

COVID-19: Implications for food, water, hygiene, sanitation, and environmental safety in**Africa-A case study in Ghana**

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Abstract

Governments all over the world are currently grappling with the COVID-19 pandemic. While some countries were very hard hit, others were only mildly hit but all are still taking measures to mitigate the consequences. The disease emerged in December 2019 in Wuhan, China and spread to most continents by the beginning of March 2020, which led to the World Health Organization declaring it as a pandemic on the 11th of March 2020. Since it was a novel disease, there was limited information on the virus. Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) belongs to the same family as the Severe Acute Respiratory Syndrome Coronavirus 1 (SARS-CoV-1) and the Middle East Respiratory Syndrome Coronavirus (MERS-CoV). Researchers all over the world started working simultaneously to understand the virus to provide the necessary treatment regime or vaccine in order to reduce its impact on victims. Developing countries in Africa, Asia and southern America with limited resources and poor planning and management are expected to be among the worst hit in the long run. The implications of COVID-19 on food, water, hygiene, sanitation, and the environment in Africa have been reviewed in this paper, as well as possible implications they may pose to the population, based on the existing common practices and their immediate impacts. This information can assist policymakers in Africa to adequately plan the management of the COVID-19 in order to lessen its impact on the population.

Keywords: COVID-19, food, water, hygiene, sanitation, environment, safety, Ghana, Africa

Introduction

Governments of all countries worldwide are currently grappling with the COVID-19 pandemic.

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In Africa two common perceptions, rather unfounded, were that Africans were immune to whatever was happening in Wuhan, China and rest of Asia, Americas and Australia, Italy and the rest of Europe, secondly SARS-CoV-2 could not survive the high temperatures in tropical African.

Unfortunately, the first case of COVID-19 in Africa was recorded on the 14th of February 2020 in Egypt. The first case in sub-Saharan Africa was reported on the 27th of February, 2020 in Nigeria, West Africa. The disease has since spread to all 54 countries and the number of confirmed cases is rapidly increasing.

The fear of most experts in Africa is that, with weak healthcare service systems and poor sanitation the continent will be hit harder than the rest of the world. As of the 18th of May 2020, Ghana has recorded more than 5,735 cases with 29 deaths (Ghana Health Service, 2020), and the situation in the country as well as in other African states raises further concern about the burden of COVID-19 on African economies. The world bank has projected that COVID-19 will drive sub-Saharan Africa toward its first recession in 25 years (World Bank 2020).

It has been estimated by the WHO that Africa is likely to report 199,000 deaths as a result of COVID-19 pandemic (WHO, 2020). This estimate takes into consideration the the level of preparedness, availability of healthcare systems to cater for vulnerable populations, ability to detect, isolate and treat, among several other predisposing factors.

The main objective of this review is to discuss COVID-19 and its possible implications on food, water, sanitation, hygiene and environmental safety during the pandemic and the impact it will have now and in the near future. This can assist policymakers in Africa to plan adequately in the management of COVID-19 to lessen the impact on the population.

Prior to reading this article, it is important to note that many studies of the SARS-CoV-2 virus are highly dependent on the RT-qPCR analysis. This assay has an inherit limitation in that it interacts with small genetic components of the virus rather than viable virus. This is important to keep in mind when interpreting current SARS-CoV-2 studies because a positive PCR result does not necessarily indicate the presence of live virus.

The Game Changers: SARS-CoV-2 in faeces, food and stability on surfaces

When COVID-19 outbreak begun, the transmission routes of the SARS-CoV-2 were not well understood. The known transmission routes are the eyes, nose and mouth. It was not until February and March of 2020 that scientists published first articles about the presence of the genetic materials of the SARS-CoV-2 being identified in the faeces of patients in China (Xiao et al., 2020; Zhang et al. 2020), where the disease started. This raises a concern about the possible transmission of the SARS-CoV-2 through the faecal-oral route which has implications on food, water, hygiene, sanitation, and the environment. On the 7th of April, 2020, the Food and Agriculture Organization (FAO) and World Health Organization (FAO and WHO, 2020) published a document on "COVID-19 and food safety: guidance for food businesses" even though it stated that it is highly unlikely that people can contract COVID-19 through food or food packaging. Transmission through faeces and food can be considered as the game changer in food safety. Another important finding was that the genetic material of the virus could be stable for several hours to days in aerosols and on surfaces (van Doremalen et al.,

2020), but the live virus was not detected. Such stable genetic material contaminates the environment even in absence of the live virus, which could have far reaching implications on genetic modifications.

Surprisingly, the SARS-CoV-2 genetic material has also been detected in faeces of humans just three days after infections, unlike the nasopharyngeal samples that take 5 days or more to manifest in patients (Madema et al., 2020). This finding may be very important in most parts of Africa, since open defecation is widely practiced (**Fig 1**) due to lack of sanitary facilities. Based on the current literature, it is not impossible that people may spread the virus through faeces to the environment as a result of open defecation, several days before symptomatic infection starts. Thus, there is a risk of the SARS-CoV-2 being transmitted through people's faeces, but no evidence of such transmission exists currently.

The stability of SARS-CoV-2 in the environment, as reported by van Doremalen et al. (2020), is another problem. This calls for very effective disinfectants to defeat the virus in the environment. Africa, which is already the 'playing ground' for fake drugs (Antignac et al., 2017; Laing et al., 2019), may also have to battle with the influx of counterfeit disinfectants that lack the necessary activity. The use of such products may give a false sense of security to the users and lead to further spread of the disease if stringent regulatory frameworks are not put in place. In a research work done by my group in March on the efficacy of alcohol-based sanitizers (Saba et al., 2020a), 54% of sanitizers in Ghana were not effective against laboratory and ATCC strains of bacteria. Per the research, the number of unregistered alcohol-based hand sanitizers outnumbered the registered ones as at the time of purchasing samples in four major cities in Ghana. Most of the unregistered hand sanitizers were allegedly made in China with made in China labels. The high demand for such products gave a leeway for unscrupulous individuals to flood the market with counterfeit or diluted disinfectants. In one instance, a

producer of fake hand sanitizer was arrested by the police in Techiman, the Bono East Regional for using water and some unprescribed ingredients to produce and sell substance to the public (Nyabor, 2020). Such practices may produce fake disinfectants which are not effective and contribute to the wider spread of the virus, coupled with the widespread insanitary conditions.

Food safety

Food safety is complex as it involves a combination of multifaceted interdisciplinary processes. Food safety includes producing, harvesting, processing, handling, packaging, storing (freezing), transporting and distributing or selling food in an acceptable manner (by standards) that will prevent the food from changing its biological/microbiological, chemical and physical form beyond acceptable limits until it reaches the last consumer for consumption.

In food safety, there are basically three types of hazards that may be encountered.

- 1) Physical hazards which deals with the presence of physical object such as hair, glasses, papers, bones, rubbers, nails, pieces of face masks, etc. in the food which may be harmful to consumers.
- 2) Chemical hazards which deals with the presence of chemical agents such as formalin, DDT, disinfectants etc., or the higher proportion of recommended chemical above the recommended daily dose in food.
- 3) Biological hazards which deals with the presence of microorganisms (bacteria, viruses, fungi, and protozoa) and their toxins and other biological agents in food that may be hazardous for human consumption. Examples of the microorganisms are *Escherichia coli*, *Salmonella* spp., *Campylobacter* spp., Coronaviruses, Rotaviruses, Noroviruses, Hepatitis A, *Aspergillus* spp. *Cryptosporidium* spp. etc.

Foodborne diseases and outbreaks in Africa

A foodborne disease is any disease triggered by the consumption of food and water. An outbreak occurs when the same source of food causes three or more people to be sick of the same causative agent. In the developed countries, where stringent measures are put in place to detect foodborne disease outbreaks rapidly, outbreaks or recalls occur frequently because they have effective processes in place to monitor and track when there is any problem. This makes the citizenry to have confidence in the food production chain. There is also a constant update of issues concerning food safety through various channels of communication in order to act swiftly and avert any loss of life.

Foodborne diseases and outbreaks and recalls are hardly reported in developing countries and there are virtually no effective guidelines or implementation strategies when they occur. Africa is ranked first when it comes to deaths associated with diarrhea and related foodborne illnesses (Kirk et al., 2015). Issue of availability and accessibility to food (food security) is also a big challenge. However, an unwholesome food may kill the consumer. Food security and food safety must, therefore, go hand in hand to solve problems of the food production and supply, as well as utilization or consumption in Africa.

Food safety on the farm

In most urban and peri-urban areas in Africa, vegetable producers are heavily dependent on irrigated water or sewage for the production of their crops (**Fig 2**). Some also depend on dams, dugouts, streams and rivers for water to irrigate their crops. There is a high risk of using this untreated water to irrigate crops. Already, *Escherichia coli* has been found on many leafy vegetables cultivated using untreated and sewage water in Africa (Seidu et al. 2014; Pesewu et al., 2017). This makes it a clear possibility for the SARS-CoV-2 to contaminate leafy

vegetables and allow transmission to consumers who buy and eat these products without any proper processing to eliminate or reduce microorganisms.

Food transportation and distribution

Delays in transportation as a result of lockdown restrictions may also have a toll on food safety. In cases where selected cities are locked down, alternative and probably longer routes are considered for essential food items to be transported. This increases the time and cost of transportation. The end result might be breakage in the food chain, and the food quality being compromised.

Another concern which is worthy of note is the health of the transporters, such as the driver of the vehicle, the assistant driver or those who help in offloading the food from the vehicle. Any of the actors mentioned above could serve as a source of transmission of the COVID-19 in case they are infected and may possibly transmit it onto the food when they come into direct contact or indirectly, through the packaging materials.

The frequent disinfection of vehicles used for the transportation of food is necessary to break the chain of contamination of the virus from contact surfaces in the vehicle.

Sensitization of actors in the food chain about the COVID-19, as well as constantly monitoring their health status will go a long way to prevent spread of the disease.

Food processing/cooking

In the case of the SARS-CoV-2, there are no known toxins to be released into food. However, the live virus could find its way into food when there are gaps in the processing and cooking practices. A typical example to expatiate this point is when an infected sewage or untreated water is used to irrigate a leafy vegetable such as lettuce for example, that is harvested for immediate sale on the market, without further basic processing on farm to eliminate potential pathogens. Lettuce may continue to harbour the virus, until it is consumed and if the

appropriate receptor of the virus is found, proliferate and may result into COVID-19. This applies to other vegetables and fruits from the farm that are not processed well before consumption. The processor or cook may also be a source of the infection and may transmit the virus into the food during cooking without following good hygienic practices.

Food packaging

SARS-CoV-2 could live up to four hours on copper, up to 24 hours on cardboard and up to two to three days on plastic and stainless steel (van Doremalen, 2020). The local packaging materials is sometimes made of leaves of certain trees, old newspapers, in some cases old cement packaging bags, etc. and the conventional packaging materials such as the polyethylene bags, paper bags, plastic containers etc. Considering the local and conventional packaging materials and environmental temperature and conditions, the survival of the virus may vary.

Apart from the materials that are cardboard-like (e.g. old newspapers, leaves of exercise books or text books, old cement packaging bags, paper bags) and plastic-like (polyethylene bags and, plastic containers) of which the survival of the SARS-CoV-2 may be predicted or extrapolated, the survival on the leaves of trees is not known. Generally, the virus is likely to die faster on local packaging materials than the conventional ones. Unfortunately, the viability of the virus in different food products is not documented yet.

Two factors are noteworthy in food packaging:

- i) The ability of the packaging personnel to introduce the virus directly from him or herself into the food or on the packaging material through sneezing, coughing or with a contaminated hand and

ii) The ability of the personnel to introduce the virus from a contaminated contact surface either into the food directly or indirectly when touching or cleaning the material to package the food.

After sterilization of packaged product is done, the outer part of the packaging material is still vulnerable to microbial contamination. The sterilization of the outer packaging materials may not be done for most local packaging materials. Cardboard-like materials have been reported to harbour the virus for just a few minutes to hours while the stainless or cans may harbour them for up to 3 days based on PCR analysis (van Doremalen, 2020). Those involved in packaging food must be mindful of the good packaging practices and take precautions to avert any possible spread of the virus through the food packaging materials of the food itself.

Food retailing

Small scale retailing of fresh cooked food is present everywhere on the African continent. This is an informal activity, commonly practiced by women in Ghana. The sanitation and hygiene levels of these retailers are generally low, due to lack of training. Some food items such as oranges, yam, water melon, cabbage etc. are generally sold from the ground, which may also harbor pathogens, possibly including the SARS-CoV-2. Some may argue that there is no problem with produce that will be cooked before consumption, but cross contamination of other food products or contact surfaces may occur and put the consumer at risk of infection. Another behavior of concern is that many people are allowed to touch directly these retail foods to check for their quality before purchase. Flies that might have landed on infected faeces may also land on such produce on the market and therefore, increase the risk of acquiring the disease. Small-scale retailers buy their stock in a well packaged form, but open the package to further retail in smaller quantity to make them affordable. This practice also

predisposes the retail products to contamination. Awareness creation on these practices is needed to reduce the possible spread of COVID-19.

Street food safety

Street foods in Africa are generally ready-to-eat foods sold in stationary stalls, opened, semi closed or closed tables or by hawkers who roam about with the foods to find customers. Hawkers are commonly found in schools, at bus stations, government work places or offices, markets, social events, at places where major construction works is going on, by the windows of vehicles in heavy traffic and from door to door. These foods are normally prepared by vendors without training and certificates. Those that are well- organized and stationary have some supervision by the local authorities intermittently, because they are charged taxes. They are generally not well regulated and operate unhygienically (**Fig 3**) (Rheinländer et al., 2008; Saba and Gonzalez-Zorn, 2012). There has been a report in Accra, Capital of Ghana of ten street vendors at the Achimota Government Hospital who tested COVID-19 positive in a routine surveillance (Wemakor, 2020). Another street vendor, who sold peeled oranges to the public was confirmed dead of COVID-19 in the Tamale Metropolis on the 11th of May (More, 2020). These pose risk to consumers of their products and any other persons who came into contact with them. Where there are enough testing centers and kits, it is recommended to test all those involved in the food production chain, especially chefs at hotels and restaurants, street food vendors, waiters, etc. This will lead to early detection and treatment to prevent the further spread of the disease.

Zoonotic potential of SARS-CoV-2 and implications in Africa

Even though most coronaviruses are zoonotic (Schoeman and Fielding, 2019), there is no evidence that the SARS-CoV-2 is zoonotic and there has been no evidence of animal to human transmission yet.

The World Organization for Animal Health (OIE) has declared that the infection of animals with SARS-CoV-2 can be considered as an emerging disease because it is a disease causing infection or causing a significant impact on animal or public health resulting from: i) a change of a known pathogenic agent or its spread to a new geographical area or species or ii) a previously unrecognised pathogenic agent or disease diagnosed for the first time.

The Food and Agriculture Organization and World Health Organization (2020), have already warned about the potential transmission of the SARS-CoV-2 through food even though there is no scientific proof. The decision of the WHO to pronounce the COVID-19 a potential foodborne came as a result of the presence of the genetic material of the virus in faeces of patients. Another potential risk of the COVID-19 being zoonotic stems from the fact that it is also present in water bodies, where it may get into contact with both humans and animals (Fig 4).

Last, but not the least reason for which the COVID-19 could be a potential zoonotic disease was its detection in a number of animals; dogs in Hong Kong, cats in Belgium, France, Germany and USA, lion and tiger in the USA, mink farms in the Netherlands (OIE, 2020). According to an unpublished research conducted by the Erasmus University of Rotterdam but presented to the Dutch parliament by the Minister of Agriculture, Nature and Food, rabbits are sensitive to SARS-CoV-2 (International Society for Infectious Diseases, 2020). A research work published by Shi et al. (2020), about susceptibility of ferrets, cats, dogs, and other

domesticated animals to SARS-CoV-2 found that virus replicates poorly in dogs, pigs, chickens, and ducks, but ferrets and cats are permissive to infection. They also found experimentally that cats are susceptible to airborne infection. A report from the Dutch Ministries of Agriculture and Health indicated that an investigation on the mink farms suggest there has been a transmission of new coronavirus from mink to human (Dutch Ministry of Agriculture, Nature and Food Quality, 2020).

In Africa, there is no report and evidence that an animal has contracted the SARS-CoV-2. However, a report from Egypt showed killing of their cats by several owners because of the baseless believe that cat was transmitting the disease to human beings (Jansen, 2020). So far, the closest animals that are known to carry permissible infection dose of the SARS-CoV-2 are cats (Shi et al., 2020). Cats, both domestic and wild, are delicacies of certain tribes in Ghana. Although it has not been proven yet, eating cat meat in areas where the COVID-19 is highly endemic in Ghana may pose a considerable risk to consumers. The viral RNA of SARV-CoV-2 was detected in the faeces of two virus-inoculated subadult cats by Shi et al. (2020). Even though the live virus was not cultures from this study, it must be considered as a risk factor, especially in highly endemic areas of the diseases. There might be a risk of faecal-oral transmission through contaminated food and water. Faeces of cats must be handled with care especially in the endemic regions of COVID-19 in Ghana. However, the risk may be higher in companion cats whose owners have been infected with the virus.

As mentioned above, rabbits could be sensitive to the virus (International Society for Infectious Diseases, 2020). This may also mean that, rabbits in close contact with infected person or endemic areas must be monitored in Africa. Even though the virus has not been proven to be transmitted to human as a result of consuming rabbits, there is also a possible

risk of its transmission through eating infected rabbit. One of the main issues of concern will be the way these animals are slaughtered and processed in Africa. Hygienic precautions are not normally followed during slaughtering and processing and hence, there may be a risk of cross contamination of the virus. Most of the slaughtering and processing of cats and rabbits is done in the house, but not the abattoir.

With the detection of the SARS-CoV-2 human faeces, animals, both waste water and rivers, there is also potential of animals acquiring the virus through contaminated waste water, sewage or rivers if they have the appropriate receptacle for the virus.

The role of food safety authorities and stakeholders

The role of food safety authorities is very crucial in the enforcement of stringent guidelines in order to mitigate against the spread of the disease through food. Even though the enforcement of the law is generally relaxed during ordinary times, more efforts must be put in during crisis period even if it demands employing more people. The effects of the pandemic might be more than the financial commitment to employ more hands to help educate and enforce the law effectively to prevent the spread of the disease. This calls for the authorities to redouble their efforts and if possible fast track some of the processes to respond to the demands of the of the pandemic.

The major problem of food regulation in Ghana is the centralization of activities in the headquarters in the capital, Accra. Very simple procedures and analyses that could be done by regional offices are still sent to Accra, which is very far away from some of the regions. It takes about 600 km to 800 km to get to the headquarters in Accra from some regions. Food authorities must make conscious efforts and make it a priority to decentralize their activities in order to serve the population better. They must locate subsidiary laboratories in the

regions and build their capacity to be able to perform very simple but important tests to ensure basic safety.

Since samples from almost the whole Ghana must be analyzed in the central laboratory in Accra, there are unnecessary delays of test results. This can be avoided by using the tertiary institutions with laboratory facilities in the various regions. Central authorities must be ready to provide simple equipment and training to staff in those subsidiary laboratories to meet the required standards.

Water, Sanitation and Hygiene

Water, Sanitation and hygiene, collectively named WASH, have attracted a lot of attention in Africa for the past decades (Metwally et. al., 2017; Sanou et al., 2015; Hutton and Chase, 2017; Apanga et al., 2020). Higher burden of diseases, as a result of unsafe water, poor sanitation and hygiene have been reported to have a significant impact on the lives of Africans (Wolf et al., 2014; Wolf et al., 2018; Kwami et al., 2019). Even though enough data is not yet generated to link the spread of COVID-19 through water and lack of sanitation and hygiene, possible impact cannot be overemphasized.

Hand washing in the era of COVID-19: an opportunity to improve hand hygiene and food safety

As part of the preventive measures worldwide for the COVID-19, people are being encouraged to wash their hands with soap and clean water. Where there is no water, people are advised to use alcohol-based hand sanitizer in order to kill the virus on the hands so as to prevent it from entering the nose, mouth and eyes.

It is estimated that washing hands with soap and water could reduce diarrheal disease-associated deaths by up to 50% (WHO, 2001). Ghana and several other countries, until now, have a very poor hand washing culture. There are still concerns if people wash hands well

enough before using them to eat (Oppong et al., 2019). There is the saying that 'Ghanaians only wash their hands with soap after eating, to prevent the food from smelling on their hands but not before eating for the fear of the scent of the soap in the food'. This means that some people are still not aware of the essence of hand washing with soap.

Until recently, it was not uncommon to see many Ghanaians washing their hands without soap. It was not also very strange to visit an eatery that is without soap, because the food vendor is reluctant to buy more when certain quantity is exhausted. The concentration of the liquid soap used in such establishments, is of concern, to ensure that the hands of customers are very clean. Food business operators tend to dilute liquid soap to increase the volume without thinking if it will enable customers to wash their hands effectively. Even though the primary action of hand washing is the mechanical removal of viable transient and resident microorganisms, the concentration of the soap is very important to achieve the needed result. With the advent of the COVID-19, almost every street food vendor, restaurant or food business operator in Ghana provides either liquid soap or cake soap with water from the sink which is connected directly to a pipe borne water or a container filled with water with a tap fixed on it and called "Veronica" bucket in Ghana, after its inventor. Although the Veronica bucket concept is a very good one, there are a lot of concerns when it is publicly used.

The first concern is that, the taps expose users to contamination since everybody uses hands to open/close the tap in an attempt to wash the hands. We have worked on the prevalence of *Escherichia coli* (*E. coli*) and *Staphylococcus aureus* on the taps of Veronica buckets from various establishments including food business operators in the Tamale Metropolis of Ghana (Saba et al., 2020b). The presence *E. coli* indicates contamination with faeces, since it is naturally found in the faeces of humans and animals. Its presence also indicates that there is

poor hygiene regime. Furthermore, the presence of *Staphylococcus aureus* on taps, may also indicate generally poor hygienic practices. Our results showed that 20% (25/124) and 50% (62/124) of the taps of Veronica buckets samples analyzed were contaminated with *E. coli* and *Staphylococcus aureus* respectively, in the Tamale Metropolis. These results above have a very considerable implications for food safety.

Nonetheless, the “Veronica” bucket has revolutionized the act of hand washing in most of the food operating businesses in Ghana. This is probably the single most dramatic change in food safety behavior in the country.

With the emergence of the “Veronica” buckets, most restaurants and street food vendors require hand washing before entering their premises or when they are about to eat their foods. This encourages customers to wash their hands with soap under running water. Due to this dramatic change of food safety behavior in this COVID-19 period, we can promote proper hand washing among Ghanaians to reduce the burden of diseases that are oro-feacally transmitted.

Implications for water resources for livelihood in Africa

The SARS-CoV-2 has been detected in raw waste water for up to 8 days and in rivers as well in the Milano Metropolitan Area, Italy through Polymerase Chain Reaction, however, it was not detected in treated water samples (Rimoldi et al., 2020). Traces of the SARS-CoV-2 were also found in several wastewater treatment plants in the Netherlands (Mallapaty, 2020) and Paris (Wurtzer et al., 2020) where the SARS-CoV-2 has been established to stay for few days. Fortunately, the waste water or water from rivers in those advanced economies is not drank in the raw form. In developing countries, there is often no choice but to make use of untreated

water for drinking (Kangmennaang et al., 2020) or to perform other functions (washing, cooking, etc.) in the house (**Fig 5**).

According to the WHO, from a work that was done by Casanova et al. (2009), coronaviruses could remain infectious in water contaminated with faeces for days to weeks (WHO, water sanitation brief 2020) and was also been documented to survive in wastewater for 2 to 4 days (Gundy et al., 2009).

It is estimated that about 780 million people worldwide do not have access to improved portable water (WHO and UNICEF, 2012) and 2.5 billion people are extrapolated not to have access to improved sanitation (Prüss-Üstün et al., 2008). Most of the affected populations are located in developing countries and to a greater extent, in sub-Saharan Africa. Even though there is no evidence of transmission from waste water of rivers to humans, people who utilize polluted water may be at risk when they drink water contaminated with SARS-CoV-2.

Perennial flooding in Ghana: Implication for the spread of COVID-19

Due to the poorly designed and maintained drainage systems in most cities in Ghana, flooding after seasonal rains is a common occurrence. Flood waters normally carry waste and sewage into homes of residents in the affected areas (**Fig 6**). Since the SARS-CoV-2 has been found in faeces, with the resultant presence in waste water and its presence in flood water cannot be ruled out. Open defecation, over flooded manholes and pit latrines may also pose risk of spreading the virus.

The potential role of house flies and other domestic flies in the spread of COVID-19 through faeces

House flies (*Musca domentica*) and other insects are known to be vectors of diseases either through exudates from within their body that contains the disease-causing agent or through contact by carrying the disease agent on the body and transmit it when it comes into contact with surfaces. House flies have been reported to carry many pathogens (bacteria, fungi, viruses, and parasites) which can cause serious infections in humans and animals (Pava-Ripoll et al., 2012; Khamesipour et al., 2018).

In Africa and Ghana, most people live in compound houses and cook in the open, where flies abound. Asymptomatic carriers and patients with SARS-CoV-2 who practice open defecation are likely to shed the organism in their faeces, which may be spread by houseflies to humans, either directly or indirectly. It is unlikely due to the small viral load that they carry but the transmission cannot be completely ruled out.

Open defecation: implications for the spread of COVID-19

Apart from treated water, which is a preserve for only a few, millions of Africans depend on other sources of largely untreated water for their livelihood (WHO and UNICEF, 2012). These sources of untreated water include but are not limited to dugouts, dams, streams, rivers, wells, as well as rain water.

In Ghana many people fetch water from possibly contaminated surface water reservoirs, such as dugouts and dams. They drink water from such sources, without any preliminary treatment (**Fig 5**). This water is used for many household chores such as cooking, washing

bowls and cloths, drinking, bathing, etc. The situation is not different from other African countries (Teklehaimanot et al., 2014; Kayembe et al., 2018). Several studies in Ghana and elsewhere in Africa have reported that most of the dugouts, dams, streams, rivers, wells were polluted with faecal coliforms and viruses (Cobbina et al., 2010; Lutterodt et al., 2018). The microbiological risk occurs when faeces from asymptomatic carriers and patients upstream find their way to them through runoff.

Another risk factor to these water bodies is the disposal of waste from the hospitals and residential areas. The waste disposal systems of most hospitals in Ghana is very poor, even though some waste may undergo certain level of treatment before being released into the environment (Asante et al., 2014).

Toilet facilities and their potential role in the spread of COVID-19

Apart from the open defecation, there are open and semi-opened toilet facilities exposed to flies. The Kumasi Ventilated Improved Pit (KVIP), is commonly used in Ghana. The whole pit is covered, apart from where one eases himself/herself but an additional perforation is normally made on another side to allow for the stench to go out. Another type of toilet is a dug pit crossed with wood to squat (**Fig 7**). They are located in the house or a bit distant from the house -especially the open types. These types of toilets can be either public and private. House flies normally move to and from the pits after settling on the pile of faeces. Although, the pile of faeces may generate heat that may kill the virus, flies may settle on the fresh faeces which are normally on the top and has not yet mixed with old faeces. Thus, toilet facilities as described may also pose some risk to food and water safety since they are normally exposed to flies that fly in and out and may settle on food.

Environmental safety

The impact of the COVID-19 on the environment and ecosystem cannot be left out. Humans may impact negatively on the environment as a result of measures they will take to curb the spread of the disease. The positive impact of the COVID-19 has been that the lockdowns throughout the world slowed down human activities and led to the reduction of pollution in the environment (Chen et al., 2020). Moreover, African practices may have their peculiar implication on the environment as far as the disease is concerned.

Disposal of personal protective equipment in the environment

The disposal of 'supposed' infected face masks and personal protective equipment (PPE) into the environment may find their way through sewage and finally, enter the water bodies that are used by the populace. The face masks and PPE, if not disposed properly, could also directly enter such water bodies through drainage, because of improper disposal and possibly contaminate the water bodies with the SARS-CoV-2 even though it is unlikely. This is a very big issue that must be considered by all governments in Africa, where these governments are enforcing the compulsory wearing of face masks in public. Most countries in Africa are already fighting a losing battle against plastic bags in the environment.

A simple analysis below may help appreciate the waste problem that will be posed by the face masks and other PPE. Assuming that the adult population of Ghana is seventeen million (17,000,000), half the total population. Half of the adult population again, eight million (8,000,000) may go to formal or informal work. If half of the eight million, four million (4,000,000) wears disposable face masks, there will be four million face masks to be disposed daily. Assuming that they work for 5 days in a week, 20 million face masks will be disposed

per week. The monthly estimate of face masks to be disposed of will be approximately 80 million. The same analogy could be applied to the thousands of frontline workers who also don several PPE that are not reusable. One could imagine the total tonnage of waste from PPE that will be generated during the time of this pandemic. Are African governments ready for this? The tasks seem daunting, since they must struggle to acquire the PPE and at the same time struggle to dispose of them.

Disposable tissue papers in the environment

The amount of waste generated by using the tissue is also alarming. The disposable tissue paper may not only cause physical nuisance in the environment but also microbiological hazard. Waste tissues of those who did not wash their hands properly and might be carrying the virus risk spreading the disease. The good news is that, research have shown that the virus may only live on cardboard for that matter tissues for only up to 24 hours. However, the virus could be washed away on to another surface where it can survive for a longer period and increases the risk of spreading the disease.

Disposal hand sanitizers containers in the environment

There is currently high demand for sanitizers, especially alcohol-based. There is also a very high demand for stock alcohol since it is the major ingredient in the production of hand sanitizers. With the massive use of hand sanitizers, the disposal of their empty plastic containers becomes a very big concern. This will significantly increase the existing burden of the disposal of plastics already overwhelming most urban environments.

Environmental contamination with detergents

Due to the increase in the frequency of the hands washing with soap and other cloths, as well as other surfaces to reduce or eliminate any possible SARS-CoV-2, there will be excessive use of detergents. The disposal of the waste water, "soapy water" from the "Veronica" buckets and other hand washing devices developed is normally done by pouring it on the open soil without passing it through a sewage system. The ingredients used in detergents vary, but to a large extent consist of lipids, alkaline bases that are either sodium hydroxide or potassium hydroxide and water. According to Mousavi and Khodadoost (2019), detergents affect fauna and flora directly or indirectly in the following effects on the environment; eutrophication, foaming, and altering parameters such as temperature, salinity, turbidity, and pH are more important, and their effects need to be managed and controlled. These may affect the lives of organisms in rivers, streams and finally in the sea since most of these water bodies end up in the sea. Waste water with detergent that may pass through agricultural lands before getting into water bodies may also change the chemical properties of the soil and hence, affect the ability of the soil to support crop production. That may call for soil amendment which is an extra cost to the already poor farmers in Africa.

Increase in antibiotic residues leading to antibiotic resistance genes in the environment

In 2019, work on global sewage from 60 countries including several countries in Africa, including Ghana, also indicated a diverse nature of bacterial resistance in the untreated waste water in certain cities in Africa and several places in the world (Hendriksen et al., 2019).

The COVID-19 pandemic, which has no definite treatment yet, has resulted in a lot of different combinations of drugs used within countries, across countries and continents for its

management. The drug combinations for patients usually consist of antibiotics especially azithromycin, together with other drugs. When Ghana had the two first cases and there was a publication that azithromycin was given to patients, a survey of pharmacies showed a shortage of the drug in most pharmacies in Accra.

Resistance of microorganisms to azithromycin could occur in two ways;

- i) through the disposal of empty bottles that may contain smaller quantities of the drugs and may be broken in the dustbins during the cause of transportation to landfill sites
- ii) microorganisms in the body may develop resistance to it if they are not judiciously prescribed and taken according the dosage instructed.

Milaković et al. (2019), concluded that discharge of pharmaceutical effluents altered physicochemical characteristics and bacterial community of receiving river sediments, which contributed to the enrichment of macrolide-resistance genes and integrons. This may increase the already higher burden of antimicrobial resistant genes found in sewage and waste water in African countries by Hendriksen et al. (2019). Several studies have shown that the misuse of antibiotics lead to the development of resistance in microorganisms (Baggs et. Al., 2016; Chang et al., 2019; López Romo and Quirós, 2019).

Just as the education on COVID-19 is going on, people must also be informed about the consequences of misusing antibiotics without prescriptions from the appropriate healthcare workers.

Some of the detergents and hand sanitizers being currently used may also contain antimicrobial elements which could also trigger resistance of both the skin and environmental microorganisms. The issue of antibiotics resistance until the pandemic remains on top of the

agenda of the World Health Organization (Prestinaci et al., 2015; Brinkac et al., 2017; Bennani et al., 2020).

The role of particulate matter in the spread of SARS-CoV-2 in the environment

There has been a lot of controversies whether the SARS-CoV-2 could be transmitted through the air or dust particles. The WHO is also not very affirmative on the disease being transmitted through air and aerosol even though studies have suggested otherwise and unfortunately, it currently remains unknown.

According to Setti et al. (2020a), the rapid COVID-19 infection spread observed in selected regions of Northern Italy is supposed be related to PM10 pollution due to airborne particles able to serve as carrier of pathogens. They advised that pollution control should be taken into account when making policies on the prevention of the COVID-19. Other researchers have also reported that there is high possibility of airborne transmission (Setti et al., 2020b; Morawska and Cao, 2020).

The capital cities of African countries are noted to be heavily polluted (Amegah and Agyei-Mensah, 2017). Studies in Accra have already reported elevated figures of air pollution (Zhou et. al. 2011; Rooney et al., 2012). Soil particles, biomass burning, mineral dust, sea salt, and other biogenic sources have also been found to be the major components of polluted air in most African cities (Petkova et al., 2013). There is also evidence that these particulate matters could carry pathogenic organisms including bacteria, viruses, fungi etc. with their associated cause of respiratory diseases (Yu et al., 2016; Sun et al., 2018; Sarkar et al., 2019; Matus et al., 2019). Just as in Northern Italy, there has been a sharp increase in cases of COVID-19 in Accra compared to other cities in Ghana. Even though Accra may not be comparable to Northern Italy, because of the ambient temperature difference and several other factors, the issue of pollution as a risk factor must be seriously taken into consideration in educating the

public to prevent further spread of the disease. An evidence has also been established in the Harvard University about the possible link between exposure to air pollution and COVID-19 mortality in the USA (Wu et al., 2020) as well as in China (Zhu et al., 2020). In addition, dust particles are generally prominent during the dry season (from November to March) and the humidity also decreases towards the North of the country. Further research needs to be conducted to find the link between the rapid spread of COVID-19 and pollution in Accra and other major cities in Africa. There have been sharp increases in cases in Accra, the Capital City which is noted to be polluted as well as Obuasi, which is a very busy Gold mining town in the Ashanti region of Ghana. Strict adherence to the wearing of face masks must be complied with until the dynamics of the disease is well understood.

Contact surfaces likely to transmit SARS-CoV-2 in the environment

Contaminated contact surfaces have been known to spread the SARS-CoV-2 among the population (van Doremalen et al., 2020; Fathizadeh et. al, 2020).

In Africa, one of the commonest contact surfaces that may transmit the virus are probably the door knobs. Most doors in Ghana and other African countries remain manually operated. This may be one of the major risk factors of contact. There have been studies that implicated door knobs, rails and other contact surfaces to contamination, before the outbreak of the COVID-19 (Genet et al., 2012; Saba et al., 2017; Ejechi and Ochei, 2017).

Strict adherence to preventive measure of limiting oneself from touching contact surface is very critical. Potential contact surfaces, especially in the public that may spread the virus are door knobs, ablution water containers that are usually shared by Muslims to clean themselves before prayers, contact surfaces in the public transport, public telephones, the taps of the Veronica buckets used for hand washing, the taps of the sinks in public places, ATM keypads etc.

Conclusion and Recommendations

COVID-19 has been present globally for the past five months and its impact is been felt throughout the world. The impact is expected to be more pronounced in developing countries, which are still struggling with the basic necessities of life. Until a vaccine or a cure is found for the disease, the direct health effects and their related issues will continue to raise concerns. It is likely that the COVID-19 has come to stay, just like HIV/AIDS that remains present for decades. There are also a lot of gaps to be filled to fully understand the behavior and implications of the SARS-CoV-2 in humans, animals, and the environment. The impact and implications of the COVID-19 within the African continent is particularly worrisome, as far as food, water, hygiene, sanitation and environmental safety issues are concerned.

The possible implications are described here, based on previous experience and understanding of similar diseases of this nature in the African Continent. Notwithstanding, some positive implications may be brought by COVID-19. The hand washing culture and hygiene level of the general population in many African countries has been improved. African researchers are developing innovations to reduce the spread of not only the SARS-CoV-2 but also, other infectious diseases transmitted from the hands to the mouth.

For now, African governments could do more as research on the COVID-19 and its attendant issues are concerned. There are no concrete plans the management of the COVID-19 apart from efforts to detect, isolated, manage and prevent the disease. All the current research studies on SARS-CoV-2 and COVID-19 in this review were performed outside of Africa.

Africa bears further many possible predisposing factors, taking into account the current knowledge of the disease. Thus, a lot of efforts must be made by various governments to properly address the problems during and after the epidemic has subsided.

African governments must be up-to-date regarding the current trends of detecting, isolating, managing and preventing the COVID-19 in order to adapt them to what pertains in their countries, as well as share good practices among themselves in order to benefit most from the existing knowledge of the disease. At the same time, they must invest in research and development and encourage researchers to bring out innovative ideas to tackle the disease and any impact it might have caused thereof.

It has been proven that clean water, good sanitation and hygiene and safe environment improve the living conditions of communities across the world. Efforts must be made by African governments and development partners to provide clean and affordable water to the continent's population. More homes should also be assisted to build toilets. The individuals and communities must be sensitized on the need of clean environment and water, good sanitation and hygiene and their maintenance. Culturing of microorganisms from their hands, water sources, contact surfaces and their environment could be a good way to demonstrate disease presence and to appreciate the existence of microbes and take measures needed to prevent infections.

The authorities involved should sensitize the populace to treat water from open sources and if possible, provide them with relevant materials or chemicals. This will go a long way to reduce the impact of waterborne diseases, and possibly COVID-19, if confirmed to be transmitted to humans through water.

Food safety and environmental protection authorities must be actively involved to curb the spread of the COVID-19. Food regulations must be strictly enforced not only for imported, but also local products that are put on the market without following good manufacturing practices. Environmental protection activities must be evaluated and those practices that can potentially spread the COVID-19 must be strictly regulated.

The disinfection exercises carried by the Government of Ghana are very welcome. However, disinfection should be backed by evidence of sampling and testing the contact surfaces positive for the SARS-CoV-2 if the intention is to kill the virus.

Now that the virus is widely spread in certain cities, especially Accra and Obuasi, there should be intermittent sampling of environmental samples at public places of common contact to possibly detect the virus and advise the managers of those facilities to disinfect the contact surfaces to prevent the further spread of the disease if it is possibly spread through the air.

Last, but not least, there is a possible link between the air pollution levels, the particulate matter concentrations in the atmosphere and the rate of spread and mortality of COVID-19.

The same pattern is likely to be the case in Ghana, where there is an upsurge of cases in Accra and Obuasi, which are both polluted cities. Research to establish the possible link between air pollution/particulate matter levels and the COVID-19 cases should be encouraged in Ghana and other African countries to confirm or disprove the assertion, which will further help understand the disease and its effects in Africa.

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Figures



Fig.1. An opened sewage canal with faeces heaped on the wall from people who defecate directly into it openly



Fig. 2. A vegetable farmer watering his lettuce with waste water in a city in Africa



Fig. 3. A street food vendor using the bare hand to serve customers



Fig. 4. Animals drinking from a dugout that is also patronized by human beings



Fig. 5. People drinking water from untreated water sources



Fig. 6. A flooded bedroom after a heavy downpour



Fig. 7. An open public pit latrine