Environmental Factors: Vector Borne Diseases

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Outline or Presentation

• Basic definitions

• Burden of Vector Borne Diseases (VBDs)

• Epidemiological triad

• Environmental factors related to VBDs

• Climate change
What is environment?

- All that is external to the individual human host

- Environment provides the food people eat, the water they drink, the air they breathe, the energy they command, the plague and pests they combat and the mountain, seas, lakes, streams, plants and animals that they enjoy and depend upon

- Physical, biological, social, cultural and other dimensions of the environment commonly interact and influence the health status of individuals and populations

(Definition: Dictionary of Epidemiology, IEA)
Vector

• An **insect or any living carrier** that transports an infectious agent from an infected individual or its wastes to an susceptible individual

• The organism may or may not pass developmental cycle within the vector
Vector Borne Diseases

- Human illnesses caused by parasites, viruses and bacteria that are transmitted by mosquitoes, sandflies, triatomine bugs, blackflies, ticks, tsetse flies, mites, snails and lice
Vector borne diseases

- Mosquitoes
  - *Aedes*: Chikungunya, Dengue fever, Rift Valley fever, Yellow fever, Zika
  - *Anopheles*: Malaria, Lymphatic filariasis
  - *Culex*: Japanese encephalitis, Lymphatic filariasis, West Nile fever

- Sandflies:
  - *Leishmaniasis*, Sandfly fever (pheeplebotomus fever)
Vector borne Diseases…

• Ticks:
  • Crimean-Congo haemorrhagic fever, Lyme disease, Relapsing fever (borreliosis), Rickettsial diseases (spotted fever and Q fever), Tick-borne encephalitis, Tularaemia,

• Fleas:
  • Plague (transmitted by fleas from rats to humans), Rickettsiosis

• Lice:
  • Typhus and louse-borne relapsing fever
Vector Borne Diseases…

- Triatomine bugs:
  - Chagas disease (American trypanosomiasis)

- Tsetse flies:
  - Sleeping sickness (African trypanosomiasis)

- Black flies:
  - Onchocerciasis (river blindness)

- Aquatic snails:
  - Schistosomiasis (bilharziasis)
Burden of VBDs

• Vector-borne diseases account for more than 17% of all infectious diseases, causing more than 7,00,000 deaths annually.
• More than 3.9 billion people in over 128 countries are at risk of contracting dengue, with 96 million cases estimated per year.
• Malaria causes more than 4,00,000 deaths every year globally, most of them children under 5 years of age.
• Other diseases such as Chagas disease, leishmaniasis and schistosomiasis affect hundreds of millions of people worldwide
Malaria Cases and Deaths in India: 1995 - 2014

- Total Malaria Cases (million)
- P. falciparum cases (million)
- Deaths due to malaria

Axis Title

Malaria Cases (in Millions) vs. Deaths
Dengue Cases and Deaths in India: 2010 – 2017*

Number of Cases vs. Deaths

Cases and Deaths:
- Cases: Blue line
- Deaths: Red line

Year:
- 2010
- 2011
- 2012
- 2013
- 2014
- 2015
- 2016
- 2017*

Deaths:
- 0
- 50
- 100
- 150
- 200
- 250

Cases:
- 0
- 20000
- 40000
- 60000
- 80000
- 100000
- 120000
- 140000

*Estimation
Chikungunya Cases in India: 2010 - 2017*

Number of Cases

2010 2011 2012 2013 2014 2015 2016 2017*

0 10000 20000 30000 40000 50000 60000 70000

Cases
Epidemiological Triad

Agent

Viruses
Bacteria
Protozoans
Nematodes

Environment

Temperature, humidity, rainfall

Hosts

Vertebrates – Humans, horses, rodents, birds, & reptiles

“Vectors”

Mosquitoes
Sand fly
Vectorial Capacity

- The potential for a population of mosquitoes to transmit of a vector borne disease like malaria (Vectorial Capacity) is determined by:
  - ratio of mosquitoes : humans
  - mosquito bites /day
  - daily mosquito survival probability
  - parasite extrinsic incubation period
  - vector competence
Life Cycle of Plasmodium

**Cycle in Mosquito**
- Sporozoites (to salivary gland)
- Bursting cyst
- Oocyst
- Mosquito midgut
- Ookinetes
- Zygote
- Macrogamete
- Microgamete

**Cycle in Human**
- Hepatic cell
- Hypnozoite (hepatic dormancy)
- Mature liver schizont
- Merozoites
- Erythrocyte
- Trophozoite
- Erythrocytic schizont
- Ruptured erythrocyte
- Erythrocyte
- Gametocyte
Environmental Factors in VBDs

• Importance of ecological factors in the emergence of VBDs: Early 1935

• “need to have a thorough knowledge of breeding places and habits and to apply the most suitable methods to the situation” – Klinger
Environmental Factors related to VBDs

1. Deforestation
2. Agriculture and animal husbandry
3. Water control projects
4. Urbanization
5. Loss of biodiversity
6. Introduction of alien species
7. Climate change
Deforestation

- Altered vegetation
- Introduction of livestock
- Development of human settlements
- Loss of biodiversity
- Forest related activities: Exposure to vectors of Malaria, Yellow fever, Leishmaniasis
Deforestation

• Creation of ecological niches favourable for vector proliferation

  • Water puddles in deforested land have lower acidity and salinity favourable for breeding of certain species of Anopheles

  • Increased Malaria transmission in deforested areas due to altered biting habits of Anopheles spp: Amazon

• Black fly vectors of Savannah cause severe form than black fly vectors of forest region
Agriculture and Animal husbandry

• Availability of farm animals
  • Additional feeding options leading to growth of vector population and in turn increased frequency of frequent feeding on humans
  • Potential reservoir hosts resulting in wide spread disease
  • Eg: Transmission of JE in SE Asia and western Pacific
Rice fields: Environmental Niche for Japanese Encephalitis
Agricultural and Animal Husbandry

• Changes in land cover effects micro climates
  • Eg: Replacement of swamp vegetation by agricultural land causes raise in temperatures leading to increased risk of Malaria
Water Control Projects

• Dams and Canals: Breeding sites for mosquitoes
  • Eg: Emergence of Plasmodium falciparum malaria in the Thar Desert of India coincided with the construction of irrigation canals
  • Outbreak of schistosomiasis affecting thousands of people occurred after the construction of the Diama Dam on the Senegal River
• Settlers can inadvertently bring infection to the community who might have had little or no immunity
Urbanisation

- Direct effects by conversion of natural habitat into human settlements
- Indirect effects by waste generation
- Expanding cities encroaching upon neighboring environments may increase exposure to some vectors and nonhuman hosts of vector borne diseases. Eg: Yellow fever, trypanosomiasis, and Kyasanur Forest disease
Urbanisation

- Migrants to new areas may lack immunity to the prevalent endemic vector borne diseases
- Migrants may introduce new pathogens and vectors to their resettled locations
- Inadequate clearance of standing water collected in used containers and tires etc, facilitating mosquito vector reproduction. Eg: Dengue, yellow fever
- Eg: Spread of visceral Leishmaniasis from rural to urban areas in Brazil
Loss of Biodiversity

• The threats to biodiversity from human activities include stratospheric ozone depletion; pollution; introduction of invasive species; global warming; and most important, habitat degradation

• Reduction in global biodiversity is likely to contribute to vector borne disease transmission
  • Biodiversity protects against VBDs because of dilution effect
  • Eg: Low incidence of Lyme disease in areas with high biodiversity
Introduction of Alien Species

• Introduction of non indigenous species because of air and sea travel

• Eg: Aedes albopictus in America

• A.albopictus was implicated as a vector of the chikungunya virus on several Indian Ocean islands involved in a 2006 chikungunya fever outbreak
Climatic Factors Influencing VBDs

- Temperature
- Relative Humidity
- Rainfall
El Nino Phenomenon

• The El Nino phenomenon, cycling with a frequency of every 2-7 years
• Strongest driver of weather variability in many regions of the world
• Resulting in drought in some regions of the world and flooding in others
• El Nino- Triggers natural disasters & related outbreaks of infectious diseases (Malaria, Cholera)
Climate Change

• A statistically significant difference noted either in the mean state of the climate or in its variability, persisting for an extended period (decades or longer)
• Natural factors contributing to climate change:

• Glaciation

A schematic of modern thermohaline circulation
• Volcanoes

• Continental drift

• The Earth's Tilt
Anthropogenic factors driving climate change:

- Greenhouse effect
- Land use
- Deforestation
- Livestock
- Aerosols
Direct Climate Change Effects on Disease Vectors

- **Temperature**
  - Changes in distribution boundaries: higher latitudes and altitudes
  - Effects on biology and physiology

- **Global Wind Patterns**
  - Acceleration of pathogen development
  - Completion of cycle at higher latitudes and altitudes

- **Global Precipitation Patterns**
  - Changed migration of certain vectors
  - Changes in length of season that vectors can survive

- **Changes in Relative Humidity**
  - Effect on vector lifespan
  - Effect on the genetic composition of vector populations

Indirect Climate Change Effects on Disease Vectors

**Desertification and Drought**
- Reduction in density of water-related vectors
- When drinking water sources become scarce, more chance of Guinea worm transmission
- Changes in distribution of rodent reservoirs/sandfly, thus affecting black fever

**Other Changes in Vegetation**
- Affects tsetse fly distribution and risk factors
- Affects tick distribution, bacterial and viral tick-borne diseases

**Hydrological Changes**
- Formation of more brackish water lagunae, extending the breeding or brackish water species
- Changes in riverbeds, affecting tsetse fly ecology

**Changed Agricultural Practices**
- A wide range of effects on mosquito-borne and snail-borne diseases
- Changes in irrigation practices, cropping patterns, pesticide application, livestock

## Temperature thresholds (0C) for pathogens and vectors of major vector borne diseases

<table>
<thead>
<tr>
<th>Disease</th>
<th>Pathogen</th>
<th>Minimum Temp</th>
<th>Maximum Temp</th>
<th>Vector</th>
<th>Minimum temp for vector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Malaria</td>
<td><em>Plasmodium falciparum</em></td>
<td>16–19 C</td>
<td>33–39</td>
<td><em>Anopheles</em></td>
<td>8–10 (biological activity)</td>
</tr>
<tr>
<td></td>
<td><em>Plasmodium vivax</em></td>
<td>14.5–15 C</td>
<td>33–39</td>
<td><em>Anopheles</em></td>
<td>8–10 (biological activity)</td>
</tr>
<tr>
<td>Dengue</td>
<td>Dengue virus</td>
<td>11.9</td>
<td>not known</td>
<td><em>Aedes</em></td>
<td>6–10</td>
</tr>
<tr>
<td>Chagas disease</td>
<td><em>Trypanosoma cruzi</em></td>
<td>18</td>
<td>38</td>
<td><em>Triatomine bugs</em></td>
<td>2–6 (survival) 20 (biological activity)</td>
</tr>
<tr>
<td>Schistosomiasis</td>
<td>Cercaria</td>
<td>14.2</td>
<td>&gt;37</td>
<td><em>Snails (Bulinus and others)</em></td>
<td>5 (biological activity) 25±2 (optimum range)</td>
</tr>
<tr>
<td>Lyme disease</td>
<td><em>Borrelia burgdorferi</em></td>
<td>Not yet determined</td>
<td>Not yet determined</td>
<td><em>Ixodes ticks</em></td>
<td>5–8</td>
</tr>
</tbody>
</table>

IPCC, 2001
Climate Change and VBDs

- For many diseases minimum temperatures lie in the range 14–18°C at the lower end and 35–40°C at the upper end.

- Warming in the lower range has a significant and non-linear impact on the extrinsic incubation period and consequently disease transmission, while, at the upper end, transmission could cease.

- At around 30–32°C, vectorial capacity can increase owing to a reduction in the extrinsic incubation period, despite a reduction in the vector’s survival rate.
Climate change and VBDs

• Increased precipitation has the potential to increase the number and quality of breeding sites for vectors such as mosquitoes, ticks and snails, and the density of vegetation, affecting the availability of resting sites

• Small change in larval diet leads to 45-fold difference in transmission potential
Effect of temperature and rainfall on mosquito population and *Plasmodium* species dynamics. (A) The mean number of mosquitoes per unit area as a function of temperature and rainfall. (B) Estimated doubling times of *P. falciparum* and *P. vivax*; high and low refer to vector density values.
EFFECT OF CLIMATE CHANGE ON VBDS IN INDIA

Source: Climate Change and Vector Borne Diseases: Dr. R C Dhiman, NIMR
Distinct Physiography and malaria endemicity in District Nainital

API in 2007: Hills- 0 ; Bhabhar- 0.43 ; Tarai- 0.41

Cases reported from Hilly area also
Chikungunya in India

a Circles indicate old foci of chikungunya (till 1973) b. Filled circles indicate new foci of chikungunya (2005 onwards); figures indicate number of districts affected.
Re-emergence of kala-azar in India

Circles indicate old foci of kala-azar; filled squares indicate kala-azar cases that occurred till 1982; squares indicate re-emergence of cases; rhombus indicate new foci of kala-azar after 1982

Dhiman et al 2010
Evolution of Approaches for Control of VBDs

• Late 19th and early to mid 20th centuries: Focus was on explaining the natural history, taxonomy, biology, and distribution of organisms and using this knowledge for control of measures

• 1960s: Emergence of Ecology based Vector control measures as use of DDT has been questioned
  • Ecology was equated to research and policy that deals with natural environment and protection
Control of VBDs

• Growing shift in ecological research towards concern with not only the degradation of the natural environment but an acceptance and recognition by a growing number of ecological scientists and researchers who focus on the “human-built” environment of our inseparable role as part of all ecosystems

• 1990s: Ecosystem Approach
<table>
<thead>
<tr>
<th>Type</th>
<th>Intervention</th>
<th>Targets</th>
<th>Products</th>
</tr>
</thead>
<tbody>
<tr>
<td>Community education</td>
<td>behavioral change, application of all other interventions</td>
<td>all vectors</td>
<td></td>
</tr>
<tr>
<td>Environmental management</td>
<td>natural environment changes</td>
<td>mosquitoes, blackflies, snails, etc.</td>
<td>polystyrene beads in standing water bodies</td>
</tr>
<tr>
<td>and sanitation</td>
<td>improved housing quality</td>
<td>vectors of Chagas disease, malaria, dengue</td>
<td></td>
</tr>
<tr>
<td></td>
<td>physical barriers to breeding sites</td>
<td>vectors of filariasis, trachoma</td>
<td></td>
</tr>
<tr>
<td>Biological control</td>
<td>larvivorous fishes</td>
<td>mosquitoes</td>
<td>microbial larvicides, organophosphates, neem extracts and other herbal insecticides</td>
</tr>
<tr>
<td></td>
<td>predators and competitors</td>
<td>snails</td>
<td></td>
</tr>
<tr>
<td></td>
<td>larviciding</td>
<td>urban mosquitoes, blackflies</td>
<td></td>
</tr>
<tr>
<td>Chemical control</td>
<td>space spraying</td>
<td>urban mosquitoes</td>
<td>pyrethroids, organophosphates</td>
</tr>
<tr>
<td></td>
<td>indoor residual spraying</td>
<td>vectors of malaria, lymphatic filariasis, leishmaniasis</td>
<td>pyrethroids, organophosphates, carbamates, DDT (malaria only)</td>
</tr>
<tr>
<td></td>
<td>insecticide-treated materials</td>
<td>vectors of malaria, leishmaniasis, lymphatic filariasis, trypanosomiasis</td>
<td>pyrethroids</td>
</tr>
<tr>
<td></td>
<td>household products</td>
<td>mosquitoes, flies, fleas</td>
<td>aerosols, coils, mats, repellents, natural products, etc.</td>
</tr>
</tbody>
</table>
Figure 2: Trends Parasitol. 2014 Aug; 30(8): 394–400.
Thank you!