

Epidemiological risks in international travel in the 19th century

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Abstract

International travel is a factor in the risk of transmission of infectious diseases and their spread to new areas. Because infections have a limited incubation period, their spread is significantly affected by people's speed of travel, which has greatly increased in the past 100 years. The authors of this article have attempted to carry out a comparative analysis of the risks of transmission of infectious diseases. They have assessed the epidemiological risks for travellers at the end of the nineteenth century (using the information in Jules Verne's novel *Around the World in Eighty Days*) and in the twenty-first and analysed potential ways for infectious diseases to spread. Data on the speed of passenger travel (in the nineteenth century and 2020) has been taken into account and compared with the incubation periods of endemic infectious diseases. The authors analyse endemic diseases (cholera, plague, smallpox, leprosy, malaria, filariasis and equine influenza) in the regions mentioned in *Around the World in Eighty Days*, and disease incubation periods are compared with travel times. There is also an assessment of sanitary conditions in nineteenth-century London. The warfare and poor sanitary conditions in nineteenth-century Europe meant that the risk of being infected with many highly contagious diseases remained extremely high, whereas the likelihood of catching tropical diseases was low because travel was slower than it is today. In the twenty-first century, social conditions have improved, but the speed of travel has made it possible for any infectious disease to reach anywhere in the world within 48 hours.

Keywords

history of medicine, movement of people, infections, pandemic, transmission of infectious diseases, spread of infections, risk of infection, contagion

Introduction

The number of people travelling abroad has significantly increased in the past 50 years. International tourism encompasses every continent and takes place all year round. When travelling, tourists may encounter many factors affecting their health, such as injuries, the harmful effects of solar radiation, frostbite, or violence from the local population.¹

¹ For example, Ferdinand Magellan was killed by locals in the Philippines during the first circumnavigation of the globe.

Infectious diseases are not the greatest risk to travellers, but visiting endemic regions significantly increases the chance of catching them and bringing them to non-endemic regions. Today, travellers can obtain advice from various organisations: information on the epidemic situation in different regions is available from resources provided by the World Health Organization (WHO), and the US Centers for Disease Control and Prevention. A number of infections can be avoided by getting vaccinated or taking prophylactics. However, even in the "enlightened" twenty-first century, travel, particularly around the world, in-

volves dangers. The goal of this study was to carry out an epidemiological assessment of the risks of contracting infectious diseases and carrying them to other regions at the end the nineteenth century, using the information in Jules Verne's novel *Around the World in Eighty Days*, and to compare those risks with the situation in the twenty-first century.

London

Around the World in Eighty Days starts in London, when Phileas Fogg bets that he will be able to travel around the world in eighty days. When the book starts (in 1872), London, where, we are told, Phileas Fogg had lived for a long time,² had a population of more than 3 million, having doubled in the 50 years since the 1820s.³ In the mid-to-late nineteenth century, sanitary conditions there remained poor because of the lack of a mains sewerage system (people used cesspits) and mains water supply system (people drew water from pumps), and the prevalent use of horses for transport: horse dung was left lying in the streets for a long time, creating a favourable environment for germs.⁴

In 1854, there was an outbreak of cholera in Soho, a densely populated district of London where there were cowsheds and slaughterhouses (Paneth et al. 1998). There was no sewerage system, so sewage was collected in cesspools, from which it was removed and dumped into the Thames at night (doing so by day was illegal). The main source of water for the locals was

a pump with contaminated water on Broad Street. The first cases were described on 31 August 1854, and more than 600 people died. This was the first epidemic in the history of medicine to be the subject of a full-scale epidemiological study, in which Dr. John Snow marked all the cases of the disease on a map and correctly identified its source as the pump. Once its handle had been removed, there were no more new cases (Paneth et al. 1998). This district is right next to Savile Row, and Phileas Fogg would have passed it on his way to the Reform Club, so he was at risk of catching cholera long before the start of his journey (see fig.).

The improvement in London's sanitation was the result of the efforts of Edwin Chadwick, whose work led to the adoption of a number of laws, including the world's first Public Health Act in 1848. In 1851, Chadwick proposed that London's water supply companies (of which there were nine at the time) be brought together under a single centralised authority. This idea was rejected, but in 1852, the Metropolitan Water Supply Act was passed. This was intended to ensure a constant supply of water for the capital, and filtered water for its domestic users, by 1857.

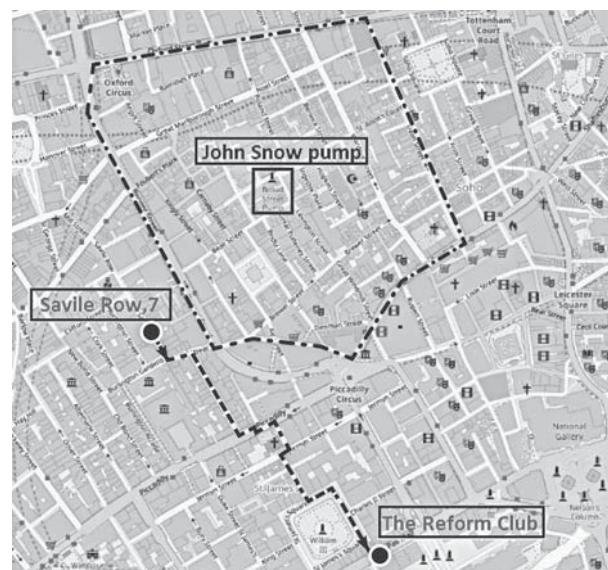


Fig. Phileas Fogg's possible route to the Reform Club (dashed line) and the boundaries of the focus of the 1854 cholera outbreak (dashed-dotted line). *Author's reconstruction.*⁵

² “Mr. Phileas Fogg lived, in 1872, at No. 7, Savile Row, Burlington Gardens, the house in which Sheridan died in 1814... It was at least certain that Phileas Fogg had not absented himself from London for many years.” Verne, Jules. *Around the World in Eighty Days*. Translated by Geo. M. Towle, Boston: James R. Osgood and Company, late Ticknor and Fields, and Fields, Osgood, and Co., 1873, p. 1–3.

³ See “A vision of Britain through time.” *Vision of Britain*, www.visionofbritain.org.uk/data_cube_page.jsp?-data_theme=T_POP&data_cube=N_TOT_POP&u_id=10097836&c_id=10001043&add=N (accessed on 07 April 2021).

⁴ See Salas, Fidel. “Sanitation During The Victorian Era.” *Prezi*, 18 April 2013, prezi.com/4k7_6t171-to/sanitation-during-the-victorian-era/ (accessed on 06 April 2021).

⁵ Based on www.openstreetmap.org.

However, this was not achieved until 1899, while the Metropolitan Water Board was founded in 1902.⁶

In 1853, Britain introduced compulsory vaccination against smallpox, thanks to which cases fell from 3,000 per million people in 1799 to 214 in 1866. However, the smallpox pandemic of 1870–1874, exacerbated by the Franco-Prussian War, also affected the British Isles, causing the worst smallpox outbreak in the nineteenth century. Thanks to the compulsory vaccination, though the number of deaths in England was high, at more than 40,000, it was still three times lower than in Prussia (Krylova and Earn 2020). Nevertheless, the outbreak prompted tighter legislation on vaccination, and the introduction of enforced smallpox vaccination led to the infection rate dropping to 10 cases per million.⁷ Despite the hard-hitting pandemic, which affected most of Europe, the word “smallpox” is not mentioned once in Verne’s novel. However, this is understandable, given that most Londoners were vaccinated by 1872, so Phileas Fogg might well have been.

Suez – Bombay

In the nineteenth century, the Red Sea region lay at the crossroads of various trade routes, and was also on the pilgrimage routes taken by Christians to Ethiopia and by Muslims to Mecca and Medina. The opening of the Suez Canal in 1869 significantly shortened the time taken to sail from Europe to Asia, which had previously involved going around Africa. At the same time, these links made it easier for infectious diseases

to spread in both directions. In particular, the Red Sea region was affected by all the well-known cholera pandemics, including the fourth (1863–1879), which peaked in 1869–1872 (Serels 2020). The reservoirs of fresh water mentioned in the novel⁸ (the Cisterns of Tawila), artificial rainwater collectors with a total capacity of more than 68,000 tonnes, could have been a source of infection, since *V. cholerae* can live in the external environment, while the density of people in the port of Aden helped the disease to spread, because the bacteria could be carried asymptotically.

Smallpox was endemic in a number of countries around the Red Sea. In particular, it has been suggested that orthopoxviruses jumped from animals to humans via camels roughly 3,500–4,500 years ago (Babkin and Babkina 2015). In the nineteenth century, however, there were large populations in what are now South Sudan, Somalia and Djibouti, as well as in the lowlands around the Ethiopian plateau, who had had no contact with the outside world and had no immunity to smallpox (Serels 2020). The opening of the Suez Canal might have facilitated the spread of the disease during the European smallpox epidemic (in 1870–1875). Phileas Fogg’s journey from London to Aden took 13 days, less than the two-week incubation period for smallpox.

Apart from cholera and smallpox, which were prevalent in the nineteenth century, East Africa was endemic for malaria, which was already known about then, and Rift Valley fever, which was discovered in 1931 (Hartman 2017). Since the average annual air temperature in Aden in October, when our heroes were in India, was 33 °C,⁹ the risk of infection with communicable diseases for travellers remains high in this month.

⁶ See Salas, Fidel. “Sanitation During The Victorian Era.” *Prezi*, 18 April 2013, prezi.com/4k7_6t171-to/sanitation-during-the-victorian-era/ (accessed on 06 April 2021); Picard L. “Health and hygiene in the 19th century.” *British Library*, 14 October 2009, www.bl.uk/victorian-britain/articles/health-and-hygiene-in-the-19th-century (accessed on 08 January 2021).

⁷ See O’Neill, Aaron. “Average number of annual smallpox deaths per million inhabitants in England during the various stages of vaccination implementation between 1700 and 1898.” *Statista*, 8 July 2020, www.statista.com/statistics/1107661/smallpox-vaccination-impact-england-historical (accessed on 09 January 2021).

⁸ “Passepartout, according to custom, sauntered about among the mixed population of Somanlis, Banyans, Parsees, Jews, Arabs, and Europeans who comprise the twenty-five thousand inhabitants of Aden. He gazed with wonder upon the fortifications which make this place the Gibraltar of the Indian Ocean, and the vast cisterns where the English engineers were still at work, two thousand years after the engineers of Solomon.” Verne, Jules. *Around the World in Eighty Days*, p. 57–58.

⁹ See “Aden Climate & Temperature.” *Climatemps*, www.aden.climatemps.com (accessed on 30 January 2021).

Bombay – Calcutta

Our heroes reach India on 20 October 1872, (the eighteenth day of their journey), and spend five days there. During this period, they encounter various situations increasing their risk of infection. India's geographical location and high temperatures, combined with high atmospheric humidity (except in its mountainous regions) created favourable conditions for the natural circulation of many micro-organisms potentially pathogenic for humans. From the mid-eighteenth century, the European expansion around the Indian Ocean, the development of transport and the increase in trade, combined with the growth of cities and ports, troop movements, pilgrimages, poverty, famine, poor sanitary conditions, labour migration and environmental degradation, created the conditions for infectious diseases to spread (Bayly 2004, p. 234). The first six cholera pandemics originated in India (the events of the novel take place when the fourth pandemic was dying down). Furthermore, Hindustan was historically hyperendemic for other diseases with faecal–oral transmission, primarily typhoid fever and amoebic dysentery, which even today are found mainly in South Asian countries (John, Van Aart, Grassly 2016; Cooke et al. 2007).

Malaria in India was for a long time caused predominantly by *P. vivax*. In the twentieth century, *P. falciparum* extended its range, becoming epidemic in various Asian countries and significantly increasing the case fatality rate. Historically, malaria was unevenly distributed in India, and was hyperendemic in the northeast. Around the turn of the twentieth century, almost a quarter of India's population suffered from malaria, particularly in the provinces of Punjab and Bengal (Tren 2002). The jungle described in the novel lies in the region of Bundelkhand (straddling the border between the modern states of Madhya Pradesh and Uttar Pradesh), where tertian malaria had historically been endemic, with a relatively low infection rate. In late October, however, when the events described in the novel take place, the temperature drops significantly at night, reducing the risk of transmission of the disease, which requires a mean daily temperature of at least +16 °C – an essential condition for the completion of *plasmodium*'s sexual cycle. Interestingly, our heroes complete part of their

journey on an elephant.¹⁰ Elephants are susceptible to infections common to many mammals (rabies, tetanus, anthrax, salmonellosis and foot-and-mouth disease). There have been cases of tuberculosis being transmitted from elephants to humans (Murphree et al. 2011). In addition, elephants are susceptible to specific infectious diseases. Elephant pox, caused by a variety of cowpox, is a serious, potentially fatal disease, and can be transmitted to humans (Kurth et al. 2008). Elephant endotheliotropic herpesviruses (EEHVs) were first discovered in the 1970s. In African elephants, they cause benign skin nodules, but in Asian elephants, they can cause acute haemorrhagic disease with a mortality rate of up to 80%. Six EEHVs have been described to date. No cases of transmission to humans have been recorded¹¹ (Atkins et al. 2013).

The states of Madhya Pradesh and Uttar Pradesh have historically been endemic for lymphatic filariasis. In India, this is caused by *Wuchereria bancrofti* (Agrawal and Sashindran 2006; Sabesan et al. 2000) and the main vectors of transmission are mosquitos of the *Culex* genus. The disease has a long incubation period. Nematodes can survive in the human body for six to eight years, and the disease can be asymptomatic, with the person infected remaining a carrier.¹² Because of the low air temperature, which is mentioned in the novel, the chances of travellers contracting lymphatic filariasis, like malaria, were low, but the local residents could have carried it asymptotically for a long time. This disease was recorded in India in the sixth century BC by the physician Sushruta in the *Sushruta Samhita* ("Sushruta's Compendium") (Agrawal and Sashindran 2006). Today, quantile mapping clearly shows that the risk of lymphatic filariasis in India is not uniform throughout the

¹⁰ "Provisions were purchased at Kholby, and, while Sir Francis and Mr. Fogg took the howdahs on either side, Passepartout got astride the saddle-cloth between them. The Parsee perched himself on the elephant's neck, and at nine o'clock they set out from the village, the animal marching off through the dense forest of palms by the shortest cut." Verne, Jules. *Around the World in Eighty Days*, p. 78.

¹¹ See International Committee on Taxonomy of Viruses (ICTV). Virus Taxonomy: 2018b Release, March 2019.

¹² See "Lymphatic filariasis." *World Health Organization*, 18 May 2021, www.who.int/news-room/fact-sheets/detail/lymphatic-filariasis (accessed on 21 February 2021).

country, but shows strong regional variation, occurring mainly in the eastern half of the country. A programme to eradicate the disease is being implemented, but it remains endemic there (Sabesan et al. 2000).

Leprosy is a chronic, slowly progressing infectious disease transmitted during close contact with those infected. First recorded in the fifteenth century BC, it is mentioned in both the Old and New Testaments (Erina and Sadretdinov 2018). Studies of bones from Indian burials dating from 2000 BC have revealed lesions typical of leprosy (Robbins et al. 2009). In the nineteenth century, British scientists studied the spread of leprosy in detail. In 1872, the Norwegian Gerhard Hansen reported the consistent presence in pus from lepromatous lesions of bacilli, which were found both within cells and freely between them (Erina and Sadretdinov 2018). In 1898, the all-India Leprosy Act confined those suffering from the disease to special institutions. In 1983, India launched a National Leprosy Eradication Programme (Mittal 1991), but the country still sees 120,000 to 130,000 new cases every year, more than 50% of the global total (Sengupta 2018, p. 131). Catching leprosy is believed to require a long period of close contact with someone infected by the disease. Given that our heroes spend just five days in India, and have little contact with the local population, their risk of catching leprosy can be regarded as low.¹³ However, they are joined in the country by a local woman, Mrs. Aouda, who, given the incubation period for leprosy, could have developed the disease in the next few years.

The opening of the Suez Canal in 1869 turned Bombay into one of the biggest ports on the Arabian Sea. According to census data, Bombay's population in 1891 was 820,000. The majority of immigrants to the city, including workers (roughly 70%), lived in the slums, which had their own endemic diseases. The ineffectiveness of the pest control measures, and the prevalence

of bubonic plague, primarily among farmers and hired farmworkers, was evidence that plague is a vector-borne disease. The first case of plague was recorded in September 1896 in the port of Mandvi, and the arid climate helped the disease to spread rapidly through the subcontinent all the way to Calcutta. By 1901, Bombay's population had shrunk by 40,000. According to statistics, the city had mortality rates of 12 per 1,000 people for tuberculosis, around 14 per 1,000 people for cholera, and 22 per 1,000 people for plague ("Bombay fever") (Echenberg 2007).

Calcutta and Bombay are two of India's biggest ports, and the large numbers and flows of people and presence of rodents there made them potential reservoirs for infections even at the best of times (Echenberg 2007; Gupte, Ramachandran, Muttakar 2001).

Calcutta – San Francisco

Unlike injections, inhaling opium¹⁴ did not lead to the spread of blood-borne infections, but the huge numbers of people smoking the drug brought China to the edge of a humanitarian catastrophe, and led to the opium wars, political instability and increased migration, including from regions where plague was endemic. The most obvious feature of the Chinese plague was the existence of at least two separate plague areas in the north and south of the country (Ben-Ari et al. 2012). The third plague pandemic possibly originated in the northwest of Yunnan Province, to which it had remained confined since the time of the earliest confirmed records of it in Dali (in 1772 or earlier according to different sources) (Kraminskii 1964).

Hong Kong, which became part of the British Empire after the First Opium War, was a key link with the USA at the end of the nineteenth century, and was a destination for many emigrants from the politically unstable Chinese mainland (Carroll 2007). The residents of such districts actively im-

¹³ "Passepartout, however, thinking no harm, went in like a simple tourist, and was soon lost in admiration of the splendid Brahmin ornamentation which everywhere met his eyes, when of a sudden he found himself sprawling on the sacred flagging. He looked up to behold three enraged priests, who forthwith fell upon him; tore off his shoes, and began to beat him with loud, savage exclamations." Verne, Jules. *Around the World in Eighty Days*, p. 65–66.

¹⁴ "Fix and Passepartout saw that they were in a smoking-house haunted by those wretched, cadaverous, idiotic creatures to whom the English merchants sell every year the miserable drug called opium, to the amount of one million four hundred thousand pounds—thousands devoted to one of the most despicable vices which afflict humanity!" Verne, Jules. *Around the World in Eighty Days*, p. 145.

peded the quarantine measures taken by the colonial authorities when, following a period of few cases of plague in Hong Kong, there was a sudden jump in the infection rate in 1894, with up to 100 deaths a day (Pryor 1975). The 1894 plague epidemic in Hong Kong was one of the fastest-spreading in the history of medicine in East Asia, reaching Macau in 1895, Taiwan in 1896, and India in 1896–1898 (Sihm 2017). The existence of shipping routes allowed the plague to spread eastwards – to India – and westwards – to San Francisco,¹⁵ i.e. along the route taken by our heroes.

The plague is not the only epidemic for which Hong Kong is notable in the history of epidemics. In 1968, the first cases of the Influenza A virus subtype H3N2, which would become known as “Hong Kong flu” were recorded on the Kowloon Peninsula.¹⁶ In March 2003, Hong Kong recorded cases of the SARS-CoV virus, which subsequently spread to Canada and Thailand, (Hung 2003), and in 2020 a resident of Hong Kong was “patient zero” in the Covid-19 outbreak on board the cruise ship *Diamond Princess* (Nakazawa, Ino, Akabayashi 2020).

Thus, Hong Kong, located in the tropics, in one of the most densely populated regions in the world, with international ports, was and remains a site of epidemic risk for both zoonotic and anthropogenic infectious diseases.

San Francisco – London

Our heroes’ voyage across the Pacific Ocean is described in just one sentence: “Eleven days later, on the 3rd of December, the General Grant entered the bay of the Golden Gate, and reached San Francisco.”¹⁷ However, it was by this route, via the Hawaiian Islands, that plague was introduced into the USA in 1900. Within just a few years, it had become endemic in a number of southwestern

states.¹⁸ Because the sailing time described in the novel exceeds the maximum incubation period for plague, had anyone on board contracted the disease, a yellow flag would have been hoisted immediately, and the ship would have been quarantined. Evidently, plague entered the US through rodents arriving on ships.

The North American leg of our heroes’ journey takes place in December 1872, at the same time as a real-world outbreak of equine influenza (Judson 1873). It is currently believed that this illness is caused by Influenza A virus subtypes H7N7 and H3N8. The disease is highly contagious among odd-toed ungulates, and is marked by fever, rhinorrhoea, coughing and a long recovery period (up to six months) (Paillot 2014). We do not know how contagious these genotypes of the virus are for humans, but in the nineteenth century the epidemic crippled postal and transport services and army cavalry units. The outbreak began in Canada in October 1872, spread throughout the continent, and reached the US West Coast by April 1873, doing serious damage to the US economy: 63% of all the horses in New York fell ill (the case fatality rate was from 1 to 10%), and transport services stopped working in major cities (Judson 1873; Paillot 2014). In December 1872, the disease was widespread in the states of Iowa and Nebraska, where our heroes meet the Sioux. Verne does not mention the disease, but the reason why the novel does not talk about the use of horses by the Sioux or the army, becomes clear in the context of the outbreak.

Conclusion

The development of transport resources in the second half of the twentieth century enabled significantly faster travel. The opening of the Suez Canal made communications between Europe, on one hand, and Africa and Asia, on the other, easier. However, these developments also allowed the fourth (in 1863–1875) and subsequent cholera pandemics and the third plague pandemic (in 1855–1959) to

¹⁵ See The Editors of Encyclopaedia Britannica. “Plague.” *Encyclopaedia Britannica*, 6 August 2020, www.britannica.com/science/plague (accessed on 28 February 2021).

¹⁶ See “1968 Pandemic (H3N2 virus).” *Centers for Disease Control and Prevention*, 2 January 2019, www.cdc.gov/flu/pandemic-resources/1968-pandemic.html (accessed on 06 March 2021).

¹⁷ Verne, Jules. *Around the World in Eighty Days*, p. 202.

¹⁸ See “Maps and Statistics / Plague in the United States.” *Centers for Disease Control and Prevention*, 27 May 2021, www.cdc.gov/plague/maps/index.html (accessed on 06 March 2021).

spread more quickly to Europe.¹⁹ The spread of the diseases followed practically the same route as that described in Verne's novel. Bearing in mind the travel dates and locations described in the novel, our heroes were at the greatest risk of contracting infectious diseases in India, because of the relatively long time they were there, as well as their visit to the jungle region, and the contacts they had with locals and animals. Diseases with long incubation periods, such as leprosy, lymphatic filariasis, rabies, or those that were subclinical and asymptomatic, primarily the carrier state of *v. cholerae*, could have been brought to Europe. Most diseases have an incubation period of two or three weeks, so they should have emerged during the journey before Europe was reached.

Today, travelling times have significantly reduced: starting from London, one can fly around

the world in 47 hours via Hong Kong and San Francisco using scheduled passenger services.²⁰ Of course, one would not be able to leave the airport between flights, reducing the risk of infection with zoonotic infectious diseases. However, the large number of people in confined spaces, travelling in different directions, presents a risk of the spread of airborne infections (this is how Covid-19 spread around the world). It is becoming clear that round-the-world air travel in the twenty-first century fits into the incubation periods of the overwhelming majority of infectious diseases: the International Health Regulations ratified in 2005²¹ cover 25 infectious diseases, and this list will be expanded as new infectious agents with the potential to cause pandemics or public health threats are discovered.

¹⁹ It is worth noting that the third cholera pandemic (in 1833–1860) spread by land routes via the South Caucasus and the Black Sea region, before hitting Western Europe.

²⁰ See www.skyscanner.com

²¹ See World Health Organization. International Health Regulations (2005), 2nd ed., Geneva, 2008, 82 pp. ISBN 978 92 4 458041 7.

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