Public Health, Climate and Infectious Diseases Interactions

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Workshop on Mathematical Models of Climate Variability, Environmental Change and Infectious Diseases
Outline

- Conceptual frameworks
- Public Health Approach
- Public Health and Climate interactions
Setting the scene*

F1: Medical
“individual, patient-based model”: germ theory
Research goal: to develop a drug or a vaccine
Clinical Trial

F2: Epidemiological
“population based model”: Incidence, Prevalence, # cases are f(Host Pathogens / Risk Factors).
Research goal. To understand the web causality - complex inter-relationship of numerous direct and indirect factors that interact to alter the risk of disease – in space and time
Risk factor analysis (statistical models)

F3: Ecological
“host–pathogen interactions model”: biology and evolutionary ecology principles.
Research goal: to examine patterns of ID occurrence as a product of biological processes (contact rate, transmissibility...)
Mathematical models (Differential Equations): SIR, SEIR models

Getting back to F3: last week wrap up

Some of the challenges:

(i) how to introduce extrinsic and intrinsic factors to diseases dynamics. (???)

(ii) how to match/test epi-data with those mathematical models using statistical/simulation models. Issues: estimation initial conditions; stochastic behavior {noise treatment}; parameters uncertainties {literature, pdf, likelihood} (????);

(iii) How to get a good balance between model complexity and model usefulness. (???)

(iv) how to use those models to improve/help the decision making process of public health officers. (??????)
Public Health: the scope

Public Health is what we, as a society, do collectively to protect, promote and restore the people’s health

“the art and science of preventing disease, prolonging life and promoting health through the organized efforts of society” (Acheson, 1988; WHO).

“public health was founded on the principle of social justice as a basic right” APHA.
Public Health Approach

Problem

Surveillance:
What /Where/is the problem?
How frequently It happens?

Risk Factor Identification:
What is (are) the Cause/Driver(s)?

Response

Intervention
What actually works?

Implementation and evaluation:
How do you do it?
What do you learn?

Scientific Evidence Behind
Population, space and time scales
Identification of information chains and networks

Key: Surveillance/Info-systems/Resources
Public Health Approach

Diseases Risk Factor Identification: (diff-options)
Example: Societal, Environmental, Economic factors?

Problem

Key: Surveillance/Info-systems/Resources

Response

Societal
Health/Education (HE): access/status/policies
Demographic/Housing conditions
life-styles, political/ inequality situation

Environmental
Water/Land: access/mgmt/conditions
Climate/Weather conditions
Sanitation conditions
Ecosystems: mgmt/conditions

Economic
Income/Consumption Trade/Labor Development Programs poverty situation

Data availability and quality are the major constraints

Measurement of the factors depends on assumptions about time and space scales and the characteristics of the population at risk

Surveillance/Info-systems/Resources
Questions

- How much disease is caused by a particular risk factor (the attributable burden of disease)?
- How much could be avoided by making plausible reduction in the risk factor (the avoidable burden of disease)?
- Why do certain people develop disease (or experience an adverse health outcome) when challenged with harmful environmental exposures, while others remain healthy?
- Should we intervene?
- Where should we intervene?
- How much intervention is required?
- What are the costs? Can we afford it?
- How frequently?
- What tools should we use for monitoring progress?
- How will we measure the success of the program?
Climate and Public Health:

a very old and renovated relationship

Hippocrates, Father of Medicine
Born in 460 B.C. - Died in 377 B.C.
“Airs, Waters, Places”.

Dr. Margaret Chan
Director-General WHO

“Climate change will affect, in profoundly adverse ways, some of the most fundamental determinants of health: food, air, water.”
Climate and Public Health: a very old and “stable” relationship

Hippocrates, Father of Medicine
Born in 460 B.C. - Died in 377 B.C.
“Airs, Waters Places”.

EPA USA
Climate Impacts on Human Health
Key Points

“Climate change can affect human health in two main ways: first, by changing the severity or frequency of health problems that are already affected by climate or weather factors; and second, by creating unprecedented or unanticipated health problems or health threats in places or times of the year where they have not previously occurred.”

Public Health and Climate: the menu

Public Health: strategies

**Primary:** to prevent the onset of injuries or illness.
Examples-> immunization, safe water, campaigns of: safe sex, clean water/air, anti-smoking, safe car-bicycle practices, bed nets....

**Secondary:** to diagnose disease early to control/prevent its progress and diminish the resulting health burden;
Examples-> screening/testing for: malaria, diabetes, cancer, hypertension, hyperlipidemia...

**Tertiary:** to elude complications, and restore functions in order to decrease/prevent morbidity and mortality.
Examples-> using specialized-scientific driven short/medium/long term treatments: chemotherapy

Climate: strategies

**Mitigation:** “A human intervention to reduce the sources or enhance the sinks of greenhouse gases (GHGs)”, (IPCC).
Examples-> promoting/providing: afforestation, clean energy sources/uses at all levels; public transport for communities.

**Adaptation:** “Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities”, (IPCC).
Examples-> promoting/providing proper/tailor made interventions at all levels under expected/observed weather/climate events
Examples of climate sensitive Communicable Diseases (CD)

**Vector-borne**
- Malaria *
- Dengue Fever ,
- Zika*, Chikungunya *
- Lyme disease @
- West Nile (R,T)
- Rift Valley fever (R, CV[ENSO])
- Hantavirus pulmonary syndrome & Leishmaniosis, (T, CV[ENSO])
- African trypanosomiasis (T)
- Tularemia (*)
- Plague (&)
- Onchoceriasis (river blindness) (T)

**Water and Foodborne**
- Cholera &
- Leptospirosis &
- Schistosomiasis (T,R)
- Giardiasis &
- Cryptosporidiosis &
- Human enteric viruses (Enteroviruses, . Norwalk and Norwalk-like viruses) (T)
- Campylobacteriosis &
- Salmonella enteritidis (T,D)

**Airborne (and others)**
- Meningococcal Meningitis (H,S,W)
- Coccidiodomycosis (D,P,T,W)
- Respiratory syncytial virus (Coldwaves ,S,T)
- Influenza (T,H)

**Climate and Extreme weather/climate conditions:** (R)ain, (T)emperature, (H)umidity, (W)inds, (F)looding, (D)rought, (ET) Heatwaves/ColdWaves, (S)easonal * (R,T,H), &(R,F) ^(ET,H,R), @(T,R,S), (CV) climate variability
Public Health Approach:
Malaria risk factors

Public Health Approach
Another malaria glimpse:
Global vector distribution: published 2012

Sinka, M., et al. (2012), Parasites & Vectors 2012, 5:69
Public Health Approach
Another malaria glimpse:
Global endemic distribution: 2016 geo-unit: country

At the start of 2016, nearly half of the world’s population was at risk of malaria.

Malaria was considered to be endemic in 91 countries and territories in 2016, down from 108 in 2000. Most of the change can be attributed to the wide-scale deployment of malaria control interventions.

Countries endemic for malaria in 2000 and 2016
Public Health Approach

Malaria Transmission Mechanism (MTM)

Infectious Agent: Parasite (Pf, Pv, Pm,...)

Susceptible Hosts (Sus)

New Infected Host

{t_h1}

New Infectious Host (Inf) gametocytes

{t_h4}

Susceptible Host (Inf)

Infectious Host (Inf)

{t_h2}

Infective Vector

{t_v1}

{t_v2}

{t_v3}

Immune Hosts (Imm)

{t_h3}

Eggs

Larvae

Pupae

Climatic(Weather) patterns

T

H

P

Pop= Sus+ Inf+ Imm

New Infectious Host (Inf)

Public Health and Malaria Interventions (IPT, ITN, BC, IRS, DT, S)

Pop = Sus + Inf + Imm

Susceptible Hosts (Sus)

New Infected host

New Infectious Host (Inf) gametocytes

Infectious Host (Inf)

DT, S

Immune Hosts (Imm)

Infectious Vector

Infected Vector

IPT, IRS, ITN

Climatic (Weather) patterns

Public Health Intervention

Danger!

Infectious vector sporozoites

BC

DT, S

S

Susceptible vector

Pupae

Larvae

Eggs

### Public Health and Malaria Interventions (ITN, BC, IRS, DT, S)

#### Individual Annual cost

<table>
<thead>
<tr>
<th>Intervention</th>
<th>Cost (U$)</th>
<th>Cost Prevention (U$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITN</td>
<td>2.2</td>
<td></td>
</tr>
<tr>
<td>IRS</td>
<td>6.7</td>
<td></td>
</tr>
<tr>
<td>IPT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Infants</td>
<td>0.6</td>
<td>9.5</td>
</tr>
<tr>
<td>Under 5 years</td>
<td>4.03</td>
<td>12.93</td>
</tr>
<tr>
<td>Pregnant women</td>
<td>2.06</td>
<td>10.96</td>
</tr>
<tr>
<td>Dx</td>
<td>4.32</td>
<td></td>
</tr>
<tr>
<td>Treatment</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uncomplicated</td>
<td>5.84</td>
<td></td>
</tr>
<tr>
<td>Severe malaria</td>
<td>30.26</td>
<td></td>
</tr>
</tbody>
</table>

Public Health Approach

Another malaria glimpse:
Malaria control activities by founding source

Investments in malaria control activities by funding source, 2005–2015

Global Fund, Global Fund to Fight AIDS, Tuberculosis and Malaria; UK, United Kingdom of Great Britain and Northern Ireland; USA, United States of America
Annual values have been converted to constant 2015 USS using the gross domestic product implicit price deflator from the USA in order to measure funding trends in real terms.

Sources: ForeignAssistance.gov, Global Fund to Fight AIDS, Tuberculosis and Malaria, national malaria control programme reports, Organisation for Economic Co-operation and Development (OECD) creditor reporting system, the World Bank Data Bank, WHO estimates of malaria cases and treatment seeking at public facilities, and WHO CHOICE unit cost estimates of outpatient visit and inpatient admission.
Public Health Approach

Another malaria glimpse: Africa situation

Vector Distribution: published 2012

Evolution PfPR_2-10 (2015/2000)

Sinka, M., et al. (2012), Parasites & Vectors 5:69

Public Health Approach

Another malaria glimpse:

Africa situation

Country Incidence rate evolution: (# cases by 1000 per annum) after interventions

Public Health Approach

Another malaria glimpse:

Issues regarding surveillance and interventions

Public Health Approach
Another malaria glimpse:
Evolution some indicators associated with risk factors
Public Health Approach

Another malaria glimpse:

Evolution some indicators associated with risk factors

World Bank, Development Indicators
Public Health Approach

Another malaria glimpse:
Evolution some indicators associated with risk factors

World Bank, Development Indicators
Public Health Approach

Another malaria glimpse:

Evolution some indicators associated with risk factors

World Bank, Development Indicators
Public Health Approach

Another malaria glimpse:
Africa situation

Evolution: PfPR_2_10:
(2015 relative to 2000)

Poverty Indicator: 2011

doi:10.1038/nature15535

doi: 10.12688/f1000research.9682.1
Climate and Public Health issues: How to close the information gaps?

- All infectious diseases (ID) cases must be notified, epidemiologically investigated and centrally registered.
- There is a need to either organize or/and to gather under GPS standards data on diseases, cases, vectors, parasite, interventions and risk factors under a proper temporal framework.
- For the math-models, climatic factors will continue to be highly important (extrinsic factor), but, all remaining risk factors are also important to be consider. For example: intervention {clean water, sewage, IBN...} => recovery, contact, transmission rates).
- Allocation of resources for Public Health and other institutions associated with the surveillance of CD should be prioritize.
- Special efforts should be done regarding incorporating local risk factors conditions to models, to try to explain successful or unsuccessful disease risk management among different spatial units.

SEIR Model: \{S\}usceptible-{E}Exposed-{I}Infectious-{R}Recovered

$$\frac{dS}{dt} = \lambda - [\Phi + \mu] S$$  \hspace{1cm} \lambda:\ crude\ birth\ rate

$$\frac{dE}{dt} = \Phi S - [\mu + \kappa] S$$  \hspace{1cm} \mu: death\ rate

$$\frac{dI}{dt} = \kappa E - [\gamma + \mu] I$$  \hspace{1cm} \gamma: recovery\ rate

$$\frac{dR}{dt} = \gamma I - \mu R.$$  \hspace{1cm} \kappa: progression\ rate : E\rightarrow I

\(\Phi = \beta I\)

\(\beta = \tau v\)
“The way we understand the causes or origin of disease and health defines the way we act on them"

Thank you!
Reference (associated with the public health practices and policy issues)


[2] Lindgren, E. et al. (2010), Climate Change and Communicable Diseases in EU members states, ECDC.


Reference (associated with the models)


[9] De Leo, G., (2013), Seasonality an Diseases, ICTP-Seminar PP-Presentation


Reference  (associated with models)


[16] Deyle, E. et al. (2014), Global environmental drivers of influenza, PNAS, vol. 113 no. 46 13081–13086


Reference (associated with the public health practices and policy issues)