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Yemen: Battling the World's Worst Cholera Outbreak

As the second largest country on the Arabian peninsula, Yemen boasts a population of more than 29.5 million (Worldometer). Over 35% of the population live in urban areas, the other 65% live in rural areas (Worldometer). The 53 million hectares that make up Yemen are split into 21 governorates and one municipality (Mapline). Yemen is a republic with executive, legislative, and judicial branches similar to those of the United States (GlobalEDGE). A President is elected every 7 years and they appoint a Prime Minister as head of government (GlobalEDGE). In 2015, the Houthi rebel movement grew in size and power, sparking a civil war and humanitarian crisis (BBC News). Currently, control of Yemen is split between the Hadi government, Houthi rebels, UAE-backed anti-Houthi forces, al-Qaeda in the Arabian Peninsula (AQAP) and the Islamic State (IS) groups (BBC News). The country is ravaged by conflict, leaving civilians with little to no food and water, poor healthcare, no housing, and widespread destruction (BBC News).

While 34% of Yemen's land is considered agricultural, only 3% is utilized for cultivation (Wenner). Farmers often own 5 or fewer hectares of land on which they grow crops and raise livestock to sustain their family (Countries and their Cultures). In comparison, the average farm in the United States is 180 hectares (US Farm Data; Wenner). Typically, each farmer has just enough to provide for his family and perhaps a small amount of outsourcing (Countries and their Cultures).

The average household has seven family members (United Nations). Commonly eaten foods are bread, chicken, mutton, goat, porridge, vegetables, and eggs (US Agency...; Countries and their Cultures). The most common drinks are coffee and tea (US Agency...). In 2018, nearly 18 million Yemeni were food insecure (OXFAM 2). Now, more than two-thirds of the population does not know where their next meal will come from (OXFAM 2). The conflict throughout Yemen has resulted in an obstruction of food imports and a destruction of arable land (OXFAM 2). In cities, small markets sell food products when available (World Food Program USA). Most of the population is self-employed, performing odd-jobs for their family to survive (Rethinking Yemen's Economy). For those that do have jobs, roughly 30% are in the agricultural sector, followed by 23% in the trade sector (Rethinking Yemen's Economy). Yemen is the poorest country in the Middle East (Fanack). The average annual per capita income is equal to \$2,213, well below poverty line (Fanack).

More than two-thirds of the population do not have access to clean, safe drinking water or proper sanitation facilities (Jabbari). The biggest barrier to a normal, healthy lifestyle is the conflict between the Hadi government, Houthi rebels, and now insurgent rebel groups. 22 of 29 million Yemenis are in need of humanitarian assistance (Strochlic). At least 2 million are displaced and 100,000 are dead (Strochlic). The economic and health care systems are in shambles with little hope for near future recovery (Strochlic).

Many doctors have fled the country or moved to private hospitals, leaving very few left to treat the majority of the population (Strochlic). The lack of clean drinking water, proper nutrition, sanitation facilities, and health care has led to Yemen facing the worst outbreak of cholera in history (Strochlic).

The world's largest cholera epidemic is currently sweeping across Yemen (World Health Organization, 2020). Cholera is "an acute diarrhoeal infection caused by ingestion of food or water contaminated with the bacterium *Vibrio cholerae*" (World Health Organization, 2019). It causes diarrhea, nausea and vomiting, severe dehydration, muscle cramps, shock, and then death (World Health Organization, 2019; Mayo Clinic). As of September 2019, there have been more than 1.3 million confirmed cases with a suspected one million more unconfirmed cases (World Health Organization, 2020). Fortunately, the number of cases of cholera reported daily in Yemen has decreased roughly tenfold from April 2017 to November 2019 (World Health Organization, 2020; BBC News). Two waves of cholera have swept through Yemen; one beginning October 2016 and ending April 2017, and the second beginning April 2017 with no current end (BBC News). As the number of cases reported daily decreases, the end for the second wave looks to be in sight (BBC News). However, the underlying causes of Yemen's cholera outbreaks are far from resolved, leaving plenty of opportunity for another wave to begin in spring 2020 (World Health Organization, 2019).

Both rural and urban populations are affected by cholera. In industrialized countries, modern sewage and water treatment have virtually eliminated cholera (Mayo Clinic). However, in Yemen and other third-world countries, there are no sanitation systems or water treatment plants (Mayo Clinic). Those living in urban areas have a slightly higher risk of contracting cholera because people are living in crowded conditions without proper sanitation (Mayo Clinic). As well, those with reduced or virtually no stomach acid are more likely to contract cholera (Mayo Clinic). This includes children, the elderly, and those taking antacids (Mayo Clinic). Studies have also shown that people with Type O blood are two times as likely to contract cholera than those with any other blood type, though the reason why is unknown (Mayo Clinic). As with many diseases, cholera is especially fatal to the extremely young and the extremely old (Mayo Clinic).

Refugee populations are extremely susceptible to contracting cholera because of the crowded, dirty conditions they live in (Shannon). With the current conflict in Yemen, refugee camps are prolific (Shannon). These camps experience large-scale cholera outbreaks quite regularly because of a combination of overcrowding, scarce clean water, and "poor sanitation and hygiene practices" (Shannon). Death rates were as high as 60% in some camps because of pre-existing malnutrition or other conditions and limited access to medical care (Shannon).

Global organizations have attempted to provide a solution for the cholera outbreak. The World Health Organization (WHO) has funded the creation of 146 treatment centers throughout Yemen to provide treatment for patients with severe cases of cholera as of February 2020 (World Health Organization, 2019). They also sent out 6,261 cholera kits which contain 6 modules with different supplies to help prepare for a potential cholera outbreak and then support for the first month of initial response (World Health Organization, 2020). The Global Task Force on Cholera Control has also launched plans to end

cholera by 2030 (Centers for Disease...). Their strategy aims to reduce cholera deaths by 90% and eliminate cholera entirely in 20 countries, including Yemen (Centers for Disease...). Their plan includes three main steps that focus on early detection of outbreaks, a quick response, and then prevention of recurrence (Centers for Disease...). This plan is currently just starting to take action, so no results of success are currently available (Centers for Disease...).

While all of these actions are having a positive impact, they only address the effects of cholera, not the cause. In other countries, such as Peru, similar challenges have been prevented by providing clean, safe, drinking water alongside the implementation of proper sanitation (World Health Organization, 2011).

One possible way of preventing cholera by providing clean drinking water would be rainwater harvesting. Rainwater harvesting is the process of “capturing, diverting and storing non-potable water for later use”

(Kellogg). After capturing and storing the rainwater, debris is removed using mesh and the water is boiled to kill disease and parasites (Kellogg). It is now ready for consumption. This has been successfully used in Cameroon, saving dozens of lives by suppressing cases of cholera daily (Kellogg). In a country that receives plenty of rainfall, rainwater harvesting is a great solution to provide clean drinking water for a community. However, Yemen’s climate and geography could pose some problems. Some areas of Yemen, such as the mountaintops, receive upwards of 30 inches of rain per year, which would be sufficient to use as a main source of water (WeatherOnline). Most areas of Yemen receive little to no rainfall, meaning that rainwater harvesting would not be a sustainable source of drinking water for a majority of the population of Yemen (WeatherOnline).

Another way to prevent cholera in Yemen by providing clean drinking water would be through desalination. Desalination is the process of turning saltwater into freshwater (USGS). Researchers at MIT and Shanghai Jiao Tong University have developed a solar-powered desalination system that provides approximately “1.5 gallons of fresh drinking water per hour for every square meter of solar collection area” (Chandler). This system has the potential to provide a low-cost, efficient water source to coastal areas in developing countries. Yemen does have a rather extensive coastline on both its southern and western borders spanning a total of 1,184 miles (Encyclopedia of the Nations). However, 44.25 million square meters of space would be needed for enough desalination systems to provide enough freshwater for everyone (Worldometer). This is just shy of 27,500 miles of coastline - much more than Yemen has. This makes it impossible for desalination alone to be the solution for cholera with the current systems. Using desalination systems to provide freshwater for those living on or near the coast and then finding some other solution for those further inland is a more likely solution.

At this time, there is no clear solution to provide clean freshwater to all of Yemen. A combination of solutions might be able to work together to provide enough water in the future. Though there is no immediate solution to the unclean drinking water problem in Yemen, cholera can also be prevented through the use of oral cholera vaccines. Shanchol™ and Euvichol-Plus® are two WHO pre-qualified oral cholera vaccines that prevent cholera for up to three years (World Health Organization, 2019). They require one dose for short term protection and two doses for a three-year protection against cholera

(World Health Organization, 2019). Each vaccine, including production and transport to Yemen, only costs about \$10, so with proper funding, it would be possible to pay for the vaccination of all Yemeni people (World Health Organization, 2019). The United Nations Children's Fund (UNCF) and WHO have already funded the distribution of over 540,000 oral cholera vaccines throughout Yemen (Kennedy). The effectiveness of these oral cholera vaccines after the standard two-dose treatment is around 76% (Kennedy). Though not a perfect percentage, over time, if enough people are treated, cholera will not be able to be spread due to herd immunity, so those for whom the vaccine was not effective for will still not get cholera. Unfortunately, though the oral cholera vaccines would be able to temporarily prevent cholera, they would not solve all of the other problems of the Yemeni people. Millions would still not have access to clean drinking water, proper sanitation facilities, enough food, long-term cholera prevention, or a safe place to live with the current turbulent conflict.

Considering cost, effectiveness, and reality of what can actually be done on a large scale, oral cholera vaccines are the best option for mitigating cholera in Yemen. WHO, in partnership with Gavi, the Vaccine Alliance, have established a stockpile of oral cholera vaccines (World Health Organization, 2018). WHO would likely be the best manager of the project as they have been focused on cholera in Yemen for decades. As well, they have a special sub-section, The Global Task Force on Cholera Control, that focuses all of their energy on fighting cholera (Centers for Disease...). This shows a commitment to the cause, meaning they will not just give up if it becomes hard to get the vaccines to the people of Yemen. In the past, UNCF and WHO have provided funding for oral cholera vaccines (World Health Organization, 2018). If all of these organizations work together, they could provide enough funding for the medical staff needed and the purchase, transportation, and administration of the oral cholera vaccines. Additionally, funding could be procured through donations and fundraising.

Even if all of the vaccines are paid for and acquired, the involvement of community members, the government, and the organizations is pertinent to the success of the oral cholera vaccines in preventing cholera in Yemen. The Yemenis need to be responsible for keeping track of their health and helping others in their community. It is important that when the oral cholera vaccines and the medical team arrive in communities throughout Yemen that everyone is present so no one misses out on treatment. One way to keep Yemenis informed would be through government funded educational campaigns in the school system. The campaign could focus on principles of proper sanitation and the needs and benefits of the oral cholera vaccination program, such as improved health and decreased mortality rates. By articulating the benefits of sanitation and oral vaccinations, the government will be able to sway the public to take part in such efforts. 73% of children in Yemen regularly attend school so a majority of the population would be able to stay informed through these campaigns (Education in Yemen). The government also has a role in making sure all of the citizens of Yemen are able to get vaccinated. Many Yemenis are currently suffering due to the situation of the current conflict between primarily the Hadi government and the Houthi rebels (BBC News). It is the government's responsibility to step up and work out some sort of agreement with the Houthi rebels to allow for the treatment of the citizens that live in battle areas or areas currently not controlled by the government. Organizations other than WHO can help make this successful. UNCF has funds, resources, and connections that would be extremely useful (Kennedy). As well, the continued support and procurement of the vaccines by Gavi, the Vaccine Alliance, is extremely important in making sure that there are enough vaccines for everyone.

For this project to be successful, policies would need to be put in place to maintain the regimen of treatment. To maintain immunity against cholera, two doses of the oral cholera vaccines would be required every three years (World Health Organization, 2019). Policies would have to be enacted to make sure that a medical team returned every three years to each community to administer the oral cholera vaccines. The government of Yemen would have to play a large role in both creating and upholding these policies for the good of their people. It doesn't matter how many vaccines or medical teams there are, without the cooperation of the Yemeni government, this solution will not work.

Though the public health system in Yemen has collapsed due to the Quasi War, one approach the government could use to attain high compliance with vaccination policies would be to focus on three basic components: education, distribution, and record keeping. By funding nation-wide campaigns advocating for compliance with the oral cholera vaccination schedule, citizens may be more likely to take the time to get vaccinated. Once the citizens are educated about the program, it is important that the government and World Health Organization collaborate to provide the oral vaccination for all citizens. In cities, schools could be used as vaccination centers. Students could be vaccinated while attending school and adults and young children could come after school to get vaccinated. To account for Yemenis living in rural areas, the World Health Organization would have to provide multiple traveling teams of health care workers that can administer the vaccination to those unable to make the trip to the nearest city. The final step would be successful record keeping. Because a nation-wide census has not been conducted since 1994 due to the Quasi War, other means of tracking the population need to be considered (U.S. Census Bureau). By using school records, birth certificates, and death certificates, the government would be able to account for the majority of its citizens. Then, as citizens are being vaccinated, it can be recorded to make sure that all citizens are vaccinated with both doses.

The three biggest challenges to overcome for this solution to work are cost, transportation, and the ongoing Quasi War. Though each vaccine costs only \$10, it would cost \$295 million to purchase enough oral cholera vaccines for all of Yemen (World Health Organization, 2019; Worldometer). Keeping in mind that the vaccine needs to be given every three years, the cost adds up quite quickly. Another challenge would be transporting the oral cholera vaccines to Yemen and then throughout Yemen. Because of the current conflict between the Hadi government and the Houthi rebels, it is very unsafe in many parts of Yemen. Sending medical personnel into the middle of a deadly conflict is not a good idea, but the civilians still need the vaccines. This is where the Yemeni government really needs to step up to make sure that medical teams can be safely dispatched to administer the oral cholera vaccines. The final struggle is the Quasi War. The Hadi government, Houthi rebels, UAE-backed anti-Houthi forces, al-Qaeda in the Arabian Peninsula (AQAP) and the Islamic State (IS) groups are all fighting for control of Yemen (BBC News). This conflict may require international commitment to mediate and enforce a lasting resolution. Until this is completed, it is extremely difficult to safely and effectively enforce the oral cholera vaccination program.

Given the heterogeneous landscape and the lifestyle of the Yemeni people, a two-pronged approach is necessary for the eradication of cholera - ongoing administration of the oral cholera vaccines and provision of clean drinking water. For this to succeed, there will need to be peace and a commitment to

policy development and implementation by a stable Yemeni government.

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