**DEVELOPMENT OF ENVIRONMENTAL HEALTH ENGINEERING FACILITIES, EQUIPMENT, SENSORS AND PUBLIC HEALTH SYSTEMS FOR TACKLING COVID-19 PANDEMIC**

**WRITTEN BY**

**ONORIODE THANKGOD**

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**ABSTRACT**

Coronaviruses are a large family of viruses that are known to cause illness ranging from the common cold to more severe diseases such as Middle East Respiratory Syndrome (MERS) and Severe Acute Respiratory Syndrome (SARS). All viruses are like zombies -- they try to take over people's bodies -- but they aren't really alive. Outside the host's body they are dormant, surviving without living. Once touched or inhaled and brought inside, their [ancient machinery springs into action,](https://www.niaid.nih.gov/diseases-conditions/coronaviruses) using proteins to latch onto and invade human cells. There they set up shop, producing millions of copies of themselves and causing those cells to rupture. Like the famous scene from the movie "Alien," the viral offspring shoot out into the bloodstream, with the goal of invading more and more cells. As they multiply, humans began to spit them out into the universe with each exhalation, making us contagious days before we begin to cough, sneeze or have diarrhea -- all symptoms the virus creates to ensure it can leap from human to human, thus ensuring its survival.

This "virus zombie invasion" comes in all sort of shapes, sizes and genetic strategies. All coronaviruses are covered with pointy spires of protein, giving them the appearance of having a crown or "corona" -- hence the name. Coronaviruses use these spikes to latch onto and pierce our cells. Coronaviruses are part of the RNA brigade of viruses, which are much less stable than their DNA-based comrades. Why is that important? Because instability leads to mistakes in copying genetic code. That leads to mutations -- thousands, millions, billions of mutations. Sooner or later, one mutation hits pay dirt and allows the virus to cross the great divide between different species. A few million/billion/trillion more mistakes creates another mutation that allows that virus to spread easily. Now the virus is both in its new host and it is contagious. It's that type of mutation which gives humanity viruses like SARS-CoV-2.

**1.0 INTRODUCTION**

The coronaviruses that cause MERS and SARS are though to have crossed from mammals to humans, where they mutated to become contagious. MERS-CoV first appeared in Jordon and Saudi Arabia in 2012 and it's thought to have [crossed over to humans](https://wwwnc.cdc.gov/eid/article/25/9/19-0143_article) from dromedary camels in Africa, the Middle East and southern Asia. "MERS is extremely deadly, about 30% of people who are infected with MERS will die," Williams said. "So the virus got over one of the barriers -- it's able to infect humans, grow in them and cause disease -- but thankfully it really doesn't spread well person to person, other than very, very close contacts."

Besides the newly hatched novel coronavirus, there are actually six[additional coronaviruses](https://www.cdc.gov/coronavirus/types.html) that infect humans -- four of them cause the common cold. Two more can be deadly. MERS-CoV is the villian behind [Middle East Respiratory Syndrome, or MERS,](https://www.cdc.gov/coronavirus/mers/about/index.html)which has killed over 800 people worldwide since it first appeared in 2012. SARS-CoV causes a serious form of pneumonia that can also be life-threatening. Globally, it killed 774 people between 2002 and 2004. [No other cases have been reported worldwide since.](https://www.nhs.uk/conditions/sars/%22%20%5Ct%20%22_blank) {To put that into context, the death toll of the novel coronavirus since it burst on the scene in December is approaching 40,000).

The [animal kingdom](https://www.ncbi.nlm.nih.gov/books/NBK92442/) is teeming with coronaviruses. They are found in cats and dogs, pigs and cattle, turkey and chickens, mice, rats, rabbits and of course, humans. Insects too. Some of those coronaviruses can cross species, such as between pigs, cats and dogs, but for the most part coronaviruses stay loyal to their original hosts. Until, of course, they become that lucky mutation. "Usually viruses from one animal really don't effectively transmit to other animal species or even to people," said Dr. John Williams, chief of the division of pediatric infectious diseases at the University of Pittsburgh Medical Center Children's Hospital of Pittsburgh. "So usually if a virus goes from an animal to a human, it's sort of dead end. That person gets sick but it doesn't spread further," said Williams, who has studied coronaviruses for decades.

SARS has been more difficult to pin down. Because one of the most common carriers for coronaviruses are bats, it's thought that the virus may have started there. Then it supposedly mutated to the masked palm civet, a small cat-like mammal eaten in some parts of China. But even that theory is [disputed](https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3747529/). "SARS caused death in about 10% of people that became infected and it did spread person to person but not super effectively," Williams said. "There weren't many people walking around without symptoms or with mild symptoms, who could be spreading it. "This new virus, SARS-CoV-2, has overcome more barriers," Williams added. "It spreads easily person to person and a lot of people can have either mild disease or they might not even have symptoms, yet they can have the virus and spread it."

The novel coronavirus appears to have [originated in bats.](https://www.cnn.com/2020/01/29/health/bats-viruses-coronavirus-scn/index.html) A [study published in February](https://www.biorxiv.org/content/10.1101/2020.01.22.914952v2.abstract) found the coronavirus found in bats shared 96% of the same genetic makeup as the novel coronavirus. But it wasn't a direct link, so the bat had to have infected another species, which then infected humans. Early reports pointed to snakes bought at a "wet market" in China were people buy live animals to eat. A [recent report of the initial cases](https://www.thelancet.com/journals/lancet/article/PIIS0140-6736%2820%2930183-5/fulltext)of coronavirus in China debunks the "snake flu" theory, reporting that in 13 of the 41 early cases the infected patients had no link to the wet market. A recent hypothesis claimed the intermediate host was the pangolin, an [endangered scaly, ant-eating creature](https://www.cnn.com/2020/03/27/opinions/pangolin-coronavirus-pandemic-breiman/index.html) beloved for its meat and scales, which are used in traditional Chinese medicine. But critics have been skeptical, sending genetic scientists back to their labs to continue the search. At this time, scientists don't know where the novel coronavirus began.

"These things are more difficult than [identifying] dinosaurs, because there's no fossil record of a virus," Williams said. "For example, the main virus I study, human metapneumovirus, is clearly a virus that has circulated in humans for decades if not a few centuries. "However, when you look at the genetics of the virus, its closest genetic relative is a bird virus," he added. "So, did that virus jump to humans way back and become established? That's what we think. But it isn't impossible that a human virus jumped to birds and became established there." The source of the coronavirus is believed to be a "wet market" in [Wuhan](https://www.telegraph.co.uk/news/2020/01/23/inside-wuhan-ground-zero-coronavirus-epidemic/) which sold both dead and live animals including fish and birds.

Such markets pose a heightened risk of viruses jumping from animals to humans because hygiene standards are difficult to maintain if live animals are being kept and butchered on site. Typically, they are also densely packed allowing disease to spread from species to species. The animal source of Covid-19 has not yet been identified, but the original host is thought to be bats. Bats were not sold at the Wuhan market but may have infected live chickens or other animals sold there. Bats are host to a wide range of [zoonotic viruses](https://www.telegraph.co.uk/news/disease-x-virus-hunters/) including Ebola, HIV and rabies.

There is no specific treatment, although doctors are trialling existing drugs for viruses such as Ebola, malaria and HIV. Early results seem promising but, until full clinical trials have been concluded, doctors cannot be certain that the drugs are effective. Work to develop a vaccine is accelerating but it is unlikely to be available until next year.

**2.0 LITERATURE REVIEW**

2.1 ENVIRONMENTAL HEALTH ENGINERING FACILITIES FOR SOLVING COVID-19

2.1.1 THE USE OF VENTILATORS

It has been gathered that the isolation centre in the Mainland Infectious Disease Hospital (IDH), Yaba has nine ventilators and the newly built isolation centre donated to the state by GTB at Onikan, has some ventilators. Sources at the Lagos State University Teaching Hospital, Ikeja, said there were about 15 ventilators there, while the Lagos University Teaching Hospital has four ventilators. While answering questions from newsmen on Monday, the Minister of Health, Dr. Osagie Ehanire, said even though there were no enough ventilators in Nigeria, the country might not need many of them for the treatment of patients suffering from COVID-19, an ailment that attacks respiratory system. The minister said most of the over 130 cases so far recorded in the country were being managed without ventilators because the patients showed mild symptoms.



Fig 1: A Ventilator Machine In Use.

2.2. THE APPLICATION OF SENSORS FOR SOLVING THE ISSUE

An ERDF-funded project is helping to tackle the COVID-19 crisis in Italy. New sensors created by the project allow healthcare staff to monitor patients suffering from the disease at a distance. The biosensors, created by the MEDIWARN project, can monitor a patient’s vital signs such as heartbeat, respiratory rate, blood pressure and body temperature. It is difficult and dangerous for medical and nursing staff to monitor COVID-19 patients in person. Patients infected and symptomatic need to be isolated in rooms with negative pressure. The new sensors allow staff to more easily monitor such patients from another room.

2.4 PUBLIC HEALTH SYSTEMS TO THE RESCUE
Existing modern solutions in diagnostics, monitoring, and molecular development are being used as powerful tools to help fight the current pandemic. These technologies can help identify outbreak hotspots, prevent infections, reduce the need for physical contact in diagnostics, and even work towards developing a vaccine for COVID-19.

Molecular Diagnostics

As of March 20, 2019, the CDC has identified [15,219 confirmed cases](https://www.cdc.gov/coronavirus/2019-ncov/cases-updates/cases-in-us.html) of COVID-19 in the United States and 201 deaths. However, public health experts say the only reason why those numbers have not exploded is that the nation has far too few diagnostic test kits. Lagging inventory has slowed testing. That means people simply don’t have them where and when they need them. The need for a scalable diagnostic solution is beyond doubt. Here are a few startups taking on this challenge.

Biomeme

[Biomeme's platform](https://biomeme.com/) transforms your smartphone into a mobile lab for advanced DNA diagnostics and real-time disease surveillance. The system includes a docking station for real-time PCR (Polymerase Chain Reaction), a mobile app to control the system and analyze results, and targeted test kits for preparing samples and identifying pathogens or diseases by their specific DNA or RNA signatures. The cutting edge platform performs to the gold standard used by the world's most advanced central labs but requires no lab equipment or special experience to use. The low-cost, user-friendly system enables mobile testing at the point-of-need for health care, such as in mobile clinics, for disease tracking and home use.



Fig 2: Biomeme Platform

Biomeme allows pharma companies to quickly set up pop up labs all over the world by leveraging smartphone devices. From sample collection to data management, Biomeme’s end-to-end mobile platform empowers them to take real-time PCR everywhere they need it. Biomeme SARS-CoV-2 tests allow the detection of the RNA of the severe acute respiratory syndrome coronavirus 2 which causes the COVID-19. The two novel coronavirus RNA targets are multiplexed together with Biomeme's RNA extraction and RT-PCR control (MS2). Each order contains your exogenous positive controls and everything is shelf-stable (15-30C). Each reaction contains lyophilized master mix, multiplexed primers, and probes for the following triplex: SARS-CoV-2-Orf1ab gene, SARS-CoV-2-S gene, RNA Process Control (RNA extraction and RT-PCR control utilizing MS2 bacteriophage)

Genomtec

[Genomtec](http://genomtec.com/) developed a smartphone-sized genetic analyzer for infection detection in the doctor's office in less than 15 minutes, thanks to patent-pending optical, contactless heating technology. Their technology combines optical heating and detection with microfluidics and reagents stable at room temperature.



Fig 3: Geomtec

Genomtec technology offers fast, inexpensive and reliable molecular diagnostic testing. The device works independently and automatically, it is enough to apply a drop of biological material to the reaction card and then place it in the analyzer. The test results can then get directly sent to an email address or fed into the medical records of the patient. Thanks to its ease of use and its automated diagnostic approach, Genomtec is able to effectively fight complications that result from viral infections, such as COVID-19. Genomtec is currently operating in the US and European markets.

Mammoth Biosciences

[Mammoth Biosciences](https://mammoth.bio/) offers a CRISPR platform for nucleid acid diagnostics. Mammoth Biosciences, [in collaboration with Charles Chiu, MD, PhD](https://www.ucsf.edu/news/2020/02/416671/how-new-coronavirus-spreads-and-progresses-and-why-one-test-may-not-be-enough), is developing a rapid diagnostic test that could more quickly and widely monitor for the disease. The new test is a color-changing test strip that uses CRISPR to detect viral RNA and can be run in 30 minutes to an hour. “We’ve been able to run this rapid test on both control samples and patient samples and it appears to be working,” said Chiu. He hopes to optimize the test so that it can be run by anyone and deployed in low-resource areas.

BioMedomics

[BioMedomics](https://www.biomedomics.com/) focuses on building fast and easy-to-use testing kits for various diseases at a patient's point of care. BioMedomics specialized in product offerings that help in the diagnosis of blood disorders and in the identification of microorganisms and pathogens which are of global concern. They recently developed a quick immunoassay diagnostic test for COVID-19 in two ways: antibody and PCR (polymerase chain reaction) testing. At the point of care, the BioMedomics solution can deliver results within 15 minutes using just a blood sample. This blood sample can be used for rapid screening for carriers of the virus that are symptomatic or asymptomatic.

Recent studies around the new COVID-19 outbreak suggest that a high percentage of patients show no clinical symptoms of the virus, thus screening patients is key. This kind of testing is perfectly tailored for hospitals, clinics, and test laboratories, but can also be effectively deployed in businesses, schools, airports, seaports and train stations giving it the potential to become a compelling force in the fight against this global threat.

Bat-Call

[Bat-Call](https://www.bat-call.com/) is a startup that focuses on respiratory and cardiovascular diagnosis through chest sound and machine learning classification. They developed a wide range of devices to use in different settings. Their latest invention is a vest that patients can wear to collect sound samples from various angles and which get wirelessly communicate to doctors for an accurate diagnosis. Another device they developed is called CompuSteth, which is a digital Stethoscope that enables doctors to use them at patient’s bedside, the device is able to detect inaudible sounds, analyze them and visually present them to doctors, thus making the diagnosis faster and more precise.

To combat COVID-19, constant monitoring and quick diagnosis are key. Chest CT is widely used in China to rapidly diagnose and screen for people who got infected and has proven to be as accurate for testing as a testing kit which may not be accessible in some areas. Bat-call can offer a more accessible and faster scan that could significantly help in triaging patients and thus in relieving the limited capacities of healthcare providers.

Codagenix

[Codagenix Inc.](https://codagenix.com/) utilizes a breakthrough platform technology called SAVE to construct live-attenuated viral vaccines against multiple targets. All live-attenuated vaccines that are currently used in clinics were created using a trial-and-error based testing developed in the 1880s, pre-dating the discovery of the DNA double helix. The SAVE platform relies on synthetic biology and the “re-designing” of a target virus’s entire genome to yield a vaccine strain. This customization process uses software-based algorithms to ‘re-code’ the genome of a target virus.

Codagenix is currently developing a live-attenuated vaccine that will carry all proteins from a natural virus. They will be targeting the spike protein, along with all other structural and non-structural proteins of SARS-CoV-2. A coronavirus vaccine is now a part of the pipeline.

Codagenix is working on bringing the vaccine into Phase I trials within the next 4 months. After that, through a partnership with the Serum Institute, they will manufacture and distribute the vaccine under a US EUA.

Meissa Vaccines

[Meissa Vaccines](https://www.meissavaccines.com/) is a pharmaceutical development startup focused on the in-licensing and advancement of vaccines for the respiratory syncytial virus (RSV, the largest unmet respiratory medical need in pediatrics) and rhinovirus (the leading cause of infectious disease worldwide).

Meissa Vaccines is applying synthetic biology and genetic engineering to respiratory viruses for the rational design of vaccine strains that solve challenging obstacles in modern vaccinology such as suboptimal immune responses, vaccine stability, and manufacturing. Initially developed at Emory University, proprietary technologies of reverse genetics, codon deoptimization, and stabilization of key antigenic conformations allow for the rapid generation of best-in-class vaccine formulations.

Sonovia

[Sonovia’s](http://sonoviatech.com/) special chemical formulations give textiles the ability to [destroy pathogens](https://www.jpost.com/HEALTH-SCIENCE/Israeli-startups-anti-pathogen-fabric-could-stop-spread-of-coronavirus-615476), providing protection for doctors and patients alike against potentially harmful bacteria and infections. Patients in hospitals are exposed to millions of bacteria causing post-treatment infections, which can result in medical complications, longer hospital stays, and death.  30% of patients in ICU are affected by healthcare-associated infections. 130k deaths every year are attributed to Hospital Acquired infections in the USA and Europe. COVID-19 is transmitting with droplets or by touch, general protection is necessary to lower the chance of being infected.

BlueDot

[BlueDot](https://bluedot.global/) protects people around the world from infectious diseases, leveraging human and artificial intelligence. The startup has developed a patented global early warning system to track and predict the spread of dangerous infectious diseases. BlueDot benefits from a strong track record and reputation built off of repeated success stories, including predicting the spread of Zika into the Miami area Florida 6 months before the first case got detected. BlueDot can help governments to protect their citizens, hospitals to protect their staff and patients, and businesses to protect their employees and customers.

Sickweather

The [Sickweather](http://www.sickweather.com/%22%20%5Ct%20%22_blank) app is the world's first real-time map of human health. It uses social listening to track reported illnesses and symptoms and delivers an overview of all illnesses that are going around in your community – like the flu. Thanks to its patented algorithm, Sickweather can analyze social sentiment data to generate a flu forecast and deliver daily SickScore. The app can minimize stock-outs, supporting the effective distribution of vaccines, over-the-counter medication, and disinfectants, serving different geographic areas at the right time.

**3.0 CHALLENGES**

1. As the number of confirmed cases from the deadly COVID-19 pandemic increases in the country, there are only 169 ventilators in sixteen out of the 36 states. This means there is an average of 10 ventilators in each of the states, and in real terms, some of the states do not have more than five ventilators.

2. There are some states that are yet to procure any ventilator for the treatment of COVID-19, while others say they have placed orders and were expecting the delivery of the equipment any moment from now. Credible sources said most of the 169 ventilators in the states covered by this report have been there for long, indicating that they were not purposely procured to manage the crisis that might likely come with the coronavirus. The states include Kano, Ogun, Edo, Delta, Adamawa, Kwara, Bayelsa, Katsina, Borno, Yobe, Benue, Bauchi, Kaduna, Ebonyi, Gombe and Plateau.

3. Findings revealed that a hospital-grade ventilator is between $25,000 (N9.175million) and $50,000 (N18.350 million) each, based on the official CBN rate of N367 as of Monday, March 30, 2020. Though Lagos and Abuja were the worst hit by the coronavirus, efforts to get the exact number of ventilators in the two cities were not successful.

4. A respiratory expert who craved anonymity said Nigeria requires about 10, 000 respirators for emergency cases. He said at the moment, there are less than 50 in both public and private hospitals in the Federal Capital Territory (FCT). He estimated that the country had less than 500 ventilators, adding that it was mostly public tertiary hospitals that have them. He said ventilators were very important equipment, not only being used for treatment of COVID-19, but other respiratory illnesses, adding that it was important for all hospitals to have them. "I pray the country does not find itself in emergency situations like what is presently happening in the US because there wouldn't be enough ventilators to handle the situation," he said.

5. There aren’t enough A.I engineers in Nigeria and it takes years of rigorous training for a person to become adept in machine learning and artificial intelligence.

**4.0 RECOMMENDATIONS**

1. The immediate use and successful application of digital technology to tackle a major, global public-health challenge in 2020 will probably increase the public and governmental acceptance of such technologies for other areas of healthcare, including chronic disease in the future. As the saying goes, ‘a crisis provides an opportunity’; this first great crisis of 2020 provides a great opportunity for digital technology.

2. Vaccines

Vaccines are an effective tool to quickly gain immunity against infectious diseases. A vaccine typically contains an agent that resembles a disease-causing microorganism and is often made from weakened or killed forms of the microbe, its toxins, or one of its surface proteins. Vaccination is a key contributor to the population’s health but underlies a very expensive and time-consuming development process. However, innovative technologies like machine learning and computer simulations are gradually changing how scientists develop vaccines.

3. Patients who are feeling ill can schedule an appointment with a doctor through video, allowing them to remain at home while they may be contagious, instead of interacting with other patients and medical staff at a local facility. This is especially relevant in times of pandemic outbreaks such as COVID-19 that ask to avoid close personal contact.

4. Remote Patient Monitoring

Remote patient monitoring solutions collect medical health data and vitals, including heartbeat, weight, blood pressure, and oxygen rate from the user's device. This data is then transmitted to providers, who can remotely monitor these patients and take action when necessary. Often in the form of apps and medical wearables, remote patient monitoring can allow physicians and hospitals to monitor patients outside of the conventional clinic setting. Remote monitoring can either be performed contactless or through medical devices. Given most patients with initial signs of fever and cough will visit their healthcare providers, a common behavior shown in COVID-19 is that patients revisit or visit multiple clinics when they do not recover from initial flu medication, causing further infections. With remote monitoring, patients that have increased temperatures or decreased blood oxygen levels can be advised to seek help from stipulated centers directly.

5. Population Outbreak Management

Outbreak management systems offer software solutions that help to detect an imminent outbreak of infectious diseases. Powerful AI and algorithms run on the backend of those management systems and build predictive models to alert people of the danger.

**7.0 CONCLUSION**

The development of environmental health engineering facilities, equipment, sensors and public health systems such as ventilators for tackling the coronavirus pandemic will help to quickly eradicate the spread of the virus.

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