

Overall Conclusion

The thesis introduces fractional-order epidemiological models (Caputo, Caputo-Fabrizio, Atangana-Baleanu) that better capture memory effects and nonlocal dynamics in diseases compared to classical ODE models. It provides a solid mathematical framework for existence, uniqueness, and stability (local and global) of fractional models, with an analysis of fractional boundary value problems and eigenvalues. Numerical simulations demonstrate the effectiveness of fractional models in predicting disease progression and treatment outcomes. Fractional models outperform classical ODE models, capturing the complexity of immune interactions and long-range dependencies in chronic diseases like cancer and viral infections. This research opens up new possibilities for refined disease modeling with applications in mathematical epidemiology and clinical practice.

Societal Benefits: The societal benefits of this research extend far beyond the theoretical realm, offering practical applications in public health, medical treatment, and disease prevention:

- **Improved Disease Control & Public Health:** Fractional-order models enhance disease surveillance and forecasting systems, leading to more accurate predictions for outbreaks (e.g., Chikungunya) and cancer risks (e.g., smoking-related). This allows policymakers to design effective interventions, allocate healthcare resources efficiently, and simulate the long-term impact of control measures like vaccination or quarantine.
- **Personalized Cancer Treatment:** The research contributes to personalized cancer care by optimizing chemotherapy and other treatments. Fractional models account for

patients' historical responses, helping clinicians tailor treatment schedules, minimize side effects, and improve outcomes for advanced-stage cancers.

- **Long-Term Risk Assessment:** Fractional models offer insights into the long-term impact of lifestyle factors (e.g., smoking) and environmental risks (e.g., hard water exposure) on disease development. This aids in preventive strategies, identifying vulnerable populations, and informing public health campaigns.
- **Better Understanding of Complex Biological Systems:** By modeling immune responses and disease progression more accurately, fractional-order derivatives deepen understanding of biological processes, potentially leading to novel therapies and diagnostic tools.
- **Adaptability to Other Health Challenges:** While focused on cancer and viral diseases, fractional models can be applied to a wide range of epidemiological challenges like infectious diseases, antibiotic resistance, and chronic conditions, providing powerful tools for addressing global health issues.