Predictive assessment of transmission conditions of cholera in the environment and human population using earth observations

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UK Met Office  
OCHA  
UNICEF  
WHO  
WHO  
Red Cross  
State Department-Africa
Goal of Research Project

We thematically envision “Cholera Ready Nations” where satellite based prediction (of risk of trigger and likelihood of transmission of cholera in the human population) will provide sustainable and resilient readiness to prevent outbreak of disease, saving human lives and improving quality of life.

Objectives

• Systematically validate the epidemic and endemic cholera hypothesis for trigger component of cholera in Africa
• Develop, calibrate, and validate predictive model for transmission component of cholera.
Research Pathway

**Relevant earth observations**

**EPIDEMIC CHOLERA**
- MODIS/VIIRS [LST, Land cover]
- TRMM/GPM [Precipitation]
- SRTM [DEM]

**ENDEMIC CHOLERA**
- MODIS/VIIRS [Chlorophyll, SST, Organic matter, Land Cover]
- AVHRR [SST]
- TRMM/GPM [Precipitation]
- SRTM [DEM]
- TOPEX/JASON [SSH]
- Aquarius [Salinity]

**SST:** Sea Surface Temperature; **SSH:** Sea Surface Height; **LST:** Land Surface Temperature; **MODIS:** Moderate Resolution Imaging Spectroradiometer; **TRMM:** Tropical Rainfall Measuring Mission; **GPM:** Global Precipitation Mission; **AVHRR:** Advanced Very High Resolution Radiometer; **DEM:** Digital Elevation Model; **SRTM:** Shuttle Radar Topography Mission

**Use of earth observations to advance science of cholera (Section 2.1)**

**Validation of trigger hypothesis for Epidemic mode of cholera (Task 1)**

**Validation of trigger hypothesis for Endemic mode of cholera (Task 2)**

**Cholera Transmission Model (CTM) (Task 3)**

**Anticipated Results (Section 3)**

- Risk maps showing probabilities of occurrence of inland cholera infection
- Risk maps showing probabilities of occurrence of cholera infection along coasts

**Ensemble scenarios on how cholera infection may spread in human population**

**Capacity building initiatives (Section 2.2)**

- Communication plan with African partners identified by GEO Secretariat to identify core working group for cholera (Task 4)
- Determine feasibility of encourage use of earth observations and testing algorithms by partner foundations (Task 5)
- Workshop on African Cholera Initiative, social media and dissemination kit to advance Agenda 2030 plan (Task 6)
Knowledge transfer from previous project

**Epidemic Cholera**
- Sporadic outbreak
- Usually occurs following floods or inundation of large landscapes
- Warm temperatures may increase growth of bacteria in aquatic bodies.

**Mixed-mode Cholera**
- Usually two seasonal peaks
- One peak related to seawater intrusion; Second peak associated with widespread inundation
- Specific to Bengal Delta region

**Endemic Cholera**
- Cholera persists throughout year in coastal regions
- Seawater Intrusion from coasts to inland
- Cholera outbreaks occur during low river flow season

Background image: Bangladesh and Bay of Bengal
Epidemic cholera model

Warm temperature = above climatological average temperature
Heavy rainfall = above climatological average precipitation
Water insecurity = lack of access to water and sanitation access
High cholera risk = probability of cholera greater than 50%
Epidemic algorithm: Hydrology + Microbiology + Sociology

CHOLERA ALERT SYSTEM (CAS-version 4)

Air temperature anomalies +

Precipitation anomalies +

Population density +

Disaster and population movement +

Drinking water accessibility +

Sanitation infrastructure +

\[ W_{ij} \]

\( i = \) variable of interest
\( j = \) risk level

In house algorithm

Cholera Risk Map

Hydrology + Microbiology

Hydrology + Microbiology + Sociology
Cholera outlook for Yemen September 9 – October 6, 2019

Yemen County Cholera Risk September 9 - October 6, 2019

Value
High
Low
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<th>MEAN</th>
<th>Action Recommended</th>
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Antar,

What are the possibilities/limitations of running your cholera risk model for Mozambique, given the current situation and increasing concerns re cholera risk?

Thanks,
Cholera outlook for three districts of Beira, Dondo and Nhamatanda, April 2019* (see note below)

Cholera Risk Map for April 2019
Cholera outlook for the provinces of Sofala, Zambezia and Manica, April 2019* (see note below)

Cholera Risk Map for April 2019

Value
- High : 1
- Low : 0

[Map showing cholera risk distribution with color coding for high and low values]
Mechanistic algorithms: Hydrology-Environment-Microbiology-Epidemiology: A new generation of mathematical models

\[ \frac{dS}{dt} = \eta(S + E + I + R) - [(\sigma R + (\mu + \alpha)S] \]

\[ \frac{dE}{dt} = \alpha_{WASH} \cdot N_{Exp} \cdot S - \left( \mu + \beta_{inf} \cdot \frac{B_{Env}}{K + B_{env}} \right) E \]

\[ \frac{dI}{dt} = \beta_c \cdot \frac{B_{Env}}{K + B_{env}} E - (\mu_I + \tau + \gamma) I \]

\[ \frac{dR}{dt} = \gamma I - (\mu + \sigma) R \]

\[ \frac{dB_I}{dt} = \tau I - \psi B_I \]

\[ \frac{dB_{Env}}{dt} = \psi B_I + \left( \omega_{Env} \times Pr(Disease_{hydroclimate}) - \theta \right) B_{Env}; \quad Pr(Disease_{hydroclimate}) = \frac{e^{a+b \cdot n}}{1 + e^{a+b \cdot n}} \]

Jutla et al., 2016: Plos-One
Trigger -> Transmission

![Graph showing suspected cases and probability over weeks]

- **Suspected Cases**: Blue bars
- **Probability**: Red line
ARL information

Starting ARL: 3

Current ARL: Approaching 5

Target ARL: 8
# Overall timeline for research objective and activities at end user organization

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<th>Activity</th>
<th>Year 1</th>
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#initiate discussion with GEO Secretariat; x¹: planning; x²: workshop at UMD or UF; Q1, Q2, Q3, Q4 represent quarter in a given year.
Retire statistical significance

Valentin Amrhein, Sander Greenland, Blake McShane and more than 800 signatories call for an end to hyped claims and the dismissal of possibly crucial effects.

**Wrong Interpretations**
An analysis of 791 articles across 5 journals* found that around half mistakenly assume non-significance means no effect.

- Appropriately interpreted: 49%
- Wrongly interpreted: 51%

Thank you