**Title:** Yemen’s Cholera Epidemic is A One Health Issue

Running title: Cholera and One Health

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**Contributions**

Qin Xiang Ng conceived the original idea. Qin Xiang Ng, Wayren Loke, Michelle Lee Zhi Qing De Deyn and Wee Song Yeo carried out the study, and the relevant data analysis and interpretation. All authors contributed to the data analysis and interpretation. All authors discussed the results, contributed to the writing of the paper and approved the final manuscript.
ABSTRACT

Yemen has been faced with the worst Cholera epidemic of modern times, with more than two million suspected cases and 3000 deaths till date. This problem is largely due to the longstanding civil war between pro-government forces and the Houthi armed movement, which has severely damaged sanitation and healthcare facilities and systems in the country. It is further compounded by a dire lack of basic amenities, chronic malnutrition states and unfavourable weather conditions. To contain the spread of Cholera in Yemen, a nation-wide ceasefire should be negotiated and there must be national and local committees convened to coordinate efforts on the ground. Community isolation facilities with proper sanitation, reliable disposal systems and a clean water supply should be set up to isolate and treat sick patients. The continuity of vaccination programmes should be ensured. Public health campaigns to educate the local communities about good hygiene practices and nutrition are also necessary. The One Health paradigm emphasizes a multi-sectoral and transdisciplinary understanding and approach to tackle a communicable disease. It is most applicable to the ongoing Cholera crisis in Yemen as it demands a holistic and whole-of-society approach at the local, regional and national levels.

Keywords: Cholera; Yemen; One Health; environment; public health
PERSPECTIVE

Yemen has been faced with the worst Cholera epidemic of modern times, with more than two million suspected cases and 3000 deaths till date [1]. The Cholera epidemic is of unparalleled scale and the situation is still not contained despite ongoing efforts by the World Health Organisation (WHO) and other nongovernmental agencies [1]. Years of strife and civil war between pro-government forces and the opposing Houthi movement severely disrupted the already vulnerable Water, Sanitation and Hygiene (WaSH) and healthcare infrastructures in Yemen, leaving more than 16 million people without basic commodities, sanitation or healthcare. The prolonged conflict has also resulted in increased migration of people in and out of the region, and more than 2 million internally displaced individuals and refugees, who are forced to live in deprived, unsanitary and squalid conditions. These are hotbeds for Cholera transmission and outbreak. When sanitation and waste management systems become damaged, the waste materials can also easily leach into the groundwater and contaminate vegetables and surface water sources. This is especially significant as Yemen already has a dwindling water table and serious shortage of potable water [2] and Cholera transmits via the faecal-oral route.

A related issue is the lack of proper healthcare facilities. Due to the shortage of healthcare facilities and amenities, patients with Cholera do not receive adequate treatment and may go on to infect other persons. Patients with Cholera shed large amounts of highly infective organisms in their stools [3], thereby propagating a chain of infection and epidemic situation. Without proper sanitation and waste management systems, water sources can become further contaminated, and the water scarcity problem is even worse during periods of drought or flooding [4].

Even before the civil war, many people in Yemen were living in poverty and suffering from chronic malnutrition [5], which lowers their immunity to Cholera. There was also a shortage
of oral Cholera vaccination in Yemen and many young children below age 5 years did not receive proper vaccination, which increases their susceptibility to disease [6]. Many critics have also attributed the worsening Cholera epidemic to a delayed deployment of oral Cholera vaccination on the ground. A vaccination program was only initiated after nearly a million cases had occurred in the country [5].

Environmental changes also play a contributory role. Increased rainfall, flooding and a particularly strong El Niño and winds may have further contaminated water sources in Yemen and aided the spread of cholera-contaminated flying insects (chironomids) from the Horn of Africa to Yemen [7]. The infected insects can release *V. cholerae* into the external environment and contaminate food. The warmer conditions may have also favoured algal bloom and increased *V. cholerae* reproduction and survival in the environment [8]. *V. cholerae* has a symbiotic relationship with many species of zooplankton.

The One Health paradigm emphasizes a multi-sectoral and transdisciplinary understanding and approach to tackle an infectious disease [9]. It is most applicable to the ongoing Cholera crisis facing millions of Yemenis as it demands a holistic and whole-of-society approach at the local, regional and national levels. To contain the spread of Cholera in Yemen, there should be national and local committees convened to organise and coordinate efforts on the ground. Community isolation facilities with proper sanitation, reliable disposal systems and a clean water supply should be set up to isolate and treat sick patients. These facilities should have enough trained healthcare personnel and the necessary equipment and medicines (including oral rehydration salts, intravenous fluids, antibiotics and oral *Vibrio* vaccines) for treating Cholera. All biohazard waste must be properly disposed. Ensuring adequate nutrition is also helpful for patients with Cholera, and young children may benefit from further supplementation of certain micronutrients such as zinc.
To prevent the spread of Cholera, local governments and humanitarian efforts must focus on rebuilding Water, Sanitation and Hygiene (WaSH) and healthcare infrastructure. This may be quite difficult to achieve due to the political instability in the region, hence it is imperative for rival parties to negotiate a nation-wide ceasefire. Regardless, communities must have access to basic healthcare, clean water and proper sanitation for effective long-term Cholera prevention. Water sources should be disinfected, household water treatment should be carried out and food safety should be ensured through routine quality checks. Public health education, health promotion and a whole-of-society approach are also essential. The public should be reminded of the importance of good hygiene, including thorough hand-washing with soap before handling food or eating, after defecation as well as the proper handling of food and thorough cleaning of vegetables meant for human consumption. As many people in Yemen suffer from chronic malnutrition [5], a national nutrition programme and interventions at the community level are necessary to improve the nutritional status of young children. This would decrease their susceptibility to Cholera and its severe complications. Health and nutrition services should be provided to lactating mothers and these mothers should also be educated on infant and young children feeding.

In terms of prevention, a reliable surveillance system modelled after the WHO’s Early Warning, Alert and Response Network (EWARN) should also be put in place to detect a potential outbreak in its early stages. This would require multi-sectoral support and collaboration to ensure smooth transfer of data from the provincial and community to the national level. The government must also invest in laboratory testing capabilities for the rapid diagnosis of Cholera. Another important preventive measure is the administration of oral Cholera vaccine, which has been shown to be safe, cost-effective and confer protection for at least three years [10]. Yemen should invest in and ensure the continuity of a national vaccination programme for Cholera. There may be herd immunity benefits as well.
In short, it is evident that the Cholera epidemic in Yemen is a One Health problem and thus requires a collaborative, multi-sectoral and trans-disciplinary approach.
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