Transplant Research Fellow at the University of Stellenbosch as well as a Consultant Clinical Haematologist, Constantiaberg Bone Marrow Transplant Unit, Tygerberg Academic Hospital, Cape Town, South Africa. He was Head of Division, Department of Pathology, Faculty of Medicine and Health Sciences, Stellenbosch University, Cape Town, South Africa. He has held various positions in the field of medicine including Consultant, Lagos State Biosecurity and Genomic Project, Lead Consultant to the West African Health Authority (WAHO), ECOWAS and President, Federation of South African Society of Pathology, Nigerian Institute of Medical Researcher, (NIMR) among others.

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Prof. Akin Osibogun is an experienced professor with a demonstrated history of working in the medical practice industry. He is skilled in Epidemiology, Management, Global Health, Healthcare Management, and Healthcare. He is a strong education professional with a FMCPH (National Postgraduate Medical College of Nigeria), FWACP (West African College of Physicians) focused on Health/Health Care Administration/Management, Health Care Financing from College of Medicine, University of Lagos; Columbia University, New York; University of Zagreb, Croatia.

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He is a member of various advisory committees in the fields of research, vaccination, and evidence-based policy in Africa and globally. Professor Wiysonge obtained an MD from the University of Yaoundé I Cameroon in 1995, an MPhil from the University of Cambridge UK in 2000, and a PhD from UCT in 2012.

Prof. Angela Chukwu has over fifteen years of teaching and research in Statistics with applications in the life sciences and Public Health. She is a proficient in classical Statistical methodologies including experience in the analysis of experimental data using parametric and nonparametric methods, sampling and sample size estimation, mathematical demography, survival analysis and probability. She is committed to mentoring and facilitating international partnerships on research for national development.

Prof. Sunday Omilabu is an internationally renowned virologist with over 30 years of experience in teaching and consultancy. He is an experienced professor with a demonstrated history of working in the medical practice industry. He is currently a Director at the Centre for Human and Zoonotic Virology (CHAZVY), College of Medicine University of Lagos Lagos University Teaching Hospital (LUTH).

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Prof. Abiodun A. Denloye is a professor in the Department of Zoology and Environmental Biology at Lagos State University, Lagos, Nigeria. He is specialized in Medical and Applied Entomology with strong passion for Biosafety and Biosecurity Risk (Biorisk) Management. His pioneering efforts contributed to the formation of the Nigeria Biological Safety Association (NiBSA) in 2010. He was the pioneer Secretary of NiBSA, former Vice President and now the President. He is a well grounded Biosafety and Biosecurity expert as an International Foundation for Biosafety Associations (IFBA) Certified Biorisk Management Professional, IFBA Certified Biosecurity Professional, and Certified Biorisk Management trainer with access to the Global Biorisk Management Curriculum (GBRMC) Library. Also, he is a certified Trainer and Shipper of Biological Samples, he is well versed in deploying the science and skills underpinning decision-making in respect of the biosafety of Genetically Modified Organisms (GMOs), having trained at different times at the International Centre for Genetic Engineering and Biotechnology (ICGEB), Trieste, Italy. He creates time to engage in birding, and enjoys reading writing, and travelling as his hobbies. His forte is service, creating platforms for people to express themselves and bringing up opportunities in place of despair. He is a Fellow of the Entomological Society of Nigeria (FESN), Fellow of the Nigerian Biological Safety Association (FNiBSA) and Fellow of the Society for Educational Administrators of Nigeria (FSEAN).

Dr. Kirk Douglas is a professional senior scientist recognized both regionally and internationally for impactful scientific research in the fields of microbiology, infectious diseases, biosecurity, virology and zoonoses. He has earned a Bachelor of Science (B.Sc.) degree in Microbiology (2001), a Master of Philosophy (M.Phil.) degree in Microbiology (2007) and a Doctor of Philosophy (Ph.D.) degree in Medical Microbiology (2020) from the University of the West Indies, Cave Hill, Barbados. In addition, he holds a Master of Business Administration (MBA) degree with Merit Honours (2019) from Warwick Business School (WBS), University of Warwick, United Kingdom. Dr. Douglas commenced his career as a summer student in the Virology Department at the Hospital for Sick Kids, Toronto, Canada (2001), then upon returning home to Barbados, he worked as a Veterinary Laboratory Technician at Veterinary Services Laboratory, Ministry of Agriculture, Barbados in 2001, before moving on to an international medical device manufacturer in Barbados from 2002 until 2019. In addition, he has led several initiatives to minimize product scrap and poor quality in intraocular (IOL) manufacturing processes resulting in significant corporate savings and increased profitability. His research in the fields of infectious diseases, biosecurity and virology started as an undergraduate at UWI Cave Hill involving a summer field research project on wild rats with Professor Paul Levett, which led to his first publication as a co-author, the first report of serological evidence of hantavirus infections amongst humans and rodents in both Barbados and the Caribbean (2002). He has authored multiple peer-reviewed scientific papers in the fields of microbiology, virology, biosecurity, infectious diseases and zoonoses which have received almost 100 citations.

Dr Sam Ujewe is an expert, scholar and researcher in Bioethics, Applied Ethics and Global Health Policy with specializations in: global health inequities & social justice, ethics & health policy, moral philosophy, health research ethics, health ethics, mental health ethics, international & cross-cultural bioethics, ethics of infectious diseases, public health ethics, and healthcare decision-making. He possesses a proven ability to develop research, secure funding and manage research projects and awards; and address practical health ethics and policy issues in the light of local and international ethics guidelines and regulations. His research outlook focuses on the intersection of health ethics and public policy, aiming to establish ethical reforms in local and international policies, regulations and guidelines with real-world impact, and benefiting historically disadvantaged populations and groups.

Prof. Dorcas Yole holds a PhD in Biology from the University of York, United Kingdom. Her field of specialization is Immunology and Parasitology. She is a Professor at the Technical University of Kenya (TUK). Currently she is the Director of School of Biological and Life Sciences. Previously she was the Director, Campus Outreach Programmes. Prof. Dorcas Yole is an Associate Research Scientist at the Institute of Primate Research. Before joining TU-K, she was a Senior Research Scientist at Institute of Primate Research (IPR), a biomedical research centre, where she served as the Chair of Parasitology Department and also Chair of the Institutional Scientific and Ethical Review Committee

She has been a reviewer for National Commission of Science, Technology and Innovation; and she is a reviewer for the National Research Fund. She is a Trainer of Trainers for World Health Organization (WHO) Good Laboratory Practice, and also a Trainer of Trainers for WHO Effective Project Planning and Evaluation for Biomedical Research. Her major areas of research are: Vaccine development, Drug and Molluscicide development for Schistosomiasis intervention. Prof Dorcas Yole is well published and has contributed to 8 World Health Organization Manuals/Handbooks.

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Dr. Afolabi Muhammed is a Global Health Scientist and UKRI Fellow at the London School of Hygiene & Tropical Medicine, UK. He obtained a medical degree from the University of Ibadan; a master's degree in Public Health from Obafemi Awolowo University, both in Nigeria and a PhD in Clinical Research from the London School of Hygiene & Tropical Medicine, UK. He is also a Fellow of West African College of Physicians and National Postgraduate College of Nigeria in Family Medicine, as well as the UK Higher Education Academy. Dr Afolabi has worked extensively on the clinical vaccine trials related to the control and prevention of Ebola, HIV and malaria across several African countries. He led the Ebola paediatric vaccine trials in Sierra Leone, findings of which contributed to the approval of the novel two-dose Ebola vaccine regimen (ZABDENO/MVABEA) by the European Medicines Agency. His other research interests include bioethics issues shaping the conduct of clinical trials in vulnerable populations. Dr Afolabi currently serves on several vaccines and immunisations committees including WHO Strategic Advisory Group of Experts (SAGE) Working Group on COVID-19 vaccines.

Dr. Babatunde A. Saka is a public health specialist with special attention on molecular epidemiology and prediction. Dr Saka graduated from the University of Ibadan with a Doctor of Veterinary Medicine degree where he also completed his Master of Science and PhD in Preventive Veterinary Medicine. He worked in the private sector until 2011 when he was appointed as a Research and Teaching Assistant for the Department of Veterinary Public Health and Preventive Medicine in the University of Ibadan. He served in this capacity as a clinical instructor, project design and monitoring as well as research assistant to the leading aquatic epidemiologist and toxicologist in the university for five years. Dr Saka presently works with the GET Consortium as the Project, and he currently serves as a technical consultant on Biosecurity and One Health as well as the Secretary of the Data Safety and Monitoring Board to Lagos State Ministry of Health. He is a member of the Lagos State Biosecurity and Biobanking Governing Council, Nigerian Biological Safety Association, Genetic Toxicologist Association of Nigeria, Nigerian Veterinary Medical Association and International Federation of Biosafety Associations. He is serving as the laboratories coordinator as well as the Deputy Incident Manager for Lagos State Covid Response. His hobbies include reading and watching movies especially epics.

Prof. Olanike Kudirat Adeyemo is a Nigerian professor of Veterinary Public Health and Preventive Medicine at University of Ibadan. She is the current Deputy Vice Chancellor (research, innovation and strategic partnership), the first person to attain the role at the University. Her research areas are on Aquatic toxicology, Aquatic veterinary medicine and fish food safety. She is the first female veterinarian to be inducted into the African Academy of Sciences and the Nigerian Academy of Science. Prof. Olanike's research is focused on Aquatic and Wildlife Epidemiology and Toxicology, Food Safety and Global Public Health. In 2011, Adeyemo was appointed an epidemiological and toxicological expert on the Joint FAO/WHO Expert Committee (JECFA).

In 2019, she was named a Fellow of The World Academy of Sciences for the advancement of science in developing countries, a Fellow at the Society for Environmental Toxicology and Pollution Mitigation. In 2016, she was named a Fellow of the Nigerian Academy of Science. In 2012, she was named a Fellow of the African Academy of Sciences. In 2010, she was named a Fellow of the African Scientific Institute (California, USA) and listed in ASI's 2011 edition of "Black Achievers in Science and Technology. In 2007 she was named a Fellow of the Eisenhower Fellowship Program and in 2002 she was named a Fellow of the Leadership for Environment and Development program in the UK.

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From HIV/AIDS through Ebola to COVID-19: The Unlearnt Lessons from Epidemics in Africa: A Personal Perspective

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ABSTRACT

Within the four decades spanning the 1980s to the year 2020 and counting, the continent of Africa has witnessed many deadly epidemics, notable among which are HIV/AIDS, Ebola, and COVID-19. For anyone in Africa who has lived through these epidemics and critically observed their impacts on the continent, it is evidently clear that the lessons that should be learned from them have not yet been fully learned. These unlearned lessons are related without being limited to the political, economic, healthcare, and ethical domains. The events accompanying COVID-19, globally and on the African continent, have underscored these lessons that must be learned, or else the continent has no future except as an entity of colonial and global exploitation. In this article, I propose to highlight and briefly discuss some of these lessons that should be learned, failing which we, Africans, need to be studied as a strange species of human beings, completely devoid of rational self-interest, inhabiting the most endowed continent on planet Earth, without being aware of it.

Keywords: Africa; Epidemics; Colonialism; Exploitation.

INTRODUCTION

The Global Emerging Pathogens Treatment Consortium (GET) was created in August 2014 at the height of the West African Ebola Epidemic (2013-2016). It was an attempt by indigenous African experts from several relevant specializations, in collaboration with interested foreign counterparts, to mount a holistic response to an emerging infectious disease (EID). They drew lessons from past epidemics where they had watched global foreign experts, foreign capital, and foreign interests take complete charge and command of the situation in their own interest and that of their own homes and locality [1]. A part of the work of the GET Consortium is captured in the following publication: *Socio-cultural Dimensions of Emerging Infectious Diseases in Africa: An Indigenous Response to Deadly Epidemics* [2].

New Existential Paradigm

To be effective, a locally grounded indigenous outfit against EIDs and Bio-insecurity in the African context must be accompanied by the adoption of a strong new existential paradigm involving mental decolonization, self-reliance, rejection of all forms of colonial hegemony and unjustified dependency. Only in this way can it hope to replace the current dominant paradigm based on colonial heritage, predatory exploitation, hegemony, and the attempt to impose a global

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mono-culture through scientific myths and pretentious philanthropy.

There is an urgent need for decolonizing our minds [3, 4] and even the concepts and terms that we are habituated to use unthinkingly or uncritically. We must abandon terms and concepts imposed without justification from our own point of view and perspective by colonialism, neo-colonialism, and the colonial legacy. These terms and concepts have had a long evolution and, basically, consider and look at Africa and Africans as a colonial asset and an economic resource to be guiltlessly wantonly exploited. Usage of such terms and expressions anchors us firmly within a paradigm from which we must radically break to be able to make any meaningful progress as an autonomous people and as a continent side by side with all others in the world. Many Africans unconsciously use and apply these concepts and terms without awareness of their historical evolution necessitated by the shifting political correctness of the different succeeding historical epochs.

Examples of Externally Coined Nomenclatures

Here are some examples of some of the terms and concepts in question, coined and imposed by colonialism, neo-colonialism, and the colonial legacy, beginning from the current and contemporary and going backwards in the history of their evolution: Emerging countries/Low- and middle-income countries (LMICs) ↘Least Developed Countries (LDCs)/Low-income countries (LICs) ↘ low resourced settings↘ poor resource countries↘ countries with limited resources↘ developing countries↘ underdeveloped countries↘ undeveloped countries↘ backward peoples ↘uncivilized peoples↘ uncultured peoples↘ barbarians↘ savages.

While some of us may hesitate to describe our own particular country as "a heavily indebted poor country", many of us are quite happy describing it as an "emerging country", forgetting that both descriptions are the coinage of external stakeholders imposed at different times to achieve their own aims and purposes. All these colonial/neocolonial terms and concepts seek to throw a single blanket over very diverse peoples and countries for the convenience of their external colonizers and exploiters. There is nothing wrong with accurately descriptive terms like north Africa, south Africa, east Africa, west Africa, Africa north/south of the Sahara, etc., if these are used purely descriptively, but every part and every country of Africa is diverse and significantly different in many respects from the others. The communalities of Africans are in the historical, socio-cultural, and metaphysico-religious domains, in shared ideas, beliefs, experiences and practices. But every African country or region ought to be called by its proper name as well as appreciated with all its specificities and not blanketed with others for the convenience of external stakeholders, let alone colonizers and exploiters.

The Environment, Biodiversity, and Artificiality

Biodiversity is a very important human and environmental value, and some of the emerging health risks the world is facing are directly related to the destruction of biodiversity and climatic systems through the increasing discovery, introduction, and use of artificial systems /devices, mono-cultures, highly profitable for their inventors but of dubious value for the long-term safety and security of human beings and the other creatures with which we share our planet.

The question about the origin of the COVID-19 virus has been lazily addressed by scientists and swept under the carpets in the interest of marketing experimental vaccines, but it is plausible to hypothesize that the virus originated from a laboratory rather than from the environment and is artificial rather than natural in its composition. If it is plausible to think, on the basis of traditional medicine in all parts of the world, that every dangerous virus that springs out of nature itself has an effective antidote in nature, the COVID-19 virus, given its resistance to existing treatments and experimental vaccines and its tendency to mutate into different new forms indefinitely, is likely of artificial rather than natural origin.

All recent deadly infectious epidemics, whether of natural or artificial origin, have been present on the African continent but so far failed to wipe out its whole population in the way that prior informed 'objective' calculations would indicate, given general poverty, dangerous habits/practices, ignorance, unawareness, and lack of modern medical facilities [4]. The resilience of African populations against epidemics and pandemics is likely due to **their** biodiversity, nutritional varieties, and living relatively close to nature, far from artificiality.

Greatest Unlearned Lesson

Perhaps, the greatest unlearned lesson is that the pandemics we have experienced in recent times and maybe expecting in the future are likely the resultant consequence of the artificial global culture (an aspect of the exo-somatic evolution), epitomized in artificial intelligence and machine learning/teaching, the continuous banishment of nature by technology, that the world has witnessed increasingly since the Western Industrial Revolution. Much of the African continent is relatively still close to nature and undestroyed by technologies, and this should at least be

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maintained. Moreover, in the industrialized Western world, Exo-somatic evolution and artificiality have clearly reached their logical limits and insisting on pushing them any further will likely push human life over an evolutionary precipice. Reversing this trend is more important than the current obsession with manufacturing vaccines, mass vaccinating the global populations, let alone assuring equitable access to vaccines for any of our epidemics or pandemics. There is a need for a counter-revolution to the exaggerated industrial and technological revolutions that should start in Africa!

CONCLUSION

As a continent, Africa has remarkable biodiversity on account of which or in spite of which it has borne the heaviest burdens of the deadly epidemics and pandemics of the past several decades under the controlling guidance of foreign interests, both philanthropic and exploitative. The unlearned lessons that must be learned from this situation have to do with genuinely decolonizing the continent and freeing it from its colonial legacy/hegemony to assume its destiny in a self-reliant and autonomous manner. In accomplishing this task, human, non-human animal, and plant biodiversity, naturalness, and techno-cautiousness shall be some of the most important assets. The GET Consortium seems in a very good position to contribute to the revolution with its ONE HEALTH policy that conceives of health, biosafety and biosecurity in holistic terms, beginning from the environment through plants and animals to human beings.

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Re-Emergence of Monkeypox Amidst COVID-19 Pandemic in Africa: What is the Fate of the African Healthcare System?

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ABSTRACT

The continuous rise in the number of monkeypox cases amidst the ongoing COVID-19 pandemic in Africa calls for concern, especially regarding its possible impact on the healthcare system. The current state of the healthcare system contributes substantially to the limitation of COVID-19 elimination in the region, which shows the poor state of the system. The re-emergence of the monkeypox virus amidst the pandemic means that the system must be strengthened to provide quality healthcare delivery for Africans. Therefore, it is high time that African health policymakers and governments begin to make decisions, decisions that will determine the fate of the African healthcare system and, consequently, the lives of people living in Africa in the ongoing event of COVID-19 and monkeypox.

Keywords: COVID-19; Monkeypox; Africa; Healthcare System.

INTRODUCTION

Right before the pandemic, the healthcare system in Africa is not a priority [1]. The pandemic revealed how dilapidated the healthcare system and health infrastructures in most African countries are [2]. More than 250,000 people have lost their lives to the event of COVID-19 pandemic in Africa. This, again, among many other things, shows the fragility of the healthcare system and its resuscitative power amidst infectious burdens [2]. The impacts of the COVID-19 pandemic are felt all over the world. Its effects are not limited to the apparent socioeconomic impact but also cut across the global healthcare systems leading to the advancement of the already existing health inequity [3].

In July 2022, the World Health Organization (WHO) declared the monkeypox outbreak a global emergency of international concern [4]. As of 17th August 2022, 37,736 laboratory-confirmed cases of monkeypox, 179 suspected cases, and 12 fatalities have been recorded in all the WHO six regions. African countries bear most of the disease burden and casualties [5].

In this paper, we are evaluating the impacts of the re-emergence of monkeypox amidst the ongoing COVID-19 pandemic in Africa on its healthcare system and provide recommendations to improve healthcare delivery amidst the disease burden.

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Current COVID-19 Elimination Approaches in Africa

Several pharmaceutical and non-pharmaceutical interventions (NPIs) have been used worldwide to contain the COVID-19 viral scourge and are still in use in Africa. The non-pharmaceutical means comprising general hygiene, such as frequent washing of hands, use of hand sanitizers, wearing of nose masks, physical distancing, self-isolation, quarantine of symptomatic individuals, and limited social engagements, are still encouraged [6,7]. Similarly, attendants in public gatherings are regulated, and workers at certain levels and grades are encouraged to work from their homes [6].

Pharmaceutical intervention includes the use of drugs and vaccines. The COVAX vaccine was the first dose of Vaccine rollout in Africa, with a percentage distribution of 61.3%. Others which came in are BILATERAL with 27.5% and AVAX with 11.2% [8]. Despite the growing public awareness of the need for vaccination and emerging more virulent variants, Africa is currently undersupplied with vaccines. In January 2022, merely 10% of Africa's population had been vaccinated. Furthermore, as of May 2022, only about 169 million people had completed vaccination [9]. So, more vaccine distribution and administration, including booster doses, are advocated in Africa [10].

Elimination of COVID-19 is progressing effectively in Africa as the number of casualties has drastically reduced [10]; however, the efforts are not without confrontations. A poor surveillance system to monitor the spread and evolution of COVID-19 in many parts of Africa and pre-existing health conditions in various classes of individuals interfere with treatment and thereby sabotage the disease elimination effort [11]. Also, the poor healthcare systems in Africa contribute substantially to the limitation of COVID-19 elimination in the region. Most COVID-19 mortality cases were related to Africa's economic status and, invariably, its healthcare facilities [11]. The vulnerability and fragility of the healthcare systems in Africa have become visible amidst the pandemic, considering the burden and the transmission rate of COVID-19 cases in the continent. The system lacks the capacity to contain the outbreak, has insufficient testing kits, and is grossly underfunded [12].

The Current Burden of Monkeypox in Africa

The first human case of monkeypox was detected in the Democratic Republic of Congo in 1970. Ever since then, the disease has become endemic in 11 African countries [13]. In May 2022, the re-emergence of the disease surfaced as more cases of the virus were recorded in Europe and North America. Most cases were from people with travel histories from endemic countries, and some were identified with sexual activities [14]. Since the outbreak, the Democratic Republic of Congo, Nigeria, and Ghana have been the most affected African countries. Some West and Central African countries like the Central African Republic, Cameroon, Gabon, Liberia, Sierra Leone, and Ivory Coast are also affected [13]. There are two major clades of monkeypox. One is the West African clade, which is less transmissible with a case-fatality rate (CFR) of about 3-6%. The second is the Central Africa clade, which is more transmissible and with a higher case fatality of about 10% [13]. Cameroon is the only country reporting the cases of both clades [13].

Since January 2022, over 3,500 cases of monkeypox have been recorded in Africa, with 107 (CFR of 3%) mortality cases [15]. Nigeria has recorded 241 cases in 34 states and 6 death cases [15]. In the Democratic Republic of Congo, the country has recorded over 160 confirmed cases and 93 deaths in 2022 alone. South Africa, Morocco, the Republic of the Congo, and Liberia have no death records but confirmed cases of 5, 3, 3, and 2, respectively [15,16]. As of September 2022, Ghana has 56 total confirmed cases and 3 death. The Central African Republic, in 2022, also has 8 confirmed cases and has reported 2 mortality cases [16].

The Fate of the African Healthcare System

Despite its first appearance many decades ago, the monkeypox virus has yet to be eradicated. Monkeypox virus has been shown to share some similarities with the smallpox virus, including belonging to the same family of orthopoxviruses. Smallpox was eradicated after several vaccination campaigns globally —the WHO identifies the smallpox vaccine to be 85% effective against the monkeypox virus [17]. The COVID-19 pandemic caught the African continent, among other regions, by surprise. Some sectors in various countries have yet to recover from this outbreak.

The African healthcare system is seen as fragile and has been heavily hit by the appearance of the novel SARS-CoV-2 disease, which ravaged the world. The poor healthcare system has been further exacerbated by the emergence of the COVID-19 pandemic [18] and the re-emergence of the monkeypox virus. This further emphasizes why no stone should be left unturned toward upgrading and overhauling the sub-par healthcare systems being run by African countries. Aside from the lack of enough facilities and infrastructures to respond to emergencies,

strategic plans, implementation, and monitoring, the risk management measures are not sufficiently enforced. Diseases will spread under uncontrolled movement to and from a nation during an ongoing pandemic or epidemic unless a way is found to control movements, especially from a highly affected region. Although most of the monkeypox cases in Africa have emanated from Nigeria, Ghana, and the Democratic Republic of Congo [19], the threat this has on the African region is not insignificant.

The fate of the African healthcare system will only be promising should all multisectoral approaches, partnerships, and recommendations by the WHO be swiftly adhered to. Infrastructures for vaccine production, quick testing, surveillance, and equitable access to interventions must be adequately set up. COVID-19 vaccination efforts in some African countries have been promising, as Mauritius, Seychelles, and Rwanda have surpassed the complete vaccination of 70% of their population; however, just 18.5% of the African population have received complete vaccination of the COVID-19 vaccine as of 31st July 2022 [20]. On the other hand, vaccination against the monkeypox virus has not begun in Africa despite recording over 580 confirmed virus cases across 11 African countries [19]. Eradicating re-emerging disease outbreaks may not be possible if serious efforts are not channelled equitably to underserved regions like Africa - a region known for its poor healthcare delivery and response. Central and West Africa have been experiencing monkeypox outbreaks. However, there have not been any vaccination efforts focused on these areas.

Beyond the re-emergence of the monkeypox virus, the preparedness level of every African country against future pandemics should be significantly strengthened [2]. The improvements so far going forward have been so little. Africa will continue to experience disease outbreaks [18] as expected or unplanned, and it is only for the best that the region is at least well prepared to respond. There is a need for a will for capacity and the capability to contain future pandemics in Africa. These can only be attained by strengthening the healthcare systems in preparedness and response to sudden health challenges such as pandemics and epidemics. Africa must stop being the last region to access improved care, vaccine, and quality healthcare delivery.

The monkeypox virus is not as deadly and spreads less quickly than the coronavirus; however, responses against this virus should be coordinated and monitored. The state of the African healthcare system needs adequate funding, support, and a multisectoral approach. Hence, efforts must be coordinated to ensure that these supports and interventions are evenly distributed and timely. Good governance and political will are jointly needed for a better healthcare system in the African region. To reduce the health burden, promote vaccine equity, increase preparedness and eradicate unprecedented outbreaks through better responses. These give a better fate and promising state to the underlying woes and rising health challenges currently faced in the continent.

CONCLUSION

The fate of the African healthcare system lies majorly on the Africans, their health policymakers and the government. The event of COVID-19 and the recent re-emergence of the monkeypox virus though pose a threat to the poor healthcare system; however, our collective, rapid and strategic responses to this threat would determine the fate of our healthcare system. We can mobilize resources to upgrade the system to improve healthcare delivery, prioritize the healthcare system and make informed health decisions that safeguard the citizens against COVID-19, monkeypox, and future pandemic, or choose to give no priority to the health system. Whatever we choose will tell what becomes of the healthcare system and, consequently, the quality of our lives in Africa.

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COVID-19 Vaccine: A Right or Privilege for Nigerian Prison Inmates

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ABSTRACT

Citizens are members of a particular country who, because of birth, registration, or application, are entitled to enjoy certain basic rights and privileges. Discrimination by reason of age, ethnicity, religious background, or liberty of any person should not be entertained at any level; hence, every citizen is to be treated equally in terms of the enjoyment of basic rights and privileges. The most important fundamental right to be enjoyed by a citizen is the right to life, mainly because a person needs to be alive to enjoy other rights and privileges as contained in the constitution. However, the right to life is not limited to the right not to take a person's life, and rather it expands to the right to enjoy unhindered access to resources that will ensure good physical and mental well-being. Unfortunately, some countries are unable to ensure the enjoyment of these rights by all their citizens. In a bid to manage the limited resources, some persons are being discriminated against, one of which is inmates who are incarcerated and serving an imprisonment term. This act of discrimination was evidenced in 2020 during the COVID-19 pandemic when immediate preventive measures were taken across the country to curb the spread of the virus. It became a cause of concern whether inmates in correctional centres were equally carried along on these measures. This article will discuss the right to life of prisoners in Nigerian correctional centres as it relates to their unhindered right to health. Using the doctrinal and empirical method, this paper will identify the local and international instruments that provide for the enjoyment of the right to health of inmates, and particularly whether inmates were discriminated against in the exercise of the various preventive measures taken during the pandemic.

Keywords: COVID-19; Vaccine; Right; Prison inmates; Nigeria.

INTRODUCTION

A prisoner is any person who is kept in custody because of being convicted and sentenced as punishment for the commission of an offence. Accordingly, a prisoner is a person who has been deprived of his right to personal liberty because of being in confinement for as long as his term requires or, in the case of a death sentence, until his life is lawfully taken [1]. The question that arises on the enjoyment of fundamental rights of inmates is usually whether, by reason of their confinement, they are still entitled to the enjoyment of their rights or they are to be stripped of those rights. The analogy will be that for the time spent in prison, they are to be treated as offenders who cannot enjoy the rights and privileges entitled to the rest of the citizens in the outside community. However, legal instruments at the international, regional, and local levels [2] have corrected this notion by constantly releasing laws, rules, and manuals to the effect that prisoners are not to be deprived of their fundamental rights because of

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their existence as humans first before being incarcerated.

A prisoner is entitled to his right to life, right to private and family life, right to dignity of the human person, right to be free from any form of discrimination, right to food, a clean and conducive environment, and other fundamental rights as if he were not in custody. Prisoners are also regarded as one of the vulnerable groups in society; vulnerable not necessarily in terms of exposure to harm but more about the limitation to give voluntary informed consent or make certain personal requests or choices. For instance, while in custody, a prisoner cannot request special medical care or special diet except where medically recommended, which even in some cases will not be respected due to lack of funds or adequate facilities. Accordingly, the presence of this vulnerability forms the basis of the obligation of the government to pay closer attention to the general welfare of prisoners in custody. In the case of *Holomiov v. The Republic of Moldov*a [3], the applicant alleged that he was detained in inhuman and degrading conditions and had not been provided with proper medical care. According to the medical certificates, he suffered from several serious illnesses, including chronic hepatitis, second-degree hydronephrosis, chronic bilateral pyelonephritis with functional impairment of the right kidney, hydronephrosis of the right kidney with functional impairment, and chronic renal failure. The court held that there had been a violation of Article 3 of the Convention Against Torture and Other Cruel, Inhuman or Degrading Treatment or Punishment. The core issue was not the lack of medical care in general but rather the lack of adequate medical care for the applicant's particular conditions, as disclosed. The court further observed, in particular, that, while suffering from serious kidney diseases entailing serious risks to his health, the applicant had been detained for almost four years without appropriate medical care; it, therefore, found that the applicant's suffering has constituted inhuman and degrading treatment [4].

The distasteful condition of prisons in most parts of the world equally puts prisoners in a disadvantaged position concerning maintaining good physical and mental well-being. Prisons are known for overpopulation, unhygienic environment, unventilated and small sleeping areas, lack of standard medical facilities to provide general and specific health care services and lack of nutritional diet. The Nigerian Correctional Service (NCS) data on the Summary of Inmate Population by Convict and Persons Awaiting Trial as of October 4th, 2021, revealed that the facilities hold 37% more inmates than it is designed to [5]. This is not a problem peculiar to Nigeria alone. In Haiti, the Philippines, and Congo, overcrowding levels remain high and are growing to chronic levels, with occupancy levels as high as 450 to 600%. In the context of the global pandemic, overcrowding has exacerbated the overall poor detention conditions in many countries, especially access to healthcare, proper hygiene, and appropriate nutrition, placing the lives of people in prison at particular risk [6]. The challenges facing the prison administration cannot be exhausted. This, however, should not deter the government and other stakeholders from putting in measures to address them. Although the above-listed challenges are all important and need to be addressed urgently, this paper has chosen to address the right of prisoners to enjoy the protection and promotion of a good healthcare system; the COVID-19 vaccination exercise will be treated as a case study.

COVID-19 PANDEMIC

The first case of coronavirus was reported on the 31st of December 2019, when mysterious cases of pneumonia were reported in Wuhan, a city in China in January 7, 2020, the causative agent was identified as a new coronavirus (2019-nCoV), and that disease was later named covid-19 by the World Health Organization [7]. Soon after, a large number of people were infected, and death cases were recorded [8]. The virus began to spread across China and other parts of the world. The spread was so rapid that most countries had to take drastic steps to protect their borders; lockdown orders and closing of country borders were announced. Countries like the USA, Egypt, India, and so on were hit seriously by this virus so much that the reported death cases increased daily. Accordingly, the World Health Organization [9] and other health-related organisations were at work trying to identify the best means to manage the spread of the outbreak. In addition to global and national lockdowns, other measures such as the use of nose masks, hand sanitisers, social distancing, online classes for students at all levels, and remote working for both public and private institutions were introduced, all in a bid to reduce physical contact which was a sure means of spreading the disease. In further response to the pandemic and its drastic effect, individuals and organisations in the international community invested immense financial and human resources to develop a safe and effective vaccine within an unprecedented period. The effect of these vaccine variants is to significantly reduce the transmission of the COVID-19 disease and mortality rate of

affected persons in addition to the other preventive measures [10].

These attempts, both at the International and National levels, are laudable because the virus came suddenly and affected all aspects of human life, particularly the health sector. To a considerable extent now, things are being managed even though the virus is still very much present and seems to be evolving in bigger forms as the reports of stronger variants are being released periodically [11]. Nigeria equally abided by international standards by enforcing a lockdown at the beginning [12] and then reducing it to other preventive and safety measures of social distancing, compulsory use of hand sanitisers and nose masks, virtual classes, remote working, and the latest which is the vaccination being administered in health centers all around the country.

During all of these, it became important to re-evaluate the health system being the most affected during the pandemic. For other developed countries, although they struggled hard at the beginning [13], it was easy for them to find ways to manage because of their technological advancement and available financial resources. Countries like the US, UK, and China are prime examples. The same cannot be reported in Nigeria, where the health system before the pandemic was struggling to be at its best due to several reasons. Citizens in Nigeria are not exactly enjoying a good health system; this then begs the question of the fate of vulnerable people (including inmates) before and, most importantly, during the pandemic. If it is difficult for free citizens to have access to good healthcare facilities or affordable healthcare, how do we guarantee that these vulnerable persons are not left to their fate and are last on the line when it comes to access to good health care; and in this case, the protection from covid-19?

FUNDAMENTAL RIGHTS OF PRISONERS

Although deprived of their right to personal liberty, several Human Right Laws [14] have provided that a prisoner who is observing a prison sentence does not completely lose his rights as a human being; in other words, such prisoner enjoys certain basic rights despite being confined to prison. These rights, particularly those promoting the health of inmates, will be discussed with a focus on the provisions of local and international instruments with emphasis on the Constitution of the Federal Republic of Nigeria since this paper is focused on Nigeria as a case study.

The United Nations Charter [15] is an instrument that strongly preaches the enjoyment of fundamental human rights by all humans equal rights without discrimination. The Charter states one of the principal aims of the United Nations as follows; "*to reaffirm faith in fundamental human rights, in the dignity and worth of the human person, in the equal rights of men and women and nations, large and small* [16] …." Furthermore, it states one of its purposes as: *"achieving international cooperation in solving international problems of an economic, social, cultural or humanitarian, and in promoting and encouraging respect for human rights and fundamental freedoms for all without distinction as to race, sex, language or religion."* These provisions are to the effect that every person without any form of discrimination, whether because of age, religion, race, sex, or condition, is entitled to enjoy the fundamental rights attributed to being human.

The International Covenant on Economic, Social, and Cultural Right (ICESCR) and the International Covenant on Civil and Political Rights (ICCPR) equally support the equal enjoyment of fundamental rights by all humans. With regard to the right to health, which is the subject matter of this paper, both covenants promote the enjoyment of the highest attainable physical and mental well-being for every human [17] without any form of discrimination against persons in detention. In doing this, States must ensure the protection, treatment, and control of any epidemic, endemic, or disease by providing adequate medical facilities that can address the health issue [18]. The ICCPR also provides for basic rights that should be enjoyed by every human person, such as the right to life to be enjoyed by everyone and protected by law such that no one is arbitrarily deprived of his life [19]; the right not to be subjected to torture, inhumane or degrading treatment or punishment [20]; the right of prisoners although deprived of their liberty to nevertheless be treated with humanity and respect to their dignity as human persons [21]. Without a doubt, these rights are equally applicable to inmates by virtue of their being human beings, notwithstanding their confinement.

The United Nations Standard Minimum Rules for the Treatment of Prisoners (the Nelson Mandela Rules) [22] is another instrument that serves as a guideline for countries to enable them to operate their prison system using an acceptable minimum standard necessary to protect the lives of inmates in prison custody. The Rules posit that the State is under an obligation to provide a safe and

conducive environment for inmates to ensure the enjoyment of their fundamental human rights even while in custody. One major proposition is the need for the State to provide adequate medical attention to the inmates, among other services. The Rules provide specific measures to ensure the provision of standard minimum medical services to protect the physical and mental well-being of inmates, some of which include the provision of a healthcare centre in the prisons having basic facilities to provide medical services when they arise, the employment, training, and retraining of professional health care provides who are professionally and psychologically fit to attend to the physical and mental needs of inmates putting into consideration their peculiarity, proper documentation of prisoners medical file containing the previous and current health status to enable adequate treatment when the need arises, provision of special accommodation for pregnant and nursing women in custody [23].

The Universal Declaration on Human Rights (UDHR) [24], like other human rights instruments, generally recognises the promotion of the inherent dignity of the human person and the equal and inalienable rights of all human beings without any discrimination. With regard to the health of the human person, the UDHR provides for the need to protect the right to life and security [25] and the prohibition of inhuman or degrading treatment of anyone [26]. These rights form an umbrella provision for the right to health of the human person, including inmates while being incarcerated, whether free or in custody; the right to life of everyone matters, and no one should be treated in an inhuman or degrading manner which might in any way affect their health. This indirectly safeguards the physical and mental well-being, i.e., the right to health of every human, inmates inclusive.

The Convention against Torture and Other Cruel, Inhuman, Or Degrading Treatment or Punishment [27] makes general provisions for the protection of every human against torture and any form of cruel, inhuman, or degrading treatment or punishment. Like the provisions of the International Covenant on Civil and Political Rights and the Universal Declaration of Human Rights, every human should be treated equally with dignity and should not be subjected to any degrading treatment. Unfortunately, the reality in most prisons is that inmates are usually tortured and treated in inhumane manners, which eventually leads to injuries, sickness, and much worse untimely deaths for the unfortunate ones; it almost seems as though it is a norm in the prisons.

The American Convention on Human Rights [28], in its Article 4, provides for the protection of the right to life of every person regardless of their condition, except where such a person is being sentenced to death by a competent court for an established crime. Article 5 [29] also specifically provides for the enjoyment of the right to humane treatment; such that every person is expected to be treated with physical, mental, and moral integrity and respect; and no one should be subjected to cruel, inhuman, or degrading treatment or punishment even where they are being deprived of their liberty. This summarily makes provision for the protection of the mental and physical well-being of prisoners.

The European Convention on Human Rights [30], like other conventions, does not expressly provide for the right to health of inmates, but it, however, supports the right to life and the need to treat humans with dignity. Article 2 provides for the right to life of every person to be protected by law and should not be arbitrarily taken except by a sentence of a court following the conviction of a crime. Article 3, in addition, prohibits subjecting anyone to torture or inhumane or degrading treatment or punishment.

The International Committee of the Red Cross (ICRC), as part of its humanitarian mandate, conducts visits to places of detention to monitor the conditions of detention and ascertain the treatment of prisoners concerning the international humanitarian law (IHL). The ICRC created a manual that serves as a set of standards and guidance on how detainees are to be treated while in custody and provides basic provisions that should be included in national laws, regulations, and policies necessary to guide the State and prison authorities on how to manage the prison facilities [31].

The provisions of the **African Charter on Human and People's Rights** [32] guarantee that the rights established under the Charter are to be extended and enjoyed by every category of persons, including prisoners, detainees, and other persons deprived of their liberty [33]. By this resolution, prisoners are equally entitled to enjoy the basic rights of every human as provided under the Charter, which include but are not limited to the right to life, the right against inhumane or degrading treatment, the right to food, the right to a good standard of physical and mental well-being like their counterpart in the outside community.

Their incarceration should not deny them the enjoyment of their rights as humans. This includes all rights provided under the Charter asides from the right to personal liberty.

The Constitution of the Federal Republic of Nigeria (as amended) [34] in Chapter IV provides for the fundamental human rights to be enjoyed by every citizen of Nigeria; without any form of discrimination, these rights are equally applicable to inmates in custody. The enshrined rights include:

- Right to Life [35]
- Right to dignity of the human person [36]
- Right to personal liberty [37]
- Right to a fair hearing [38]
- Right to private arid family life [39]
- Right to freedom of thought, conscience, and religion [40]
- Right to freedom of expression and the press [41]
- Right to peaceful assembly and association [42]
- Right to freedom of movement [43]
- Right to freedom from discrimination [44]
- Right to acquire and own immovable property anywhere in Nigeria [45]

It is important to note that inmates are not to be discriminated against based on their condition for the enjoyment of these rights except for the right to personal liberty and freedom of movement, as well as the right to private and family life. The constitution guarantees the right to life of inmates such that the State is obliged to ensure that they are in good condition while in custody and avoid any act or omission that might lead to their sudden death. In addition, the constitution guarantees the right to the dignity of a human person. Accordingly, inmates are to be treated with respect and regard for their inherent dignity as humans and are not to be subjected to inhumane treatment or punishment. These provisions indirectly promote the right to health of inmates in custody, as it guarantees the physical, mental, and moral well-being of inmates.

The constitution is the grundnorm and the fundamental law of the land, and it is evident that the provisions, particularly those relating to the fundamental rights of the citizens of Nigeria, are backed by international instruments recommended by international bodies, some of which Nigeria is a member of. It then flows that inmates, although in custody, are nevertheless entitled to the enjoyment of these rights. To guarantee their right to life, their right to health must be protected; that is, they must have access to a good healthcare system and healthcare personnel, and they should take priority in terms of any national health challenges that require immediate attention; this is due to their obvious disadvantaged position of being in an unpleasant environment.

The Nigerian Correctional Services Act [48], which was signed into law on the 14th of August 2019 to repeal the Nigerian Prisons Act [49], also contains relevant provisions for the protection of the right to health of inmates. For example, Section 15 (1) of the new law asserts the right of Prison inmates to the dignity of their person by asserting that "inmates shall not be held in slavery or servitude, and labour carried out by inmates shall not be afflictive or for the personal benefits of any correctional officer. Another major provision is the introduction of alternative correctional methods for offenders to reduce the overcrowding challenge in correctional facilities [50]. This provision will to a large extent, address the issue of overcrowding in the facilities and turn, reduce the possible health challenges. Other relevant sections include the provisions of a safe, secure and humane custody for the inmates [51], proper documentation of the health status of an inmate upon admission to ascertain the psychological and mental health status [52] of such inmate and determine whether or not he is eligible to be admitted in such facility or he should be transferred outrightly to a special center [54], prevention of torture, inhumane and degrading treatments against inmates, sexual and non-sexual violence, bullying, punishment of offenders and protection of victims of any reported case [54], prohibition of treatment of inmates under any slavery or servitude or any form of illegal hard labour [55], transfer of inmates in special cases of outbreak of diseases that might escalate as a result of overcrowding [56], continuation of treatment for a person who has completed his sentence but is still required to receive treatment for an existing ailment [57], and transfer of seriously ill inmates to a specialist hospital in order to save the life of such inmate and protect the other inmates and staff [58]. During the various stages of COVID-19, many countries responded

differently to measures to contain the virus concerning inmates. In the US, the Federal Bureau of Prisons and the different states instituted measures that include the early release of inmates, home confinement, and the release of incarcerated inmates at serious risk of contracting the virus [59]. In Indonesia, the government has released at least 36,500 prisoners, but as of April 14, the country still had 260,000 inmates, almost double the 132,000 total capacity [60]. In the United Kingdom, where COVID-19 cases have been identified in the majority of prisons, Justice Ministry authorities announced in early April that up to 4,000 prisoners would be eligible for release, but only 57 had been released by May 12 [61]. In Australia, New South Wales introduced emergency legislation in late March enabling the government to release prisoners, but as of May 18, no prisoners had been released [62]. In Turkey, a law authorising the release of up to 90,000 prisoners was limited to convicted offenders, arbitrarily excluding a high number of prisoners in pretrial detention or without finalised convictions [63]. In India, where approximately 67 percent of detainees are awaiting or undergoing trial, a high-level committee authorised the release of up to half of all detainees in the State of Maharashtra, but a requirement to post bail will prevent many from securing release [64]. Nigeria also took measures to contain the virus at various stages. As of May 2020, Nigeria had released 3,571 comprising convicts and awaiting trial inmates who meet certain criteria due to COVID concerns [65]. It is relevant to note that 70 per cent of inmates in Nigerian Prisons are awaiting trial.

Conclusively, the international, regional, and local laws all make relevant provisions for the protection of the right to health of inmates while in custody. While some of the provisions provide general protection on the right to life of inmates, which may indirectly be achieved by ensuring that the physical and mental health of the inmates is properly protected, other provisions are direct to the provisions of standard health care services in the form of health care centers, health care practitioners, conducive and healthy environment, swift and adequate medical treatment of inmates and transfer of inmates who are not fit to be in the custodial center due to lack of efficient health care facilities. These provisions, if properly implemented, will achieve the objective of complying with international standards and respecting international humanitarian laws.

ACCESS TO VACCINES

According to the World Health Organization (WHO), the use of the vaccine is critical in reducing the risks of getting a disease by working with the body's natural defenses to build protection, as well as control the infectious-diseases outbreak [66]. Several vaccines have been introduced to control various diseases, such as polio, measles, cholera, hepatitis B, Influenza, covid-19, to mention a few. Despite the remarkable effect of vaccines in controlling further outbreaks of diseases, millions of people, for several reasons, have insufficient access to these vaccines [67], thereby affecting the whole essence of the vaccines in the first place. Equitable access to vaccines is particularly important as various international, regional, and local laws have preached the enjoyment of fundamental human rights of every human, which includes their right to access good health and basic medical services, under which receiving vaccines may be classified. No form of discrimination should be entertained during the availability, accessibility, acceptability, and affordability of health products of assured quality, including receiving vaccines. Except because of age, where certain vaccines are for children of a certain age, and others are for adults of a particular age, discrimination should not be made by religion, sex, freedom, or other conditions that are not justifiable.

The report compiled by the Director-General of the WHO on the "Access to Medicines and Vaccines" [68] clearly analysed the challenges faced in the accessibility of medicines, vaccines, and other health products as a global concern and the importance of addressing it to achieve sustainable development goals, particularly as it relates to health. The report identified certain factors hindering the equal accessibility of medicines and vaccines globally, such as inadequate financing of health products, high prices of health products, lack of good governance, corruption, fraud, and lack of adequate health professionals that may be useful in sensitising citizens of certain drugs and vaccines hence encouraging or increasing the interest to access them, to mention a few. This concern, as reported by the WHO, trickles down to those at the lower end of the ladder, for example, prison inmates, who will have to face these challenges just like the larger society regarding the inadequacy of vaccines.

Furthermore, having established in the above international, regional, and local laws that everyone has a fundamental right to life, out of which the right to health must be protected, it is safe to conclude that every reasonable measure that is required to sustain the good health of a person should equally be made available with no form of discrimination. Access to medicines,

vaccines, medical tests, and screening, where necessary, which will ensure a person's right to good physical and mental well-being is to be enjoyed by every person who, because of being human, is under the protection of the government to guarantee their fundamental rights.

With direct reference to inmates, it is no longer news that the incarceration of inmates does not deprive them of their fundamental human rights, which include their general right to life and specific access to good healthcare services. This implies that inmates are eligible to be treated equally with other members of society concerning preventive and curative measures to ensure good mental and physical health. The administration of vaccines on citizens should not exclude the inmates in custody, particularly due to the fear of a catastrophic outbreak should they fail to take proper precautions.

A summary report obtained from inmates in two correctional centres in Lagos State in the form of questionnaires showed that inmates were vaccinated and other measures such as restriction of movements in and out of the centres, use of hand sanitisers and there was a swift response to suspected health-related cases. However, this is not a conclusive report on whether the same measures were taken or not in correctional centres in other states in Nigeria, considering that some centres are more neglected and in worst conditions than others [69].

CHALLENGES AFFECTING THE IMPLEMENTATION OF THE RIGHT TO HEALTH OF PRISONERS

There are a number of identified challenges that impede the enjoyment of the rights to health of inmates as provided for in the international, regional and local legal instruments. Prisons all over the world, and in Nigeria especially, are known for their common negative attributes such as congestion and overpopulation, lack of proper spacing and ventilation for its occupants, poor medical services, and provision of a poor nutritional diet [70].

A congested and overpopulated environment is a perfect habitat for all sorts of diseases, viruses, and infections, both communicable and non-communicable, hence exposing inmates to various illnesses. Inmates in custody are regarded as vulnerable members of society as a result of the unpleasing state of the prison centers. The spread of diseases in prisons is on the high side compared to the larger society. As earlier discussed, COVID-19 is a transmittable virus that can be easily spread by body fluid, hence the introduction of various preventive measures to use nose masks which will prevent the virus from entering the nose or mouth, frequent sanitisation of the hands to continually kill the germs that might have stuck to the hand after touching infected surfaces, social distancing to prevent spread or transmission of the virus. All these measures will, unfortunately, lead to wasted efforts where the environment is not conducive enough.

Another challenge is the issue of poor medical services. Due to the poor state of the correctional centres, inmates are prone to develop various illnesses which require unhindered and adequate medical attention. However, a physical inspection of these correctional centres would show that not all are well equipped with standard healthcare facilities, adequate personnel or enough medications and treatments for health issues when they arise. In some centres where healthcare facilities, personnel and drugs are available, some inmates with special cases are usually referred to government hospitals for further treatment as the former are inadequate to manage some of these cases. This inadequacy largely affects the enjoyment of the right to health of inmates in these centres, as it means that they are not guaranteed proper first aid treatment, not to mention when the need for serious medical procedures arises. For instance, people with underlying health issues were kept on respiratory machines where they are suspected of having contracted the COVID-19 disease, but for a centre where there are no proper medical records of its occupants, it will be challenging to know properly how to attend to their physical and mental well-being, in addition to the lack of adequate medical facilities and personnel.

Also, the failure to provide clean, safe and adequate food and drinking water for inmates will undoubtedly have a negative impact on their physical and mental health. This act is an obvious violation of the provisions of many local and international laws that guarantee the right to health of inmates in correctional centres. The essence of serving nutritious and adequate food and water is largely to ensure that the inmates are healthy and protected from malnutrition and other related health deficiencies, which will, in the long run, ensure the protection of their right to life. In Nigerian correctional centres, inmates constantly complain of the inadequate and malnourished food served by the system. Those who can afford it resort to alternative means of cooking by themselves or waiting on foods brought by religious or non-governmental organisations [71].

CONCLUSION AND RECOMMENDATIONS

Flowing from the above paragraphs, it can be concluded that inmates in detention or correctional

facilities are entitled to quality healthcare services like their counterparts in the outside world as provided for by several international, regional, and local human rights instruments. However, the challenge is usually the implementation of these laws by various stakeholders such as the government, the judiciary, staff of the correctional centers, and non-governmental and private organisations.

Nevertheless, all hope is not lost in achieving a sound healthcare system for inmates in incarceration amidst the obvious challenges facing the correctional system. Below are a few recommendations that can ensure the proper implementation of the healthcare policies such as vaccination of inmates, prevention, and protection of inmates from diseases by providing a conducive and hygienic environment in the correctional facilities:

1. **Exploring Alternative Correctional Measures**
   The need to explore other alternative corrective or pecuniary measures cannot be overemphasised when trying to address the issue of congestion in correctional facilities. Reports have shown that most of the occupants in the centers are those awaiting trials, that is, persons who have been in custody with no chance of appearing before a competent court to be heard or tried for whatever offence he has been remanded for. This is appalling and completely against the fundamental rights of an individual. The justice system should know better than to keep an individual in prison with other categories of inmates for an unreasonable period without trial. Majority of the time as well, individuals whose offences require just a few months of imprisonment or fine or even community service are equally dumped in these centers, thereby increasing the number of occupants without considering the available space or facilities.

   The judiciary needs to ensure that matters that do not attract punishments of imprisonment or which imprisonment are not more than 3 to 6 months are quickly treated, and alternative measures are explored instead. Offenders can be made to pay fines, partake in community services, driving disqualification for a while, restricted movement or access to certain areas, and many others. This recommendation is not strange as it has already been codified in Part II of the Nigerian Correctional Services Act. However, like other laws in Nigeria, effective implementation is the main ingredient for achieving the desired result. Also, the implementation must cut across all states of the federation as the issue of overpopulation is imminent in all states and not selected ones.

2. **Construction of Better Correctional Facilities**
   It is high time our correctional centers are rebuilt, refurbished, or even demolished and replaced with new structures. Most of the Nigerian correctional centers operating now were built decades ago; it is imperative to confirm whether these structures are up to standard considering the changes occurring now. We have more offenders than we used to, and this implies larger structures with better facilities. Inmates are humans before being incarcerated and, as such, are entitled to live and be treated humanely in hygienic, spacious, well-ventilated environments that will enable them to live a physically and mentally healthy lifestyle.

3. **Prioritising the challenges facing inmates in custody**
   Like every citizen in a country, inmates are equally humans entitled to enjoy basic rights except for the right to liberty, which they are deprived of for the time being, where the imprisonment is for a term of years. This implies that the government pays considerable attention to the challenges facing inmates in custody. Their well-being cannot be ignored because of their condition, and they should be paid more attention to achieve the objectives of rehabilitation, retribution, and reformation. When an inmate suffers health issues while in custody because of a lack of healthy food, poor health care system, poor treatment of health issues, etc., and he is released back to society, the situation becomes worse as he puts the public in danger. The present conditions of the prisons should be the driving force of the government to pay serious attention to the prevention of disease outbreaks and proffer immediate preventive and curative measures to prevent the spread and avoid an uncontrollable fatality rate.

   If the end goal is to reform these inmates so they come out to society and become good citizens again, then they must be treated as humanely as possible while they are in custody. Administration of the prison system should be given proper attention by the government and other stakeholders in terms of financing, personnel, provision of necessary

amenities, and embracing the international, regional, and local laws on the enjoyment of fundamental human rights by inmates.

Conclusively, the Nigerian Correctional Services Act is a robust law to a considerable extent in addressing custodial and non-custodial services. Nigeria may nevertheless borrow from the laws of other jurisdictions to see how our prison system can be better managed. Asides from the other International and regional laws, which might be more generic, the Nelson Mandela Rule Book [72] is an exclusive guide that sets the minimum standard for how States should take responsibility and treat inmates in their custodial centers with respect for their human dignity by prohibiting torture, inhumane treatment, ensuring that they maintain good physical and mental well-being, to achieve the reformative, and rehabilitative objective. The Rule book is not limited to access to medical services for inmates; it extends to every important aspect of the prison system, such as prisoner's inherent dignity as human beings, vulnerable groups of prisoners, medical and health services, restrictions, disciplines, and sanctions in the prisons, investigation of deaths and torture in custody, access to legal representation, complaints, and periodic inspections, and staff training. All these relevant areas apply to the Nigerian system, whose provisions should be studied and replicated in our laws and practice.

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Biosecurity in Nigeria: Emergence of the National Biosecurity Policy and Action Plan 2022-2026

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ABSTRACT

Nigeria has experienced its own share of biosecurity challenges, as evident in its exposure to some disease epidemics and pandemics. Significant outbreaks of diseases may cause devastation to humans and animals, as well as have severe economic, environmental and social impacts. Considering the multi-sectoral nature of biosecurity and the need to explore a coordinated approach to biosecurity, the National Biosecurity Policy and Action Plan 2022-2026 was developed with the aim of fostering the integration and harmonization of biosecurity strategies that will be implemented through the One-health approach for the prevention, early detection, rapid response to biothreats and recovery from biosecurity incidents. The policy document highlights Nigeria's biosecurity priorities, Institutional Governance and Stakeholders' Commitment, strategies and action plans, as well as a monitoring and evaluation framework to ensure a strong national biosecurity system. Ensuring biosecurity is a critical sector of a nation's sovereignty towards ensuring the safety of lives of its citizens and the environment and improving the socio-economic development of the country.

Keywords: Biosecurity; Biothreats; Nigeria; Policy.

CASE PRESENTATION

In our ever more interconnected world, diseases that emerge in one country can rapidly become a global threat either directly by the spread of diseases or indirectly by destabilizing already vulnerable regions [1]. Global travel, urbanization, technological advancement, and terrorist interest in biological weapons have magnified the risk of a disastrous biological incident. Significant outbreaks of diseases threaten lives and cause disruption to public services and the economy [2]. The COVID-19 pandemic highlighted how devastating an infectious disease can be within a short period of time and its potential impact on the global economy. This devastation holds true irrespective of the source of the disease outbreak, which can either occur as a natural outbreak of a well-known disease or as an emerging infectious disease. In other situations, it can be caused by an accidental release, theft, or loss of valuable biological materials from research or industrial facilities, or in some deliberate biological attack [3]. Recognition

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of all these factors, taken together, instigates the need to strengthen Biosecurity, reduce biological risks, create new approaches to improve infectious disease surveillance, and identify as well as fill gaps and fill gaps to strengthen the Biosecurity capabilities of the Nation [4].

BIOSECURITY SCENARIO IN NIGERIA

Globally, ensuring biosecurity is a critical sector of a nation's sovereignty towards ensuring the safety of lives of its citizens, and the environment and improving the socio-economic development of the country. Hence, a bio-secured Nigeria cannot be over-emphasized. Nigeria has experienced its own share of biosecurity challenges [4]. This was evident in its exposure to many disease epidemics and other biological threats with devastating effects. Distinguishable Public Health Emergencies (PHEs) of national concern in the last decade include Severe Acute Respiratory Syndrome (SARS) [5], Lassa Fever [6], Cholera [7], Cerebrospinal Meningitis [8], Yellow Fever [9,10], Rabies, Monkeypox, Ebola [11] and COVID-19 [12].

Biosecurity insufficiencies in Nigeria have also been reflected in the country-led self-assessment exercise in 2019, which involved the revision of the Health Security Capacities in the country using the updated WHO Joint External Evaluation (JEE) and WHO Benchmarks Tool [13]. Nigeria's score for Biosafety and Biosecurity technical area was two, which indicates limited capacity, although this was an improvement on the score of 1 obtained in the peer-reviewed JEE in 2017 [13]. Since infectious disease outbreaks do not respect borders [1], the country at this point remains vulnerable to both direct threats of bioterrorism and accidental exposure. Hence, the emergence of a National Policy and Action Plans on Biosecurity that recognizes the roles of all national sectors on matters of biosecurity and emphasizes the need for synergy to achieve One-health approach being canvassed globally as a strategy for preparedness and response to epidemic, pandemic, bioterrorism and other related issues.

POLICY DEVELOPMENT: STAKEHOLDERS' INVOLVEMENT

Despite the rising biosecurity threats, Nigeria is strongly determined to protect its citizens, the environment, and the economy, as well as safeguard operations of critical sectors from biological threats.

The National Biosafety Management Agency (NBMA) Act, 2015 (as amended) empowered the NBMA to put in place measures to ensure biosecurity through effective communication and collaboration (synergy) with existing Ministries, Departments and Agencies (MDAs) with biosecurity activities with a focus to strengthening her national biosecurity. As a result of this, the NBMA, under the auspices of the Federal Ministry of Environment, led the drive towards the development of a holistic policy document that aims to foster the integration and harmonization of Biosecurity strategies.

In July 2020, the Director-General and Chief Executive Officer of NBMA, Dr. Rufus Ebegba, constituted and inaugurated a 20-member committee to draft the National Biosecurity policy. The zero draft of the policy was submitted in August 2020 and was thereafter subjected to a series of internal reviews by the management staff of the Agency. Sequel to this, in December 2020, the zero draft document was officially presented to stakeholders by the Honorable Minister of State, Federal Ministry of Environment, Chief Sharon Ikeazor. One hundred and forty-five (145) participants drawn from different relevant federal government organizations, state governments, academia, professional associations, civil society organizations, and development partners, among others, convened to partake in the 1st, 2nd and 3rd stakeholders' review of the policy which held in June, August and September 2021 respectively. Following the validation of the document by biosecurity stakeholders in September 2021, the Federal Executive Council (FEC) approved the National Biosecurity Policy and Action Plan (NBP&AP) 2022-2026 in December 2021. This feat was made possible through the intensive utilization of national multi-sectoral efforts with the full recognition of biosecurity as a multi-sectoral discipline.

Synopsis of the Policy

Policy Thrust and National Priorities

The National Biosecurity Policy and Action Plan (NBP&AP) 2022-2026 is put in place to draw together diverse activities across Government to protect Nigeria from biothreats, whether naturally occurring, accidentally or as a result of deliberate attacks [4]. In consideration of the multi-sectoral nature of biosecurity, the NBP&AP 2022-2026 adopted a multi-disciplinary approach that aims to foster the integration and harmonization of biosecurity strategies that will be implemented through One-health approach for the prevention, early detection, rapid response to biothreats and recovery from biosecurity incident. The intent is to ensure synergy among stakeholders involved in biosecurity sectors in Nigeria for effective operations of the national biosecurity systems. Therefore, the NBP&AP 2022-2026 provides the framework for coordination and ensuring biosecurity in Nigeria.

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The NBP&AP 2022-2026 in the utilization of the One-health approach (Human Health, Agriculture and Food Safety, and Environment) centers on ensuring national values, interests, and objectives that define the Nation as a people concerned with collective efforts to the advancement of nation-building and international best practices. The policy document highlights Nigeria's priorities for the national biosecurity system to include but not be limited to safeguarding primary industries and food safety, preparedness, detection, response to new pests and diseases, and minimizing environmental and socio-economic impacts of pests and diseases. Others include institutionalizing an integrated approach to biosecurity enhancement, building biosecurity technical expertise and auditing high-impact laboratories dealing with dangerous pathogens.

The Principles of the Strategic Actions

The NBP&AP 2022-2026, which contains specific strategies of action, is based on the principle of shared responsibility, recognizing that many government agencies, non-governmental organizations, and the private sector have varying levels of biosecurity responsibilities in their mandate. The Policy is therefore expected to drive the following: (1) ensuring that rigorous, risk-based screening systems for evaluating the intentional and unintentional introduction of biothreats are developed; (2) identifying the pathways by which harmful organisms are moved and developing a mechanism to minimize the movement of harmful and potentially harmful organisms; (3) strengthening basic border control, risk and impact assessment and quarantine capacity by enhancing the numbers and capabilities of personnel, employing more effective technologies and improving scientific methods; (4) developing a rapid response programme with the collaboration of sub-nationals and local stakeholders to respond immediately to incidences caused by bio-organisms as soon as they are detected; and (5) establishing an easily accessible funding mechanism for emergency action.

The strategies and action plans for the national biosecurity system cover 24 thematic areas, which include human health, plant health, animal health, food safety, agriculture, environmental protection and biodiversity conservation, biotechnology and biosafety, facility establishment, management and security, biosecurity information and database, bioterrorism and biowarfare, biothreat risk assessment, border control, transport security, climate change, bioethics, surveillance, preparedness and response; waste management, human resources management, research and development, international trade, communication, education and advocacy, gender participation, and biosecurity enforcement [4].

Institutional Governance and Stakeholders' Commitment

In line with the goals of the NBP&AP 2022-2026, all stakeholders in the Nigeria biosecurity system are expected to play their specific roles in line with their specific mandates and work in synergy to produce a clear aggregation and unified effort to strengthen biosecurity in Nigeria. In addition, the NBP&AP 2022-2026 provides a mechanism for strengthening biosecurity governance and coordination that will ensure a functional and robust collaborative system for managing the national biosecurity system. It provides for the establishment of a National Advisory Council on Biosecurity that will serve as a high-level advisory body on national biosecurity issues and may make decisions on the evaluation reports for the implementation of the NBP&AP. It also provides for the establishment of the National Technical Working Group on Biosecurity that will provide technical discourse and analysis to strengthen the Nigeria Biosecurity System taking into consideration the effective implementation of the NBP&AP.

Monitoring and Evaluation

In ensuring accountability and in demonstrating effectiveness and efficiency with the implementation of NBP&AP, the NBP&AP 2022-2026 provides for the integration of a monitoring and evaluation (M&E) mechanism that is intended to ensure that programs and projects in the NBP&AP stay on track while detecting problems to reduce the risk of major cost overruns or time delays. It employs M&E strategic plan built on three main pillars that will ensure that the desired results are delivered in a functional, effective, and efficient manner: (1) Enabling environment: People, partnerships and planning required to support data use; (2) Data and Information: Mechanisms for collection, capturing and verification of data for making decisions; and (3) Decision Making: Dissemination and use of data for decision-making. The NBP&AP 2022-2026, therefore, enshrines the institutionalization of M&E logical frameworks within the implementing MDAs in line with these three main pillars that outline the objectives, inputs, outputs, and outcomes of specific programs/projects, as well as the indicators that will be used to measure and verify all results.

CONCLUSION

The development of the National Biosecurity Policy and Action Plan 2022-2026 has accorded Nigeria the opportunity to evaluate the strengths and vulnerabilities as well as the potential of its biosecurity system. A prediction of all the ways the bio-risk landscape will evolve in the future is extremely limited, and so there is a need for adequate preparedness and working in a coordinated way across and beyond government to tackle the risk of significant biothreats and bioterrorism.

LIST OF ABBREVIATIONS

COVID-19 – Corona Virus Disease 2019
FEC – Federal Executive Council
JEE – Joint External Evaluation
M&E – Monitoring and Evaluation
MDAs – Ministries, Departments and Agencies
NBMA – National Biosafety Management Agency
NBP&AP – National Biosecurity Policy and Action Plan
PHEs- Public Health Emergencies
SARS- Severe Acute Respiratory Syndrome
WHO – World Health Organization

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Public Health Risks Assessment of Bioaerosols from Different Locations in Bariga Metropolis of Shomolu Local Government Area, Lagos State, Nigeria

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ABSTRACT

The increasing human populations and their daily activities have contributed to bioaerosols generation in Bariga, leading to air pollution with consequent public health threats to exposed individuals. This study aimed to assess public health risks associated with bioaerosols generated from outdoor activities in Bariga community, Shomolu Local Government Area of Lagos State. An analytical observational study design based on the measurement of meteorological parameters in the field and laboratory analysis of bioaerosol particles collected from the study population using a handheld Kestrel 3000 weather meter and standard microbiological procedures, respectively, was adopted. Four hundred (400) samples of bioaerosol particles obtained by the Taro Yamani formula at a 5% level of precision were analyzed. Passive air monitoring using Koch's sedimentation method was employed for total viable counts, while microbial isolates were identified using cultural, morphological, and biochemical characterization. The variation in environmental parameters obtained was largely dependent on time and seasons, with a consequent adverse effect on the presence and movement of bioaerosol particles in the atmosphere. Microbial populations varied in densely and less-densely populated study areas. The study identified Bariga as a high-risk area with CFU above 10^2 –10^4 CFU/m^3, thus capable of causing bioaerosols-related diseases. A total of twelve (12) bacterial and six (6) fungal genera were isolated, with Gram-positive bacteria having a prevalence rate of 87.02% and Gram-negative bacteria at 12.99%. The predominant fungi, on the other hand, were 87.94% mold and 12.06% yeast. One-way analysis of variance (ANOVA) at 0.05 significance level showed a significant correlation (F-ratio > F-critical value) (p=0.05) between exposure to bioaerosol particles and associated health risks in the exposed individuals. We recommend that Lagos State Government should intensify efforts to reduce the public health effect of bioaerosols through policies, structural planning, development, and education on environmentally friendly activities and personal hygiene.

Keywords: Bioaerosols; Meteorological Parameters; Microorganisms; Public Health; Bariga; COVID-19.

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INTRODUCTION

The ubiquitous and diverse nature of microorganisms in an ecosystem could be beneficial and detrimental to the existence of plants and animals within the biosphere or community. The increasing human populations with their daily activities have greatly contributed to air pollution consisting of inorganic (particulate matter) and organic (bioaerosols). The generated bioaerosols could serve as a means of transmitting pathogens and thus pose a potential public health threat to the community. These pollutants have constituted an inevitable environmental issue in the world's developing countries, and it stands out among the array of global environmental hazards facing metropolitan cities such as Lagos [1]. Bioaerosols generated are suspensions of atmospheric particles of biological origin containing living and/or dead microorganisms, pollens, and their derivatives [2]. The concentration of different bioaerosols in the air varies from one location to another. The bioaerosols can be generated during sneezing, talking, laughing, and yawning [3]; pollens from plants or anthropogenic activities can influence the bioaerosol's particle size, composition, and concentration in the atmosphere [4]. Microbial spores suspended in the air could serve as a potential source of allergy and general health problems in different ways [5]. They can easily be transferred from one environment to another because of their small size (0.001-100 μm) and lightweight, which are dependent upon prevailing physicochemical properties of the atmosphere, such as temperature, humidity, solar radiation, wind, precipitation and atmospheric pressure, for transport and survival [6-9] as reported [5]. After the release of biological aerosols into the atmosphere, most of them combine with the ambient particulate matter for diffusion and transportation from one place to another over long distances [8]. The susceptibility to acquiring infections from inhaling bioaerosols is largely determined by the virulence of the biological agent, the pathogenicity of the agent, dosage and the host's immune response. The airs we breathe also contain a mixture of gaseous and particulate matter released from natural and anthropogenic sources [9].

Humans play a significant role as hosts to many microorganisms, some of which are normal flora of the body, while others are pathogens capable of causing infectious diseases in man. In developing countries like Nigeria, air pollution is mainly due to overpopulation and uncontrolled urbanization, coupled with rapid industrialization, disparity among residents and poor environmental sustainability management education [10]. The population density of bioaerosols suspended in the atmosphere in a particular environment is influenced by the human population and their interactions with such environment; for instance, human populations have been implicated in the spread of infectious diseases [11]. With the continuous growth of populations in Bariga, human mobility and interactions, production of biological aerosols becomes inevitable in a densely populated area (such as market squares, bus stops and other public gatherings) than in less densely populated area (such as residential and streets within the residential areas) thus increasing the presence of microorganisms putting forward an eco-epidemiological assumption that disease transmission at the population level could be caused by the mixing patterns of individuals within the environment [12]. Respiration and the shedding of microorganisms daily by the human populace as they interact with one another and their surrounding contribute to bioaerosols built-up in such environments [13, 14].

Potential health effects on the community caused by bioaerosols depend on the pathogenicity or immunogenic potential of specific microorganisms and/or their metabolites, as well as other environmental conditions that can influence their survival in the air, the behaviour of the bio-aerosol particles and immunogenic status of the host [15]. The short-term and long-term exposure to air polluted with bioaerosols by members of the community increases their chances of contracting bioaerosols-related infections or reactions such as acute respiratory diseases, skin reactions, cough, watery eyes, difficulty in breathing and predisposing factors to pneumonia, influenza, measles, asthma, allergies, tuberculosis, cardiovascular diseases and gastrointestinal illness as long term effects [5, 16, 17, 18]. Many countries of the world, including Nigeria, has not recovered from the economic recession due to airborne bioaerosol disease such as COVID-19. Findings revealed that Nigeria's Gross Domestic Products (GDP) fell by 23% during the lockdown, especially in the food chain, with a GDP of 11%, which was primarily due to restrictions of movement that prevented food from the North to the South leading to hunger and poverty on households at 9% [19]. In Nigeria, there is no official data on economic loss due to bioaerosols-originated infections. However, the current fight against COVID-19, which is a bioaerosols-related disease, was estimated to cost the country over N45b [20]. Thus, the influx of migrating population from rural to urban areas with

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increasing settlement in Bariga can lead to public health threats.

Despite these challenges, there was no previous study on the increasing emerging and re-emerging airborne-related infectious diseases and how there are influenced by the increasing human population, environmental factors and their implications in the study area. The aim of this study was, therefore, to assess public health risks associated with bioaerosols generated from outdoor activities in different locations in the Bariga metropolis of Shomolu Local Government Area of Lagos State, Nigeria.

METHODOLOGY

The Study Area

The study area was Bariga, a district and suburb in Lagos State, South-West, Nigeria, formerly under Shomolu Local Government Development Area (LCDA) (Figure 1). The coordinates of Bariga LCDA are 6°32′6.0″N 3°23′41.0″E with a population of 391,200 people, according to [21]. Due to the high cost of rent in Lagos Island and some parts of the Mainland, with the increasing population of rural-urban migration, low and middle-income earners patronize places like Bariga, where rent is relatively affordable, thus contributing to a high level of aerosols generation with subsequent health hazards on the community.

Figure 1: The Map of Lagos State showing red shaded study area (Bariga-Shomolu)

Study design, sampling size and study population

Multi-stage sampling technique was adopted in the study, namely: observational study design and cluster sampling methods. The amount of airborne biological aerosol particles was observed based on the frequency of anthropogenic activities that contributed to the abundance of bioaerosols in the atmosphere and which emanated from human population indices: densely populated and less-densely populated parts of the study area. The sampling units, therefore, were aerosol particles collected from bus stops, markets, residential areas and streets in the study area.

In the second stage sampling technique, four hundred (400) samples of bioaerosols from the atmosphere were randomly collected from twenty (20) clusters using random cluster sampling technique from different locations (Table 1). The sample size of approximately four hundred (400) was determined using the Yamani formula [22]. The observation was made from selected clusters to represent the sample populations; this was based on the variables, which were the frequency of anthropogenic activities resulting in the production of biological aerosols in the study area. Thus samples were taken from densely populated clusters (markets and bus stops) and less-densely populated clusters (residential areas and streets) for microbial population density enumeration (bacteria and fungi) and the likely effects it will have on the populace. This is because the more densely the populations of people engaging in different activities, the higher the probability of biological aerosol generation compared to the less densely populations. Table 1 indicates the sampling frame where samples were taken from the clusters.

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Table 1: The sampling frame where bioaerosols samples were collected in the study area

S/No	Densely populated clusters	Less-densely populated clusters
1.	Bariga Market – BM	Olanrewaju Street - OL
2.	Ilaje Bus Stop - IL	Ifelodun Street - IF
3.	New Garage - NG	Community Road - CR
4.	Odo-Eran Market - OE	Temple Residential Area - TEM
5.	Igbo-Igunnu Spare-Parts Market - IG	Adeboye Residential Street - AD
6.	Odunsi Bus Stop - OD	Olalere Street - OLA
7.	Evening Market - EM	Lawal Street - LW
8.	Murtala Bus Stop - MB	Abeokuta Residential Area - AB
9.	Bariga Bus Station - BS	Evans Adelaja Area - EA
10.	Kajola Bus Stop – KB	Oshinfolarin Street – OS

Methods of Data Collection

Total viable counts for bacteria and fungi (CFU/m^3), temperature (^oC), humidity (%), precipitation (%), wind (km/hr), atmospheric pressure (mBar), and sunlight (Ultraviolet radiation) were primary data obtained from direct observations using quantitative measurement: microbial enumeration and their probable identity, environmental factors and secondary data obtained from review of risks assessment or health effects of biological aerosols from different articles and journals.

Microbiological analyses of bioaerosol particles

The isolation, enumeration and probable identification of microbial isolates followed microbiological standard procedures, including isolation of pure culture, cultural characterization, cellular morphology (Gram staining and fungi staining) and biochemical characterization: catalase, oxidase, starch hydrolysis, coagulase, carbohydrate fermentation, gas production, hydrogen sulphide production, indole, citrate utilization, motility, hemolysis and bile esculin tests according to [23, 24, 25]. Thus, passive air monitoring, otherwise known as Koch's sedimentation method or settling plate technique [26, 28], was adopted for this study. The exposure of nutrient plates to air allowed viable biological particles to sediments out of the air onto the nutrient plate's surface over the period of exposure. The bioaerosols were collected in duplicate plates using a random cluster sampling technique from designated study locations (Table 1). Ninety millimetres (90 mm) diameter Petri dishes containing nutrient agar (CM0003 Oxoid, UK) and potato dextrose-chloramphenicol agar (M096 Himedia Lab, India) for the isolation of bacteria and fungi, respectively, were exposed to the air above the shoulder level for one h; at 10 mins interval, the exposed nutrient plates were removed and covered with lids until one h was completed. The inoculated plates were transported to the Laboratory of the Department of Microbiology, University of Lagos, Nigeria, for incubation at 35 ± 2°C (bacteria) for 24 h and 28 ± 2°C (fungi) for four days along with control plates. The developed colonies were counted in duplicates, and the mean values were taken to determine the colony forming units per cubic meter (CFU/m^3) of the isolates and were further estimated according to Polish standard PN89/2-04088/08 [26, 27].

Measurement of environmental factors affecting the survival or dispersion of microbes in bioaerosols

Since environmental factors or parameters play an important role in the survival, growth and dispersal of released bioaerosols [29], they were measured at every sampling location with handheld Kestrel (3000) weather meter and Galaxy A01 Samsung Global Positioning System (GPS); the values for Humidity, Atmospheric temperature, Pressure, Sunlight or Ultraviolet-radiation, Wind and Precipitation were recorded (Table 2A, 2B).

Table 2A: Environmental factors affecting the survival or dispersal of microbial cells suspended in the bioaerosol particles in the densely populated study area

Environmental Parameters at 95% confidence		Temperature (°C)	Humidity (%)	UV-radiation	Atmospheric pressure (mBar)	Precipitation (%)	Wind (mph)
S/N	*Locations*						
1.	Bariga Bus-station	29.2±1.46	41.0±2.05	06.0±0.3	1012.0±50.6	00.0±0.0	0.8±0.04
2.	Bariga Market	29.9±1.50	36.1±1.80	08.0±0.4	1009.0±50.5	00.0±0.0	1.0±0.05
3.	Evening Market	30.8±1.54	69.4±4.82	11.0±0.6	1010.0±50.5	20.0±1.0	0.6±0.03
4.	Igbo-Igunnu Spares-Part Market	33.0±1.65	29.4±1.47	11.0±0.6	1010.0±50.5	10.0±0.5	1.2±0.06
5.	Ilaje Bus stop	31.9±1.60	74.4±3.72	11.0±0.6	1012.0±50.6	40.0±2.0	0.8±0.04
6.	Kajola Bus stop	29.3±1.47	68.8±3.44	04.0±0.2	1010.0±50.5	25.0±1.25	0.5±0.03
7.	Murtala Bus stop	30.5±1.53	70.3±3.52	09.0±0.5	1011.0±50.6	10.0±0.5	1.5±0.08
8.	New Garage	32.1±1.61	71.7±3.59	11.0±0.6	1012.0±50.6	70.0±3.5	1.3±0.07
9.	Odo-Eran market	32.1±1.61	71.5±3.58	04.0±0.2	1009.0±50.5	30.0±1.5	2.6±0.13
10.	Odunsi Bus stop	28.2±1.41	36.6±1.83	05.0±0.3	1012.0±50.6	10.0±0.5	0.7±0.04

The meteorological parameters obtained in the tables both in densely and less-densely populated study areas showed a relatively significant rise in temperature as the ultraviolet radiation (sunlight) rises. The rising and falling of environmental factors witnessed in this study were majorly due to variations in time and season when the parameters were measured.

Table 2B: Environmental factors affecting the survival or dispersal of microbial cells suspended in the bioaerosol particles in the less-densely populated study area

Environmental Parameters at 95% confidence		Temperature (°C)	Humidity (%)	UV-radiation	Atmospheric pressure (mBar)	Precipitation (%)	Wind (mph)
SN	*Locations*						
1.	Abeokuta Street	29.5±1.48	79.0±3.95	05.0±0.25	1011.0±50.6	50.0±2.5	0.5±0.03
2.	Adeboye Street	30.2±1.51	62.8±3.14	11.0±0.55	1013.0±50.7	00.0±0.0	1.0±0.05
3.	Community road	28.8±1.44	73.2±3.66	02.0±0.10	1010.0±50.5	06.0±0.3	4.0±0.20
4.	Evans-Adelaja	32.2±1.61	80.0±4.00	11.0±0.55	1008.0±50.4	10.0±0.5	0.6±0.03
5.	Ifelodun Street	32.6±1.63	69.5±3.48	02.0±0.10	1010.0±50.5	50.0±2.5	2.3±0.13
6.	Lawal Street	29.1±1.46	75.6±3.75	07.0±0.35	1010.0±50.5	06.0±0.3	1.5±0.08
7.	Olalere Street	34.8±1.74	29.5±1.48	11.0±0.55	1009.0±50.5	10.0±0.5	1.2±0.06
8.	Olanrewaju Street	29.7±1.49	80.2±4.01	06.0±0.33	1012.0±50.6	60.0±3.0	0.6±0.03
9.	Oshinfolarin Street	32.7±1.64	59.0±2.95	11.0±0.55	1010.0±50.5	00.0±0.0	0.9±0.05
10.	Temple Area	32.4±1.62	36.5±1.83	08.0±0.40	1011.0±50.6	00.0±0.0	0.8±0.04

Public health risks assessment of bioaerosols and its economic implications

Public health risks assessment of bioaerosols was evaluated based on Occupational Safety and Health Administration recommendation [6, 30] and empirical knowledge on the pathogenicity of microbial isolates, their potential adverse health effects on the exposed population and their economic implications on the community. The economic implication involved the direct and indirect costs of the treatment of diseases caused by these identified infectious agents.

Exposure duration to pollutants of anthropogenic origin as a risk factor and ways to mitigate them

Pollutants of anthropogenic origin are pollutants that emanate from human activities that affect the ecosystem; some of these activities cause environmental pollution; for example, combustion of fossil fuel, waste disposal, urbanization, industrialization, agricultural activities, deforestation, construction, etc. [31, 32] Short-term and long-term exposure to these pollutants can cause acute and chronic respiratory diseases; it is important that careful evaluation of the findings to

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establish the relationship between duration of exposure to bioaerosols and health hazards as hypothesized was done using relevant statistical tools and empirical methods. Thus the findings were then reviewed based on the findings of other researchers, and necessary solutions were proffered to reduce their effects.

Data Analysis

The primary data obtained in this study from direct observation or measurement of samples in duplicates were sorted, processed, analyzed, presented and interpreted using mean, tables, charts, One-way analysis of variance (ANOVA) and F-distribution calculator [33].

RESULTS

This study showed variation in environmental parameters (Table 2A, 2B) at a p=0.05 significance level, which was largely dependent on time and seasons with subsequent adverse effects on the presence and movement of biological aerosol droplets suspended in the study area. The data obtained in this study showed that there was variation in the microbial concentration, with densely populated areas having the highest microbial populations than less densely populated areas. The highest bacterial populations within the exposed period of 1h were recorded in Bariga Market (BM), which ranged from $4.40x10^5$ to ND and lowest in New Garage (NG) from $2.83x10^4$ to $2.46x10^4$ (Table S1, Figure 2A), while fungal populations in the same category showed Bariga Market (BM) with highest populations ranging from $2.04x10^4$ to $3.93x10^2$ and lowest in Odo-Eran Market (OE) with $0.00x10^1$ to $1.57x10^3$ (Table S2, Figure 2B). The less-densely populated study areas, on the other hand, showed the highest bacterial populations in the Temple area (TEM), ranging from $8.33x10^4$ to $4.87x10^4$ cfu/m^3 and lowest in Olanrewaju Street (OL) from $1.18x10^4$ to $6.94x10^3$ (Table S3, Figure 3A) while the highest fungal population was observed in Temple area (TEM) $3.14x10^4$ to $8.64x10^3$ and lowest in Abeokuta Street (AB) from $0.0x10^1$ to $2.75x10^3$ (Table S1, S2, S4 - https://getjournal.org/wp-content/uploads/2023/05/Supplementary-Table-GJOBOH-2022-031.pdf and Figure 3B). Tables 3A and 3B show the microbial prevalence rate, while Table 4 shows public health risk assessment values compared to a recommended threshold.

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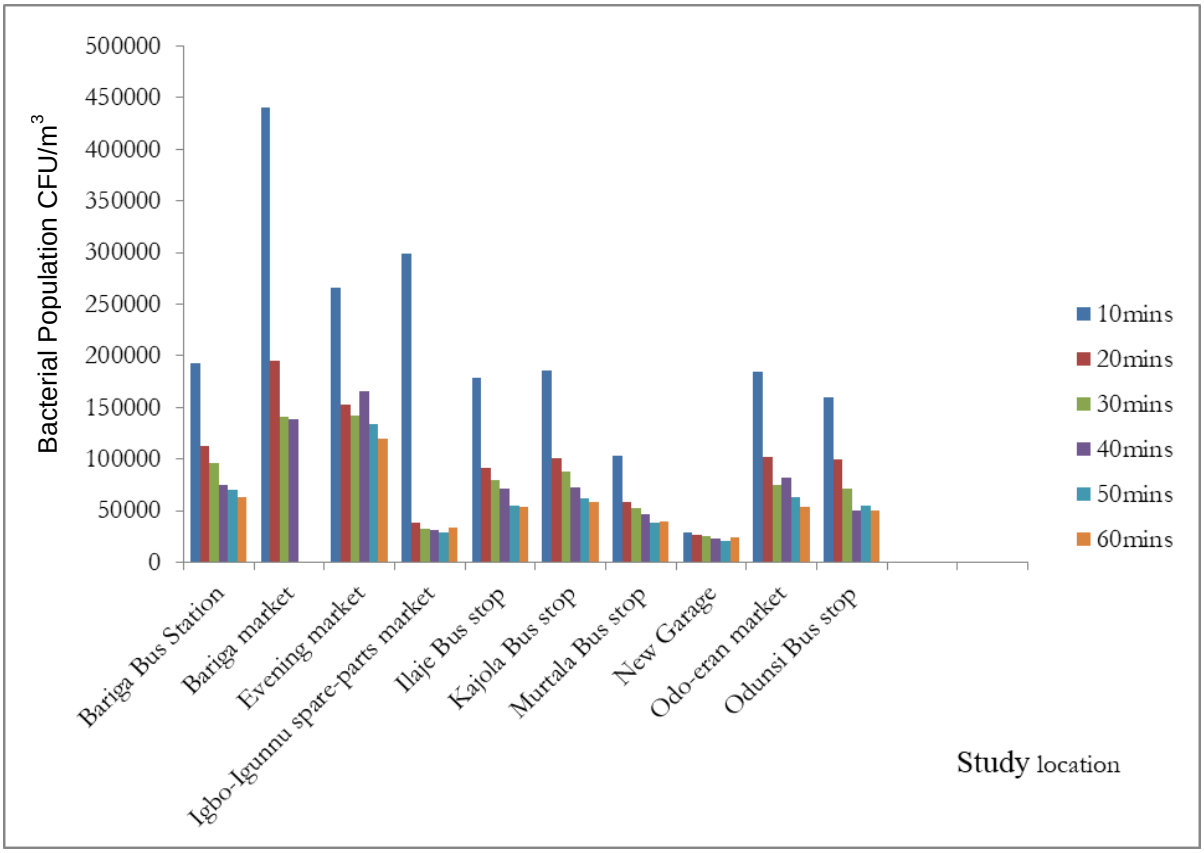

Figure 2A: Bacterial populations suspended in bio-aerosol particles in densely populated study area per hour

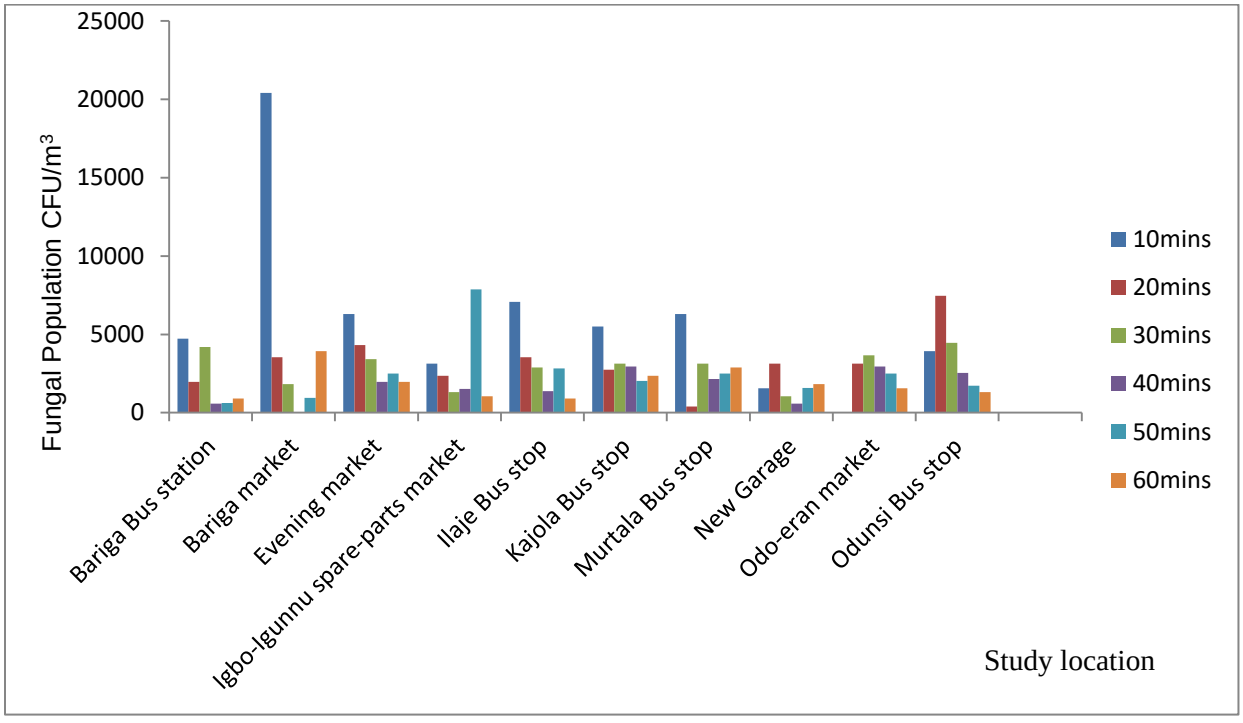

Figure 2B: Fungal populations suspended in bio-aerosol particles in densely populated study area per hour

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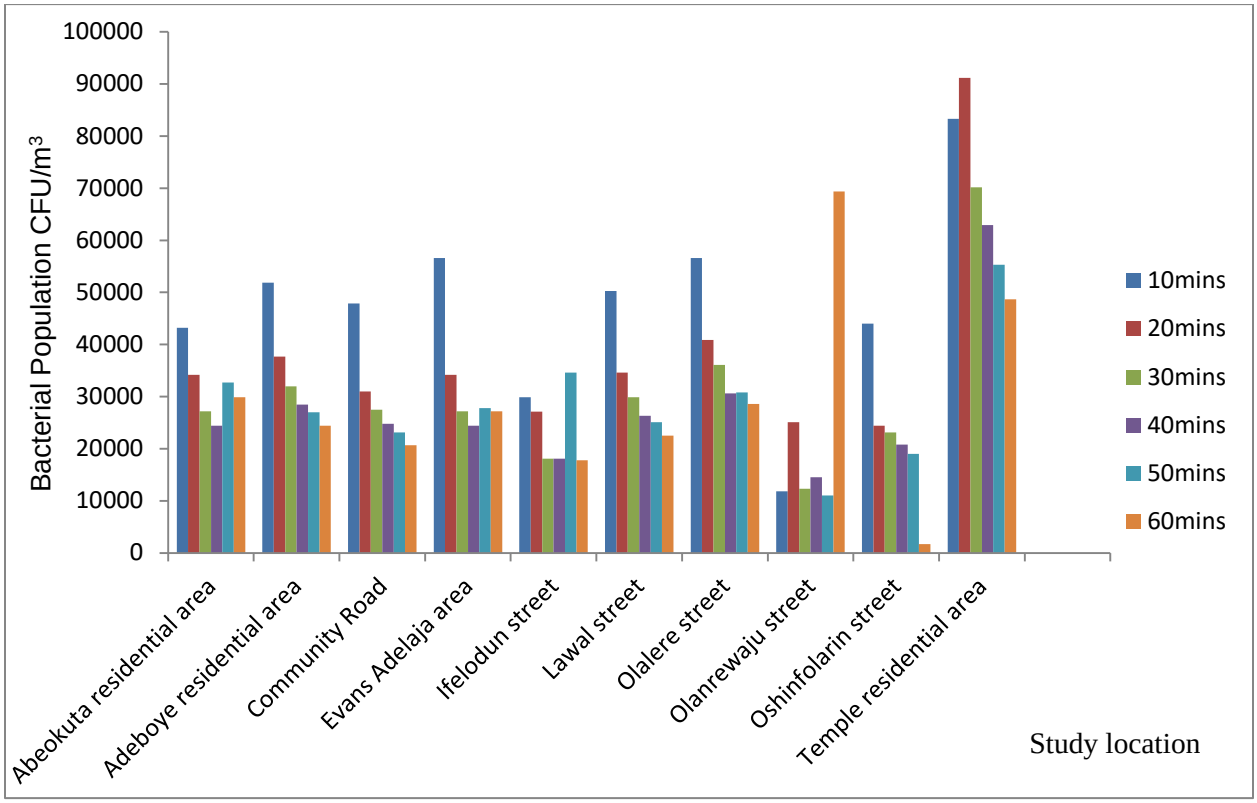

Figure 3A: Bacterial populations suspended in bio-aerosol particles in the less-densely populated study area

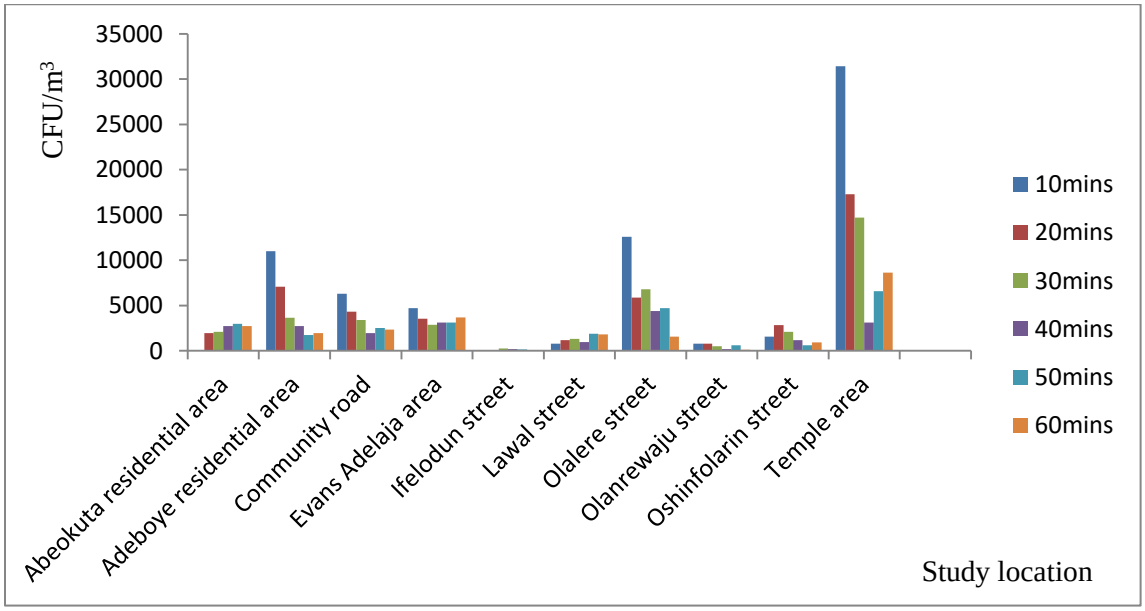

Figure 3B: Fungal populations suspended in bio-aerosol particles in less-densely populated study area per hour

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Table 3A: Prevalence rate of Bacterial Genera in the study population

S/No	Bacteria Genera	Frequency	Percentage (%)	Prevalence rate (%)
1.	*Staphylococcus*	32	41.56	8.18
2.	*Bacillus*	26	33.77	6.65
3.	*Micrococcus*	06	7.79	1.53
4.	*Pseudomonas*	04	5.19	1.02
5.	*Actinomycetes*	02	2.60	0.51
6.	*Streptococcus*	01	1.30	0.26
7.	*Shigella*	01	1.30	0.26
8.	*Serratia*	01	1.30	0.26
9.	*Enterobacter*	01	1.30	0.26
10.	*Escherichia*	01	1.30	0.26
11.	*Salmonella*	01	1.30	0.26
12.	*Yersinia*	01	1.30	0.26
	Total	**77**	**100**	

Table 3B: Prevalence rate of fungal genera in the study population

S/No	Fungi Genera	Frequency	Percentage (%)	Prevalence rate (%)
1.	*Aspergillus*	21	36.21	5.37
2.	*Fusarium*	16	27.59	4.09
3.	*Saccharomyces*	07	12.07	1.79
4.	*Neurospora*	05	8.62	1.28
5.	*Rhizopus*	05	8.62	1.28
6.	*Mucor*	04	6.90	1.02
	Total	**58**	**100**	

These tables state the prevalence rate of bacteria and fungi in the studied population.

Table 4: Public health risks or hazard assessment of bioaerosols on the study population

Study location	Mean total Bacteria CFU/m^3	Mean total Fungi CFU/m^3	Guideline CFU/m^3	Remarks
L1-Bariga Bus Station	2.88 x 10^5	5.50 x10^3	<1.0 x 10^2	Low
			10^2–1.0 x 10^3	Intermediate
			>1.0 x 10^3	High
L2-Bariga Market	4.97 x 10^5	7.86 x 10^3	*For houses*	
			<2.0 x 10^2	Low
			<1.0 x 10^3	Intermediate
			<1.0 x 10^4	High
L3-Evening Market	4.57 x 10^5	9.59 x 10^3	>1.0 x 10^3	Indicates contamination
			>1.06 x 10^2fungi/g of dust	Indicates contamination
L4-Igbo-Igunnu	1.12 x 10^5	4.72 x 10^3		
			<8.0 x 10^2	Normal
L5-Ilaje Bus Stop	2.47 x 10^5	8.02 x 10^3	<3.0 x 10^2	Common fungi are accepted
			<1.5 x 10^2	Mixedfungi other than pathogenic is accepted
L6-Kajola Bus Stop	2.67 x 10^5	9.43 x 10^3	<7.5 x 10^2	Total airborne bacteria and fungi are accepted if species are not infective or allergenic
L7-Murtala Bus Stop	1.65 x 10^5	1.04 x 10^4		
L8-New Garage	8.33 x 10^4	6.83 x 10^3		
L9-Odo-Eran Market	2.63 x 10^5	8.80 x 10^3		
L10-Odunsi Bus Stop	2.33 x 10^5	9.82 x 10^3	>1.04 x 10^2	Total fungi is a threat to health
			>5.0 x 10^2	One species of potentially pathogenic nature is a threat to health
L11-Abeokuta Street	1.05 x 10^5	8.80 x 10^3		
L12-Adeboye Street	1.03 x 10^5	1.12 x 10^4		
L13-Community Road	8.86 x 10^4	9.98 x 10^3		
L14-Evan Adelaja	1.01 x 10^5	1.18 x 10^4		
L15-Ifelodun Street	8.17 x 10^4	7.86 x 10^2		
L16-Lawal Street	9.57 x 10^4	5.27 x 10^3		
L17-Olalere Street	1.16 x 10^5	1.66 x 10^4		
L18-Olanrewaju Street	4.24 x 10^4	1.57 x 10^3		
L19-Oshinfolarin Street	7.39 x 10^4	4.56 x 10^3		
L20-Temple Area	2.16 x 10^5	3.46 x 10^4		

This remark was made based on guidelines adopted from Kim, K.-H.et al. (2017). Airborne bioaerosols and their impact on human health, J. Environ. Sci. (2017), https://doi.org/10.1016/j.jes.2017.08.027

DISCUSSION

As a result of daily anthropogenic activities in the Bariga metropolis of Shomolu, Lagos, Nigeria, microorganisms are released in the form of bioaerosol droplet nuclei, which float in the atmosphere. People are exposed to these bioaerosols being carried about by wind and other environmental factors through the exchange of gases (respiration), contaminated air containing pathogens is inhaled and equally released via talking, coughing, sneezing, yawning and laughing. The exposed individuals, especially the vulnerable ones, may come down with one form of infection or another, thus causing public health threats. Some of these environmental factors have been observed to be relatively less densely populated than less densely populated study areas, thus affecting the microbial distribution and leading to a high population of microorganisms in densely populated areas than in less densely populated study areas. This assertion was corroborated by Samaranayakea et al. [34], who stated that

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aerosols could be transported or suspended in the air for considerable periods of time depending on the humidity, airflow, and temperature of the environment into which they are expelled. Górny [35] also observed that microclimate parameters such as temperature and relative humidity of the air, together with ultraviolet radiation, oxygen and other physical factors, contribute to the influx of airborne microorganisms. These environmental factors also influence the survival of airborne microbes and affect their ability to colonize surfaces after deposition. As the ultraviolet radiation rises over time, there is a corresponding gradual rise in temperature. This rise in temperature between 28.2-34.8^{o}C, as observed in this study, favoured the survival and viability of mesophiles which are generally known to be human pathogens and capable of surviving at body temperature (37^{o}C). Humidity and precipitation support the growth of microorganisms, as bacterial cells are composed mainly of water. Though the high the precipitation, the less the microbial population is due to the fact that rainfall washes the microorganisms from the atmosphere unto open surfaces. The total microbial population densities varied from location to location depending on the human population densities. It was observed that mean microbial colonies increase with the increase in exposure period with a decline in CFU/m^3 when estimated with Polish standard PN89/2-04088/08. The high microbial population recorded in densely populated areas is attributable to the influx of people and their daily activities that resulted in the generation of bioaerosols leading to high microbial contamination above the standard limits of 0 – 1.0 x 10^3 CFU/m^3 [15]. Bariga market recorded high microbial populations. Market squares and bus terminals are heterogeneous settings where several activities are taking place daily. Human, animal, vehicular movement and unhygienic environmental practices become the order of the day with the resultant generation of one form of aerosols or another, thus polluting the air and exposing the market and bus patrons to the danger of respiratory diseases, skin diseases, systemic diseases and allergic reactions. This study is in line with Adams et al. [14], who affirmed that the population density of microorganisms in bioaerosol suspended in the atmosphere in a particular environment is influenced by human populations and their interactions with such environment. On the other hand, the high microbial populations witnessed at Temple residential area compared to others in the same categories could be a result of the poor environmental sanitation and lack of personal hygiene practised by the residents. The place was observed to be more of a 'ghetto' settlement inhabited by low-income earners that lacked the will and capacity to practice environmental hygiene compared to the Olanrewaju residential area, where the residents were middle-income earners and educated. Thus the level of environmental and personal hygiene was relatively acceptable compared to other study locations within the populations. This study shows that the predominant bacteria isolated were Gram-positive bacteria (87.02%), with the genus, *Staphylococcus* having (41.56%) population frequency and the least prevalence rate (1.79%). The high occurrence of Gram-positive bacteria and moulds in this study may be due to their ubiquitous nature, ability to survive longer in the air, colonization of the skin and other body orifices, presence of thick layers of peptidoglycan in their cell wall (20 – 80 nm), possession of spores by some genus *Bacillus* and mold, presence of small protective molecules such as sugars, amino acids, alcohols and betaine, expression of heat shock proteins [36]; whereas least occurrence of Gram-negative bacteria which are majorly enteric bacteria recorded in this study could be due to their inability to survive outside their natural habitat (human body) and the presence of a thin layer of peptidoglycan in their cell wall (2 – 3 nm) surrounded by an outer membrane containing lipopolysaccharide [37]. This observation is in conformity with earlier findings [1, 6, 26, 38] which isolated some predominant bacterial genera of *Staphylococcus, Bacillus, Streptococcus, Escherichia, Micrococcus, Pseudomonas, Serratia, Salmonella, Shigella* and fungal genera of *Aspergillus, Fusarium, Rhizopus,* and *Saccharomyces*. Some of the bioaerosols in this study are capable of causing infections in exposed individuals to contaminated air; for instance, *Staphylococcus* sp is a potential cause of sepsis, infective endocarditis, osteomyelitis, skin and soft tissue infections [39]; *Bacillus* sp has also been implicated in previous studies as a potential cause of abscesses, bacteremia, wound and burn infections, ear infections, endocarditis, meningitis, ophthalmitis, osteomyelitis, peritonitis, respiratory, urinary tract infections and food poisoning [40]. *Micrococcus* spp. are capable of causing opportunistic infections in immuno-compromised HIV patients [41], *Actinomyces* which causes Actinomycosis [42, 43], *Streptococcus* has been identified in previous studies to be responsible for Strep throat infection, scarlet fever, impetigo, cellulitis, streptococcal toxic shock syndrome and rheumatic fever [44]. *Pseudomonas, Shigella, Serratia, Enterobacter, Escherichia, Salmonella* and *Yersinia* are Gram-negative, enteric bacteria

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responsible for gastrointestinal diseases in infants, adults and the elderly with characteristics of abdominal cramps and diarrhoea, nausea and vomiting, gastroenteritis, fever, and other clinical infections such as neonatal meningitis and pneumonia [45-47]. Moulds and *Bacillus* are generally spore-producing organisms which can withstand unfavourable environmental conditions; their spores can easily be carried about from one place to another by the wind until they come in contact with a suitable medium that supports their growth. The presence of these spores in the study area is a public health threat, thus exposing individuals, especially those with underlying diseases such as asthma and respiratory diseases, to inhaling contaminated air leading to allergic reactions and severe respiratory infections. Some *Aspergillus* species have been implicated in causing mycoses in humans, allergic sinusitis, and systemic and respiratory diseases in exposed hosts [1, 45, 48]. *Fusarium* spp. is known to cause superficial, locally invasive, diffuse infections and keratomycosis in humans [49]. *Saccharomyces* sp can cause opportunistic infections on exposed hosts [52]; *Neurospora* sp is a non-human pathogen useful as an experimental model in genetics [48]. *Rhizopus* sp and *Mucor* are known for causing Mucormycosis [51]. The predominance of bioaerosols in the study area and their ability to survive harsh conditions of the atmosphere other than their physiochemical properties might be due to the presence of dust in the air, which supports their existence in spore form [16]. This is in conformity with the World Health Organization, which postulated that exposure to microbial agents of aerosol origin increases the risks of rare health conditions. The variation and prevalence of bacterial and fungal genera in the air, as observed here, are due to differences in stability and viability in the air. Gorny [35] asserted that air as a biotope does not support the survival of biological agents, but he further stated that several studies showed that numerous fine particles of biological origin were able to maintain their viability and immunological reactivity in the air much longer than bigger organisms. This also explains why the bacterial population is high in this study, considering their size, which is between 0.5 - 2.0 µm, than fungi, whose individual cell size can vary widely from 2 – 3 µm to 20 – 50 µm in length.

The potential health hazards associated with frequent exposure to bioaerosols in the study population were shown to be very high in all locations. According to Occupational Safety and Health Administration [30] and other regulatory bodies provided a guideline for microbial load threshold between 10^2 – 10^4 CFU/m^3 (low – high risk); though this value varies from country to country. In Nigeria, for instance, there is no official data from environmental and health regulatory bodies on biological aerosols threshold; the data obtained in this study were interpreted based on standards/guidelines for bioaerosols proposed by different governmental and private organizations; based on European literature databases on residential indoor air quality as reported by Kumar et al. [5]. This study showed mean microbial load of 7.86 x 10^2 – 4.97 x 10^5CFU/m^3. Hence it can be deduced that there is a high public health risk of frequent exposure to biological aerosols in the Bariga community. Therefore, adequate hazard mitigation should be employed to reduce the risk, thus promoting healthy living.

A significant correlation (p=0.05) between bioaerosols exposure duration and the likelihood of developing the onset of diseases in the susceptible, exposed host was observed. This is supported by Franchitti et al. [52], who reported a statistically significant correlation between bioaerosols exposure and the onset of health effects on humans. The economic implication of pathogens of bioaerosols origin has been estimated: the cost of treatment of infections or diseases ($10 - 720,167.22) per episode or annum, low productivity and deaths [53]. It can be challenging to treat some of these pathogens because of their multi drugs resistance, thus putting their hosts in grave danger and other life-threatening situations. Preventive measures to curb the pandemic emanating from bioaerosols include quarantine, preparation of health facilities, isolating infectious cases, and tracing contacts involving public health resources, human resources and implementation costs. It also involves health system expenditures to provide health facilities for infectious cases and the arrangement of consumables such as antibiotics, medical supplies, and personal protective equipment [56]. In Nigeria, there is no official data on economic loss from bioaerosol-originated infections. However, the current fight against COVID-19 (bio-aerosol borne) disease was reported to cost the country over N45b [25]. Bioaerosols-related infectious diseases have been reported to be responsible for economic losses, including medical expenditures of about US$21 billion globally, economic productivity losses, environmental degradation and material losses [20]. This cost is significantly high in this era of economic recessions, which can create global implications of bioaerosols-related pandemic impact on the health system and simultaneously the growth prospects of the whole countries [8]. The health risk of outbreaks of infectious diseases,

the fear and worry that accompany them, low productivity due to illness and absenteeism from work and school lead to various economic risks, thus increasing poverty within the community and the nation at large.

CONCLUSION

This study has shown a significant relationship between the frequencies of exposure to bioaerosols and associated public health risks on the exposed individuals. The statistical analysis one-way analysis of variance (ANOVA) at 0.05 significance level between exposure to bioaerosols and subsequent health hazards on the general public. The variation in environmental parameters is largely dependent on time and seasons, with subsequent adverse effects on the presence and movement of biological aerosol droplets suspended in the atmosphere. The study also revealed that the study area is a high-risk area (10^2 – 10^4CFU/m^3) for biological aerosol-related infections or diseases. Hence, the prevalence of genera, *Staphylococcus, Bacillus, Micrococcus, Pseudomonas, Actinomycetes, Streptococcus, Shigella, Serratia, Enterobacter, Escherichia, Salmonella, Yersinia, Aspergillus, Fusarium, Saccharomyces, Neurospora, Rhizopus* and *Mucor* is an indication of microbial contamination. The knowledge of the presence of biological agents and adaptation of lifestyles by the residents in the study area can help in environmental and public health sustainability, thus reducing bioaerosols-related pollution. It is therefore recommended that adequate proactive, preventive and control measures such as structural and aesthetic modification in line with urban plans should be put in place to reduce the survival, distribution, colonization and establishment of bioaerosols in the Bariga community, thus promoting the health of the residents. Lagos State Government should also intensify efforts to reduce the public health effect of bioaerosols through policies, structural planning, development, and education on environmentally friendly activities and personal hygiene.

ABBREVIATIONS

ASHRAE - The American Society of Heating, Refrigerating, and Air-Conditioning Engineers.
CFU - Colony-forming Unit
COVID-19 - *Coronavirus disease*
GDP - Gross Domestic Product
GPS - Global Positioning System
LCDA - Local Council Development Area
ND – Not Determined
OECD - The Organization for Economic Cooperation and Development
OSHA - Occupational Safety and Health Administration
TNTC - Too Numerous to Count
UK - United Kingdom
WHO - World Health Organization

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Gamma Generalized Extended Inverse Exponential Distribution: A Novel Distribution in Modeling COVID-19 Cases in Nigeria

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ABSTRACT
In this study, we developed a novel distribution called Gamma Inverse Exponential (GIE) distribution, which has proved to be a more flexible distribution in modeling COVID-19 case fatality in Nigeria. We studied some statistical properties of the new distribution, which include: moments, incomplete moments, quantile function, Renyi entropy, and mean deviation. A real-life data application to a number of reported cases of COVID-19 infection between March 2019 to 2021 shows that the GIE distribution has a better fit than some competing distributions in fitting the data. Time series analysis of the COVID-19 data is also considered.

Keywords: COVID-19; Characteristics Function; Mean Residual Function; Case Fatality; Gamma Inverse Exponential Distribution.

INTRODUCTION

In probability theory, the extreme value (EV) distribution is a family of continuous distributions developed within the framework of extreme value theory, which includes the popular Gumbel, Frechet and Weibull distributions which are respectively known as type I, II and III extreme value distributions. The EV distributions sometimes exist as a limiting distribution for the minimum or maximum of a sample of independent, identically distributed random variables. Extreme value is the theory of modeling and measuring events which occur with a very small probability. These distributions and their generalized forms can be applied in finance, material sciences, telecommunications, economics and many others. Frechet distribution, because of its heavy tail, has been applied in the modeling of market returns which is related to finance [1]. The cumulative distribution function (CDF) of the standard Frechet distribution is

$$F(x) = e^{\left(-\frac{\lambda}{x}\right)^{\rho}}, \qquad x > 0, \lambda, \rho > 0 \tag{1.1}$$

Where λ is a scale parameter, and ρ is a shape parameter
By letting $\rho = 1$, we obtain another distribution known as Inverse Exponential (IE) distribution which CDF is given by

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$$F(x) = e^{-\frac{\lambda}{x}}, \qquad x > 0, \lambda > 0 \qquad (1.2)$$

The associated probability density function (PDF) to (1.2) is given by

$$f(x) = \lambda x^{-2} e^{-\frac{\lambda}{x}}, \qquad x > 0, \lambda > 0 \qquad (1.3)$$

Here, the λ is a scalar parameter.

In many real-life situations, the classical distribution does not give a sufficient fit to lifetime data, most especially when the data exhibit different shapes of the hazard function. Therefore, various generators are proposed to produce a new model with improved modeling potential [2-13].

THE GAMMA INVERSE EXPONENTIAL (GIE) DISTRIBUTION

Zografos and Balakrishnan [12] and Ristic and Balakrishnan [13] proposed a family of univariate distributions generated using gamma random variables. Given any baseline CDF $F(x)$, and $x \in R$, they defined the gamma-G distribution with an extra shape parameter $\sigma > 0$ and PDF $g(x)$ and CDF $G(x)$ given by

$$g(x) = \frac{1}{\Gamma(\sigma)}[-log\{1 - F(x)\}]^{\sigma-1} f(x) \qquad (2.1)$$

And

$$G(x) = \frac{\gamma(\sigma, -log[1 - F(x)])}{\Gamma(\sigma)} = \frac{1}{\Gamma(\sigma)} \int_0^{-log\{1-F(x)\}} t^{\sigma-1} e^{-t} dt, \quad (2.2)$$

respectively, where $f(x) = d\,F(x)/dx$, $\Gamma(\sigma) = \int_0^\infty t^{\sigma-1} e^{-t} dt$ and $\gamma(\sigma, y) = \int_0^y t^{\sigma-1} e^{-t} dt$ are the gamma and the incomplete gamma functions. The shape parameter σ controls skewness and kurtosis through the tail weight

Putting (1.1) and (1.2) in (2.1), we obtain the PDF of the GIE distribution given by

$$g(x) = \frac{\lambda\sigma}{\Gamma(\sigma)} x^{-2} e^{-\frac{\lambda}{x}} \left[-log\left\{1 - e^{-\frac{\lambda}{x}}\right\}\right]^{\sigma-1} \qquad (2.3)$$

And the corresponding CDF to (2.3) is given by

$$G(x) = \frac{\gamma\left(\sigma, -log\left[1 - e^{-\frac{\lambda}{x}}\right]\right)}{\Gamma(\sigma)} \qquad (2.4)$$

An expression for the survival and the hazard function is, respectively as

$$S(x) = 1 - \frac{\gamma\left(\sigma, -log\left[1 - e^{-\frac{\lambda}{x}}\right]\right)}{\Gamma(\sigma)}, \qquad (2.5)$$

And

$$h(x) = \frac{\lambda\sigma x^{-2} e^{-\frac{\lambda}{x}}\left[-log\left\{1 - e^{-\frac{\lambda}{x}}\right\}\right]}{\Gamma(\sigma) - \gamma\left(\sigma, -log\left[1 - e^{-\frac{\lambda}{x}}\right]\right)}. \qquad (2.6)$$

The graphs of the density and the hazard function are given in Figures 1 and 2 for various values of the parameters.

QUANTILE FUNCTION OF GIE DISTRIBUTION

From Nadarajah et al. [9], we can generate GIE random variables from the quantile function given by

$$F^{-1}(u) = \lambda\left[-log\left(1 - e^{\left(-Q^{-1}(\sigma, 1-u)\right)}\right)\right] \qquad (2.7)$$

Where $Q^{-1}(\sigma, u)$ denote the inverse function of $Q(\sigma, x) = 1 - {\gamma(\sigma, x)}/{\Gamma(\sigma, x)}$; setting $u = 0.5$

in (2.7), we obtain the median (M) of GIE distribution as

$$M = \lambda\left[-log\left(1 - e^{\left(-Q^{-1}(\sigma, 0.5)\right)}\right)\right] \qquad (2.8)$$

PROPERTIES OF GIE DISTRIBUTION

Here, we obtain an expression for the moment, incomplete moment, mean deviation and the entropy of the GIE model.

MOMENTS AND INCOMPLETE MOMENTS OF GIE DISTRIBUTION

We now obtain the r^{th} moment about zero of X, say $E(X^r)$. The r^{th} moment of $X \sim GIE\ (\lambda, \sigma)$ is found by

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$$E(X^r) = \int_{-\infty}^{\infty} x^r f(x)dx \qquad (3.0)$$

Substitute from Equation (2.3) into Equation (3.0), and we will get the r^{th} moment as follows.

$$E(X^r) =$$

$$\lambda^r \Gamma(1-r) \sum_{i,l=0}^{\infty} \frac{(-1)^{l+1}(i+1)V_i}{(1+l)^{(1-r)}} \binom{i}{l} \qquad (3.1)$$

Where

$$= \frac{(-1)^i}{(i+1)!} \sum_{k=0}^{\infty} \frac{(\sigma+k)}{\Gamma(\sigma+k-i)} \Gamma(\sigma+k)$$

Next, we derive a simple formula for the r^{th} incomplete moment of *X*, say $m_r(t) = E(X_r|X < t)$. From equation (2.3), we obtain

$$m_r(t) = \lambda^r \Gamma(1-r) \sum_{i,l=0}^{\infty} \frac{(-1)^{l+1}(i+1)V_i}{(1+l)^{(1-r)}} \binom{i}{l} \left\{[(1+ l)\lambda]^{-(1-r)} - \gamma\left[1-r, (1+l)\frac{\lambda}{t}\right]\right\} \qquad (3.2)$$

MEAN DEVIATIONS

The mean deviations about the mean $\left(\delta_1(\mathrm{X}) = \mathrm{E}(|\mathrm{X} - \mu_1'|)\right)$ and about the median $\left(\delta_2(\mathrm{X}) = \mathrm{E}(|\mathrm{X} - \mathrm{M}|)\right)$ of X can be represented as:

$$\delta_1(\mathrm{X}) = 2\mu_1' F(\mu_1') - 2m_1(\mu_1') \; and \; \delta_2(\mathrm{X}) = \mu_1' - 2m_1(M) \qquad (3.3)$$

Respectively, where $\mu_1' = E(X)$ can be obtained from (3.1), $M = median\ (X)$ is the median given in (2.8).$F(\mu_1')$ can be easily obtained from the CDF (2.2), and $m_1(t) = \int_0^t xf(x)dx$ is the first incomplete moment obtained from (3.2) by setting $r = 1$.

Applications of these equations can be used to obtain an explicit expression for the Bonferroni and Lorenz curves defined for a given probability π by $B(\pi) = \frac{m_1(h)}{\pi\mu_1'}$ and $L(\pi) = \frac{m_1(h)}{\mu_1'}$, respectively, where

$h = F^{-1}(\pi)$ is the GIE function at π defined from (2.7).

RENYI ENTROPY

The entropy of a random variable *X* with density function *f* (*x*) is a measure of the variation of the uncertainty. For any real parameter $\rho > 0$ and $\rho = 1$, the Renyi entropy is given by

$$I_R(\rho) = \frac{1}{1-\rho} log \int_0^{\infty} f^{\rho}(x)dx \qquad (3.4)$$

Putting equation (2.3) in (2.4), we have an expression for the moments of GIE distribution as

$$\frac{1}{1-\rho} log \left\{ \frac{(\sigma-1)\rho\lambda^{\rho}}{[\Gamma(\sigma)]^{\rho}} \sum_{k,l,m}^{\infty} (-1)^{k+l+m+1} \frac{\binom{k-(\sigma-1)\rho}{k}\binom{k}{m} p_{m,k}}{(\sigma-1)\rho - m} \frac{\Gamma[(\sigma-1)\rho+1]\Gamma(w)}{l!\,[(k+l+\sigma w)]^w} \times \Gamma[(\sigma-1)\rho+1-l] \right\} \qquad (3.5)$$

Where,

$$w = \rho[(\sigma-1)\rho+1-l] \; and \; p_{m,k} = k^{-1} \sum_{j=0}^{k} \frac{(-1)^j[j(m+1)-k]}{(j+1)} p_{m,k-j}$$

For $k = 1,2,\ldots, and\ p_{m,0} = 1$

ESTIMATION

Here, we determine the maximum likelihood estimates (MLEs) of the parameters of the GIE distribution from complete samples only. Let $x_1, \ldots, x_n$ be a random sample of size *n* from the GIE (λ, σ) distribution. The log-likelihood function can be expressed as

$$l(\lambda, \sigma) = -nlog\Gamma(\sigma) + nlog(\lambda\sigma) - \lambda \sum_{i=1}^{n} x_i^{-1} - 2\sum_{i=1}^{n} log(x_i)$$

$$+(\sigma-1)\sum_{i=1}^{n} \left[log\left(-log\left[1-e^{-\frac{\lambda}{x_i}}\right]\right)\right]$$

The element of the score vector for GIE model is given as

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$$\frac{\partial l}{\partial \lambda} = \frac{[n-\lambda\sum_{i=1}^{n}(x_i^{-1})]}{\lambda} + (\sigma-1)\sum_{i=1}^{n}\left[\frac{\frac{\sigma}{x_i}e^{\frac{\sigma}{x_i}}}{\lambda\left(1-e^{\frac{\sigma}{x_i}}\right)log\left(1-e^{\frac{\sigma}{x_i}}\right)}\right] \quad (4.1)$$

$$\frac{\partial l}{\partial \sigma} = n\psi(\sigma) + \sum_{i=1}^{n} log\left(-log\left[1-e^{\frac{\sigma}{x_i}}\right]\right) \quad (4.2)$$

APPLICATION

In this section, we present the usefulness of the GIE distribution by applying it to the case fatality COVID-19 data set, Nigeria's experience between the months of March 2020 to December 2021 and compare the performance of the model with its sub-model. Now, we apply the Akaike information criterion (AIC), consistent Akaike information criterion (CAIC), Hannan-Quinn criterion (HQIC), and Kolmogorov-Smirnov(K) goodness of fit test to verify which distribution fits better to these data. In general, the smaller the values of the statistics AIC, CAIC, HQIC and KS, the better the fit to the data. Table I contains the exploratory data analysis for the COVID-19 data. Table 2 shows the measure of goodness of fit test. Table 3 presents the Auto-Regressive Integrated Moving Average (ARIMA) model for the COVID-19 data. The graph of the daily number of reported cases is drawn in Figure 4.

CONCLUSION

The Gamma Inverse Exponential model is considered a better model when compared to its sub-model in modeling the COVID-19 data because it returns the minimum values of information criteria. ARIMA (1, 0, 1) is the best model under the ARIMA scheme, and the point forecast obtained indicates that if a drastic step is not taken by January 2023, the monthly reported cases of COVID-19 patients will be 23008.

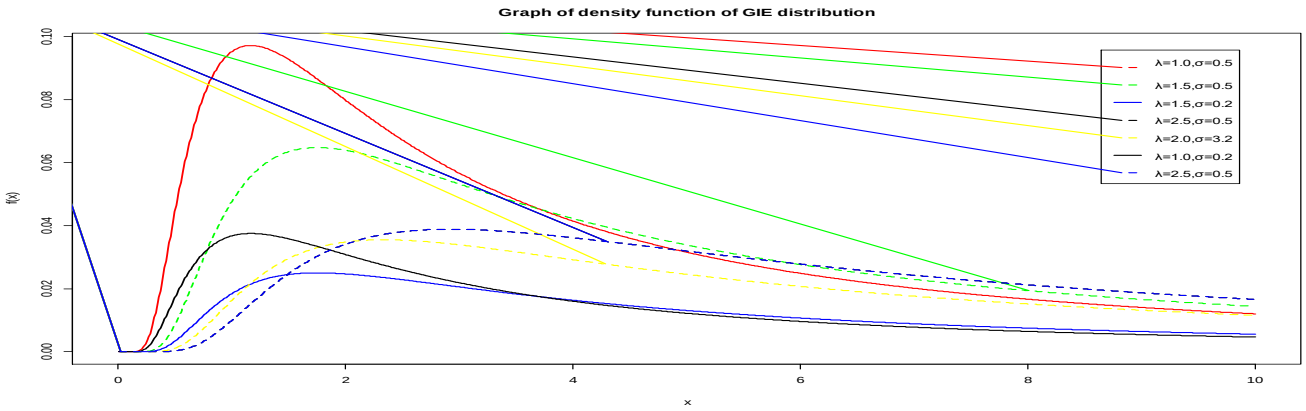

Figure 1: Graph of the density function of GIE distribution

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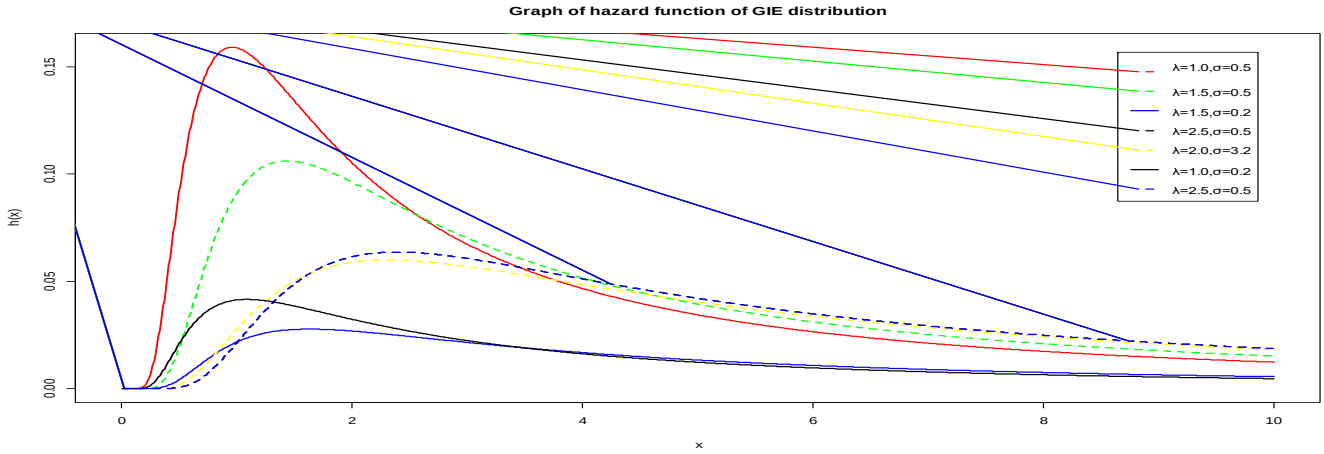

Figure 2: Graph of the hazard function of GIE distribution

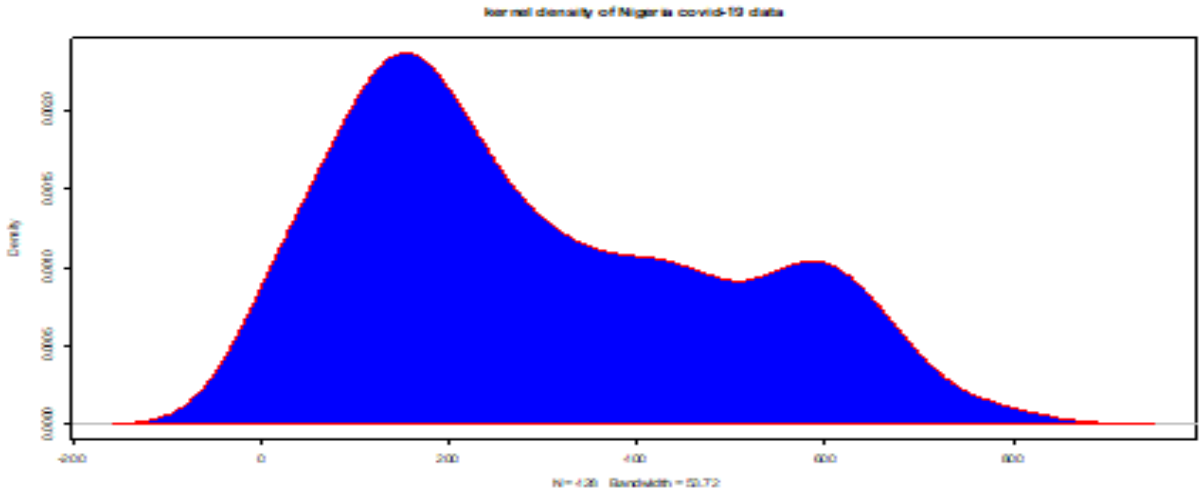

Figure 3: Kernel density curve for COVID-19 data

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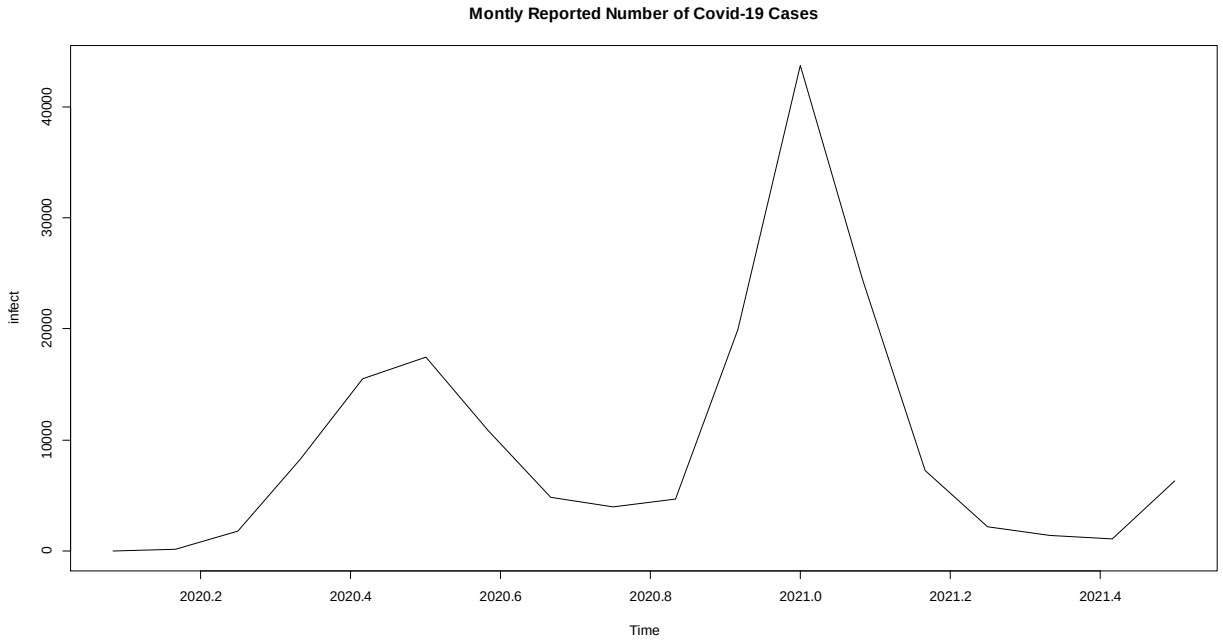

Figure 4: Graph of daily reported cases of COVID-19 in Nigeria.

Table 1: Exploratory data Analysis of COVID-19 data

Min.	q_1	q_2	**Med.**	**Mean**	**Max.**	**Var.**	**Skew.**	**Kurt.**
1.0	86.0	499.5	203.0	345.4	2314.0	139613	2.0	7.3

Table 2: Measures of goodness of fit of GIE model

$\boldsymbol{Model}$	$\boldsymbol{\lambda}$	$\boldsymbol{\sigma}$	$\boldsymbol{-l}$	$\boldsymbol{AIC}$	$\boldsymbol{CAIC}$	$\boldsymbol{HQIC}$	$\boldsymbol{KS}$
GIE	20.05 (0.93)	1.46 (0.04)	4403.42	8810.85	8810.87	8814.29	0.2347
IE	5.72 (2.23)	– (–)	4585.35	9172.72	9172.71	9174.42	0.3090

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Table 3: Models with information criterion

$ARIMA\ models$	$Value\ of\ mean$	AIC
$ARIMA(2,0,2)$	$With\ nozero\ mean$	376.3729
$ARIMA(0,0,0$	$With\ non-zero\ mean$	506.9031
$ARIMA(1,0,0)$	$With\ non-zero\ mean$	391.5391
$ARIMA(0,0,1)$	$With\ non-zero\ mean$	398.7286
$ARIMA(0,0,0)$	$With\ zero\ mean$	504.9151
$ARIMA(1,0,2)$	$With\ non-zero\ mean$	374.1229
$ARIMA(0,0,2)$	$with\ non-zero\ mean$	394.9124
$ARIMA(1,0,1)$	$with\ non-zero\ mean$	384.8265
$ARIMA(1,0,3)$	$with\ non-zero\ mean$	374.6944
$ARIMA(0,0,2)$	$with\ non-zero\ mean$	396.022
$ARIMA(2,0,1)$	$with\ non-zero\ mean$	386.9209
$ARIMA(2,0,3)$	$with\ non-zero\ mean$	377.9495
$ARIMA(1,0,2)$	$with\ zero\ mean$	372.4052
$ARIMA(0,0,2)$	$with\ zero\ mean$	393.029
$ARIMA(1,0,1)$	$with\ zero\ mean$	383.1155
$ARIMA(2,0,2)$	$with\ zero\ mean$	374.5912
$ARIMA(1,0,3)$	$with\ zero\ mean$	372.9165
$ARIMA(0,0,1)$	$with\ zero\ mean$	396.9129
$ARIMA(0,0,3)$	$with\ zero\ mean$	394.151
$ARIMA(2,0,1)$	$with\ zero\ mean$	385.072
$ARIMA(2,0,3)$	$with\ zero\ mean$	376.1708

ARIMA (1,0,2) with zero mean : 392.2688

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Themed: Strengthening Health Security and Mitigating Biological Threats in Africa

Held on Wednesday, 2nd – 4th November 2022 at the Civic Centre, Victoria Island, Lagos State, Nigeria

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PREAMBLE

The 8th African Conference on One Health and Biosecurity with the theme *Strengthening HealthSecurity and Mitigating Biological Threats in Africa* was held Wednesday, 2nd November- Friday 4th November, 2022. The 8th edition of the annual conference was organized by the Global Emerging Pathogens Treatment Consortium (GET Africa) with the support of *Lagos State Ministry of Health*, and in partnership with major non-state institutions across the World. The conference focused on ways of improving health security in the African Continent and addressing emerging biological threats. The 3-day conference presented a unique forum to raise National, Regional and Continental awareness and engage in deep introspection and robust interactions on existing health security measures and how to strengthen them, as the first urgent step toward mitigation of emerging biological threats in Africa. The conference, attended by professionals and stakeholders across the various strata of the health and allied sectors of the society, received presentations from resource persons in the healthcare sector and related fields. The following observations and recommendations emerged from exhaustive deliberations:

OBSERVATIONS

i. One of the major lessons of recent outbreaks is that biosecurity has myriad dimensions permeating social, political, cultural, economic, ethical, legal, and technological aspects of human endeavors, thus necessitating an integrated multidisciplinary approach to healthsecurity.

ii. Recent climate change incidents and emerging infectious diseases, particularly resurgence of Ebola, Lassa fever, and monkey pox, coupled with global inflation and food security issues, have negatively impacted ability of individuals, institutions, and government especially in Africa, to meet their obligations in various critical areas of life including health.

iii. Destruction of the environment, biodiversity loss, and consequent increase in conflict and terrorist activities as well as the ease of genetic manipulation has necessitated a rethinking of security ideology, architecture, and apparatus with increased emphasis on biological threats and how to detect, prevent and mitigate them.

iv. In the next 50 years, Africa will be a continent of mega cities with health, toxicity, and biosecurity threats being the major footprint of its population explosion.

v. African countries rate low in terms of biosafety and biosecurity awareness,

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capacity, and regulatory regime even as pitfalls of waterborne diseases, foodborne diseases, and antimicrobial resistance threaten health security and total wellbeing of significant proportion of her population.

vi. The African ecological and biodiversity landscape is not only a source of public health and biosecurity challenges but also offers sustainable solutions to such threats, drawing especially on the continent's diverse and entrenched ethno-cultural appropriation of natural resources. However, there is poor involvement of Africa in bioeconomy with onlya few African countries having existing policy frameworks for promoting bioeconomy.

vii. Addressing health security issues in Africa requires much more than mere adoption of operational models from the developed world, where formal sectors are well-established. Thus, the African informal sector cannot be ignored in building biosecurity measures and developing health strategies.

viii. The passion, energy, and resilience of the youth, which are key factors driving change in any society, must be considered as a huge factor when elucidating biosecurity issues and can also be harnessed to mitigate biosecurity threats.

ix. Civil society organizations (CSOs) and Non-governmental organizations (NGOs) play significant role in promoting health security consciousness through advocacy and engagement of critical stakeholders on proactive and reactive measures needed to minimize the danger and impact of acute public health events.

x. Dual use potential of valuable biological materials (VBMs) and biotechnological research has implication for health security and nations have responsibility to promote and ensure responsible use of such materials and technologies.

xi. While there have been increase awareness and deliberate efforts to develop strategies for mitigating the public health impacts of climate change, the mental and psychosocial dimensions have received comparatively insignificant attention.

xii. Globally, and particularly in Africa, climate change impacts gender differently due to their historical and structural inequalities, promoted by social norms and laws that impose differentiated power roles and responsibilities on women and men in respect of life.

xiii. Recent epidemics in Africa and responses at various levels within and outside the continent have further demonstrated that Africa is yet to fully dismantle the foundations of perpetual exploitation of our countries and dependency while striving to be politically correct at the expense of wholesome development.

xiv. Overlapping activities of health organizations such as Centre for Disease Control Africa (CDC Africa), West Africa Health Organization (WAHO), and World Health Organization (WHO) among other, have resulted in duplication of efforts, poorly coordinated responses and frittering away of scarce human and material resources.

xv. Corruption, poor accountability, and poor budget monitoring remain the scourge of healthcare financing in Africa.

xvi. Digitalization of disease surveillance records, standardized data collection, and big data management, which are important requirements for biological threats mitigation preparedness, are still poorly developed in Africa, thereby posing serious impediment to the resilience of health infrastructure.

CONFERENCE DECLARATION

Cognizant of the ravaging impact of emerging and re-emerging infectious diseases and the diverse dimensions and proclivities of biological threats in Africa; not unaware of the poor state of health infrastructure across the continent; convinced that Africa's vast ecosystem and biodiversities are the reservoir as well as veritable source of solution to biological threats; committed to leveraging on Africa's natural, ethno-cultural and intellectual resources in a harmonious, collaborative, and coordinated manner; and mindful of the importance of healthy and mutually beneficial global engagements in addressing health issues, Conference hereby agreed and declare as follows:

To pursue constructive engagement in demanding 15 percent of national budgetary allocationsto the health sector in line with the 2001 Abuja Declaration as first line charge, and commitment of at least 1.5% of nation's

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Gross Domestic Product to medical education and health work force training, as fiducial benchmark for building resilient health infrastructure needed to strengthen health security in Africa; reaffirmed unalloyed commitment to all aspects of the Convention on Biodiversity (CBD), including the Nagoya Protocol on access to genetic resources and equitable sharing and demand African government and all stakeholders activate same commitment in principle and practice; promote bioeconomy and ecofriendly exploitation of natural resources; relentlessly and vigorously demand full implementation of existing national policies on biosecurity, biosafety and one health as well as total commitment to obligations at regional, continental and national levels including the Biological Weapons Convention (BWC), Resolution 1540, and Global Health Security Agenda (GHSA).

Resolutions

i. In order to bolster health security, African governments should put in place robust and effective disease surveillance strategies premised on state-of-the-art, high through put genomic facilities and manpower, to promote early warning systems for impending outbreaks, monitor and evaluate the impacts of intervention; and helps to track progress towards specified goals.
ii. There is need for increase budgetary allocation to the health sector by African governments, concomitant with a shift in health financing perspective to more Afrocentric donor funding and innovative financing models, incorporating both entrepreneurial and corporate social responsibility-based private sector participation.
iii. Budget monitoring for health financing should be people centered drawing on the participation of CSOs, the academia and health workforce.
iv. There is an urgent need for African governments to prioritize and expand the scope of medical education and practice to include multi-sectoral collaborations and incorporation of technology-based medical treatments such as personalized medicine, telehealth, and artificial intelligence and machine learning.
v. African governments, institutions and relevant agencies should embark on massive communication and market incentive-driven, sustainable energy and natural products-based, bioeconomy revolution, focusing on small and medium scale agro-allied value chains.
vi. In order to be able to build sustainable health security infrastructure, and be well-prepared to mitigate future outbreaks, Africa must engage in deliberate rejection of global monoculture and decolonization of the language of scientific discourse, while appropriating foreign support in ways that fit into indigenous socio-cultural peculiarities.
vii. There is need to streamline outbreak preparedness and response through strategic coordination and collaboration among African countries, and the various health agencies and organizations in order to ensure effective utilization of available resources.
viii. African countries need to demonstrate total commitment to their international obligations with respect to health governance, particularly the International Health Regulations (IHR), One Health Agenda, and the Global Health Security Agenda (GHSA).
ix. Climate change awareness, biodiversity conservation, One Health paradigm, and biosecurity training should be integrated into the curricula at the basic and high school levels to build consciousness and culture of sustainable development in Africans right from formative age.
x. Generation and management of public health data should be focused on timely collection, interrogation, storage, and analysis, while leveraging on communities for wholesome surveillance.

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