# Malaria and Colonial Development Projects in India, 1927–1935

By

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I acknowledge and respect the ləkʷəŋən peoples on whose traditional territory the university stands and the Songhees, Esquimalt and W̱SÁNEĆ peoples whose historical relationships with the land continue to this day.

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# Abstract

The 1920s and 1930s were a period of rapid urban growth and intensive changes to rural Indian geography through the construction of irrigation project to increase agricultural output. The work of several key researchers at this time demonstrated that these projects could lead to an increase in malaria prevalence. However, this period was also the site of a complicated entanglement of environmentalist and bacteriological thinking, which sometimes resulted in a disconnect between the research and the fieldwork that impacted the quality of research and the message malaria researchers were trying to send to the British administration in India.

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# Acknowledgements

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# Introduction

Bombay (renamed Mumbai since November 1995) was a crucial economic and military site for the British throughout their colonial presence in India, from the late seventeenth century until Indian Independence in 1947. Between 1710 and 1728 the British joint stock East India Company undertook construction to drain periodically flooded tidal flats and connect the islands of Bombay (see figure one below).[1] Consolidating its presence on a unified island of Bombay enabled stronger military defences and the growth of the city's urban centre for economic benefit.[2] Letters in the Indian Office Records from London to the Bombay Council (at the time comprised of British administrative officials in India) insisted on land reclamation at this time not only for military benefit but to "render the island more healthful."[3] Margaret Hunt and Philip Stern argue land reclamation between the tidal islands was viewed within the British colonial administration as a part of an emerging public health policy in India during British colonization. Throughout the British colonial presence in India, public health policy remained intertwined with development undertaken for British economic benefit.[4]

[1] Frequently cited as originally being seven islands, the number varied depending on the tide and different numbers were accepted by Europeans. The first European colonizers of Bombay, the Portuguese, accepted there were four separate islands in the sixteenth century whereas the English argued there were two islands. Tim Riding, "Making Bombay Island': land reclamation and geographical conceptions of Bombay," *Journal of Historical Geography* 59 (2018): 36.
[2] Margaret R. Hunt and Philip J. Stern "Bombay: the genealogy of a global imperial city," *Urban History* 48 (2021): 477.
[3] IOR E/3/99, fol. 112, London to Bombay, 29 Mar. 1717 in Hunt and Stern "Bombay: the genealogy of a global imperial city," 476.
[4] India will be used as shorthand in this thesis to refer to the lands and peoples of what was referred to as India by the British during occupation by British colonizers. These lands and peoples include present-day India, Pakistan, Myanmar, and Bangladesh. The term present-day will be used to refer to the modern geographic boundaries of these nations. See Figure 2 below for the geography of India during British colonization. This is not meant to denote any homogeneity in the peoples, cultures, religions, or languages of India as it was and is a highly diverse sub-continent and treating it as a cohesive whole is inaccurate.

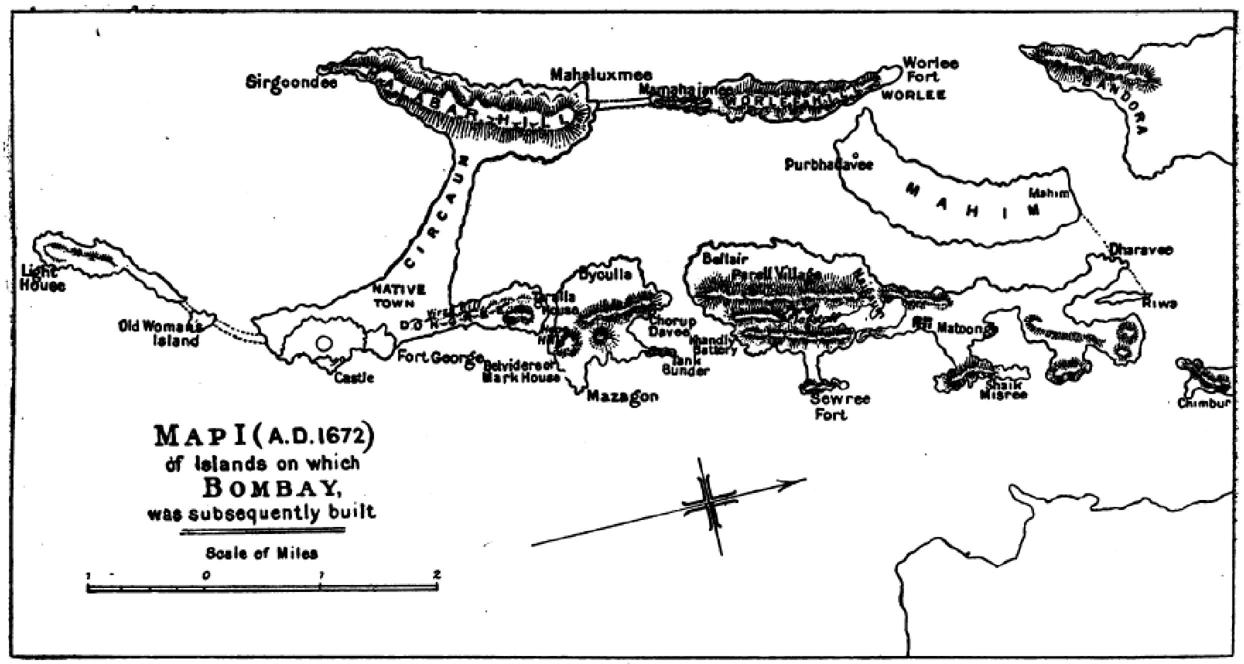


*Figure 1. A map of the original topography of the islands of Bombay (referred to as Colaba, Bombay Island, Malabar Hill, Girgaum and Dongree by European colonizers).*[5]

India first came under British rule in the eighteenth century as a direct result of the East India Company's domineering trading practices in the seventeenth century. The Battle of Plassey in 1757 marked the onset of official East India Company rule in India. From 1858 onwards, following the First Indian War of Independence in 1857, the British Crown formally assumed direct rule (see figure two below for a map of India under British colonial rule). Indian Independence was finally won in 1947 which resulted in creation of the present-day countries India, Pakistan, and Bangladesh.[6]

[5] "The Sanitary Difficulties of Bombay," *The British Medical Journal* April 9, 1898.
[6] Philip Lawson, *The East India Company: A History* (New York: Longman, 1993), 145,


*Figure 2. Map of the "Indian Empire" in 1909 from the Imperial Gazetteer of India. Red= British India, Pink= territories permanently administered by the Government of India, Yellow= Native states and territories.* [7]

In the summer of 1896 bubonic plague arrived in India via Hong Kong, its spread being exacerbated by the development of railway systems within Asia.[8] Bubonic plague is caused by the *Yersinia pestis* bacterium and spread by a flea vector through small mammals, commonly

[7] Edinburgh Geographical Institute; J. G. Bartholomew and Sons, Oxford University Press, 1909. https://commons.wikimedia.org/wiki/File:British_Indian_Empire_1909_Imperial_Gazetteer_of_India.jpg
[8] Anil Kumar, *Medicine and the Raj: British Medical Policy in India 1835–1911* (Walnut Creek, California: AltaMira Press, 1998), 191. David Arnold, *Colonizing the Body: State Medicine and Epidemic Disease in Nineteenth-Century India* (California: University of California Press, 1993), 203.

rats.[9] India was the most severely impacted country in the world, suffering an estimated ninety-five percent of global deaths during the pandemic.[10] The British administration recognized that implementing effective public health policies was essential to prevent large numbers of lower class and caste workers, critical to Bombay's functioning, from either dying or refusing to work in resistance of those policies.[11] Bombay was of central economic importance to the British in India due to the value of its ports for importing and exporting goods. In 1897 "bheesties, sweepers, carters and coolies," low caste roles that provided essential labour for cleaning the city, organized a strike in protest of forced segregation and inoculation in Calcutta (renamed Kolkata in 2001) in the northeast presidency of Bengal.[12] Gyan Prakash argues the British colonial administration's increased focus on public health at this time was part of a shift in colonial urban policy. That shift was from a focus on using infrastructure development for economic growth to a realization that improving the urban population's health would increase productivity for British financial gain.[13]

The public health policies enacted by the British administration against the plague were influenced by a complex blend of bacteriological and environmentalist frameworks. This set the stage for not just the overlap, but the entanglement of miasma and germ theory and the clear expression of both in public health measures undertaken in India to control diseases. Prashant

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[9] L. Fabian Hirst, *The Conquest of Plague: A Study of the Evolution of Epidemiology* (Oxford: The Clarendon Press, 1953), 107 and 118-119.
[10] Ira Klein, "Plague, Policy and Popular Unrest in British India," *Modern Asian Studies* 22, no. 4 (1988): 725.
[11] Chopra, *Joint Enterprise: Indian Elites and the Making of British Bombay* (Minnesota: University of Minnesota Press, 2011), 26.
[12] "The Quarter," *The Calcutta Review* 107 no. 213 (1898): 197. *The Calcutta Review* was based in India but written by and for the British perspective in India. Following resistance to British public health measures during the plague pandemic, another wave of resistance that ultimately won Indian Independence from Britain in 1947 was led by Mahatma Gandhi, who first assumed leadership of the Indian National Congress in 1921. Like the strikes decades earlier during the plague pandemic, Gandhi's resistance was characterized by non-violent actions and civil disobedience.
[13] Gyan Prakash, *Mumbai Fables* (Princeton and Oxford: Princeton University Press, 2010), 69–70.

Kidambi argues “localist” ideas that connected a disease with its environment strongly influenced public health policies during the plague.[14] Even after breakthroughs in germ theory, environmentalist thinking continued to influence policies and actions of the British administration to control diseases. Scientific breakthroughs by Louis Pasteur on microorganisms in 1859 and by Robert Koch in discovering the bacteria that caused anthrax in 1876 provided the foundation for bacteriological research on malaria. Malaria was the disease of greatest concern to the British administration in India as it had significant negative impact on the economy due to reduction in Indians labouring for the British through debility and death.

Infection with malaria in humans causes a wide range of symptoms including fever and chills (the characteristic symptoms), damage to the kidneys, spleen, muscles, liver, lungs and brain as well as increased instance of miscarriage.[15] Five species of malaria protozoa can infect humans: *Plasmodium falciparum, Plasmodium vivax*, *Plasmodium malariae*, *Plasmodium knowlesi,* and *Plasmodium ovale.* The presentation of symptoms varies according to species and *Plasmodium falciparum* is the deadliest.[16] When a blood meal is taken from humans by a female mosquito of the *Anopheles* genus, malaria is transferred to the human host through the mosquito’s saliva.[17]

The mechanism of transmission through the mosquito vector was not discovered until the late eighteenth century through the individual yet cumulative efforts of several European

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[14] Prashant Kidambi, “An infection of locality’: plague, pythogenesis and the poor in Bombay, c. 1896–1905,” *Urban History* 31, no. 2 (2004): 250–251.
[15] Juliana Carvalho Tavares, *Malaria,* ed. D. Neil Granger & Joey Granger *Colloquium series on integrated systems Physiology: from molecule to function to disease* (EBOOK: Morgan & Claypool, 2013), 6.
[16] Elemaran Meibalan and Matthias Marti, “Biology of Malaria Transmission,” *Malaria: Biology in the Era of Eradication* eds. Dyann F. Wirth and Pedro L. Alonso (Cold Spring Harbor, New York: Cold Spring Harbor Laboratory Press, 2017), 28; Greene and Danubio, “Introduction” *Adaptation to Malaria*, 1.
[17] Javier E. Garcia, Alvaro Puentes, and Manuel E. Patarroyo, “Developmental Biology of Sporozoite-Host Interactions in *Plasmodium falciparum* Malaria: Implications for Vaccine Design,” *Clinical Microbiology Reviews* 19, no. 4 (2006): 687; Yannis Michalakis and François Renaud, “Malaria: Evolution in Vector Control,” *Nature* 469, no. 19 (2009): 298.

researchers. French physician Alphonse Laveran first pigmented particles in blood samples of malaria infected humans in 1878. By 1880, Laveran had confirmed that a commonality among malaria sufferers was the presence of a living organism in their blood.[18] British researcher Ronald Ross was the first to publish in 1887 that *Anopheles* mosquitoes transmitted malaria to humans. Later, Ross also demonstrated in 1897 malaria protozoa in the digestive tracts of *Anopheles* mosquitoes and in 1898 the transmission of malaria in birds by *Anopheles* mosquitoes. The discovery that mosquitoes transmit malaria between humans was finally made by Italian researcher Giovanni Grassi in 1898.[19] Grassi discovered another crucial element in vector-based transmission when he identified a specific species of mosquito which transmitted malaria to humans in 1899.[20] Together, these discoveries provided a critical foundation for subsequent malaria research.

Prior to key discoveries that developed bacteriology, miasmatic theory was the dominant way of thinking about disease among European researchers. Miasmatic theory is the belief that miasma (foul air) produced by stagnant water, swamps, or decomposing organic material subsequently causes disease. For example, an 1898 article in *The British Medical Journal* criticizes the infill of the Bombay tidal flats and the subsequent improper drainage of water from the city for having “aggravated the dampness and foulness of subsoil, which poisons the inhabitants at the present day.”[21] Through this framework, disease was believed to be only found

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[18] Snowden, *The Conquest of Malaria: Italy, 1900–1962* (E-book ed. 2019. Yale University Press, 2006), 35–36.
[19] Ronald Ross, “Peculiar Pigmented Cells Found in Two Mosquitoes Fed on Malarial Blood,” *Indian Medical Gazette* 32, no. 9 (1897): 357–358; Ronald Ross, “On some Peculiar Pigmented Cells Found in Two Mosquitos Fed on Malarial Blood,” *British Medical Journal* 18, no. 2 (1897): 1786–1788; David Arnold, “India's place in the Tropical World, 1770–1930,” The Journal of Imperial and Commonwealth History, 26, no. 1 (1998): 1; Randall M. Packard, *Making of a Tropical Disease* (Baltimore, United States of America: The Johns Hopkins University Press, 2007), 115; Mark Harrison, *Public Health in British India: Anglo-Indian preventive medicine 1859-1914* (Cambridge: Cambridge University Press, 1994), 158; Robert E. Sinden, “Malaria, mosquitoes and the legacy of Ronald Ross,” *Bulletin of the World Health Organization* 85, no. 11 (2007): 894–896.
[20] Ferroni, Eliana, Tom Jefferson, and Gabriel Gachelin, “Angelo Celli and research on the prevention of malaria in Italy a century ago,” *Journal of the Royal Society of Medicine*, 105, no. 1 (2012): 36.
[21] “The Sanitary Difficulties of Bombay,” *The British Medical Journal* April 9, 1898.

in specific locations that suffered from foul air and was not thought to be contagious between humans or transmissible to different areas.[22] There was a resurgence in this way of thinking in the nineteenth century based on work from the early eighteenth century which itself had drawn on the older miasmatic theory. Later, in the 1920s and 1930s, environmentalism was entangled with bacteriological and vector-based thinking and a mixture of both frameworks motivated researchers and government administrators.

The British administration in India first established a formal medical presence in 1763 by founding the Bengal Medical Service. By 1775, each of the Indian presidencies had at least one hospital providing Western medicine to both Indians and the British. The Indian Medical Service (IMS) did not emerge until 1858 when it separated from the Indian Civil Service into two distinct establishments. By then, the British had had a medical presence in India in some form since surgeons came with an East India Company ship in 1600.[23] The IMS was closely tied to the publication *The Indian Medical Gazette*, a source used within this thesis. Alison Moulds argues that since its inaugural issue in 1866, *The Indian Medical Gazette* was implicitly viewed by medical practitioners in India as essentially a government publication.[24] A crucial turning point for Indian participation in formal public health structures enacted by British colonialists occurred in 1905, when Secretary of State Morley limited the number of IMS places for Europeans. As a result, the number of Indians in the IMS rose from just 5% in 1905 to 25% by 1914. Despite the long history of the presence of British physicians and surgeons in India, Mark Harrison argues that members of the IMS were held in poor regard by other members of the British

[22] Harrison, *Public Health in British India*, 57
[23] Harrison, *Public Health in British India*, 7.
[24] Alison Moulds, *Medical Identities and Print Culture, 1830s–1910s* (EBOOK: Palgrave Macmillan, 2021), 219–220.

administration in India, due in part to the lower-class status of many of its members.[25] While the number of Indians in the IMS was growing, its ranks were still dominated by British researchers, schooled in ways of Western European thinking and of practising medicine.

A key turning point in malaria research was a field experiment undertaken at the military cantonment (established military camp) of Mian Mir located in northern India. Nida Rehman argues British malaria research and eradication attempts evolved in “antagonistic terms” within government reports, proceedings of medical conferences, and scientific journal articles over the twenty-five years following the failed experiment at Mian Mir, which concluded in 1909.[26] These antagonistic terms are characterized by frequent differences in opinion amongst researchers and between researchers and the British administration. The eradication techniques applied were drawn from the research of Ronald Ross and emphasized the general destruction of mosquito larvae and modifying the landscape to make it uninhabitable for mosquitoes. Mian Mir became synonymous with the failures of environmentalist approaches to malaria eradication as after nearly a decade of work there was no improvement in infection levels.[27] An article in the Indian Medical Gazette published in July 1904 said early Mian Mir experiment results “well illustrate the difficulties that lie before us in this branch of hygiene.”[28] Rehman notes Mian Mir is often seen in the historiography as a turning point in malaria policy away from modifying the environment to *control* mosquito vectors to administering the drug quinine to *treat* the disease in individuals.[29] However, viewing this moment as a turning point in this way ignores subtleties of

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[25] Harrison, *Public Health in British India*, 34–35.
[26] Nida Rehman, “Epidemiological landscapes: the spaces and politics of mosquito control in Lahore,” (PhD Dissertation, University of Cambridge, 2020), 16.
[27] William F. Bynum, “An Experiment That Failed,” *Parassitologia* 36 (1994): 110–112.
[28] “The Antimalarial Operations at Mian Mir,” *the Indian Medical Gazette*, July 1904, 261.
[29] Nida Rehman, “Unsettling a sanitary enclave: malaria at Mian Mir (1849–1910),” *Planning Perspectives* (2021): 3.

the ongoing entanglement of and slow transition from environmentalist to bacteriological thinking.

The complex relationship between researchers and British colonial administrators lies at the heart of my thesis and through this relationship seeks to nuance the complexities of colonialism in India. This thesis argues that environmentalist and bacteriological theories were still inextricably intertwined into the 1930s, and that this entanglement and inconsistency hindered efforts to control malaria during a period of rapid urban growth and intensive changes to rural Indian geography. The entanglement of these ideas and the related failures in malaria control are demonstrated by connections between the disease and development projects. This transition was both gradual and inconsistent among administrators and researchers. Acceptance of germ theory was slow in India and malaria eradication efforts often still relied on environmentalist solutions while the research increasingly incorporated bacteriological thinking. Development initiatives examined include the urbanization of Bombay, which was initially enabled by the infill of tidal flats between islands and the construction of dams to feed irrigation canals that resulted in increases in malaria prevalence.

The first chapter examines the historiography of malaria research and the frameworks of environmentalism and bacteriological thinking in the 1920s and 1930s. Nida Rehman's work commences a more recent historiography of malaria as it relates to public health and to geography and development more broadly. This thesis also builds on the work of Sheldon Watts which examines the research and attitudes of senior British malariologists and criticizes British attempts to downplay the impact irrigation projects had on malaria prevalence in India. Further, I build on Watts' argument that the 1880s to 1930s were the transitional years between environmental and bacteriological thinking and examine the later part of this period.[30] This thesis complicates and nuances existing scholarship by investigating how British researchers were not always disinterested themselves but were instead ignored by the British administration.

The second chapter examines the thinking of malaria researchers in an urban context. Examining malaria activities in Bombay in 1928 demonstrates how malaria research and eradication were approached in an urban environment. It also shows the lasting negative impacts of the first action the British took in changing the Indian landscape for their benefit when the Bombay tidal flats were infilled in the early seventeenth century. The research of Charles A. Bentley, a medical officer in the British Administration, and Gordon Covell, a prominent figure in British malaria research in the IMS, is used to demonstrate the entanglement of environmentalist and bacteriological thinking.

The third chapter explores malaria research in a rural context through the Sukkur Barrage project. The barrage (a type of dam with many gates to control outflow), spanning the width of the Indus, is situated at Sukkur in the province of Sind and feeds the Dadu, Rohri, Jamrao, and Nara perennial canals.[31] The barrage is a case study into the British administration's wilful ignorance towards the established connection between flooding caused by irrigation projects and increased malaria prevalence. Water development projects in the late nineteenth and early twentieth centuries in India had unintended negative economic and health effects arising from problems such as waterlogging (rising water table levels that negatively impact crops), which could increase the prevalence of malaria in an area post-construction. Further, the barrage project

[30] See Sheldon Watts, "British Development Policies and Malaria in India 1897-c. 1929," *Past & Present* 165 (1999): 141–181 and Watts, *Epidemics and History*.
[31] Gilmartin, *Blood and Water*, Map 7 and 183.

illustrates the ongoing entanglement between environmentalist and bacteriological thinking in the British administrators overseeing the project and researchers investigating malaria in Sind.

# Chapter One

## Historical Context and Historiography

A prominent theme in the historiography of malaria research and eradication methods in early twentieth century India is the relationship between bacteriological and environmentalist thinking. Discussions among historians centre on how quickly and when the transition from environmentalist to bacteriological understandings of disease happened among British administrators and researchers. The failed experiment at Mian Mir is seen by many historians to be a pivotal moment in the transition between environmentalist and bacteriological thinking within malaria research and eradication attempts in India. Mian Mir was a military cantonment that was chosen by the Royal Society's Malaria Committee as a site to study malaria eradication techniques.[32]

The notoriety of Mian Mir as highly malarious was so pervasive among British army troops that the name was changed to Lahore to reduce negative sentiments about postings to the cantonment.[33] Eradication efforts at Mian Mir relied heavily on vector control efforts to destroy larvae by applying oil to surface water to suffocate larva and by reducing overall surface water by improving drainage. These techniques were influenced by environmentalist theories of disease. In a letter to the editor of *The Indian Medical Gazette*, prominent British malariologist Samuel Rickards Christophers argues that not only were the efforts at Mian Mir unsuccessful in eradicating malaria but also showed antilarval operations were exorbitantly expensive. Further, in the last year of the experiment, Christophers wrote that Mian Mir was "visited by an epidemic

[32] William F. Bynum, "An Experiment That Failed," *Parassitologia* 36 (1994): 109.
[33] The word "malariology" was popularized in 1915 by the Naples, Italy-based journal *La Malariologia* and editor Ernesto Cacace, see H.E. Shortt and P.C.C. Garnham, "Samuel Rickard Christophers. 27 November 1873-19 February 1978," *Biographical Memoirs of Fellows of the Royal Society* 25 (1979): 186.

of the disease probably more severe than any previously experienced."[34] The failure at Mian Mir as British administrators poured money into the experiment subsequently made researchers wary of proposing antimalaria tactics that involved antilarval operations or surface water drainage.

In the Western European intellectual tradition, the connection between symptoms of malaria and wet, swampy land has been recognized for thousands of years. For example, the connection between enlarged spleens (a common symptom of malaria) and marshy areas with foul air is mentioned as early as the text *De aere, aquis et locis* (*Airs, Waters and Places*) from the Hippocratic Corpus written around the fourth or fifth century BCE.[35] In the Middle Ages, the term *mal'aria* referred to intermittent fevers caused by foul air. It was not until the nineteenth century that the word malaria increasingly referred to the *disease* of intermittent or seasonal fevers, rather than the foul air which caused them.[36] A resurgence of environmentalist thinking in early modern Europe can be traced to the work of the French polymath Montesquieu.

In the 1735 version of his work *Pensées*, Montesquieu included climate as one of the five key attributes of "l'esprit Générale," the ethos he argues governs all men (humanity) and states (nations).[37] Further, Montesquieu's work *De l'esprit des lois*, first published in 1748, solidifies his belief that climate impacts a population's general disposition, with heat associated with lethargy and temperate zones associated with vigour.[38] Shackleton argues it was Hippocrates'

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[34] S. R. Christophers and S. P. James, "Malaria in India: What can the State do to Prevent It?" *The Indian Medical Gazette* (July 1909), 273.
[35] François Retief and Louise Cilliers, "Malaria in Graeco-Roman Times," *Acta Classica* 47 (2004): 131.
[36] Russell, *Man's Mastery of Malari*a (London: Oxford University Press, 1955), 18.
[37] "Les hommes sont gouvernés par cinq choses différentes : le climat, les manières, les moeurs, la religion et les lois." (Men are governed by five different attributes: climate, manners, mores, religion and laws). Robert Shackleton, "The Evolution of Montesquieu's Theory of Climate," *Revue Internationale de Philosophie* 9, no. 33/34 (1955): 321.
[38] Arnold, Colonizing the Body, 29.

work that influenced Montesquieu in writing that climate influenced different characteristics between people in northern and southern climates.[39]

Environmentalism was associated with the concepts of climatic determinism and the tropics. Climatic determinism is the belief climate strongly influences the physical composition and external appearance of humans within a specific climate zone. Also bound up in the definition of climatic determinism was the idea that people were naturally suited to the environment in which they lived. In India, this meant Europeans believed Indians had an innate tolerance to heat and natural resistance to diseases such as cholera and malaria. In the eighteenth and early nineteenth century, Europeans believed that acclimatization, then known as "seasoning," through time spent in India would also confer adaptation to the heat and resistance to diseases.[40] As Rituparna Ray Chowdhury notes, the legacy of climatic determinism was "a never-ending illusion about India's climate and its people."[41] The illusion Chowdhury is referring to is the connection between the hot and humid tropics (India) with laziness and femininity and between temperate areas (Britain) with robustness and manliness, qualities highly valued by European men. Thus, this illusion rendered Indians inhabiting tropical areas inferior and as a result incapable of achieving a higher level of civilization without help from the British. The underlying ideas within climatic determinism are linked with the formation of the idea of the "tropics" as demarcated by a set of moral, cultural, geographical, and environmental boundaries.[42] The tropics not only referred to a specific set of climate conditions (hot and humid)

[39] Shackleton, "The Evolution of Montesquieu's Theory of Climate," 325.
[40] Harrison, *Climates and Constitutions*, 88.
[41] Chowdhury, "Climatic Determinism and the Conceptualization of the Tropics in British India."
[42] Harrison, *Climates and Constitutions*, 13.

but contained within the term an inherent inferiority compared to temperate regions such as Europe.[43]

An earlier work that is characteristic of scholarship which viewed the impact of British colonialism on scientific progress favourably is George Basalla's 1967 article "The Spread of Western Science."[44] Basalla's article models the diffusion of Western science from Europe into European colonies via the movement of scientists who brought their ways of thinking from the colony to the metropole. Basalla concedes that some colonies, such as India, had "ancient, indigenous scientific thought" that could be built on by Western science. However, Western science is always seen from a teleological perspective in which the ultimate goal is the adoption of Western (European) ways of thinking.[45] Warwick Anderson argues Basalla's work was part of an older perspective that venerated Western European scientists and their work with the modern Western scientific method.[46] While I do not draw on any of Basalla's ideas, "The Spread of Western Science" is still a useful starting point and summary of older ideas to contextualize the concepts the next generation of postcolonial scholars were engaging with in the 1980s and 1990s.

The general themes of this postcolonial scholarship relevant to medical history can be characterized through the work of Mark Harrison and David Arnold.[47] Anderson characterizes postcolonial historians in the 1990s as working to situate science within sociocultural and

[43] Rituparna Ray Chowdhury, "Climatic Determinism and the Conceptualization of the Tropics in British India," *Oxford Research Encyclopedia of Climate Science* (Published online October 2021), Retrieved June 2022, https://doi.org/10.1093/acrefore/9780190228620.013.836.
[44] George Basalla, "The Spread of Western Science," *Science* 156, no. 3775 (1967): 611–622.
[45] Basalla, "The Spread of Western Science," 611–612.
[46] Warwick Anderson, "Remembering the Spread of Western Science," *Historical Records of Australian Science* (2018): A.
[47] Charles Webster and Charles Rosenberg state in the introduction to Harrison's book "After years of neglect the last decade has witnessed a surge of interest in the medical history of India under colonial rule. This is the first major study of preventive medicine in British India." Harrison, *Public Health in British India*, front matter.

political contexts, acknowledge the interplay between colonial and Indigenous thought, and pay equal attention to colonial and Indigenous perspectives.[48] The postcolonial work of Harrison and Arnold moves beyond Basalla's work to investigate not only science but also medicine and public health and their relationship with Indian society, culture, and ways of thinking.[49] Harrison's work examines the ideas and language which underlay British colonial attitudes in medicine and specifically the impact of climatic determinism. Arnold argues in his seminal text in the field of colonial medicine, *Colonizing the Body*, that the consistent importance placed upon local Indian conditions by British physicians, who also emphasized practical experience in the field, was a critical component of the emergence of "colonial medical science."[50]

Watt's 1999 article "British Development Policies and Malaria in India 1897-c. 1929" makes an uncompromising argument for the overall British condescension and ignorance of other peoples' suffering and even the British administration's outright dismissal of scientific evidence that hydrological dams were contributing to increased malaria prevalence in India. As Watts writes of the period when the Mian Mir experiment began:

> Given the size of investment returns from new irrigation projects sent to England each year, it is not surprising that the government and investors did not want to know (or be reminded) that *uncorrupted* modern scientists could conclusively prove that poorly constructed, inadequately drained irrigation systems of the sort proliferating in the Punjab and elsewhere were contributing heavily to India's growing problem with malaria.[51]

Watts' work markedly differs from earlier approaches that looked favourably on British colonizers "civilizing" colonies through the introduction of Western European science and technology. Economic historians writing contemporaneously to Watts also examined the

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[48] Warwick Anderson, "Decolonizing Histories in Theory and Practice," "Forum: Decolonizing Histories in Theory and Practice," *History and Theory* 59 no. 3 (2020): 372–373
[49] See Mark Harrison, *Climates & Constitutions: Health, Race, Environment and British Imperialism in India 1600–1850* (Oxford: Oxford University Press, 1999).
[50] Arnold, *Colonizing the Body*, 19.
[51] Watts, "British Development Policies," 160.

negative impact of water development projects in India but as Watts critiques, they did not go far enough and emphatically argues that disinterest by the British administration towards the lives and health of Indian people caused irreparable harm.

Some examples of the scholarship that Watts critiques includes Elizabeth Whitcombe, who Watts argues fails to fully explore the consequences of water development projects in India.[52] Whitcombe argues that when the land's natural conditions did not permit successful irrigation, the consequences were "waterlogging, salinity and malaria."[53] Whitcombe also examined the impacts of the Sukkur Barrage, discussed in Chapter Three, on the Indus river, which aimed to improve agricultural output from 2,317,000 to 5,900,000 acres of cultivation, and discovered that waterlogging increased in the area after the project was completed. The waterlogging increased "atmospheric humidity" which Whitcombe argues was *the* critical environmental factor that influenced malaria transmission in India.[54] However, as Watts argues Whitcombe's work is flawed due to a simplistic understanding taking the early twentieth century British research on connections between malaria and development projects "at face value" instead of examining more critically.[55]

David Gilmartin argues irrigation projects in the Indus Basin were the strongest expression of an "ethos of domination over nature" that drove the British to irrevocably alter the Indian landscape in the name of irrigation.[56] Gilmartin's work *Blood and Water: The Indus River Basin in Modern History* examines how the British administration in India exerted control

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[52] Watts, "British Development Policies," 141.
[53] Whitcombe, "The Environmental Costs," 239–240.
[54] Whitcombe, "The Environmental Costs," 249 and 257.
[55] Watts, "British Development Policies," 167.
[56] David Gilmartin, "Models of the Hydraulic Environment: Colonial Irrigation, State Power and Community in the Indus Basin," in *Nature, Culture, Imperialism: Essays of the Environmental History of South Asia*, eds. David Arnold and Ramachandra Guha (Delhi: Oxford University Press, 1996), 210-211.

through large-scale water development projects.[57] However, Gilmartin's work also does not address the relationship between such projects and malaria directly. The absence of malaria within the historiography of British colonial development was recognized by Watts who argues the "full implications of development projects and malaria are ignored." Works Watts critiques for insufficiently considering the implications of development projects on malaria include Whitcombe's research on irrigation projects as well as Arnold's and Harrison's work on colonial medicine and public health in India.[58]

Watts also mentions the importance of medical and engineering schools in influencing how British engineers and malariologists approached malaria control and research in India; Deborah Neill's 2012 book *Networks in Tropical Medicine Internationalism, Colonialism, and the Rise of a Medical Specialty, 1890–1930* explores this area in depth. Neill uses a sociocultural approach to examine the human connections and networks that were built as the concept of tropical medicine emerged alongside European colonialism. David Arnold's 2000 book *Science, Technology and Medicine in Colonial India* uses an approach that is rooted in the history of science and technology.

By the late 1890s Britain had begun to take a more active role in colonial networks of Western scientific medicine. As a result, the country was the site of the first schools which later became integral hubs in the global network of tropical medicine.[59] The Liverpool and London Schools of Tropical Medicine were founded in 1898 and 1899, respectively.[60] These schools served the colonizing mission of Britain by training doctors who contributed to the health of both

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[57] David Gilmartin, *Blood and Water: The Indus River Basin in Modern History* (Oakland, California: University of California Press, 2015).
[58] Watts, "British Development Policies," 141–142.
[59] Neill, *Networks in Tropical Medicine*, 14 and 20.
[60] Harrison, *Climates & Constitutions*, 208.

the European colonizers and the native workforce within the colony. Other countries soon followed Britain's lead: France established the Institute for Colonial Medicine in Paris in 1902. A Belgian school of tropical medicine was established in 1906 and was formally named the Brussels School of Tropical Medicine in 1910. Belgium and France were following the precedent set by Britain that a dedicated school of tropical medicine would benefit a colonizing mission.

A Portuguese physician and politician named Miguel Bombarda argued his country needed to develop a school of tropical medicine to raise Portugal's level of colonial power relative to England, Germany, and France as these countries invested heavily in schools of tropical medicine. As a result, The Lisbon School of Tropical Medicine was founded in 1902. Many of these institutions also began to publish their own scientific journals which fostered discussion and collaboration among scientists working in different laboratories across the world.[61] Such schools were dedicated to researching and treating tropical diseases but were located within Europe and not within European colonies. And critically, as Watts argues, physicians are heavily influenced by what they learn in school and tend to espouse the same techniques and ideas they learned there, even decades later and thousands of miles away.[62]

Pratik Chakrabarti argues that this geographic separation of scientific and medical knowledge being produced in Europe and exported to colonies was not clearly defined for Britain and India. For example, British researcher S. R. Christophers, who was well-liked by the British administration, founded the Central Malaria Bureau within the Medical Research Department of the Government of India to conduct and analyse research in India. The British administration also constructed buildings dedicated to malaria research, thus creating institutions to promote analysis within India rather than in Europe and invested heavily in large-scale

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[61] Neill, *Networks in Tropical Medicine*, 23–24 and 33-34.
[62] Watts, *Epidemics and History*, 170.

infrastructure projects such as dams on the Indus and installing plumbing in Bombay to reduce the prevalence of malaria and cholera. This lack of geographic separation, as Chakrabarti argues, led to bacteriology in India emerging altogether differently from bacteriology in Europe as the lines between the environment and the laboratory were blurred, resulting in a definition of bacteriology inextricably tied to ideas of the "tropics," "tropical medicine," and "colonial science."[63] I use the term "colonial medicine," which is a recent definition derived from the work of historians Arnold and Chakrabarti that refers to medical knowledge produced in the colony itself and is not just the movement of European frameworks and concepts verbatim.

Medicine in India was still dominated by men of European background, although there was some involvement in India of Indian researchers, physicians, and malariologists, such as J. D. Baily, an Indian member of the IMS who rose to the rank of Sub-Assistant Surgeon Jemadar, the highest rank allowed for Indians. Syed Abdul Majid, who was enlisted with the Indian Medical Department, also reached the rank of Sub-Assistant Surgeon Jemadar. Indians were barred from holding ranks equivalent to British officers. While Baily and Majid are connected to the research throughout this thesis, as Indians they are always relegated to secondary role: assisting European lead researchers and always appearing as the second author on publications. Nonetheless, Indian researchers such as Baily and Majid were able to negotiate a European established system of medicine to reach the positions they did.

Christophers extolled the value of understanding local conditions and he is credited with introducing the concept of "species sanitation" where malaria eradication efforts are focused on the species of *Anopheles* mosquitoes which transmit malaria to humans rather than all *Anopheles* mosquitoes.[64] This methodology was enabled by extensive taxonomic study of mosquito species

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[63] Chakrabarti, *Bacteriology in British India*, 3 and 212.
[64] Shortt and Garnham, "Samuel Rickard Christophers," 195.

and through careful observation of the life cycle and breeding habits of individual species. In *How To Do A Malaria Survey*, which Christophers co-authored with Sinton and Covell, the first page of the manual highlights the high degree of variability encountered in differences within the human host, the protozoa, the mosquito, and the environment – making each malaria survey "a true piece of research work."[65] The importance of local conditions is relevant when looking at the biology of both malaria protozoa and the mosquito vector. Species of protozoa and mosquito vary widely due to geographic factors such as climate and from sociocultural influences such as urban and rural planning and development. The emphasis on local conditions developed from environmentalist explanations for disease but new concepts of bacteriology were incorporated into the idea in the late nineteenth century. The idea that diseases, such as malaria, were caused by specific biological agents instead of general environmental conditions demonstrated "the pathological specificity of the tropics."[66]

Watts uses Christophers as an example of how the British administration in India used researchers to support their assertion that irrigation projects did not cause malaria. For example, at the Simla Conference on malaria in India in 1909 (following a particularly deadly malaria year in 1908), Watts argues Christophers "was instrumental" in writing the final recommendations of the conference which denied connections between malaria and irrigation. The recommendations state "malaria is no way a necessary consequence of irrigating land near towns and villages" in relation to the cultivation of rice in wet paddies.[67] As Watts argues, Christophers was likely a critical figure in convincing British administrators waterlogging did not cause malaria and was

[65] S. R. Christophers, J. A. Sinton, and G. Covell, *How To Do A Malaria Survey*, 1928, sixth edition, revised by Jaswant Singh and I. M. Puri, Health Bulletin no. 14, Malaria Bureau No. 6 (Calcutta, India: The Government of India Press, 1959), 1.
[66] Georgina Endfield and Samuel Randalls, "Climate and Empire," *Eco-cultural Networks and the British Empire: New Views on Environmental History*, eds. James Beattie, Edward Melillo, and Emily O'Gorman (London and New York: Bloomsbury Academic), 33.
[67] Watts, "British Development Policies," 165.

not worth the government's time, effort, or focus to eliminate. Christophers' power in part derived from his appointment in 1909, after successful presentations to the Malaria Congress, to a committee which oversaw malaria control in British India. He argued emphatically that malaria epidemics in the Punjab had no direct relationship to British colonial irrigation projects, and "seem to depend entirely on floods."[68] Perspectives on malaria and development among British researchers was more diverse and did not always align with Christophers. There was some support for the casual connection between water development projects and malaria. Some of the researchers that disagreed with Christophers, such as Covell and Bentley, actually learned from or worked alongside him in malaria research.

By the early twentieth century, it was understood that climate, independent of other factors, did not make people more or less susceptible to malaria, but that climate did impact mosquito populations. Certain species of *Anopheles* mosquito are more prone to infection or have a stronger preference for biting humans rather than other animals.[69] Researchers who were trained internationally balanced their training from outside India with attention to local conditions within India. As discussed above, schools of tropical medicine were founded in Europe to treat diseases in European colonies. The "tropics" could be defined as both a physical location outside Europe and as an abstract concept within European medicine.[70]

In February 1931, the *Indian Medical Gazette* published an editorial on the findings of a League of Nations Commission that consisted of six European researchers who spent four months investigating malaria infection and prevention. That Commission divided its report on "the Indian problem" of malaria by geographic area: "a) The urban malaria problem, b) The

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[68] Watts, "British Development Policies," 165–166.
[69] Packard, *Making of a Tropical Disease*, 67.
[70] Chakrabarti, *Bacteriology in British India*, 212.

Punjab problem, c) The Bengal delta problem, d) The hill malaria problem."[71] The geography of India was critical for these League of Nations experts who structured their official findings according to those different geographies. As Nandini Bhattacharya argues, malariologists working in India operated on the belief that the success of "sanitary reform" was reliant "on the knowledge of the local conditions: the people as well as the land."[72]

Overall, the 1920s and 1930s in India did not see a paradigm shift from environmentalist to bacteriological thinking. Instead, the period was marked by these conceptual frameworks blending and overlapping with often unclear distinctions and both influenced approaches taken to study and eradicate malaria in India. The influence of this transitional thinking can be seen in both rural and urban research on malaria.

[71] *Indian Medical Gazette*, "The Report of the Malaria Commission of the League of Nations on their Indian Tour, 1929," (February 1931): 91.
[72] Nandini Bhattacharya, *Contagion and Enclaves*, *Contagion and Enclaves: Tropical Medicine in Colonial India*, (Liverpool, United Kingdom: Liverpool University Press, 2012), 160.

# Chapter Two

## Malaria Research in Bombay

Bombay is an important case study on urban malaria research due to its role in the history of British colonization in India. Bombay was one of the earliest cities in India in which the British sought to establish a colonial presence. As the site of one of only two deep water ports in India, the other one being located at the Portuguese colony of Goa, the city was critical for British export of goods. Bombay was also the location of the first EIC factory in India and later became the capital of its namesake presidency. Much of the city was near or below sea level, and as a result north and central sections flooded during the rainy season. Surrounded on three sides by the Arabian Sea, as seen below in figure three, by 1928 the city comprised twenty-four square miles and had grown to a population of about 1.2 million people. By the 1920s Bombay was one of the most populous, developed, and economically important cities in India for the British.

Malaria was not originally endemic to the islands from which Bombay was constructed. Gordon Covell established in the 1920s the role of *A. stephensi* as the only mosquito to transmit malaria in Bombay due to its ability to adapt to an urban environment.[73] Covell was a British malaria researcher who began his work with the disease in 1925 working for the Central Malaria Bureau within the Medical Research Department of the Government of India. Covell later entered the IMS and led several inquiries on malaria and was appointed Director of the Pasteur Institute in India in 1935.[74] Covell published a report on the findings from his "inquiry into malarial conditions in Bombay" in 1928 (see figure three below for a map Covell created

[73] William Horsfall, *Mosquitoes: Their Bionomics and Relation to Disease* (New York: Hafner Publishing Company, 1972), 283-285. Gordon Covell, "The Present State of Our Knowledge Regarding the Transmission of Malaria by the Different Species of Anopheline Mosquitoes," *Records of the Malaria Survey of India*, vol II, no. 1 (1931): 7.

[74] H. W. Mulligan, "Obituary," *Transactions of the Royal Society of Tropical Medicine and Hygiene* 70, no. 1 (1976) and "Naval and Military Appointments," *Supplement to the British Medical Journal* (February 23, 1935): 73.

showing variability in levels).[75] The year prior to publication, in 1927, Covell was appointed the inaugural Assistant Director of the newly created Malaria Survey of India.[76] The report recommended increased funding for malaria control as many methods were found to be inadequate and malaria rates in Bombay remained high.

[75] Gordon Covell, *Malaria in Bombay, 1928* (Bombay, India: The Government Central Press, 1928), preface.
[76] Mulligan, "Obituary," 92.

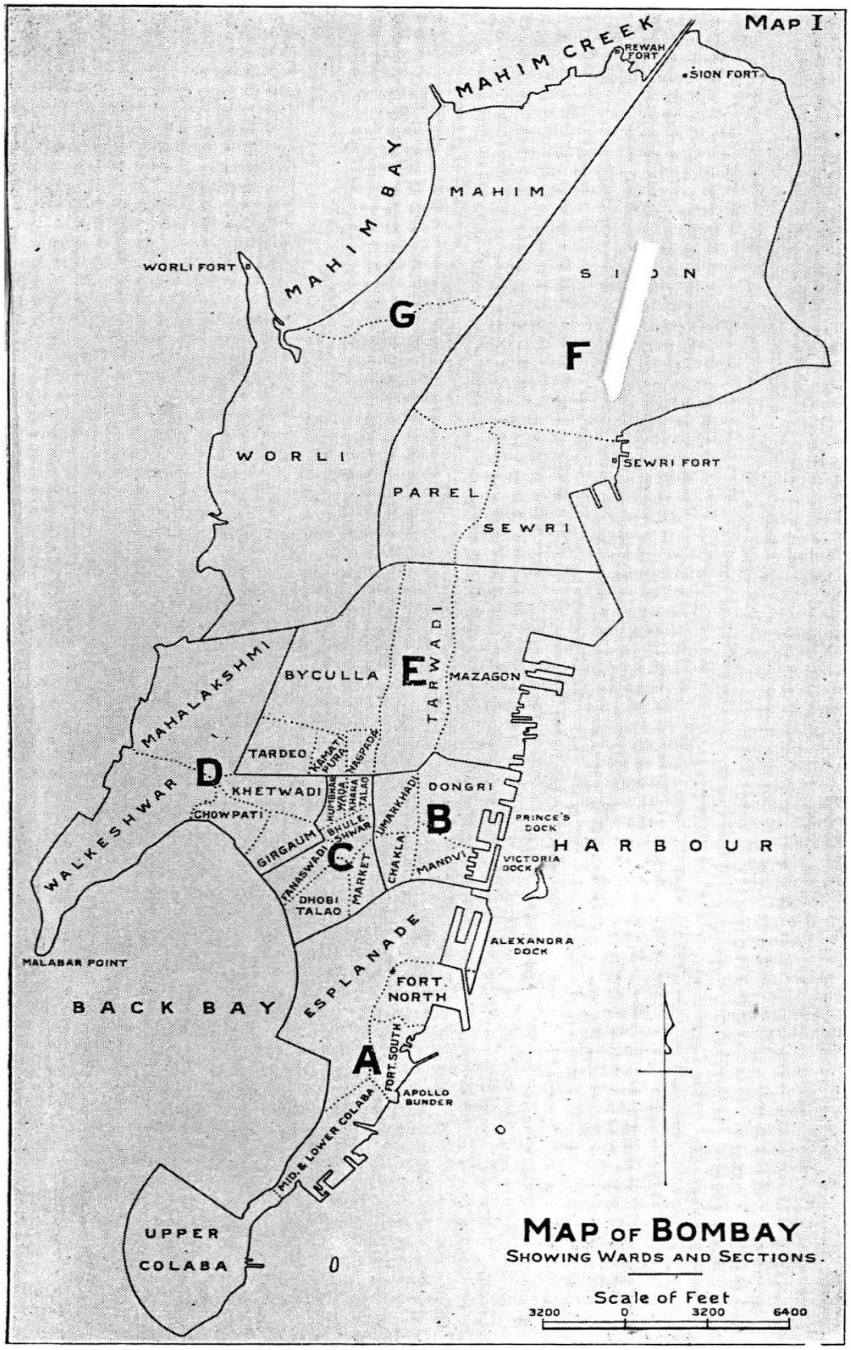


*Figure 3. A map of the city of Bombay in 1928 shows the different areas of the city that had different levels of malaria prevalence. The letters denote the different wards and sections of the city which were compared and contrasted for malaria prevalence.*

Before Covell began his inquiry in Bombay, another inquiry by a British malaria researcher was undertaken in 1911. Charles Bentley, a medical officer in the British administration in India, produced a report on causes and control measures of malaria in Bombay in 1911 while serving as an Officer on Special Duty to the city of Bombay. By this time, Europeans constituted a minority of the municipal administration with the majority being Hindu, Muslim, and Parsi Indians.[77] Bentley's critical discovery was that *Anopheles stephensi* mosquitoes preferred to breed in wells and cisterns that were frequently uncovered or left open. Before Bentley’s report, it was thought that flooding in fields during the monsoon season was a key factor in the breeding of mosquitoes in the city. The discovery substantially influenced Covell’s approach and recommendations for malaria eradication in his 1928 report. While the highest rates of malaria occurred during the monsoon season, the cause was not flooded fields that provided a highly conducive breeding environment. The monsoon season caused extra precipitation that filled the urban environment with water, from flooded cellars and poorly drained yards down to tin cans and scrap iron.[78]

As seen below in figure four, data collected on seasonal malaria prevalence over five years in Bombay show that malaria prevalence peaks at the end of the monsoon season. *A. stephensi* was discovered to breed in either darkness or light, and scant amounts of water. A highly adaptable mosquito, *A. stephensi* could hide under the surface of the water for at least twenty minutes, thus demonstrating its excellent ability to survive even the most determined efforts of humans to eradicate it.[79] Therefore, Covell’s focus during his inquiry, influenced by earlier findings such as Bentley’s, was to work on eliminating all areas where *A. stephensi* could breed. From the viewpoint of British public health officials, the goal was to prevent mosquito access to water and thus, prevent breeding. To Covell and his team, it must have seemed an

[77] Charles A. Bentley, *Report of an Investigation into the Causes of Malaria in Bombay and the Measures Necessary for its Control* (Bombay, India: The Government Central Press, 1911), 8.
[78] Covell, *Malaria in Bombay*, 13–18.
[79] Covell, *Malaria in Bombay*, 18–19.

insurmountable task to cover every last small hole on every last container of water in a city of 1.2 million people. Efforts included filling unnecessary wells with cement-concrete; constructing lids which "hermetically" sealed wells and cisterns; producing extremely fine mesh to prevent mosquitoes from entering water containers; using check-nuts to fully seal inlet pipes on cisterns; and replacing older wells with a piped water supply.[80]

During his inquiry in 1911, Bentley detailed some of the cultural and religious objections he faced from the city's residents related to water access and treatment. Bentley noted that a "Hindu gentleman" who was requested to cover a well objected:

> That the well in question is a charitable property, that it is used only for bathing purposes by persons visiting the neighbouring temple of which it is an adjunct; that the filling up of the well or even the closing it so as to shut off the rays of the sun will hurt the religious susceptibilities of the pious Hindus of the locality.[81]

He further noted that Parsis objected to the covering of wells based on their own distinct cultural and religious reasons, but were able to offer a compromise in a letter from a Parsi priest to the Executive Health Officer of Bombay:

> According to the Zoroastrian Scriptures, well water is kept in a pure condition by its complete exposure to the solar rays, considered as the best disinfecting and purifying source. Hence it is incumbent that the well water that is used for daily consecration shall be always entirely exposed to the Sun. Consequently if it is quite impossible to clean out impurities from the wells in question, or if it is indispensable for the sake of public health to cover such as wells as a safeguard against the spread of malaria, then only the suggestion made in the last para. of your letter about the covering of wire-gauze might be adopted. No doubt it will be a check to the spread of malaria and partly allow the solar rays to fall on the well water.[82]

Therefore, the work of researchers such as Bentley and Covell had to navigate the cultural context of India in their efforts to control malaria.

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[80] Covell, *Malaria in Bombay*, 21-22.
[81] Bentley, *Report of an Investigation*, 137.
[82] Bentley, *Report of an Investigation*, 139.

As Preeti Chopra argues, colonial cities are often seen by scholars to be the result of "singular visions" of the colonizer; however, local inhabitants did in fact influence urban design or architecture.[83] Indian elites in Bombay played a role in the urbanization project which resulted in a human-made landscape that was ideal for *Anopheles stephensi*. The mosquitoes' preferred conditions included large gardens with water features, wells, cisterns, and water tanks. As Bombay did not have a piped water infrastructure, wells and water tanks, funded through philanthropic efforts of European and Indian elites alike, provided essential water to the people of Bombay. Moreover, these wells and water tanks were often built with integrated platforms, steps, shrines, and trees and thus became an important cultural component and the "foci of daily rituals, spaces of public interaction, and public spaces" that encouraged the growth of neighbourhoods surrounding them.[84]

Indian elites contributed to Bombay's construction through collaboration with the British colonial administration on urban planning, sanitation, and housing initiatives as well as monetary donations and gift-giving to support hospitals, schools, cultural sites, and water infrastructure such as cisterns and wells. Charitable gifts given by elites, known as inams for Hindus and waqfs for Muslims, had a well-established tradition in India long before the British ever arrived.[85] Wells and tanks were a common item for inams and waqfs. Indian elites supported development projects which resulted in separated areas of Bombay along socioeconomic and caste lines. Indians who were both poor and of lower castes were housed in the least salubrious parts of the city.

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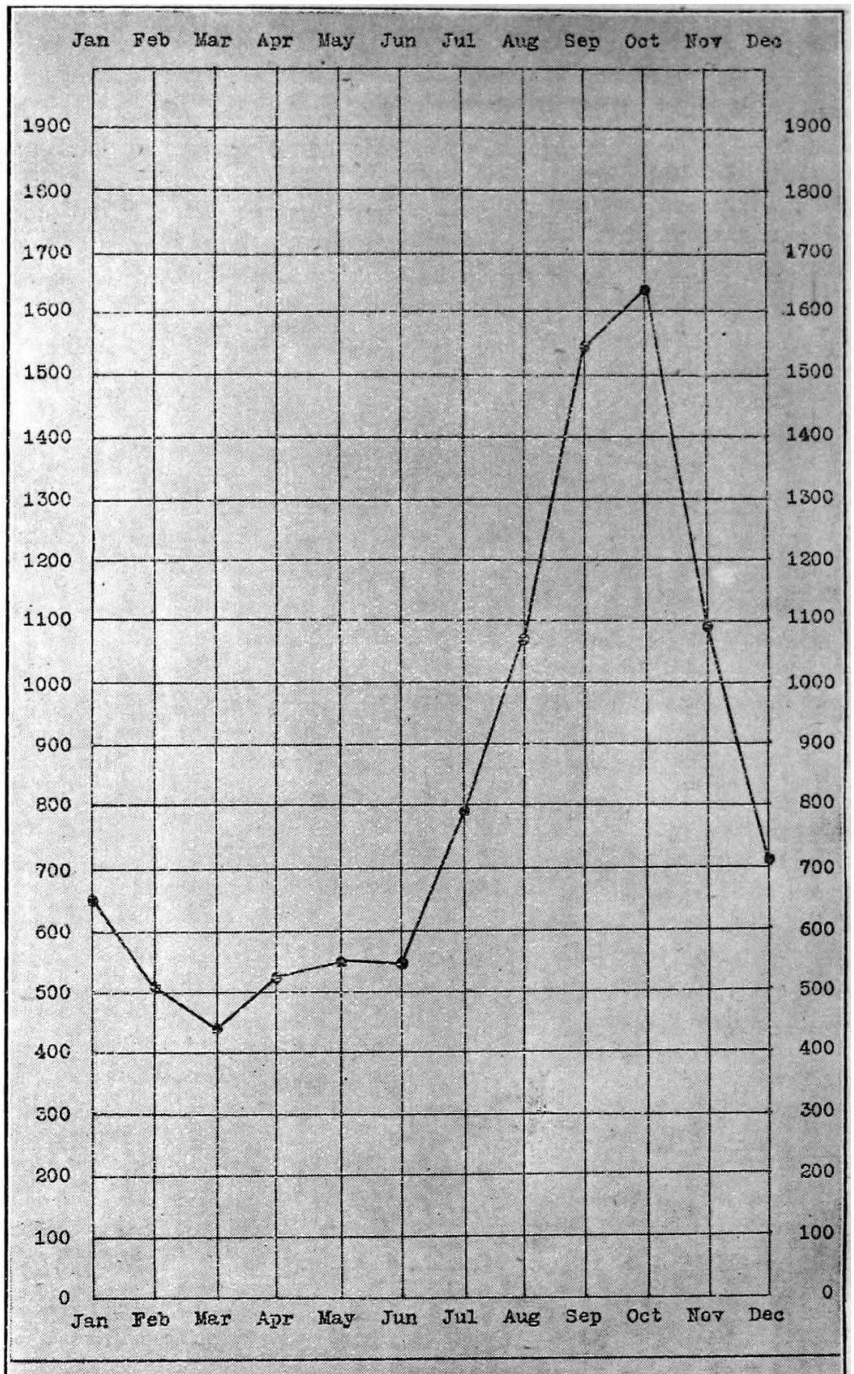
83 Chopra, *Joint Enterprise*, xv.
84 Chopra, *Joint Enterprise*, 6.
85 Washbrook, "Progress and Problems," 64.

The introduction of piped water infrastructure was meant to improve the overall health of Bombay, but it created new spaces for mosquitoes to breed. Wells, originally the sole source of drinking water in the city, began to be gradually replaced with a piped water supply as early as 1866.[86] However, as Covell warns in his report, the lack of knowledge by sanitation engineers as to the breeding cycle and general ecology of *Anopheles* mosquitoes, specifically *A. stephensi*, led to design flaws that enabled mosquito proliferation. Piped water supply fed into cisterns scattered throughout the city which created ideal conditions for *Anopheles* mosquito breeding: large quantities of fresh, frequently replenished water. The cisterns that the piped water fed into were often inadequately covered, just like wells; and improperly sealed inlet pipes leading into the cisterns had openings small enough for mosquitoes to fit through even if the cisterns had proper lids.

[86] Covell, *Malaria in Bombay*, 5.




Graph illustrating the Seasonal Incidence of Malaria in Bombay, compiled from the records of the Port Trust Dispensary, 1923-1927.

*Figure 4. Graph of average seasonal variation in malaria incidence in Bombay from 1923-1927. The peak from August through November coincides with the monsoon season and demonstrates how malaria was a seasonal problem driven by a significant annual environmental event, monsoons, which were extremely difficult to mitigate.*

Bentley estimated that the cost of eradicating malaria in Bombay would be "less than a tenth" of what malaria itself cost Bombay annually.[87] The financial benefit to eradicating malaria in Bombay is reiterated by Covell in his 1928 report:

> this can be accomplished at a cost considerably less than the amount at present lost annually by interference with labour and by expenditure on account of medical aid to those suffering from the disease.[88]

Near the end of his report, Covell again emphasizes the increased costs that could result from failing to eradicate malaria:

> I wish to emphasise here that unless the permanent measures of control which I have advocated are carried out, a very large increase in the personnel of the Malaria Department will be necessary, which will at least double the present annual expenditure under this head.

Overall, in Covell's view, leaving malaria out of control would be "a constant drain upon the resources of Bombay."[89] Even in a place with such critical importance to the British colonial presence and economy there were not enough resources to offer malaria control.

The British originally infilled the tidal flats of Bombay to increase the island's ability to serve as a central hub and deep-water port for British colonization and economic extraction in India. Now, in the 1920s the manipulation of the land and water around Bombay had fundamentally impacted the health of the people within the city as it led to the endemicity of malaria through an urban adapted mosquito. The simultaneous influence of both environmentalist influences and emerging bacteriological thinking can be seen in the work of Bentley and Covell undertaken in Bombay. While bacteriological thinking can be seen in the precise examination of mosquito and malaria species, this information was not used in service of a bacteriological based solution. By the 1920s, quinine prophylaxis was known to be a cost

[87] Covell, *Malaria in Bombay*, 10.
[88] Covell, *Malaria in Bombay*, 35.
[89] Covell, *Malaria in Bombay*, 88.

effective and efficient method of reducing malaria prevalence. Instead of quinine, Covell attempted an environmentalism-driven restructuring of the city to minimize mosquito breeding sites. This attempted solution was not successful.

# Chapter Three

# Malaria Research Along the Indus River

Malaria was introduced to Bombay through a mosquito that was not endemic to the area until the British physically altered the original geography of the tidal flats. British manipulation of the Indian landscape for economic benefit then expanded in subsequent centuries, especially for promoting agriculture. As British malaria researcher Patrick Hehir wrote in his seminal text *Malaria in India* in 1927:

> Compared with agriculture, the other industries of India, though they play a useful part in the economic life of the country, are of minor importance. Agriculture is, and always will be, the great field of industrial activity, for upon it the welfare and prosperity of the large masses of India depend.[90]

Between 1927 and 1932 British engineers constructed a barrage dam (containing many gates to more precisely control outflow than a standard dam) known as the Sukkur Barrage in the city of Sukkur in Sind Province (see figure five below). Originally in the far Northwest of the Bombay presidency, Sind was a primarily Muslim province that covered 121,730 square kilometres and separated from the presidency in 1936. It exists in present day as Sindh Province in Pakistan.[91] The barrage project was implemented on the Indus River to "give 'flow' irrigation" in perennial canals (containing water throughout the year rather than seasonally). The barrage would feed those canals and provide more consistently available water for irrigation (see figure six below). The intended outcome was to improve agricultural output from 2,317,000 to 5,900,000 acres of cultivation and thereby increase the economic and nutritional health of the local populations.[92]

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[90] Patrick Hehir, *Malaria in India* (London: Oxford University Press), 1927.

[91] T. C. McCombie Young and Syed Abdul Majid, "Malaria in Sind with Reference to the Sukkur Barrage Scheme," *Record of the Malaria Survey of India* vol. I, no. 3 (1930): 341.

[92] Young and Majid, "Malaria in Sind," 344-345.

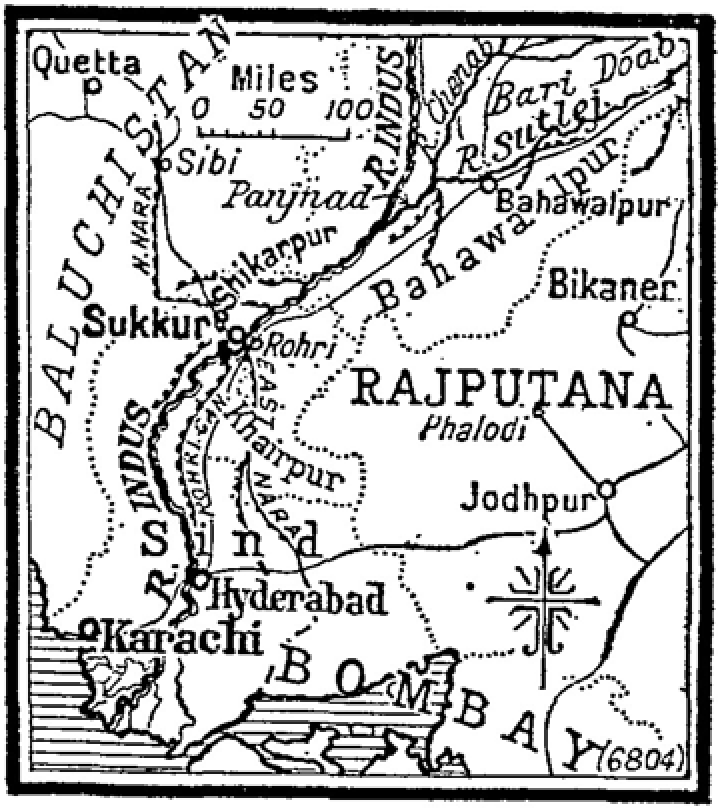


*Figure 5. A map of Sukkur's location on the Indus included in an article in The Times of India on the project's progress.*[93]

The Indian and British administration of Sind was also part of a debate with the administrations of Punjab and Bahawalpur, in the north and northwest of India respectively, over opportunities to advance their respective hydrological projects. The Sukkur Barrage is a product of Sind's Indian administrators pushing for the opportunity to construct its own large-scale project. The Sukkur Barrage also reflects the colonialist drive to bring India under "canal command" by maximizing the amount of land which was irrigated through canals and making the people who farmed that land entirely dependent on the state for their livelihood, since irrigation enabled larger-scale agriculture.[94] By the time the Sukkur Barrage was constructed in

[93] "Sind Irrigation Scheme: Standing Committee Appointed," *The Times of India* (January 3, 1930).
[94] Gilmartin, *Blood and Water*, 183.

1932, twelve other major canals had already been constructed further upstream along the Indus with this barrage being the furthest downstream.[95] See the map below in figure seven for the canalization of the Indus and the areas impacted by the barrage**.**

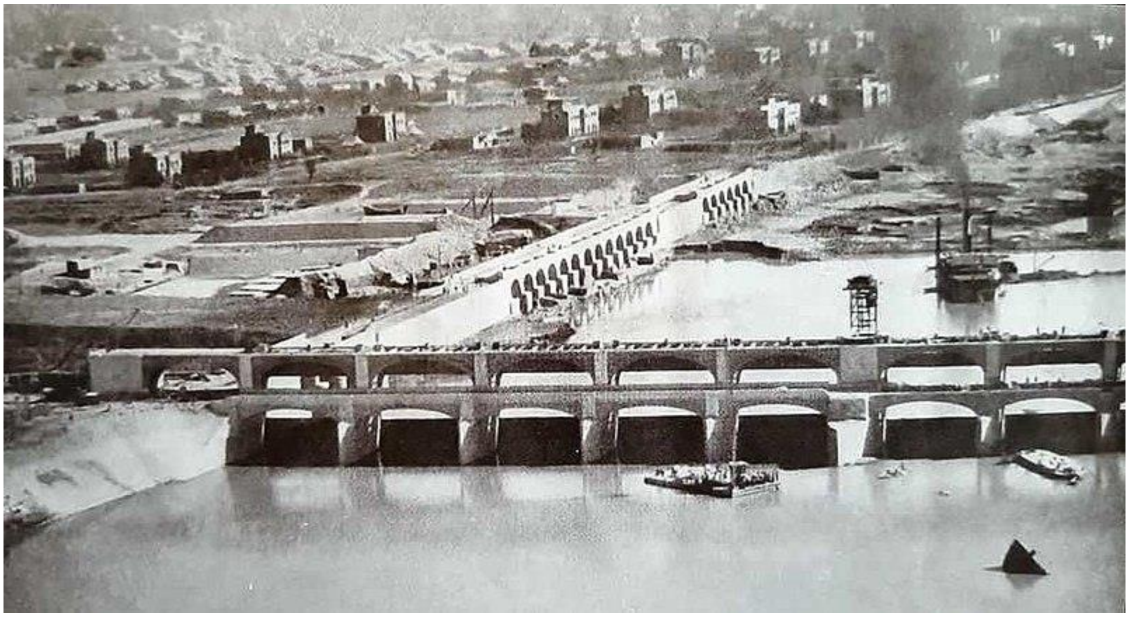

*Figure 6. The Sukkur barrage as it appeared in 1931 during the final stages of construction and before implementation in 1932.*[96]

Covell and Baily were concerned that "the outlook is grave indeed" if engineers working on the barrage could not prevent waterlogging, which is characterized by soil saturated with water from excessive irrigation. Consequently, waterlogging causes the water table to rise, at times to the surface which impedes plant growth, leads to accumulated salt in the soil (known as salinization) and creates ideal breeding grounds for certain species of *Anopheles* mosquitoes. Covell and Baily were not the first to realize the risks that irrigation projects carried. Sheldon Watts notes a provincial sanitation commissioner in the Punjab admitted that public health

[95] Gilmartin, *Blood and Water*, Map 7.
[96] Wikimedia Commons, https://commons.wikimedia.org/wiki/File:SUKKUR_BARRAGE_a.jpg.

officials had known waterlogging was a result of irrigation projects as early as 1891.[97] Despite the risks these projects posed for increased waterlogging and a negative impact on health as Watts points out, the British administration continued to invest money in such projects decades later.

Covell and Baily's report recommends that malaria treatment should be factored into the continued operation costs of the barrage. They also speculate that individuals would choose increased economic prosperity resulting from the increased agricultural output the barrage would bring over any potential increase in illness. Covell and Baily write:

> It is highly probable that if the average villager were asked whether he would rather receive a material increase in his income plus a greater liability to fever or remain in his present circumstances, he would unhesitatingly choose the former alternative.[98]

Research into the potential impacts of barrage construction on malaria began at the outset of the project in 1927. The first report mentioning "the probable effect on malaria of the Barrage," was published April 24, 1928, in the *Records of the Malaria Survey of India* by T. C. McCombie Young, a British researcher, and Syed Abdul Majid, an Indian researcher, enlisted in the IMS and Indian Medical Department respectively.[99] Young and Majid note Sind province had hyper-endemic malaria conditions but the population had generally adapted to those conditions due to the "absence of economic stress" and a "well-balanced" diet.[100] The city of Larkana in Sind Province was chosen as the headquarters of the investigation by Young and

97 Watts, "British Development Policies," 161.
98 Gordon Covell and J. D. Baily, "Malaria in Sind Part XV. The Effects Produced by the Operation of the Lloyd Barrage Scheme on the Incidence of Malaria in Sind.," *Records of the Malaria Survey of India* vol. 6, no. 3 (1936): 398.
99 Young and Majid, "Malaria in Sind," 343.
100 Hyper-endemic malaria refers to a population with an almost 100% infection rate throughout the year but that is not part of an outbreak of epidemic malaria and occurs alongside a high spleen index as well as a higher rate of acquired immunity. Young and Majid, "Malaria in Sind," 341.

Majid, beginning in September 1927, as the city had particularly high spleen rates which meant the area was highly malarious.

Levels of malaria infection can be determined by the spleen rate of a population[101] In the manual *How To Do A Malaria Survey* spleen rate is defined as the percentage of people in a population who have spleens that are enlarged and rigid enough to be felt by palpation which correlates to the percentage of malarial infection.[102] In the initial general survey of school children in Sukkur and Larkana, wheat-growing regions were found to have a lower spleen rate, at eleven percent, than rice-growing regions, at thirty-five percent, which meant the rice-growing regions had a higher prevalence of malaria than the wheat-growing regions.

At the end of their inquiry, Young and Majid concluded neither flooding nor heavy rainfall alone account for epidemic malaria in Sind, but they were likely related factors.[103] They estimated that endemic malaria occurred in the region with a roughly ten-year periodicity, meaning that endemic malaria levels peaked and bottomed in the region on a ten-year cycle. Young and Majid determined the Barrage would not increase malaria prevalence in Sind, and in fact, that it would even have the potential to reduce epidemic malaria. They reasoned the reduction in epidemic malaria would result from less flooding during high river levels due to heavy rainfall and by draining surplus water in rice-growing areas.[104]

Covell began working on the Sind Malaria Inquiry in July of 1928, building upon the initial fieldwork of Young and Majid.[105] Unlike the 1927 Bombay malaria inquiry, Covell did not conduct the field observations or collect the data upon which the reports were based. The

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[101] Young and Majid, "Malaria in Sind," 403; Shortt and Garnham, "Samuel Rickard Christophers," 188.
[102] Christophers, Sinton, and Covell, *How To Do A Malaria Survey*, 20.
[103] Young and Majid, "Malaria in Sind," 382.
[104] Young and Majid, "Malaria in Sind," 384 and 404.
[105] G. Covell and J. D. Baily, "Malaria in Sind. Part III." 549.

fieldwork and data collection for Sind were "entirely the work" of J. D. Baily.[106] In this study, a variety of sources were used to obtain data to determine the prevalence and rates of malaria in Sind. As with the Bombay inquiry, the spleens and blood of children were examined to determine malaria prevalence.[107] Data on humidity, rainfall, river levels, and subsoil water levels were also collected. Baily expanded the fieldwork started by Young and Majid to more talukas (administrative subdivisions of districts), villages, and districts.

The localized geographic area studies, discussed in more detail below, demonstrate how knowledge of local conditions, as established by Christophers, was a central component of malaria research in India. Covell and Baily approached each area, including Larkana, Nawabshah, Umarkot, Chhachhro talukas in Thar, and Parkar in Sind Province, as unique areas with their own set of environmental conditions. While there were similarities, including the presence of *A. culicifacies* in all areas, there were also important differences. These differences affected the potential outlook for distinct areas and whether the Barrage would directly or indirectly contribute to an increase in endemic and epidemic malaria for the regions after construction.

Through data on the number of fever cases from the Larkana Civil Hospital during the year of study from 1928 to 1929, Covell and Baily determined that in the city, October and November had the highest rates of malaria. Based on the spleen index previously determined by Young and Majid, Covell and Baily concluded that Larkana is an area of hyper-endemicity. Covell and Baily determined that "true epidemic or fulminant malaria does not affect the tract under review except under very exceptional circumstances," such as in 1917 when an epidemic

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[106] Gordon Covell and J. D. Baily, "Malaria in Sind. Part IV. Malaria in Nawabshah District," *Records of the Malaria Survey of India*, vol II, no. 4 (1931): 507.
[107] Covell and Baily, "Malaria in Sind. Part IV," 507 and 514.

broke out due to a “combination of excessive rainfall, high total river levels, and late high river levels.” However, the primary impact of the Barrage was ultimately not on outbreaks of epidemic malaria, but on levels of endemic malaria. As with other areas of Sind, the species of *Anopheles* mosquito most likely responsible for transmission was *A. culicifacies*.[108] The “malaria season” of *A. culicifacies* in Larkana was determined by seasonal changes in temperature and humidity.[109] Both humidity and available breeding sites for *A. culicifacies* are impacted by flooding, proximity to the river Indus, and subsoil water levels. Rice paddy agriculture has the additional impact of pancho flooding (repeated flooding, draining, and reflooding with new water) which leads to waterlogged soil with a higher water table level over time.[110]

In addition to Larkana, Covell and Baily also researched Nawabshah District. The examination of schoolchildren in Nawabshah District for spleen rates and parasite rates occurred from December 22, 1928, to January 17, 1929, which was shown by the mosquito prevalence and malaria rates in other inquiries to be the end of the malaria season that peaks in October and November.[111] As with elsewhere in Sind, *A. culicifacies* was the primary, or sole, vector responsible for the transmission of malaria. At the time of this inquiry, Nawabshah had some canal infrastructure already in place. However, the infrastructure was predominantly inundation canals which are not dammed and therefore do not provide a consistent or controlled supply of water, unlike perennial canals which can provide a controlled water supply and were to be constructed in the barrage.[112] Nawabshah had moderate levels of endemic malaria, in contrast to

[108] Covell and Baily, “Malaria in Sind Part III,” 557–558.
[109] Covell and Baily, “Malaria in Sind Part III,” 563.
[110] M. Ashraf, M.K. Marri, I. Rao, A. Salam and M.A. Khan, “Pancho-Irrigation System - A Wasteful Practice of Irrigating Rice Fields in the Lower Indus Basin of Pakistan,” *Pakistan Journal of Agricultural Research* 51, no. 4 (2014): 867.
[111] Covell and Baily, “Malaria in Sind. Part IV,” 507.
[112] Covell and Baily, “Malaria in Sind. Part IV,” 510.

Larkana's high amount of endemic malaria. The most significant factor in determining whether villages in Nawabshah had high rates of malaria was their location and whether those villages were prone to flooding due to either low elevation or proximity to the Indus. Nawabshah's central location in Sind meant that epidemics in either Upper Sind or Lower Sind could spread and result in fulminant malaria in Nawabshah.[113] Finally, Covell and Baily determined that in Nawabshah, if the barrage reduced flooding then endemic malaria "will probably be lessened," but that if the barrage raised subsoil water levels "there will probably be some increase in endemic malaria."[114]

The next areas examined by Covell and Baily were the Umarkot and Chhachhro talukas in Thar and Parkar District in Lower Sind. There was substantially less previous research on these areas than elsewhere in Sind. Despite the previous lack of research, Baily only spent one week, from January 12 to 19, 1931, in the District.[115] In contrast to other areas of Sind, Covell and Baily determined that rainfall had no impact on epidemic outbreaks of malaria in the two talukas. It was determined that endemic malaria was at a moderate level in Umarkot taluka; Covell and Baily state this result was typical for villages built on elevated ground far from rice fields.[116] That expectation of a moderate level of endemic malaria demonstrates that several years into the malaria inquiry in Sind, Covell and Baily were beginning to recognize patterns. The type of mosquito invariably found to be the primary vector for malaria transmission in Sind, *A. culicifacies*, thrives in areas near irrigation canals and wet rice paddies.[117] Villages situated on mounds that grow crops that demand less water than rice, such as in Umarkot, therefore had

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[113] Covell and Baily, "Malaria in Sind. Part IV," 525.
[114] Covell and Baily, "Malaria in Sind. Part IV," 526.
[115] G. Covell and J. D. Baily, "Malaria in Sind. Part V. Malaria in Umarkot and Chhachhro Talukas of Thar and Parkar District (Lower Sind)," *Records of the Malaria Survey of India*, vol. II, no. 4 (1931): 527.
[116] Covell and Baily, "Malaria in Sind Part V," 534.
[117] Covell and Baily, "Malaria in Sind Part V," 535.

lower rates of malaria. Chhachhro taluka had even lower rates of malaria than Umarkot. The "extremely slight" rate of endemic malaria which might even be "thought to be non-existent" was due to Chhachhro being situated in a desert environment and not having any irrigation infrastructure.[118] As seen in figure seven below, Chhachhro was not part of the area to be irrigated with canals fed by the barrage. As with Nawabshah, Covell and Baily acknowledge that if the subsoil water levels in Umarkot are raised "to any considerable extent" as a result of the Barrage, then "some increase of endemic malaria may be expected."[119]

[118] Covell and Baily, "Malaria in Sind Part V," 534.
[119] Covell and Baily, "Malaria in Sind Part V," 535.

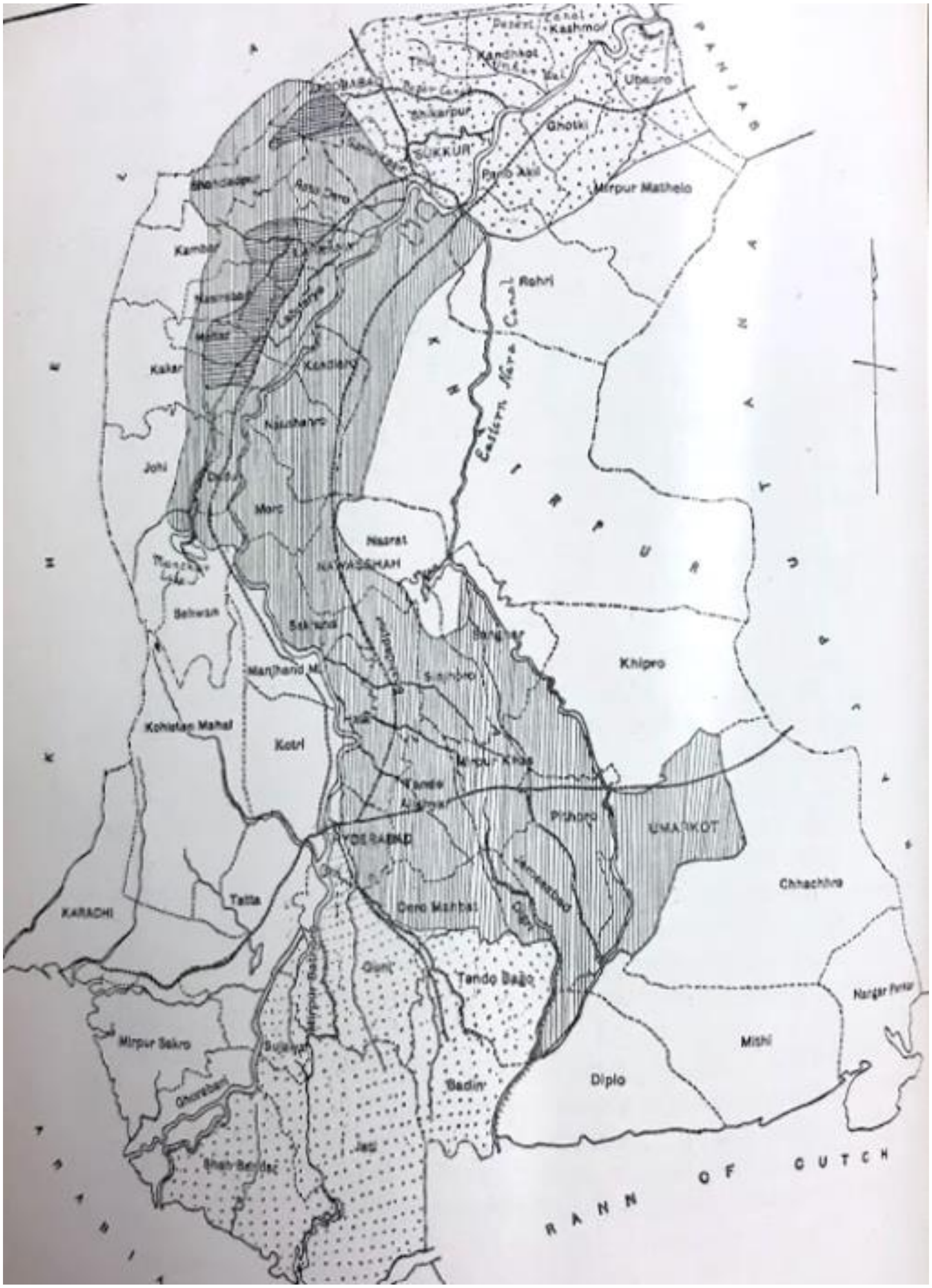


*Figure 7. A map depicting the canalization of the Indus in Sind Province in the 1920s. This map shows which areas will be irrigated by canals from the Barrage Scheme (lined area) and which areas will not be irrigated from canals by the Barrage Scheme (dotted area). The regions are discussed below.*

In 1931, Covell published an article titled "The Present State of Our Knowledge Regarding the Transmission of Malaria by the Different Species of Anopheline Mosquitoes."[120] The article notes under laboratory conditions many species of *Anopheles* mosquito carry and transmit malaria, but in nature it is "often only one species" responsible for transmission, as was the case in Bombay upon discovery *A. stephensi* was solely responsible for transmission.[121] In Sind, the mosquito primarily responsible for the transmission of malaria was consistently found to be *A. culicifacies*. Therefore, the way British malariologists needed to approach malaria research was locally contingent as different species of mosquito have different behaviours and preferred breeding locations. In contrast to the urban-dwelling *A. stephensi*, *A. culicifacies* breeds in irrigation canals and flooded rice fields.

In the Upper Sind Frontier District, some talukas saw increased subsoil water levels following Barrage construction. Along the Sind Dhoro, an old riverbed that was refilled as a result of the Barrage, several villages saw increased subsoil water levels *and* increased spleen rates.[122] Regarding Sukkur District, Covell and Baily write "the continuance of these high spleen rates is a result of conditions brought about by the operation of the Barrage Scheme." In Nawabshah District, there were increased subsoil water levels as high as six to fifteen feet in some villages in the post-Barrage period. In Nawabshah, villages with the largest increases in spleen rate had "received new distributaries and greatly increase[d] irrigation" from the Barrage.

Covell and Baily determined the Barrage caused changes that directly and indirectly contributed to an increase in endemic and epidemic malaria in certain areas but ultimately concluded that "many parts of Sind have been highly malarious for at least as far back as reliable

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[120] Covell, "The Present State of Our Knowledge," 1-48.
[121] Covell, "The Present State of Our Knowledge," 2.
[122] Covell and Baily, "Malaria in Sind Part XV," 393; David Cheesman, *Landlord Power and Rural Indebtedness in Colonial Sind 1865-1901* (Great Britain: Curzon Press, 1997), 23.

records go," before construction of the barrage.[123] This conclusion does not seem to take a firm stance on either side of the argument as to whether or not the Barrage caused an increase in malaria. Further, Covell and Baily's conclusion partially aligns with Young and Majid's original inquiry, which determined that an increase in malaria prevalence was not likely to be related to increased canalization in Sind Province. Sinton had authored a note immediately following the report by Young and Majid that warned engineers needed to be cautious about the potential for waterlogging following the construction of the Barrage. He warned that flooding could create both a larger habitat for *Anopheles* mosquitoes and  a decrease in soil fertility, which would lead to "adverse economic conditions [that] will lead to an increase of malaria."[124] The subsoil water levels rose forty kilometres upstream of the Barrage, and in many rice-cultivating regions in Northern Sind, a risk Covell and Baily had repeatedly warned about in many of the areas they examined.[125] Covell and Baily argue that in some areas, the Barrage increased the prevalence of malaria. Contrary to what Young and Majid hoped in their original report, the Barrage did not drain excess water in rice-growing regions and therefore, did not reduce the breeding habitat of *A. culicifacies*.

The difficulty in balancing agricultural prosperity and malarial control reveals the conflict that existed in reconciling economic interests with public health goals in India. The project involved constructing a large barrage on the Indus River. The goal of the project was to provide increased control over water for agricultural irrigation and to thereby increase agricultural profit. Covell and Baily acknowledge the potential agricultural benefits of the barrage due to villages and talukas subsequently increasing rice cultivation and winter cultivation

[123] Covell and Baily, "Malaria in Sind Part XV," 394–396.
[124] J. A. Sinton, "Note on the Report on 'Malaria in Sind' by Lieut.-Col. McCombie Young and S. A. S. Syed Abdul Majid," *Record of the Malaria Survey of India* vol. I, no. 3 (1930): 409; Young and Majid, "Malaria in Sind," 405.
[125] Covell and Baily, "Malaria in Sind Part XV," 390-391.

of other crops. However, they also estimated that construction would result in a "permanent increase in endemic malaria in the areas where there has been a great extension of perennial irrigation."[126]

The economic loss malaria caused to India was substantial. As demonstrated above, that economic loss was in part exacerbated by expensive, large-scale projects such as the Barrage. There is little recognition by historians of the health impacts of the Barrage in India, and what is present-day Pakistan. Watts argues the refusal to acknowledge evidence of this connection shows the British administration in India was wholly focused on profits and economic policy was more important than public health policy. However, as demonstrated above, some parts of the British administration and some researchers were concerned with the general health of the population, in particular adequate nutrition and reducing malaria.

Today, the Sukkur Barrage is considered a critical part of Pakistan's infrastructure as it enables the irrigation of about 25% of the country and about 75% of the irrigation in the Province of Sindh. Nearly 100 years after its construction, the barrage has demonstrated a positive economic impact on Pakistan, albeit at the expense of the health of people in the region due to British administrators failing to acknowledge research on the potential risks.

[126] Covell and Baily, "Malaria in Sind Part XV," 397.

## Conclusion

By 1955, British malariologist Gordon Covell already considered malaria to be a "well-worn" subject amongst the work of his peers.[127] However, nearly seven decades later, there are still new discoveries to be made about the history of malaria. The complex connections between the disease, urban and rural development, the British colonial administration in India, and British researchers in India during the early twentieth century have yet to be fully explored. Examining these connections can elucidate not only how British changes to the physical geography of India both caused and increased malaria but also how wilful ignorance of the British administration in India towards the connection between development projects and malaria influenced people's health.

In Chapter One I discussed the key historical context and historiography of the transitional period of environmentalist and bacteriological thinking within malaria research in India in the 1920s and 1930s. While earlier historians such as Basalla were not critical of British colonial development of India for economic extraction, by the 1980s the historiography began to recognize the negative impacts of British water development projects. By the 1990s, newer perspectives on water development projects recognized the negative impact these projects had on the health of Indians. Research trends have moved towards postcolonial perspectives since the 1990s. This work, characterized by the research of Harrison and Arnold, is more critical of the British colonial administration in India and how the attitudes towards Indians led to insufficient public health policies. Watts takes this further and argues the British administration in India simply did not care about the public health crises facing Indians and remained primarily focused on policies that would be to the economic benefit of the British.

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[127] Gordon Covell, "Developments in the Chemotherapy of Malaria During the Last 40 Years," Royal Society Health Journal, 1955, 75 (10): 758.

Chapter Two discussed research on malaria in Bombay in the 1910s and 1920s. It was due to British changes to the Indian landscape in the early eighteenth century that malaria became endemic to the city and enabled the proliferation of the urban-adapted *A. stephensi* mosquito. The research works of Charles Bentley in 1911 and Gordon Covell in 1928 are used to demonstrate the entanglement of environmentalist and bacteriological thinking. Ultimately, neither researcher was successful in reducing malaria prevalence in Bombay, a problem Covell argues was exacerbated by insufficient funding.

In Chapter Three I discussed, through the research of Covell and Baily in Sind, the difficulty in balancing agricultural prosperity and malarial control. While Covell and Baily acknowledge the agricultural benefits of the Barrage due to many villages and talukas increasing both their rice cultivation and winter cultivation of other crops, those agricultural benefits did not come without harm to the health of many inhabitants of Sind. The Sukkur Barrage contributed to a permanent increase in endemic malaria and the resulting waterlogging made some areas unsuitable for agriculture. As Paul Russell of the Rockefeller Foundation noted in 1942, "In some areas the water-logging which has been so detrimental to agriculture has at the same time created a malaria menace."[128] Through the continued canalization and damming of Indian waters, British administrators who planned the projects and British engineers who constructed them permanently impacted the health of Indians along canals and dams.

Watts argues the British administration in India was only focused on the potential profits to be had from agricultural development and did not care about the public health implications for Indians. By examining the work of malaria researchers more broadly, beyond the focus Watts has on Christophers, I have worked to nuance this picture. Through the work of Bentley, Covell,

[128] Paul F. Russell, Fred W. Knipe, and H. Ramanatha Rao, "On Agricultural Malaria and Its Control with Special Reference to South India," *Indian Medical Gazette* 77, no. 12: 745.

Baily, Young and Majid, I have shown that researchers were actively investigating the connection between malaria and irrigation and at times argued that this was detrimental to the health of Indians. While Indians such as Baily and Majid were becoming a larger proportion of IMS members and researchers, they were still put in secondary roles and were never the primary authors on research papers. The British administration was repeatedly shown by those researchers that irrigation projects contributed to increased malaria prevalence in India. New research emerged in the 1920s and 1930s that demonstrated the connection between such projects and malaria based on new bacteriological ways of thinking. However, since this period was the site of a complicated entanglement of environmentalist and bacteriological thinking, many efforts at malaria control proposed and undertaken by researchers were still influenced by environmentalism. Therefore, there was sometimes a disconnect between the research and the fieldwork that clouded the message malaria researchers were trying to send to the British administration in India. This disconnect impacted the quality of the research itself as inquiries and projects on malaria eradication contained both lines of thinking which did not always logically link together.

# Bibliography

***Primary Sources***

Bentley, Charles A. *Report of an Investigation into the Causes of Malaria in Bombay and the Measures Necessary for its Control*. Bombay, India: The Government Central Press, 1911.

Christophers S. R. and S. P. James. "Malaria in India: What can the State do to Prevent It?" *The Indian Medical Gazette.* July 1909.

Christophers, S. R., J. A. Sinton, and G. Covell. *How To Do A Malaria Survey*. 1928. Sixth edition, revised by Jaswant Singh and I. M. Puri. Health Bulletin no. 14, Malaria Bureau No. 6. Calcutta, India: The Government of India Press. 1959.

Covell, Gordon. *Malaria in Bombay, 1928*. Bombay, India: The Government Central Press, 1928.

Covell, Gordon. "The Present State of Our Knowledge Regarding the Transmission of Malaria by the Different Species of Anopheline Mosquitoes." *Records of the Malaria Survey of India*, vol II, no. 1 (1931).

Covell, Gordon and J. D. Baily. "Malaria in Sind Part XV. The Effects Produced by the Operation of the Lloyd Barrage Scheme on the Incidence of Malaria in Sind." *Records of the Malaria Survey of India* vol. 6, no. 3 (1936).

Covell, G. and J. D. Baily. "Malaria in Sind. Part III. The Factors Influencing the Normal Autumnal Incidence of Malaria in Larkana Taluka, Larkana District." *Records of the Malaria Survey of India* vol. I, no. 4 (1930).

Covell, Gordon and J. D. Baily. "Malaria in Sind Part IV. Malaria in Nawabshah District." *Records of the Malaria Survey of India*, vol II, no. 4 (1931).

Covell, G. and J. D. Baily. "Malaria in Sind. Part V. Malaria in Umarkot and Chhachhro Talukas of Thar and Parkar District (Lower Sind)." *Records of the Malaria Survey of India*, vol. II, no. 4 (1931).

Covell, Gordon. "Developments in the Chemotherapy of Malaria During the Last 40 Years." *R Soc Health J.* 75, no. 10 (1955).

*Indian Medical Gazette*. "Special Article: Proceedings of the International Conference on Health Problems in Tropical America." August 1925: 378–394.

*Indian Medical Gazette*. "The Report of the Malaria Commission of the League of Nations on their Indian Tour, 1929." February 1931.

Hehir, Patrick. *Malaria in India*. London: Oxford University Press, 1927.

Office of the Registrar General & Census Commissioner, India, Ministry of Home Affairs, Government of India. "Section II: Distribution and Movement." *Census Reports 1931*. https://censusindia.gov.in/Census_And_You/old_report/Census_1931n.aspx.

Ross, Ronald. "Peculiar Pigmented Cells Found in Two Mosquitoes Fed on Malarial Blood." *Indian Medical Gazette* 32, no. 9 (1897): 357–358

Ross, Ronald. "On some Peculiar Pigmented Cells Found in Two Mosquitos Fed on Malarial Blood." *British Medical Journal* 18, no. 2 (1897): 1786–1788

Russell, Paul F., Fred W. Knipe, and H. Ramanatha Rao. "On Agricultural Malaria and Its Control with Special Reference to South India." *Indian Medical Gazette* 77, no. 12: 744–754.

Sinton, J. A. "Note on the Report on 'Malaria in Sind' by Lieut.-Col. McCombie Young and S. A. S. Syed Abdul Majid." *Record of the Malaria Survey of India* vol. I, no. 3 (1930).

Sinton, J. A. "What Malaria Costs India, Nationally, Socially, and Economically." *Records of the Malaria Survey of India* vol 5. no. 3, (September 1935).

Sweet, W. C. "Irrigation and Malaria." *Proceedings of the National Institute of Sciences of India*, 4 (1938): 185–189. In Whitcombe, "The Environmental Costs of Irrigation in British India."

"Sind Irrigation Scheme: Standing Committee Appointed." *The Times of India* (January 3, 1930).

*Supplement to the British Medical Journal* (February 23, 1935): 69–76.

"The Quarter." *The Calcutta Review* 107 no. 213 (1898): 187–199.

Young, T. C. McCombie and Syed Abdul Majid. "Malaria in Sind with Reference to the Sukkur Barrage Scheme." *Record of the Malaria Survey of India* vol. I, no. 3 (1930).

***Secondary Sources***

Anderson, Warwick. "Remembering the Spread of Western Science." *Historical Records of Australian Science* (2018): A–I.

Anderson, Warwick. "Decolonizing Histories in Theory and Practice." "Forum: Decolonizing Histories in Theory and Practice." *History and Theory* 59 no. 3 (2020): 369–375.

Arnold, David. "India's place in the Tropical World, 1770–1930." *The Journal of Imperial and Commonwealth History* 26, no. 1 (1998).

Ashraf, M., M.K. Marri, I. Rao, A. Salam and M.A. Khan. “Pancho-Irrigation System - A Wasteful Practice of Irrigating Rice Fields in the Lower Indus Basin of Pakistan.” *Pakistan Journal of Agricultural Research* 51, no. 4 (2014): 867–873.

Basalla, George. “The Spread of Western Science.” *Science* 156, no. 3775 (1967): 611–322.

Bhattacharya, Nandini. *Contagion and Enclaves: Tropical Medicine in Colonial India*. Liverpool, United Kingdom: Liverpool University Press, 2012.

Bynum, William F. “An Experiment That Failed.” *Parassitologia* 36 (1994): 107-120.

Chakrabarti, Pratik. *Bacteriology in British India: Laboratory Medicine and the Tropics*. Rochester, New York: University of Rochester Press, 2012.

Cheesman, David. *Landlord Power and Rural Indebtedness in Colonial Sind 1865-1901*. Great Britain: Curzon Press, 1997.

Chopra, Preeti. *Joint Enterprise: Indian Elites and the Making of British Bombay*. Minnesota: University of Minnesota Press, 2011.

Chowdhury, Rituparna Ray. “Climatic Determinism and the Conceptualization of the Tropics in British India.” *Oxford Research Encyclopedia of Climate Science*. Published online October 2021). Retrieved June 2022. https://doi.org/10.1093/acrefore/9780190228620.013.836.

Endfield, Georgina and Samuel Randalls. “Climate and Empire.” In *Eco-cultural Networks and the British Empire: New Views on Environmental History*. Edited by James Beattie, Edward Melillo, and Emily O’Gorman. London and New York: Bloomsbury Academic.

Garcia, Javier E., Alvaro Puentes, and Manuel E. Patarroyo. “Developmental Biology of Sporozoite-Host Interactions in *Plasmodium falciparum* Malaria: Implications for Vaccine Design.” *Clinical Microbiology Reviews* 19, no. 4 (2006).

Greene, Lawrence S. and Maria Danubio. “Introduction.” In *Adaptation to Malaria: The Interaction of Biology and Culture*. Edited by Lawrence S. Greene and Maria Enrica Danubio. Amsterdam, The Netherlands: Gordon and Breach Publishers, 1997.

Gilmartin, David. “Models of the Hydraulic Environment: Colonial Irrigation, State Power and Community in the Indus Basin.” In *Nature, Culture, Imperialism: Essays of the Environmental History of South Asia*. Edited by David Arnold and Ramachandra Guha. Delhi: Oxford University Press, 1996.

Gilmartin, David. *Blood and Water: The Indus River Basin in Modern History*. Oakland, California: University of California Press, 2015.

Harrison, Mark. *Public Health in British India: Anglo-Indian preventive medicine 1859-1914*. Cambridge: Cambridge University Press, 1994.

Harrison, Mark. *Climates & Constitutions: Health, Race, Environment and British Imperialism in India 1600–1850*. Oxford: Oxford University Press, 1999.

Hirst, L. Fabian. *The Conquest of Plague: A Study of the Evolution of Epidemiology*. Oxford: The Clarendon Press, 1953.

Horsfall, William. *Mosquitoes: Their Bionomics and Relation to Disease*. New York: Hafner Publishing Company, 1972.

Hunt, Margaret R. and Philip J. Stern. "Bombay: the genealogy of a global imperial city." *Urban History* 48 (2021): 461–478.

Kidambi, Prashant. " 'An infection of locality': plague, pythogenesis and the poor in Bombay, c. 1896–1905." *Urban History* 31, no. 2 (2004): 249–267.

Klein, Ira. "Plague, Policy and Popular Unrest in British India." *Modern Asian Studies* 22, no. 4 (1988): 723–755.

Kumar, Anil. *Medicine and the Raj: British Medical Policy in India 1835–1911*. Walnut Creek, California: AltaMira Press, 1998.

Lawson, Philip. *The East India Company: A History*. New York: Longman, 1993.

Meibalan, Elemaran and Matthias Marti. "Biology of Malaria Transmission." In *Malaria: Biology in the Era of Eradication*. Edited by Dyann F. Wirth and Pedro L. Alonso. Cold Spring Harbor, New York: Cold Spring Harbor Laboratory Press, 2017.

Michalakis, Yannis and François Renaud. "Malaria: Evolution in Vector Control." *Nature* 469, no. 19 (2009): 298–300.

Moulds, Alison. *Medical Identities and Print Culture, 1830s–1910s*. EBOOK: Palgrave Macmillan, 2021.

Mulligan, H. W. "Obituary." *Transactions of the Royal Society of Tropical Medicine and Hygiene* 70, no. 1 (1976):

Neill, Deborah. *Networks in Tropical Medicine: Internationalism, Colonialism, and the Rise of a Medical Specialty, 1890-1930*. Stanford University Press, ProQuest EBook Central. 2012.

Packard, Randall M. *Making of a Tropical Disease*. Baltimore, United States of America: The Johns Hopkins University Press, 2007.

Prakash, Gyan. *Mumbai Fables*. Princeton and Oxford: Princeton University Press. 2010.

Rehman, Nida. “Unsettling a sanitary enclave: malaria at Mian Mir (1849–1910).” *Planning Perspectives* AHEAD-OF-PRINT (2022).

Rehman, Nida. “Epidemiological landscapes: the spaces and politics of mosquito control in Lahore.” PhD Dissertation, University of Cambridge, 2020.

Retief, François and Louise Cilliers. “Malaria In Graeco-Roman Times.” *Acta Classica* 47 (2004): 127–137.

Riding, Tim. “Making Bombay Island’: land reclamation and geographical conceptions of Bombay.” *Journal of Historical Geography* 59 (2018): 27–39.

Russell, Paul F. *Man’s Mastery of Malari*a. London: Oxford University Press, 1955.

Shackleton, Robert. “The Evolution of Montesquieu's Theory of Climate.” *Revue Internationale de Philosophie* 9, no. 33/34 (1955): 317–329.

Shortt, H. E., and P. C. C. Garnham. “Samuel Rickard Christophers. 27 November 1873-19 February 1978.” *Biographical Memoirs of Fellows of the Royal Society* 25 (1979): 179–207.

Sinden, Robert E. “Malaria, mosquitoes and the legacy of Ronald Ross.” *Bulletin of the World Health Organization* 85, no. 11 (2007).

Snowden, Frank M. *The Conquest of Malaria: Italy, 1900–1962*. E-book ed. 2019. Yale University Press, 2006.

Tavares, Juliana Carvalho. *Malaria*. Edited by D. Neil Granger & Joey Granger. *Colloquium series on integrated systems Physiology: from molecule to function to disease*. EBOOK: Morgan & Claypool, 2013.

Watts, Sheldon. *Epidemics and History: Disease, Power and Imperialism*. New Haven and London: Yales University Books. 1997.

Watts, Sheldon. “British Development Policies and Malaria in India 1897-c. 1929.” *Past & Present* 165 (1999): 141–181.

Whitcombe, Elizabeth. “The Environmental Costs of Irrigation in British India: Waterlogging, Salinity, Malaria.” In *Nature, Culture, Imperialism: Essays on the Environmental History of South Asia*. Edited by David Arnold and Ramachandra Guha. Delhi: Oxford University Press, 1996.