Sewage Surveillance Tool for Tracking of SARS-CoV-2 in Urban Bangladesh
(Technical Paper)

Factors Affecting Current SARS-CoV-2 Vaccine Reception
(STS Paper)

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On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Introduction

In late 2019, a novel viral infection caused a global pandemic that has resulted in millions of deaths worldwide, along with significant political, economic, and social disruption (Case et al., 2020). The viral infection was identified as a severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), which causes the coronavirus disease 2019 (COVID-19) (*Novel Coronavirus Structure Reveals Targets for Vaccines and Treatments*, 2020). COVID-19 has a high capacity for transmission between humans, even those who are asymptomatic, has a long incubation period, and there are currently no effective preventative measures to curtail the pandemic besides social distancing and masking (Case et al., 2020; CDC, 2020a). This prospectus presents two project proposals that address two different aspects of the pandemic: implementation of a future SARS-CoV-2 vaccine and current tracking of COVID-19 cases in Bangladesh.

A SARS-CoV-2 vaccine is a countermeasure that is urgently needed to end the pandemic, and development and testing of potential vaccines are currently underway (Amanat & Krammer, 2020; Callaway, 2020). The proposed STS research topic will analyze the factors that impact the effectiveness of a future coronavirus vaccine: including racial and socioeconomic inequality, anti-vaccination movements, politics, and privatized versus universal health care systems, and evaluate how this network could prevent herd immunity to COVID-19. Since there is currently no vaccine for COVID-19, accurate tracking of the virus and allocation of resources is needed to prevent further transmission and save lives, which is especially important in overpopulated areas with poor medical infrastructures.

The technical project proposal will detect and track COVID-19 cases in urban Bangladesh. Dhaka, Bangladesh is an overpopulated city whose hospitals are particularly underprepared for the patient influx caused by the SARS-CoV-2 pandemic. The effect of

asymptomatic cases, lack of testing, and weak access to healthcare makes it difficult to determine the impact and extent of COVID-19 in Dhaka (Deutsche Welle, 2020; Jubayer et al., 2020; Myelle Lansat, 2018). For the proposed technical project, the research team will be assessing qPCR data for the viral load of SARS-CoV-2 in Dhaka wastewater in order to determine the spatiotemporal prevalence of COVID-19, and developing a tool to visualize and interpret environmental surveillance data, which will provide critical information for actionable public health decisions, location-specific prevention, and tracking of SARS-CoV-2 in Dhaka.

Technical Topic

Since current methods of SARS-CoV-2 contact tracing in Bangladesh have not met the requirements of their high population density, as is possible in countries with greater health resources, a more cost-effective solution to tracking the spatiotemporal prevalence of the virus is required. Without a way to track the virus, allocating limited resources quickly becomes convoluted, especially for those who need them most. High rates of COVID-19 cases have occurred in Bangladesh because of the inability to track the spread of the virus, overpopulation, and not having a means to allocate testing and other health resources to citizens (Bodrud-Doza et al., 2020). While clinical testing is used to track COVID-19, it is biased towards those who can afford a test and towards symptomatic individuals. Clinical testing for SARS-CoV-2 leads to an underestimation of actual COVID-19 cases because COVID-19 tests in Dhaka cost a week's worth of wages for the average citizen and up to 80% of COVID-19 cases are asymptomatic, so individuals who do not show symptoms or are not wealthy are unlikely to get tested (Heneghan et al., 2020). Sewage surveillance is another tool that is used to track COVID-19 through testing for SARS-CoV-2 RNA in wastewater. Sewage surveillance is an unbiased method that can be used for tracking viruses in large populations and identifying both asymptomatic and symptomatic cases.

Fortunately, previous research has utilized sewage sampling to track other vaccine preventable diseases, such as poliovirus, norovirus, and rotavirus (Hellmér et al., 2014). Recent studies demonstrate that these same sewage surveillance techniques can track the SARS-CoV-2 virus as well. Sewage samples will be collected from different catchment areas in Dhaka, and then the amount of viral pathogen in the system will be quantified through the process of reverse transcription quantitative polymerase chain reaction (qRT-PCR). The amount of pathogen associated with one collection site is then associated with its watershed through sewage and drainage line tracing (Ahmed et al., 2020; Kitajima et al., 2020). In addition to its accuracy, sewage sampling is cheaper and requires fewer health professionals for data collection in comparison to traditional prevalence tests and contact tracing. Once the data is collected, it will be put into a dashboard that will provide public health officials with a visual tool for tracking the spatiotemporal prevalence of the SARS-CoV-2 virus in their community. With this knowledge, public health officials can visualize which regions are having higher instances of the virus and can allocate more of their testing resources to those areas to prevent further transmission. Under Mami Taniuchi and Isobel Blake, a team of three undergraduate engineering students will be normalizing environmental surveillance data from collection sites in Dhaka and forming a dashboard to represent the spatiotemporal prevalence of COVID-19 per the different catchment areas and wards of Dhaka. Dhaka is one of the top five most populated cities in the world, with 22 million residents, which means tracking COVID-19 is a crucial but difficult project (Myelle Lansat, 2018). R Studio will be used for analysis of sewage surveillance data and for mapping of the SARS-CoV-2 RNA prevalence along with total reported cases. Developed maps and graphs will be displayed in a user-friendly dashboard through R Shiny and given to the Institute of Epidemiology Disease Control and Research to aid in their disease surveillance and outbreak control in Bangladesh.

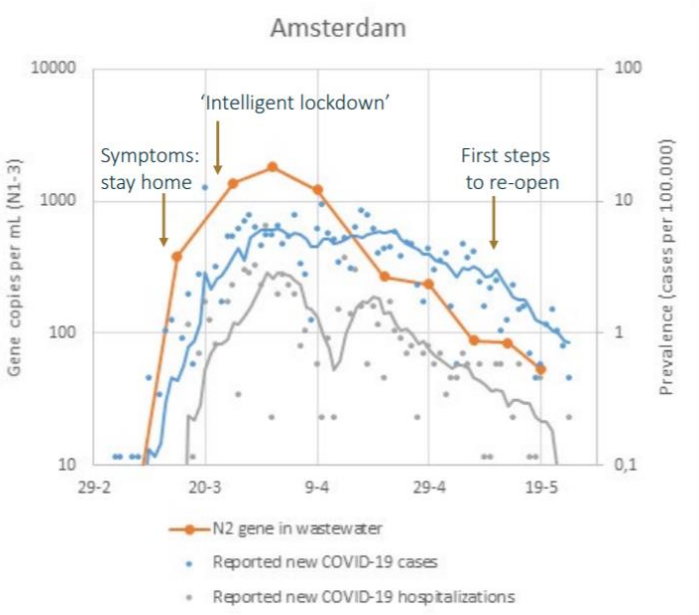

Figure 1. Graph showing the gene copies of the SARS-CoV-2 virus in wastewater (Gertjan Medema et al., 2020).

Many communities, ranging from countries to college campuses, have successfully implemented environmental surveillance to track their cases of the SARS-CoV-2 virus. A study in the Netherlands determined that there was a strong correlation between the amount of viral RNA detected by qRT-PCR and the reported COVID-19 case prevalence. To determine the correlation between sewage surveillance data and case prevalence, researchers gathered sewage data from five cities, quantified the viral load presented over the course of several weeks, and determined that it was possible to predict outbreaks of COVID-19 cases days before symptoms appeared. By drawing upon these conclusions, the Dutch were able to produce a model to best contain the spread of the virus (*Figure 1*) (Gertjan Medema et al., 2020). This same method of surveillance has been used on college campuses in the United States to prevent spreading of the virus amongst students. Sewage data is collected from student dorms, and quarantine procedures are enforced if the concentration of viral pathogens reaches a particular threshold (Kent, J, 2020). These wastewater testing methods are very effective at tracking outbreaks, giving public health officials time to react and minimize transmission rates.

Sewage surveillance is particularly pertinent for developing countries like Bangladesh, as they do not have a strong medical infrastructure and cannot properly track or contain the SARS-CoV-2 virus with their current resources. By creating a dashboard that can visually represent the spatiotemporal prevalence of the virus, public health officials in densely populated areas will be able to predict outbreaks, focus their testing resources on those areas, and implement restrictions to keep the citizens of the community as safe as possible. The largest challenges in creating this dashboard are implementing an interactive mapping system, creating accurate representations of existing data, and designing easy-to-use components that will be helpful to health officials (Hagedorn et al., 2020; Kitajima et al., 2020). Overcoming these challenges will prove that specific and distinct representation of SARS-CoV-2 is possible in heavily populated countries and will justify efforts to increase equitable representation of the disease in developing regions. By creating well documented code and methodology, the dashboard has the potential to be extrapolated to represent spatiotemporal data for other low-resource countries and play a role in decreasing disease transmission in communities that need it most. Bangladesh sewage surveillance is currently an ongoing process and preliminary maps are being created to represent the COVID-19 caseload and determine data correlation. A technical report and finalized dashboard will be completed in the Spring of 2021.

STS Topic

In an effort to end the COVID-19 pandemic, researchers and drug and biotechnology companies are rushing to develop a vaccine. Vaccinations effectively reduce infectious disease burden and mortality, preventing three million deaths a year and globally eradicating many diseases: such as smallpox and poliovirus (Rémy et al., 2015). Vaccines are recognized as one of the most cost-effective public health investments because the prevention of infectious diseases leads to lesser healthcare burden and greater economic growth (Rémy et al., 2015). Yet, just because there is a vaccine does not mean everyone will get vaccinated, so accessibility and

widespread administration of a COVID-19 vaccine is crucial to stop future outbreaks. The network of factors that affect the accessibility and administration of a vaccine, and could, therefore, affect the ability of a future SARS-CoV-2 vaccine to eradicate the COVID-19 pandemic will be researched to evaluate the proposed STS topic.

A SARS-CoV-2 vaccine will be essential to reducing mortality and morbidity of COVID-19 (Amanat & Krammer, 2020). Developing a vaccine for COVID-19 is a complex challenge because this virus has recently emerged in humans and coronavirus vaccines do not currently exist (Amanat & Krammer, 2020). Since no coronavirus vaccines exist, new manufacturing processes have to be created and novel technologies extensively tested, a process that is time-consuming and can often take years (Amanat & Krammer, 2020). As of September 17, 2020, 320 COVID-19 vaccines were in development and several dozen had progressed to clinical trials (Callaway, 2020). Funding is critical to the development of vaccines because clinical trials are costly. Several smaller companies have to stall their vaccine development because of lack of funding, but it is important to have a wide variety of vaccines in clinical trials to maximize the chances of one working (Callaway, 2020). While time and money are essential factors during vaccine development, there are multiple additional factors that affect the implementation and, therefore, the effectiveness of a vaccine once it has been approved for administration.

Once a SARS-CoV-2 vaccine has been developed and approved, the effectiveness of the vaccine in ending the COVID-19 pandemic will depend on how many people actually receive the vaccine. One factor that affects a future SARS-CoV-2 vaccine is the anti-vaccination movement, where people choose not to get vaccinated for a variety of personal reasons and fears (Seeman & Rizo, 2010). A vaccination is only effective in reducing transmission of a virus and protecting high risk groups if the vaccine is widely delivered. The anti-vaccination movement is a recent

trend seen in Western countries that threatens herd immunity to vaccine-preventable diseases. The rise in the anti-vaccination movement has resulted in multiple measles outbreaks in locations where measles was thought to be eliminated (Dunham, 2008; Hussain et al., 2018, p.). Vaccine hesitancy was ranked by the World Health Organization as one of the top 10 threats to global health, with herd immunity being compromised once vaccine compliance drops below 95% of the target population (Sharoni Bandyopadhyay, 2019). There are 45 states in the US that allow religious and philosophical exemptions, but if parents opt their children out of a future vaccination for COVID-19 then there is an increased risk for future COVID-19 outbreaks (Sharoni Bandyopadhyay, 2019). The rise of anti-vaccination sentiments is fueled by media influence and lack of accurate information about the vaccination process (Hussain et al., 2018).

While some groups purposefully abstain from vaccinations, there are other groups that abstain because they are unable to access or afford vaccinations (Sharoni Bandyopadhyay, 2019). Inability to afford vaccines introduces another factor that could influence effectiveness of a future SARS-CoV-2 vaccine: socioeconomic status. According to Sharoni Bandyopadhyay (2019), "unvaccinated children are more likely to be uninsured, live below the poverty level, and reside in rural areas." Therefore, a SARS-CoV-2 vaccine will need price controls or free distribution of the vaccine in order to ensure that economic barriers are not hindering immunization of poor countries and people (Gavin Yamey, 2020). Economic disparity in access to health care relates to racial disparity (CDC, 2020b). Black workers in the US have greater economic instability, with lower incomes and higher levels of unemployment, and also have more underlying health factors that result in adverse health outcomes for COVID-19 contraction (Elise Gould, 2020). In a study in Louisiana, 77% of hospitalized COVID-19 patients were black, while blacks only represented 31% of the population in that area (Price-Haywood et al.,

2020). These results highlight the racial differences in health care, that also stem from economic differences. Privatized health care can exacerbate economic differences because of the cost of health insurance, so privatized versus universal health care is a factor that will affect SARS-CoV-2 vaccine deliverance in different countries (Ridic et al., 2012). Health care systems in each country are molded by the political system, so government is another factor to be considered in implementation of the SARS-CoV-2 vaccine (Vladeck, 2003). Research on the network that affects the SARS-CoV-2 vaccine is important because a future vaccine is currently the only countermeasure with the potential to end the COVID-19 pandemic, which would save many lives and save society from related economic and social disruption (Amanat & Krammer, 2020).

The Actor-Network Theory (ANT) will be used to analyze the complex network surrounding a potential SARS-CoV-2 vaccine. ANT was developed by Bruno Latour, Michel Callon, John Law, Murdoch, and Jakku as a theory that sees scientific knowledge and technology as a social product that can be used to examine the power held by different human and non-human actors (Rodger et al., 2009). Rodger et al. (2009) states that "Actor-network theory examines the mechanics of power through the construction and maintenance of networks (both human and non-human). Actors become involved in networks through the process of translation." ANT helps examine who or what is within a network and how networks emerge and are maintained (Cressman, 2009; Rodger et al., 2009). A critique of ANT from critics Whittle and Spicer is that ANT cannot provide a critical account of the organization of a network (Whittle & Spicer, 2008). In *Actor-Network Theory, organizations and critique: towards a politics of organizing,* Alcadipani and Hassard state that "despite its popularity, ANT is considered a controversial approach in that it appears to promote a sociological perspective that lacks substantive political critique" (Alcadipani & Hassard, 2010). Edwin Sayes in *Marx and the*

critique of Actor-Network Theory: mediation, translation, and explanation agrees that ANT is critiqued for political determinacy, but also critiqued for relying on nonhuman agency and for being reductionist, reducing reality to networks of translation (Sayes, 2017). Despite these critiques, ANT will be utilized to determine the human and non-human actors that affect implementation of a future SARS-CoV-2 vaccine and to examine how the actors interact in and maintain the dynamic network surrounding a potential COVID-19 vaccination.

Research Question and Methods

The proposed research question is: What are the factors that influence the effectiveness of a future SARS-CoV-2 vaccine in ending the COVID-19 pandemic? How does the network of anti-vaccination movements, racial and economic inequality, politics, and differing health care systems affect widespread accessibility and administration of a SARS-CoV-2 vaccine and subsequent immunization to COVID-19? To answer this question, network analysis will be implemented. The network analysis method is used to understand and define the socio-technical network and provide evidence to explain the nature of existing relationships between actors (Hatala, 2006). Network analysis will be utilized to examine the structure among the factors affecting SARS-CoV-2 implementation and explain different possible outcomes of the vaccination in eradicating the COVID-19 pandemic. A literature review will be done to identify the different agents, while a network analysis method will determine the linkages between the agents and provide an analysis to determine the end behavior of a vaccination. Literature review is currently underway to identify actors that will negatively impact the effectiveness of a future vaccine. Research will continue through March 2021 and culminate in an STS Research Paper in April 2021 that explains how the network surrounding vaccinations will influence a future vaccine's ability to eradicate COVID-19.

Conclusion

For the technical portion of this proposal, a dashboard will be designed in R Studio to interactively display the COVID-19 cases in Dhaka. The dashboard is based on sewage surveillance of nine wards in Dhaka, using qPCR data to determine the viral load of SARS-CoV-2 RNA in the wastewater. The dashboard will be given to public health officials in Bangladesh to allow them to allocate resources and testing and stop the transmission of COVID-19. This dashboard will further provide citizens with updates and tracking of the virus and will ease medical infrastructure strain on Dhaka by allowing for proactive decisions that prevent the spread of COVID-19. A technical paper will be written to explain the technical deliverable and the process that went into the dashboard design, as well as the dashboard's application.

For the STS deliverable, a research paper will be written that addresses the important factors that will influence an effective implementation of a future SARS-CoV-2 vaccine. Once a vaccine is developed, it needs to be accessible and widely administered to allow for herd immunity from COVID-19. ANT is the framework that will be used to determine the network surrounding the potential vaccine. Some actors that will be looked at that affect vaccinations are racial and economic inequality, anti-vaccination movements, different health care systems, and the political landscape. This research paper will provide an understanding of the factors that will influence the effectiveness of a SARS-CoV-2 vaccine, in an attempt to mitigate any potential hindrances that will affect the vaccine's ability to eradicate COVID-19.

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