School of Mathematical and Statistical Sciences
Arizona State University

MEMORANDUM

DATE: 03/28/2023

TO: Faculty and Students

FROM: Professor(s) Abba Gumel

Chair/Co-Chairs of Salman Safdar

Defense for the PhD in Applied Mathematics

Committee Members

Eric Kostelich
John Fricks
Malena Espanol
Yun Kang

DEFENSE ANNOUNCEMENT

Candidate: Salman Safdar

Defense Date: Wednesday, April 12, 2023

Defense Time: 1:00 PM

Virtual Meeting Link: https://asu.zoom.us/j/83803335090

Title: Mathematics of SARS-CoV-2

Please share this information with colleagues and other students, especially those studying in similar fields. Faculty and students are encouraged to attend. The defending candidate will give a 40 minute talk, after which the committee members will ask questions. There may be time for questions from those in attendance. But, guests are primarily invited to attend as observers and will be excused when the committee begins its deliberations or if the committee wishes to question the candidate privately.

ABSTRACT
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ABSTRACT

A pneumonia-like illness emerged late in 2019 (coined COVID-19), caused by SARS-CoV-2, causing a devastating global pandemic on a scale never before seen since the 1918/1919 influenza pandemic. This dissertation contributes in providing deeper qualitative insights into the transmission dynamics and control of the disease in the United States. A basic mathematical model, which incorporates the key pertinent epidemiological features of SARS-CoV-2 and fitted using observed COVID-19 data, was designed and used to assess the population-level impacts of vaccination and face mask usage in mitigating the burden of the pandemic in the United States. Conditions for the existence and asymptotic stability of the various equilibria of the model were derived. The model was shown to undergo a vaccine-induced *backward bifurcation* when the associated reproduction number is less than one. Conditions for achieving vaccine-derived herd immunity were derived, and the vaccination coverage level needed to achieve it decreases with increasing coverage of moderately- and highly-effective face masks. It was also shown that using face masks as a singular intervention strategy could lead to the elimination of the pandemic if moderate or highly-effective masks are prioritized and pandemic elimination prospects are greatly enhanced if the vaccination program is combined with a face mask use strategy that emphasizes the use of moderate to highly-effective masks with at least moderate coverage. The model was extended in Chapter 3 to allow for the assessment of the impacts of waning and boosting of vaccine-derived and natural immunity against the BA.1 Omicron variant of SARS-CoV-2. It was shown that vaccine-derived herd immunity can be achieved in the United States *via* a vaccination-boosting strategy which entails fully vaccinating at least 71% of the susceptible populace followed by the boosting of about 81% of the fully-vaccinated individuals whose vaccine-derived immunity has waned to moderate or low level. Boosting of vaccine-derived immunity was shown to be more beneficial than boosting of natural immunity. Overall, this study showed that the prospects of the elimination of the pandemic in the United States were highly promising using the two intervention measures.