The impact of climate change on future mortality in Hong Kong

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Key Takeaways

RGA conducted a thorough review of the academic literature to assess the possible impact climate change could have on future mortality in Hong Kong in 2050 under a “middle of the road” emissions scenario.

For those physical risks where the change could be estimated, two key risks were identified: increasing average temperatures could increase the mortality of an aging population by 4%; whereas reduced air pollution could reduce mortality by 3%. The impact of climate change on mortality linked to food insecurity could be material, but it was not possible to quantify this. All other physical risks are expected to have a relatively immaterial mortality impact.

The overall impact of climate change physical risks on mortality in Hong Kong is anticipated to be relatively modest, with annual population deaths potentially increasing by around 1% in 2050. This impact would be reduced by adaptation measures taken to mitigate these physical risks.

In contrast, transition policies could have a significant positive impact on diet and active travel, leading to improved health and lower mortality, although this could be difficult to achieve as it would require widespread behavioral change and significant infrastructure investment.

This result may be counter to expectations of a more significant impact, although we need to recognize the uncertainties involved. Importantly, these findings do not absolve society from taking action – both in Hong Kong and globally – to limit greenhouse gas emissions and future climate change impacts.

Introduction

Estimates from the World Economic Forum (WEF), made in collaboration with Oliver Wyman, suggest that, cumulatively by 2050, climate change could lead to an additional 14.5 million deaths worldwide under a "middle of the road" greenhouse gas emissions scenario, driven by floods, droughts, heatwaves, and tropical storms.[1]

To a first-order approximation, the WEF/Oliver Wyman estimates imply that annual average global mortality rates could increase by around 1% by 2050.

Vulnerability to these climate change risks varies by region, and so it is to be expected that if the average impact is 1%, some regions may see a significantly higher increase in mortality rates.

Asia is expected to be affected by most risks associated with climate change. The WEF analysis points to the vulnerability of Asia to tropical storms and Southeast Asia in relation to floods and heatwaves.

Given the importance of the insurance market in Hong Kong, RGA reviewed the academic literature to assess the possible impact climate change could have on future mortality in Hong Kong by 2050 under the SSP2-4.5 "middle of the road" emissions scenario.

SSP2-4.5 is one of five scenarios used in the Intergovernmental Panel on Climate Change's (IPCC) Sixth Assessment Report (AR6) to illustrate potential climate futures.

It reflects the SSP2 shared socioeconomic pathway, under which there are medium challenges to climate mitigation and adaptation. In this scenario, social, economic, and technological trends do not shift markedly from historical patterns.[2]

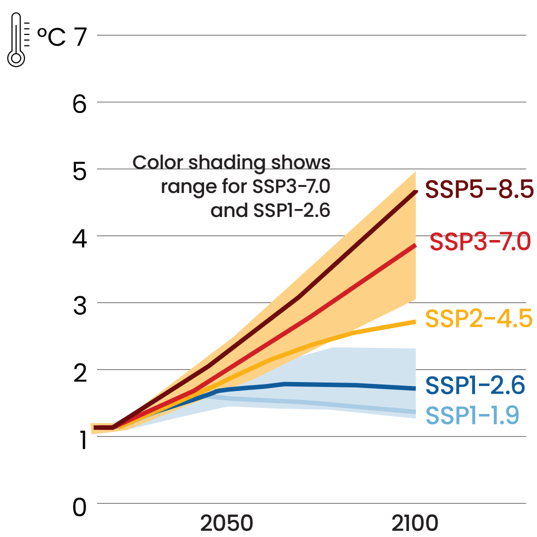
As shown in Figure 1, under SSP2-4.5, average global surface temperatures in 2050 are expected to be around 2°C higher than the pre-industrial average over 1850-1900. This would be an increase of around 1°C from today, and so we refer to this as a "1°C warming scenario" in this report.

The key physical risks that could impact future mortality considered in this report are:

- Change in average temperatures
- Noncompensable heat stress
- Air pollution
- Droughts
- Floods (extreme rainfall)
- Food insecurity
- Vector-borne diseases
- Tropical cyclones, storm surges (coastal flooding), and sea level rise

The paper also explores the potential impact associated with transition policies that could improve diet and active travel.

Figure 1: Global average surface temperature changes relative to 1850-1900



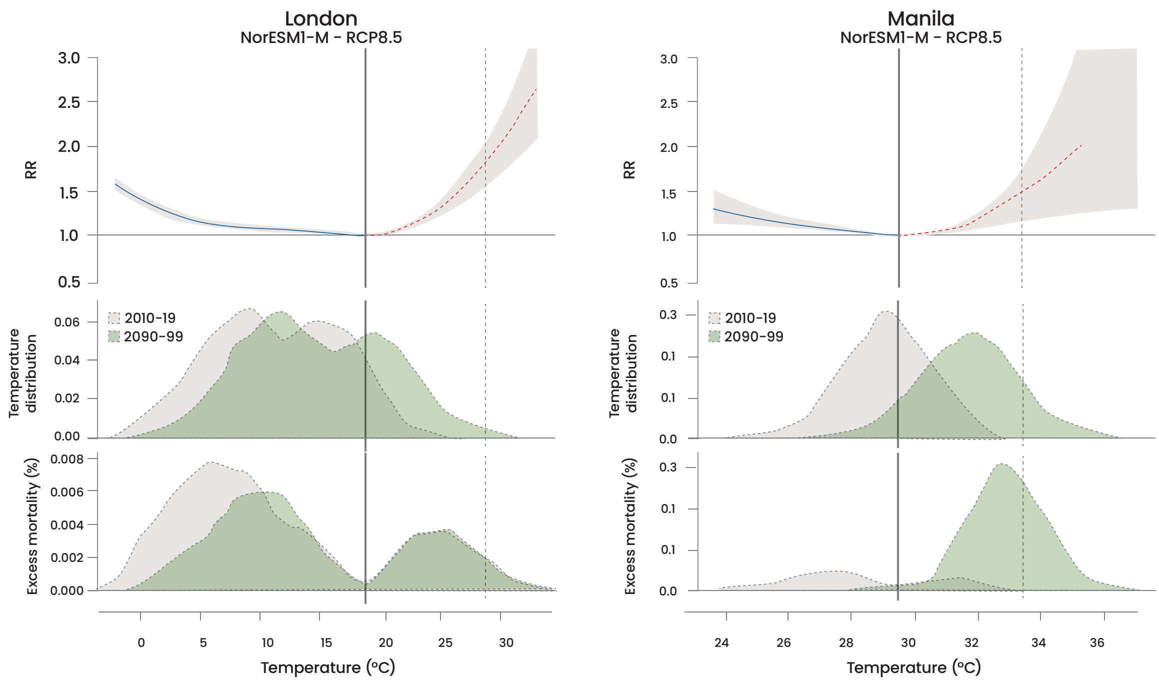
Extracted from IPCC, 2023: Climate Change 2023: Synthesis Report.[3]

Change in average temperatures

The general U-shaped temperature-mortality relationship illustrated in Figure 2 is now well established in the academic literature. Relative mortality risk is minimized at a location-specific optimum temperature. When temperatures fall below the optimum level, relative mortality risk increases, leading to "cold-related" deaths. When temperatures rise above the optimum level, mortality risk increases, leading to "heat-related" deaths.

The optimum temperature varies by location and is generally higher in warm regions and lower in cold regions because populations acclimatize to local temperatures.

Figure 2: Temperature and excess mortality in different climates, illustrated using estimates for London (left panels) and Manila (right panels); see Gasparrini et al. (2017) for full description



Extracted from Gasparrini et al. (2017), available under [CC BY 4.0](). No changes have been made.

The top graphs illustrate the temperature-mortality relationship in each city, with the solid vertical line indicating the temperature at which mortality risk is minimized. The middle graphs show the temperature distribution for the period 2010-2019 (in gray) and projected over 2090-2099 (green). The bottom graphs show the resulting distribution of excess mortality arising from non-optimal temperatures relative to the minimum risk temperature.

As temperatures rise, cold-related deaths are expected to decrease while heat-related deaths increase.

Chen et al. (2024) estimated the current temperature-mortality relationship in Hong Kong, illustrated by the black line in Figure 3.

Figure 3 also shows the relationship between temperature and all-cause mortality for different age groups. With increasing age comes increasing risk of both cold- and heat-related mortality.

Gasparrini et al. (2015) estimate that approximately 7.7% of the total mortality burden in Hong Kong is related to non-optimal temperatures. This breaks down as approximately 7.5% related to cold-related mortality and 0.2% related to heat-related mortality.

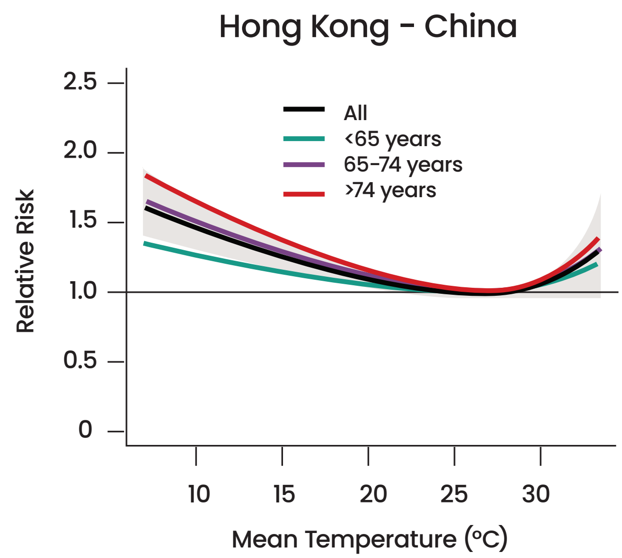
In the context of around 52,000 population deaths per year in Hong Kong,[4] this is broadly equivalent to around 4,000 deaths per year due to non-optimal temperatures, of which around 3,900 are cold-related deaths and 100 are heat-related deaths.

Projections of temperature-related excess mortality under SSP2-4.5 are not published for Hong Kong but can be estimated indirectly:

- We can compare projected temperature-related mortality under the "extreme" RCP8.5 scenario from Gasparrini et al. (2017) for Hong Kong relative to mainland China and Taiwan.
- We can assume that Hong Kong will see a similar relative temperature-related mortality impact compared to mainland China and Taiwan under the "middle of the road" RCP4.5 scenario.

We can then allow for the estimated impact of population aging on temperature-related mortality using the results from Chen et al. (2024), assuming Hong Kong experiences a similar impact to China overall.

Figure 3: Temperature-mortality relationships in Hong Kong; see Chen et al. (2024) for full description



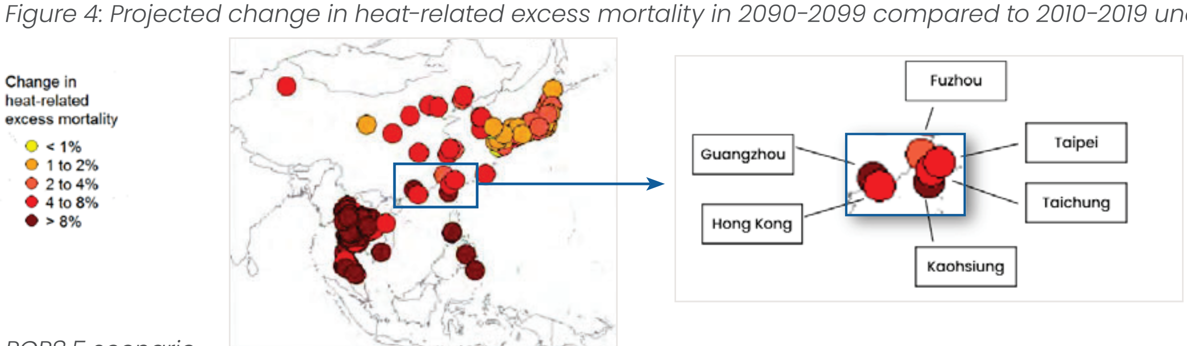
Extracted from Chen et al. (2024), available under CC BY 4.0. No changes have been made.

Projected temperature-related mortality under the RCP8.5 scenario for Hong Kong relative to China and Taiwan

Gasparrini et al. (2017) projected temperature-related excess mortality for 451 cities from 23 countries around the world, including Hong Kong, under four different future climate change scenarios over two future time periods. The exact results for Hong Kong were not provided, but we can approximate them based on the available information.

The extract in Figure 4 shows the projected change in heat-related excess mortality in 2090-2099 compared to 2010-2019 under the RCP8.5 scenario. The call-out box highlights Hong Kong, Guangzhou, and Fuzhou in China, as well as Kaohsiung, Taipei, and Taichung in Taiwan.

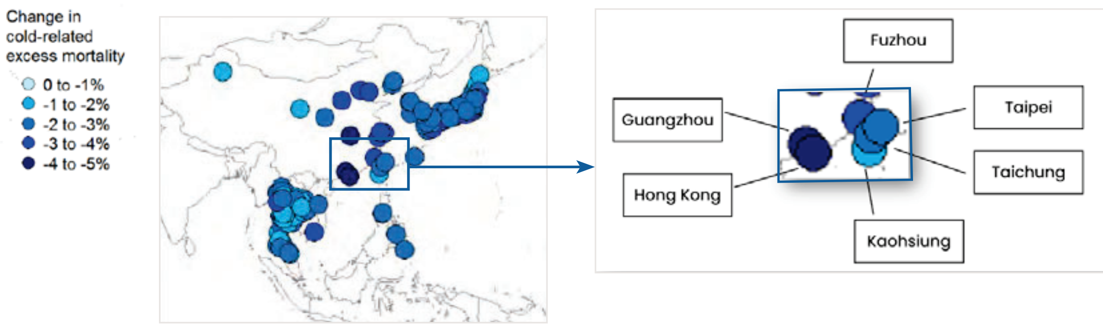
Figure 4: Projected change in heat-related excess mortality in 2090-2099 compared to 2010-2019 under the RCP8.5 scenario



Extracted from Gasparrini et al. (2017), available under CC BY 4.0. The call-out box and city labels have been added.

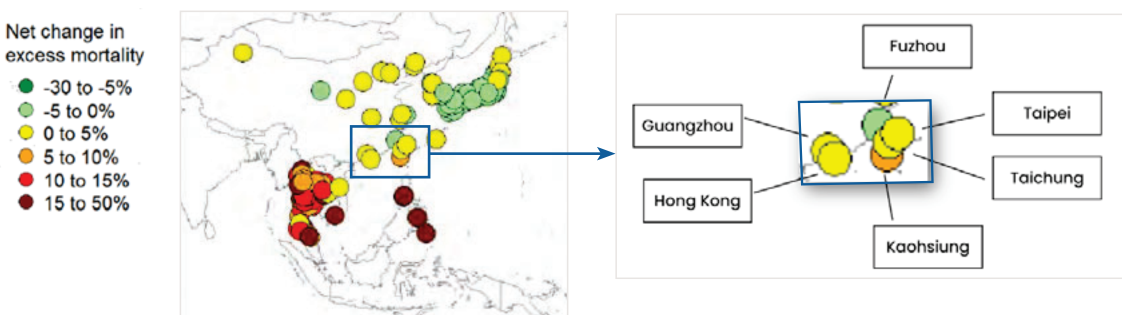
The extract in Figure 5 shows the projected change in cold-related excess mortality, and the extract in Figure 6 shows the projected net change in temperature-related excess mortality.

Figure 5: Projected change in cold-related excess mortality in 2090-2099 compared to 2010-2019 under the RCP8.5 scenario



Extracted from Gasparrini et al. (2017), available under CC BY 4.0. The call-out box and city labels have been added.

Figure 6: Projected net change in temperature-related excess mortality in 2090-2099 compared to 2010-2019 under the RCP8.5 scenario



Extracted from Gasparrini et al. (2017), available under CC BY 4.0. The call-out box and city labels have been added.

These figures indicate that under the RCP8.5 scenario, the projected net change in temperature-related excess mortality from 2010-2019 to 2090-2099 in **Hong Kong is slightly higher than the overall projected net change in China, and slightly lower than the projected net change in Taiwan.**

Estimated temperature-related mortality in Hong Kong under the RCP4.5 scenario

Table 1 shows the detailed projection results from Gasparrini et al. (2017) for China and Taiwan under RCP4.5 and RCP8.5. If we assume that under RCP4.5 Hong Kong would also fall somewhere between the overall net change in China and Taiwan, this would suggest that between 2010-2019 and 2050-2059, Hong Kong might see somewhere between a small net increase in temperature-related mortality of 0.2%, or a small reduction of 0.5%.

Table 1: Heat-related, cold-related, and net excess mortality (%) by country, period, and climate change scenario

		RCP4.5			RCP8.5		
		2010-19	2050-59	2090-99	2010-19	2050-59	2090-99
	Heat	0.8	1.7	2.3	1.0	2.4	6.1
China	Cold	10.9	9.6	9.1	10.8	8.9	7.1
	Net	-	(0.5)	(0.3)	-	-0.4	1.5
	Heat	1.3	2.3	3.0	1.3	3.2	7.3
Taiwan	Cold	4.6	3.7	3.3	4.5	3.2	2.0
	Net	-	0.2	0.5	-	0.6	3.5

Source: Gasparrini et al. (2017), available under CC BY 4.0. The highlight boxes have been added.

Estimated temperature-related mortality in Hong Kong under the SSP2-4.5 scenario after allowing for estimated impact of population aging

As shown in Figure 3, older individuals face a greater risk of both cold-related and heat-related mortality. Chen et al. (2024) estimated how future temperature-related excess mortality might change in China under different levels of global warming, allowing for the impact of population aging. They considered an "extreme" emissions scenario (SSP5-8.5), so their results should show a slightly greater mortality impact than might be seen in the "middle of the road" emissions scenario (SSP2-4.5) we are considering.

Chen et al. (2024) estimated that under 2°C warming relative to the pre-industrial (1850-1900) average, which would be reached between 2032 and 2051:

- When considering only the impact of rising average temperatures, cold-related mortality in China would decline by around 1.3% of annual population deaths, whereas heat-related mortality would increase by approximately 1.1%. (Note: this is a net reduction of 0.2%, which is broadly consistent with the projected net reduction from Gasparrini et al. (2017) of 0.4% by 2050-2059 under RCP8.5, as shown in Table 1.)
- When also allowing for anticipated population aging in the future, both cold- and heat-related deaths would increase, by around 2.3% and 1.6%, respectively, of annual population deaths. This would result in a net increase of approximately 3.9% of annual population deaths due to non-optimal temperatures.

If population aging has a similar impact in Hong Kong, the estimated temperature-related mortality impact under SSP2-4.5 could increase annual deaths by up to 4% in 2050.

Table 2: Estimated current population mortality impact from non-optimal temperatures and how this may change by 2050 under a 1°C warming scenario for Hong Kong

Physical Risk	**Estimated Current Population Impact** Current annual population deaths estimated to be attributable to risk	**Potential Change in Population Impact by 2050 in 1°C Warming Scenario** Increase/(reduction) in annual deaths estimated to be attributable to risk
Average temperatures		Net 4%
• Cold-related	7.5%	
• Heat-related	0.2%	

Chen et al. (2024) acknowledge that their analysis does not consider potential population adaptation to heat. Adaptation can be achieved in several different ways:

- **Acclimatization.** Through repeated exposure to heat, individuals develop a more efficient and effective cooling response, leading to improved thermal comfort.
- **Aerobic training.** The cooling response can place strain on the cardiovascular system; improved fitness achieved through aerobic training can help individuals cope with this strain.
- **Adjusting behaviors.** The impact of periods of extreme heat can be mitigated by reducing physical activity, increasing water intake, and seeking refuge in cool places.
- **Technology.** External cooling can be achieved by utilizing air-conditioning or electric fans.

Table 3 illustrates the estimated number of heat-related deaths that were averted by air-conditioning (AC) in several countries or regions in 2019, taken from the 2021 report of the Lancet Countdown.

Table 3: Estimates by country or region of AC- and heat-related mortality

Country or Region	Households with AC	Heat-related deaths	Heat-related deaths averted by AC	AC-related PM2.5 deaths
Japan	93%	12,400	30,415	162
South Korea	89%	2,500*	5,416	69
China	65%	72,000	5,416	5,027
ASEAN	24%	11,840*	2,678	560
USA	92%	20,500	47,807	557
UK	3%	5,600*	126	46

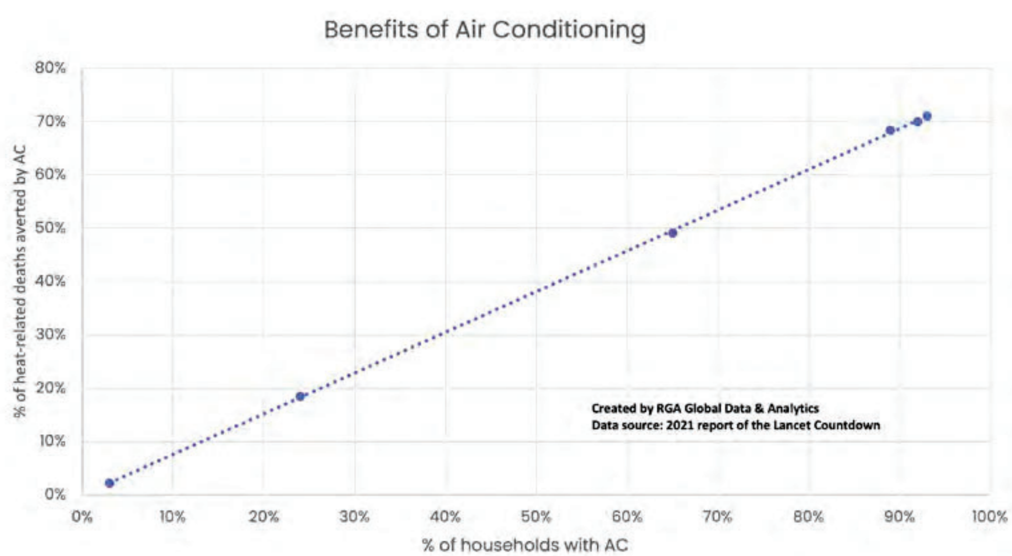
Data source: 2021 report of the Lancet Countdown. *Indicates average over 2014-2019.

Figure 7 shows a plot of this data with:

- The estimated percentage of households with AC on the x-axis
- The estimated percentage of heat-related deaths averted by AC on the y-axis

The data points lie on a line with gradient 75%, implying that AC reduces heat-related deaths by approximately 75%.

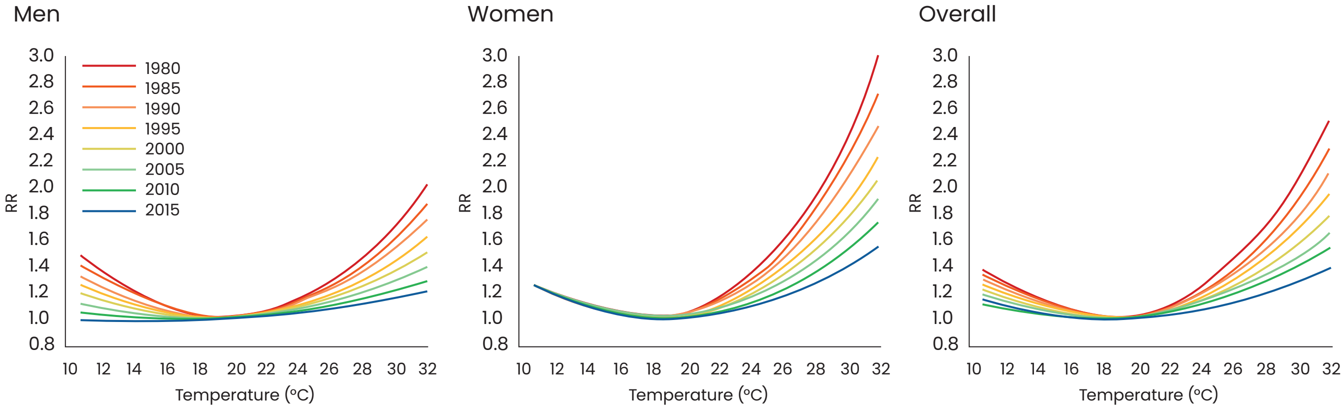
Figure 7: Plot of data from Table 3 and best-fit line.



According to government data, more than 99% of Hong Kong homes are air-conditioned.[5] If the estimates made in the 2021 report of the Lancet Countdown are correct, this would reduce heat-related mortality in Hong Kong by nearly 75%.

To illustrate the potential impact of adaptation over time, Figure 8 shows results from Achebak et al. (2018) on how the modeled temperature-mortality relationship for circulatory causes of death has changed over time in Spain (data for Hong Kong is unavailable). The top line (red) in each chart shows the estimated relationship in 1980, while the bottom line (blue) depicts the estimated relationship in 2015. Although average temperatures increased over this period, due to adaptation, temperature-mortality risk relationship has reduced for both cold- and heat-related mortality due to adaptation.

Figure 8: Estimated temperature-mortality relationships by calendar year for circulatory causes of death; see Achebak et al. (2018) for full description



Extracted from Achebak et al. (2018), available under [CC BY 4.0](). No changes have been made.

Noncompensable heat stress

In addition to increasing average temperatures, we can expect an increase in periods of extreme temperatures not yet reflected in the historical record.

Healthy human core body temperature ranges from 36°C to 37°C. If core body temperature reaches 43°C, the risk of death is very high.

Noncompensable heat stress refers to environmental conditions of temperature and humidity under which a healthy human can no longer maintain a stable core body temperature without the assistance of external cooling.

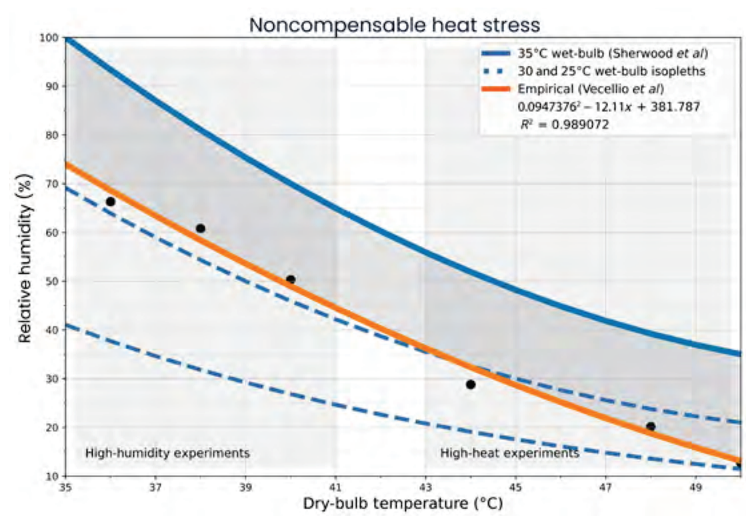
Under these conditions, without external cooling, core body temperature rises by around 1°C per hour. After about six hours of exposure, core body temperature can increase from the normal healthy range to the dangerous 43°C level.

Noncompensable heat stress occurs in environments where the combination of dry-bulb temperature and relative humidity exceeds conditions indicated by the orange line in Figure 9.

For example, if the dry-bulb temperature – the temperature a thermometer would show if held up in the air – showed 45°C and the relative humidity of the environment was 30% or higher, this combination of conditions would fall within the noncompensable heat stress danger zone.

Powis et al. (2023) estimated which regions of the world are expected to experience days including six hours of continuous noncompensable heat stress conditions, together with the expected period between such days, under different scenarios of global warming.

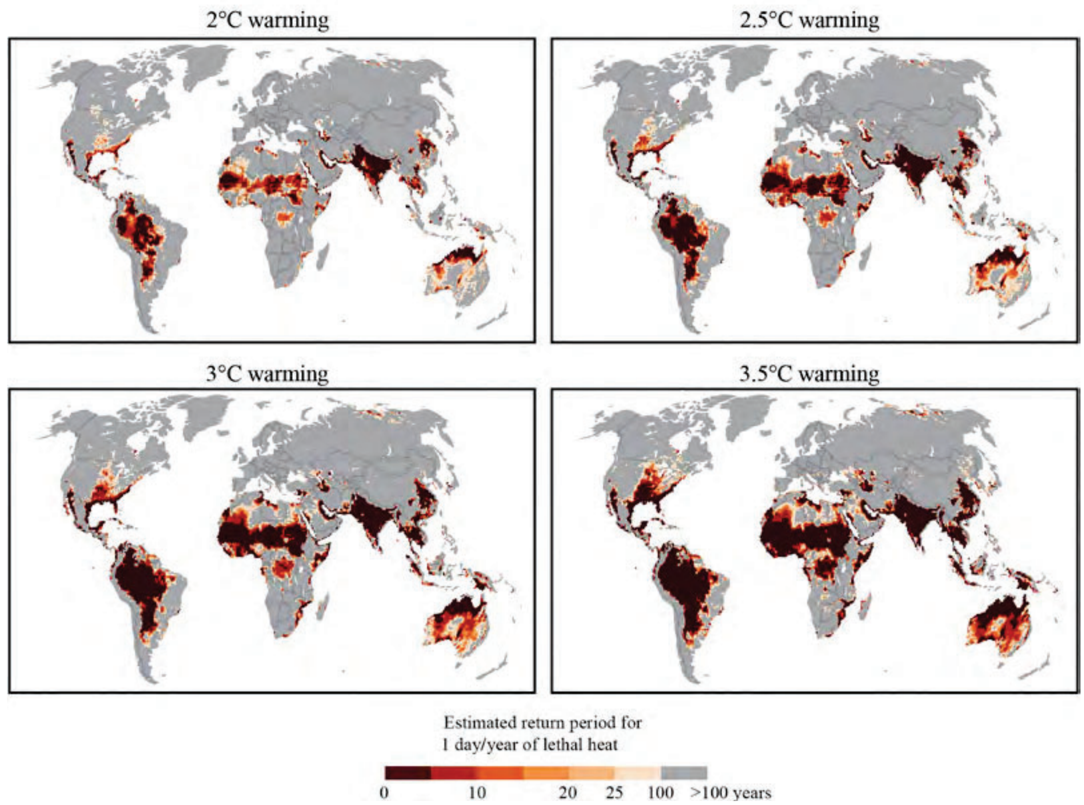
Figure 9: Noncompensable heat stress; see Powis et al. (2023) for full description



Extracted from Powis et al. (2023), available under [CC BY 4.0](). No changes have been made.

Their results are shown in Figure 10. Darker shades of orange and red indicate areas that would see shorter periods between days experiencing six hours of continuous noncompensable heat stress conditions.

Figure 10: Estimated return periods between days with at least six hours of continuous noncompensable heat stress in a given year; see Powis et al. (2023) for full description

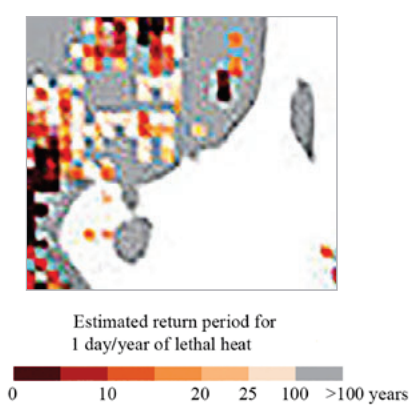


Extracted from Powis et al. (2023), available under CC BY 4.0. Panels contain results for different global average temperatures above pre-industrial levels. No changes have been made, although results for 1°C and 1.5°C warming have been omitted.

A closer look at the coast of China, between the islands of Hainan to the west and Taiwan to the east (the pixilated image in Figure 11), reveals that in the scenario of 2°C warming relative to pre-industrial average temperatures, no coastal areas are expected to experience six-hour periods of noncompensable heat stress.

Therefore, while noncompensable heat stress could be a significant issue for regions such as India, northern Australia, or areas of South America, it is not expected to be a significant issue for Hong Kong by 2050 under the SSP2-4.5 scenario.

Figure 11: Estimated return periods between days with at least six hours of continuous noncompensable heat stress in a given year, coastal China between Hainan and Taiwan, under scenario of 2°C increase in global average temperature above pre-industrial baseline



Extracted from Powis et al. (2023), available under CC BY 4.0. No changes have been made.

Air pollution

The Centre for Health Protection in the School of Public Health at the University of Hong Kong estimates that approximately 6% of all-cause deaths are attributed to air pollution (see Figure 12).

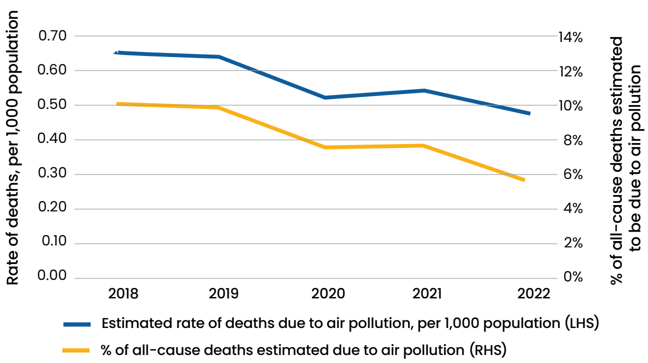
Key sources of air pollution in relation to its impact on mortality are particulate matter with a diameter less than 2.5 micrometers (PM2.5), nitrogen dioxide (NO2), and ozone. Mortality risk increases by around:

- 6% per 10 microgram per cubic meter increase in long-term exposure to PM2.5[6]
- 3.2% per 10 micrograms per cubic meter increase in long-term exposure to NO2[7]
- 0.2% per 10 microgram per cubic meter increase in short-term exposure to ozone[8]

Figure 13 shows how PM2.5 air pollution levels have changed over time at select air quality monitoring stations in Hong Kong. The green lines show the air quality guidelines (AQG) recommended by the WHO in 2005 (dashed line) and in 2021 (solid line). The red box highlights the period 2018-2022, which corresponds to the period shown in Figure 12.

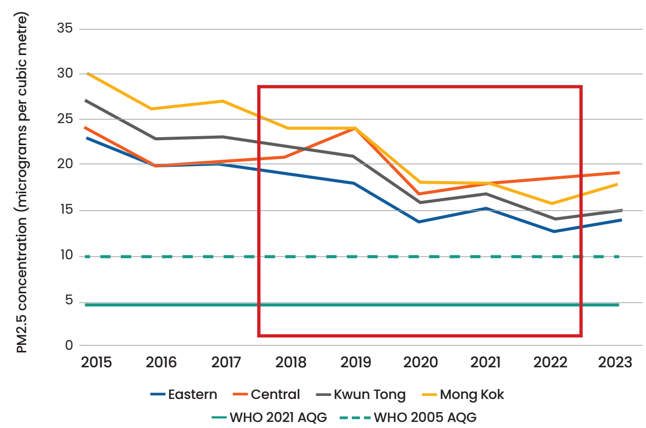
Figure 14 shows how NO2 air pollution levels have changed over time at select air quality monitoring stations in Hong Kong. Again, the green lines show the AQG levels recommended by the WHO in 2005 (dashed line) and in 2021 (solid line), and the red box highlights the period 2018-2022.

Figure 12: Estimated deaths due to air pollution in Hong Kong



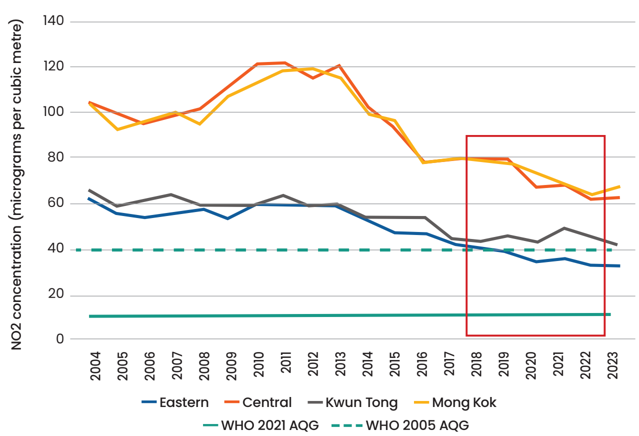
Data source: Centre for Health Protection, School of Public Health, University of Hong Kong.

Figure 13: PM2.5 air pollution levels at select air quality monitoring stations in Hong Kong



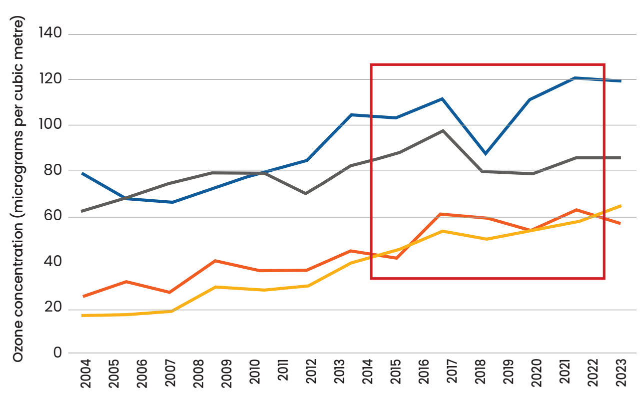
Data source: Environmental Protection Agency, Hong Kong.

Figure 14: NO2 air pollution levels at select air quality monitoring stations in Hong Kong



Data source: Environmental Protection Agency, Hong Kong.

Figure 15: Ozone air pollution levels at select air quality monitoring stations in Hong Kong



Data source: Environmental Protection Agency, Hong Kong.

Figure 15 shows how ozone air pollution levels have changed over time at select air quality monitoring stations in Hong Kong. Again, the green lines show the AQG levels recommended by the WHO in 2005 (dashed line) and in 2021 (solid line), and the red box highlights the period 2018-2022.

PM2.5 and NO2 levels – the air pollutants with the greatest impact on mortality – generally declined over the period 2018-2022, driving the reduction in estimated deaths from air pollution during this period. Ozone levels increased over the period, but this is expected to have only a small negative impact on mortality.

However, although PM2.5 and NO2 levels have declined, they remain well above the AQG levels recommended by the WHO in 2021,[9] indicating further room for reduction.

The Clean Air Plan for Hong Kong,[10] published in June 2021, builds upon an earlier version from March 2013. The plan aims to:

- Transform Hong Kong into a livable city with air quality comparable to major international cities by 2035.
- Ultimately, achieve air quality targets established by the WHO guidelines.

Table 4 shows the annual average concentration of PM2.5 and NO2 in Hong Kong in 2023, taken from the Clean Air Network's 2023 annual air quality review,[11] along with the 2021 air quality guideline from the WHO.

Table 4: Annual average concentration of PM2.5 and NO2 in Hong Kong in 2023, and WHO air quality guideline from 2021

	Hong Kong 2023 Micrograms per cubic meter General/Roadside	**WHO 2021 AQG** Micrograms per cubic meter
PM2.5 (annual)	18 / 22	5
NO2 (annual)	34 / 63	10

To meet the WHO AQG 2021 targets, general PM2.5 and NO2 levels in 2023 would need to decline by approximately 70%.

Is this reduction achievable? The Hong Kong Environmental Protection Department's 2021 emissions inventory indicates that approximately 35% of PM2.5 air pollution originates from hill fires. As a result, hill fires alone would take PM2.5 levels above the WHO AQG 2021 limits, and hill fires are a difficult source of PM2.5 air pollution to control.

For our purposes, we assume that air pollution levels in Hong Kong will decline by approximately 50% by 2050 and will reduce mortality from air pollution proportionately.

Table 5: Estimated current population mortality impact from air pollution and projected changes by 2050 under a 1°C warming scenario for Hong Kong

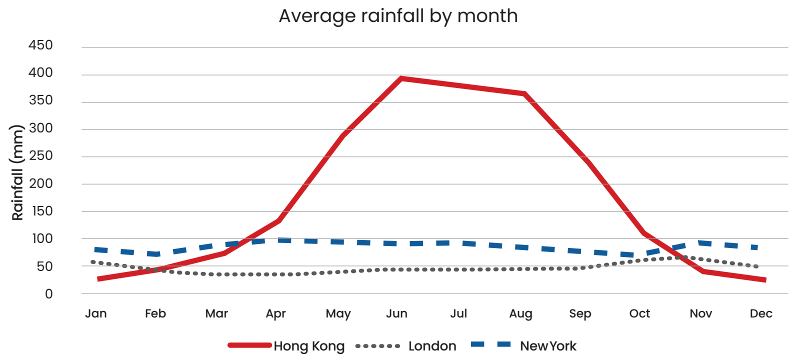
Physical Risk	**Estimated Current Population Impact** Current annual population deaths estimated to be attributable to risk	**Potential Change in Population Impact by 2050 in 1°C Warming Scenario** Increase/(reduction) in annual deaths estimated to be attributable to risk
Air pollution	6%	(3)%

Droughts

Hong Kong has a subtropical climate with substantial levels of annual rainfall, as illustrated in Figure 16, which compares it to rainfall in London and New York.

However, Hong Kong has no natural lakes, rivers, or substantial underground water sources and relies on man-made reservoirs to store rainfall. Since the 1960s, these reservoirs have been insufficient to meet the city's annual water needs, necessitating that water be supplied from the Dongjiang River in mainland China.

Figure 16: Average rainfall in Hong Kong by month



Data source: UK Met Office.

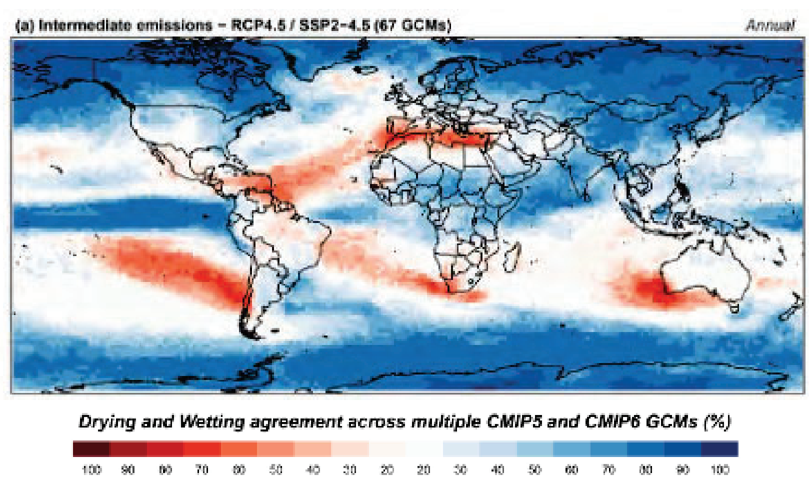
In 2023-2024, Hong Kong's freshwater consumption was estimated to be 1,064 million cubic meters. Of this, 816 million cubic meters (around 77%) was supplied from the Dongjiang River and the rest (some 248 million cubic meters) from local reservoirs.[12]

The current agreed ceiling for the annual supply of water to Hong Kong from the Dongjiang River is 820 million cubic meters. However, the system has capacity to provide 1,100 million cubic meters, intended to ensure continuous water availability even during extreme drought conditions with a return period of 1-in-100 years.[13]

Because Hong Kong depends on water supplied from the Dongjiang River, it faces the risk of drought in the Dongjiang River basin.

The Dongjiang River also supplies more than 90% of the water consumed in the mainland city of Shenzhen (population: over 17 million). Media reports in December 2021[14] and January 2022[15] stated that Shenzhen faced its most severe drought since the city was established in 1979, while the Dongjiang River experienced its worst drought since 1963. The same media reports projected that Shenzhen could face a water shortage of 890 million cubic meters by 2030. The implications of Shenzhen's projected shortage for the water supply to Hong Kong are not clear but could be negative.

Figure 17: Map indicating the level of agreement among 67 global climate models as to whether the future will be drier (red) or wetter (blue); see Trancoso et al. (2024) for full description



Extracted from Trancoso et al. (2024), available under CC BY 4.0. No changes have been made.

The risk of drought in the Dongjiang River depends on future precipitation levels, and projecting future precipitation levels is difficult. There are large areas of the world where global climate models (GCMs) don't necessarily agree whether the future will be wetter or drier. This is illustrated in Figure 17.

Trancoso et al. looked at 67 GCMs and identified areas where the models agreed the future under the SSP2-4.5 scenario would be drier (colored red on the map) or wetter (colored blue). The darker colors indicate where there was a greater level of agreement among the 67 GCMs.

A closer analysis of the coast of China, between the islands of Hainan in the west and Taiwan in the east, suggests some agreement among the models that this region, including Hong Kong and the Dongjiang River basin, will experience a wetter future under the SSP2-4.5 scenario.

With no recent, significant drought events in Hong Kong and the Dongjiang River basin linked to increased mortality, and with a wetter future likely under SSP2-4.5, we will assume that droughts related to climate change will not be a significant driver of future mortality in Hong Kong.

However, it is possible that water security could be a risk for Hong Kong in the event of an extreme drought in future.

Figure 18: Map indicating the level of agreement among 67 global climate models as to whether the future will be drier (red) or wetter (blue) along the coast of China; see Trancoso et al. (2024) for full description

Floods

As noted earlier, Hong Kong does experience substantial rainfall, and this can lead to significant floods. As shown in Figure 18, there is some agreement among global climate models that Hong Kong could see higher rainfall in the future, which would increase flooding risk.

In September 2023, Typhoon Haikui passed approximately 250km northeast of Hong Kong, bringing the heaviest rainfall recorded in 140 years – about 25% of annual rainfall fell in 24 hours.[16] This led to widespread flooding and landslides. Schools were closed and the stock market was suspended. More than 140 people were injured, but only two fatalities were reported.[17] As these deaths were reported during the floods arising from Typhoon Haikui, they are likely to have been direct deaths.

Yang et al. (2023) examined the link between floods and mortality, looking at both direct deaths, such as drowning, and indirect deaths caused by food and water contamination. They found that, in mainland China and in Taiwan, during the period up to 60 days after exposure to floods, all-cause mortality risk increased by 13% and 11%, respectively, although these results were not statistically significant.

Applying the findings of Yang et al. (2023) to the severe flooding event caused by Typhoon Haikui suggests that, even if indirect deaths were included, the overall mortality impact would still be very low.

Even if climate change were to double the risk of extreme rainfall by 2050 in a 1°C warming scenario and we make the broad assumption that this would lead to a proportionate increase in the number of deaths, the increase in deaths due to flooding in Hong Kong in 2050 would still be below 0.1% of annual population deaths.

Table 6: Estimated current population mortality impact from floods due to extreme rainfall and how this may change by 2050 under a 1°C warming scenario for Hong Kong

Physical Risk	**Estimated Current Population Impact** Current annual population deaths estimated to be attributable to risk	**Potential Change in Population Impact by 2050 in 1°C Warming Scenario** Increase/(reduction) in annual deaths estimated to be attributable to risk
Floods (extreme rain)	< 0.1%	< 0.1%

Food insecurity

Food insecurity refers to barriers to access sufficient nutritious food for a healthy life.

Hong Kong imports around 95% of its food and is significantly exposed to changes in global food prices and supply. Approximately 20% of the population of Hong Kong is estimated to live in poverty.

Food insecurity can increase mortality risk, as shown in Table 7, which is based on research from Ma et al. (2024) using data for the United States. Data on deaths due to food insecurity in Hong Kong is unavailable.

Table 7: Hazard ratios for categories of food security and premature mortality; see Ma et al. (2024) for full description

Hazard ratio	Full food security (reference)	Marginal food security	Low food security	Very low food security
All	1.00	1.26	1.19	1.35
Women	1.00	1.34	1.24	1.61
Men	1.00	1.23	1.15	1.14

Data source: Ma et al. (2024)

Climate change physical risks, such as increasing temperatures, droughts, floods, and storms, are all expected to negatively affect crop yields, which could worsen food insecurity. Unfortunately, there is little research quantifying this negative impact.

If 20% of the population of Hong Kong had 25% higher mortality risk due to food insecurity, which seems to be a reasonable risk elevation based on the results from Ma et al. (2024), this would translate to approximately 2,500 deaths per year linked to food insecurity.

However, because we cannot validate whether this estimate is reasonable, we will leave the estimated impact as unknown. Nonetheless, it should be recognized as a potentially significant driver of population mortality compared to other climate risks.

Because food insecurity is linked to poverty, it is likely to have less impact on insured groups, who generally have higher socioeconomic status than the general population.

Table 8: Estimated current population mortality impact from food insecurity and projected changes by 2050 under a 1°C warming scenario for Hong Kong

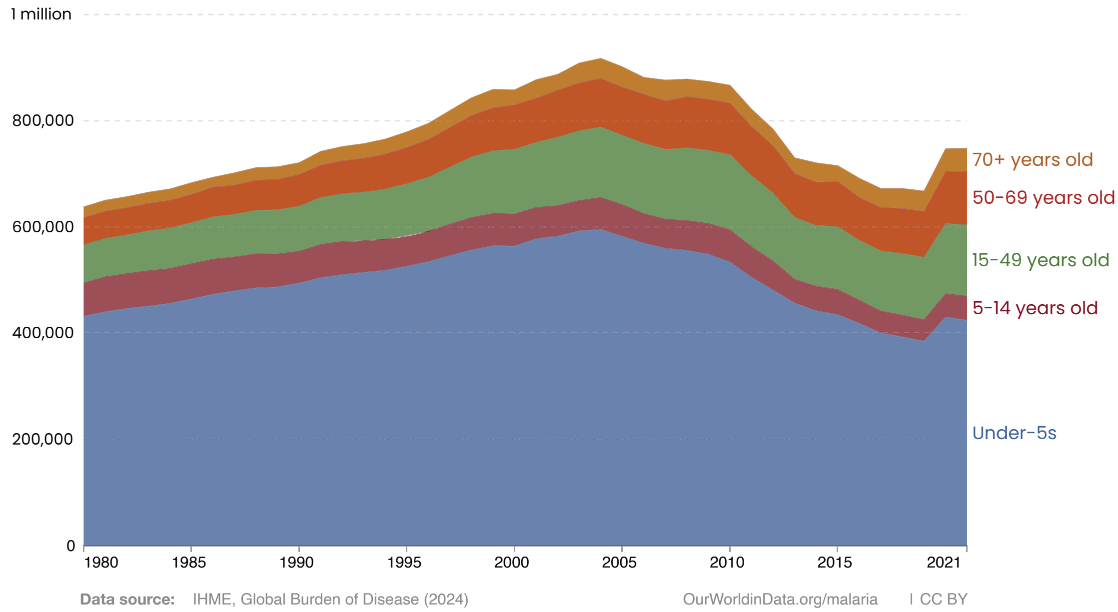
Physical Risk	**Estimated Current Population Impact** Current annual population deaths estimated to be attributable to risk	**Potential Change in Population Impact by 2050 in 1°C Warming Scenario** Increase/(reduction) in annual deaths estimated to be attributable to risk
Food insecurity	unknown	unknown

Vector-borne diseases

Vector-borne diseases, such as Zika and Lyme disease, are transmitted by vectors such as mosquitoes, ticks, and flies. The two vector-borne diseases with the highest mortality impact are malaria and dengue, with malaria having the biggest global impact.

As shown in Figure 19, IHME estimates that malaria caused more than 600,000 global deaths in 2019, primarily among children under age 5.

Figure 19: Malaria deaths by age, World, 1990-2019

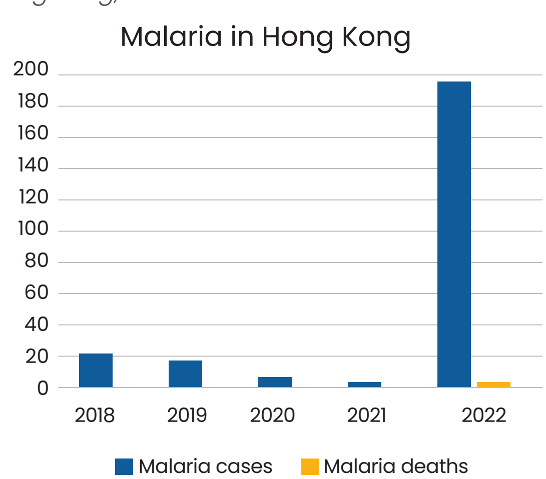


Source: Our World in Data, available under CC BY 4.0. No changes have been made.

There are cases of malaria in Hong Kong, but these are imported cases. According to government officials, the last local malaria infection occurred in 1998.[18] As shown in Figure 20, imported malaria cases have generally remained low, although a substantial increase in 2022 resulted in two malaria-related deaths.

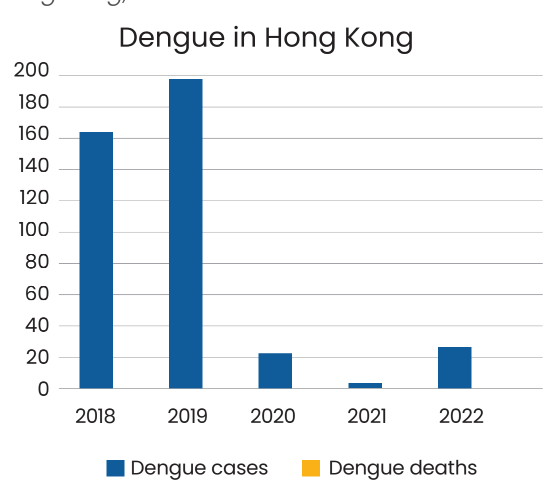
As shown in Figure 21, dengue is also present in Hong Kong, although these cases are also overwhelmingly imported.

Figure 20: Malaria cases and deaths in Hong Kong, 2018-2022



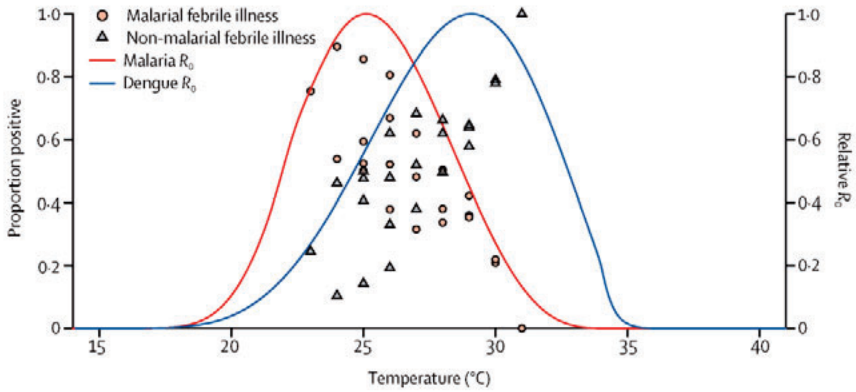
Source: Data from Health Facts for Hong Kong.

Figure 21: Dengue cases and deaths in Hong Kong, 2018-2022



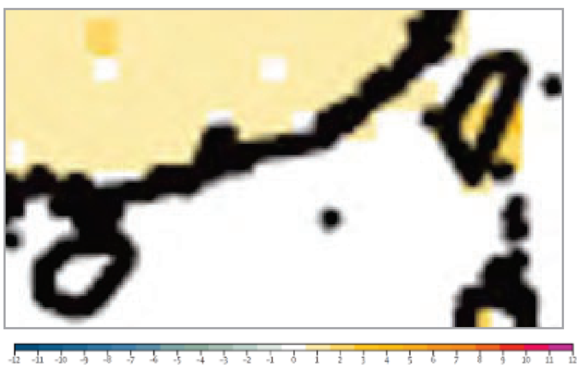
Source: Data from Health Facts for Hong Kong.

Figure 22: How temperature affects malaria (red line) and dengue (blue line) relative transmission; see Mordecai et al. (2020) for full description



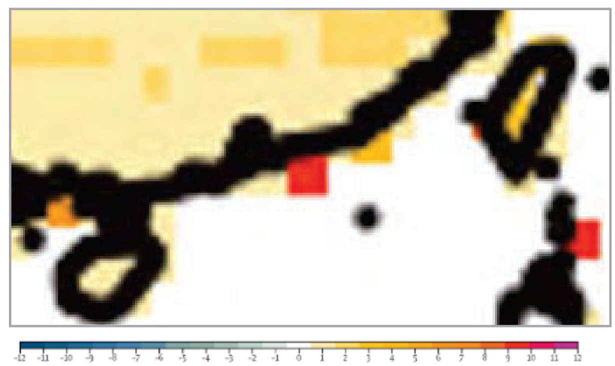
Extracted from Mordecai et al. (2020), available under CC BY 4.0. No changes have been made.

Figure 23: Simulated change in length of transmission season (LTS) for malaria under RCP4.5-SSP2; see Colón-González et al. (2021) for full description



Extracted from Colón-González et al. (2021), available under CC BY 4.0. No changes have been made.

Figure 24: Simulated change in length of transmission season (LTS) for dengue under RCP4.5-SSP2; see Colón-González et al. (2021) for full description



Extracted from Colón-González et al. (2021), available under CC BY 4.0. No changes have been made.

Temperature plays a significant role in malaria and dengue transmission. The red line in Figure 22, from Mordecai et al. (2020), shows how malaria transmission varies with temperature, with a peak in transmission at around 25°C. The blue line in Figure 22 shows how dengue transmission varies with temperature, with a peak at just under 30°C. With increasing average temperatures, many regions of the world will see malaria transmission reducing but dengue transmission increasing.

Colón-González et al. (2021) estimated that over the period 2070-2099, relative to the period 1970-1999, many areas near China's coast, including Hong Kong, will see the transmission season for malaria (see Figure 23) and dengue (see Figure 24) increase by one to two months. It is possible that Hong Kong and other isolated areas may see a larger increase in the transmission season for dengue, as indicated by the red areas of Figure 24.

Even if the transmission season increases, malaria has been well controlled in Hong Kong for decades, making a significant rise in mortality unlikely.

Dengue is also unlikely to cause significant mortality in Hong Kong, even if cases increase significantly, due to its relatively low case fatality rate (approximately 1 death per 2,300 cases).

We will assume that even if climate change increases deaths from vector-borne diseases by 2050 in a 1°C warming scenario, deaths in 2050 will still make up less than 0.1% of annual population deaths.

Table 9: Estimated current population mortality impact from vector-borne diseases and projected changes by 2050 under a 1°C warming scenario for Hong Kong

Physical Risk	**Estimated Current Population Impact** Current annual population deaths estimated to be attributable to risk	**Potential Change in Population Impact by 2050 in 1°C Warming Scenario** Increase/(reduction) in annual deaths estimated to be attributable to risk
Vector-borne diseases	< 0.1%	

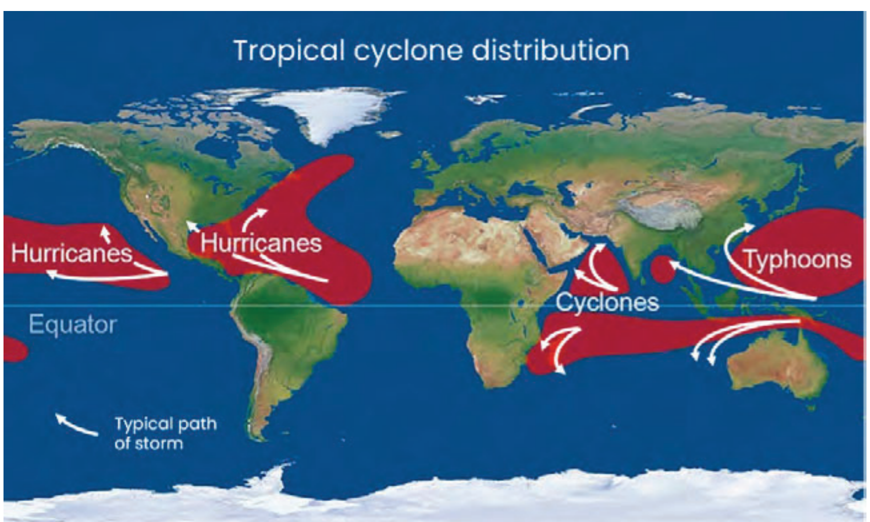
Tropical cyclones, storm surges (coastal flooding), and sea level rise

Tropical cyclones

Tropical cyclones are powerful storms that form over warm, tropical oceans and can cause significant damage upon landfall. They may be called typhoons in Southeast Asia or hurricanes when they form in the western Atlantic or eastern Pacific oceans.

Figure 25 shows in red the areas in which these tropical storms typically form. White arrows show the typical paths the storms take.

Figure 25: Global distribution of tropical cyclones showing areas where tropical cyclones typically form (in red) and paths they typically take (in white)



Adapted from https://www.metoffice.gov.uk/weather/learn-about/weather/types-of-weather/hurricanes/location. Contains public sector information licensed under the Open Government License v3.0 (https://www.nationalarchives.gov.uk/doc/open-government-licence/version/3/). Use of this material does not imply endorsement by the Met Office.

Tropical cyclones regularly hit Hong Kong. Tropical cyclone warning signals issued by the Hong Kong Observatory alert the public of the threat of high winds. The highest warning – Hurricane Signal No. 10 – indicates hurricane-force winds with sustained speeds of 118km per hour or more.

Table 10 shows the number of casualties or missing individuals from all Hurricane Signal No. 10 storms that have hit Hong Kong since 1960.

Table 10: Number of casualties or missing individuals from Hurricane Signal No. 10 storms in Hong Kong since 1960

Name	Year	Casualties/ missing	Name	Year	Casualties/ missing	Name	Year	Casualties/ missing
Mary	1960	56	Shirley	1968	0	York	1999	2
Alice	1961	4	Rose	1971	115	Vicente	2012	0
Wanda	1962	183	Elise	1975	0	Hato	2017	0
Ruby	1964	44	Hope	1979	12	Mangkut	2018	0
Dot	1964	36	Ellen	1983	22	Saola	2023	0

Data source: Data from Hong Kong Observatory warnings and signals database.

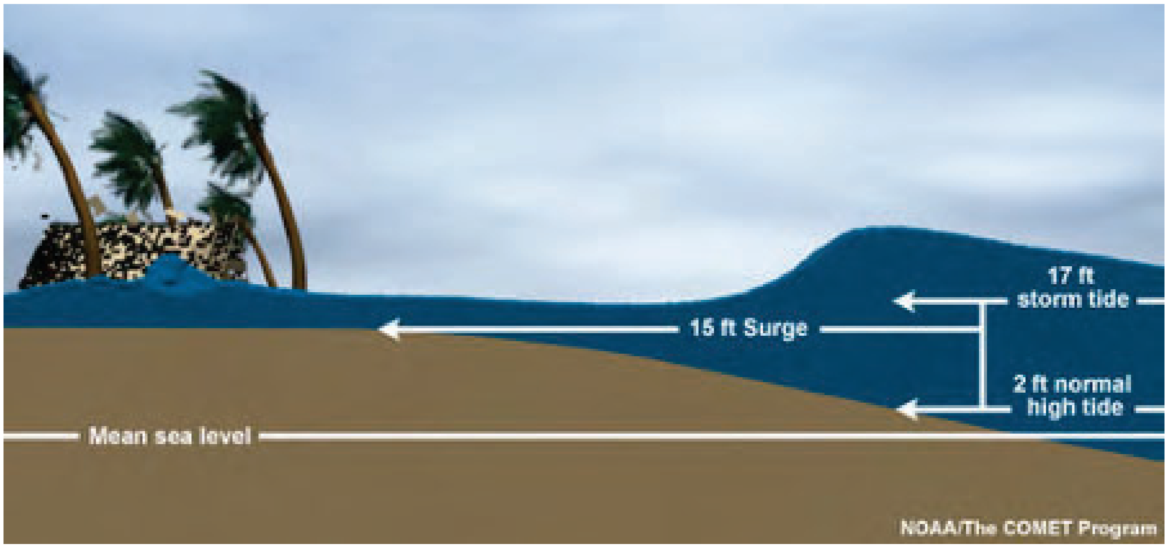
Storm surges

Of the mortality hazards associated with storms, storm surges causing coastal flooding pose one of the greatest risks.[19]

Storm surges occur when strong storm winds push sea water toward the coast, causing sea levels to rise. A smaller contribution comes from the low pressure associated with the storm pulling up the sea level.

As Figure 26 shows, storm surges can raise the water level by 15 feet. This can happen on top of a normal high tide, causing a storm tide to surge 17 feet, or approximately 5 meters.

Figure 26: Storm surge vs. storm tide



Source: National Weather Service (NWS)/National Oceanic and Atmospheric Administration (NOAA); use of this material does not imply endorsement by the NWS/NOAA.

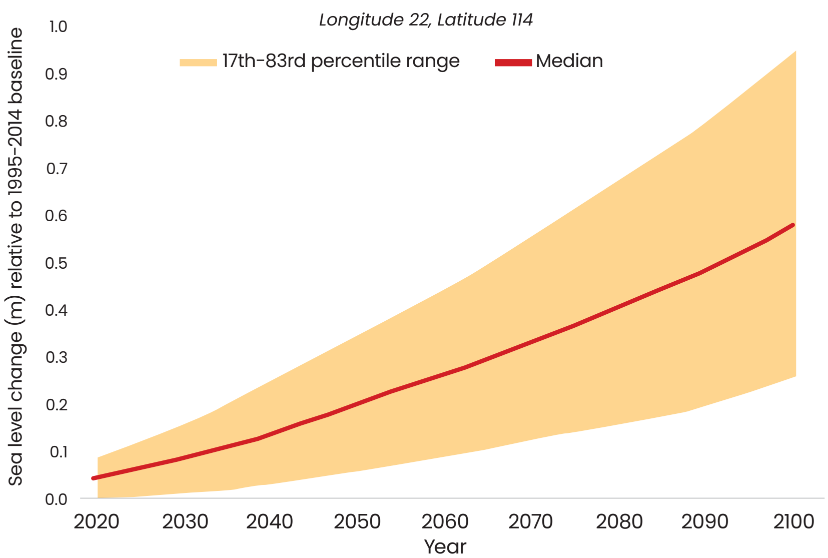
Maximum sea level in Hong Kong is measured above what is known as "chart datum" at the Quarry Bay station (prior to 1985, this was at the North Point station). The average baseline sea level over 1995-2014 was 1.45m above chart datum. The maximum sea level during Typhoon Mangkhut was 2.43m above the 1995-2014 average sea level.

Typhoon Mangkhut in 2018 saw near-record maximum sea level rise across all Hurricane Signal No.10 storms since 1960. As noted in Table 10, there were no casualties or reported missing persons during Typhoon Mangkhut.

Sea level rise

As Figure 27 shows, the projected sea level rise for Hong Kong under SSP2-4.5 is estimated to be approximately 0.2m by 2050.

Figure 27: Projected sea level rise for Hong Kong under SSP2-4.5



Data source: IPCC AR6 Sea-Level Projection Tool; see page 25 for acknowledgement.

As shown in Table 11, all but one Hurricane Signal No. 10 storm since 1960 had a maximum sea level that was more than 0.2m below the maximum sea level associated with Typhoon Mangkhut in 2018.

Table 11: Maximum sea level associated with Hurricane Signal No. 10 storms in Hong Kong since 1960

Name	Year	Maximum sea level	Name	Year	Maximum sea level	Name	Year	Maximum sea level
Mary	1960	2.77m	Shirley	1968	2.79m	York	1999	2.39m
Alice	1961	2.59m	Rose	1971	2.56m	Vicente	2012	2.76m
Wanda	**1962**	**3.96m**	Elise	1975	2.30m	Hato	2017	3.57m
Ruby	1964	3.14m	Hope	1979	2.78m	**Mangkut**	**2018**	**3.88m**
Dot	1964	2.65m	Ellen	1983	n/a	Saola	2023	3.07m

Data source: Data from Hong Kong Observatory storm surge records.

Taken together, annual deaths in Hong Kong linked to tropical cyclones, including from storm surges, remain at extremely low levels. Even if these fatalities increase due to stronger storms and rising sea levels, we assume annual deaths linked to tropical cyclones will remain below 0.1% of annual population deaths in 2050.

Summary of physical risk impacts

Table 12 summarizes how the mortality impact of physical risks related to climate change might change by 2050 in a 1°C warming scenario in Hong Kong.

Table 12: Current and projected population mortality impact from climate-related physical risks in Hong Kong

Physical Risk	**Estimated Current Population Impact** Current annual population deaths estimated to be attributable to risk	**Potential Change in Population Impact by 2050 in 1°C Warming Scenario** **Increase/(reduction)** in annual deaths estimated to be attributable to risk
Average temperatures	7.7%	4%
Air pollution	6%	(3%)
Droughts	n/a	
Floods (extreme rain)	< 0.1%	< 0.1%
Food insecurity	unknown	unknown
Vector-borne diseases	< 0.1%	
Tropical cyclones, storm surges (coastal floods), and sea level rise	<0.1%	
Overall physical risk impact (for quantified risks)		**1%**

Based on around 52,000 annual population deaths currently experienced in Hong Kong, physical risks associated with climate change under this scenario would account for slightly more than 500 additional annual population deaths. However, this estimate does not factor in anticipated population growth through 2050 or, except for the impact on average temperatures, the expected aging of the population.

We are unable to quantify the potential change in relation to the impact of food insecurity, although it is likely to increase annual population deaths.

Transition risks

Transition risks are risks associated with the transition to a lower-carbon economy. Depending on how transition policies are implemented, they have the potential to improve health in the following scenarios:

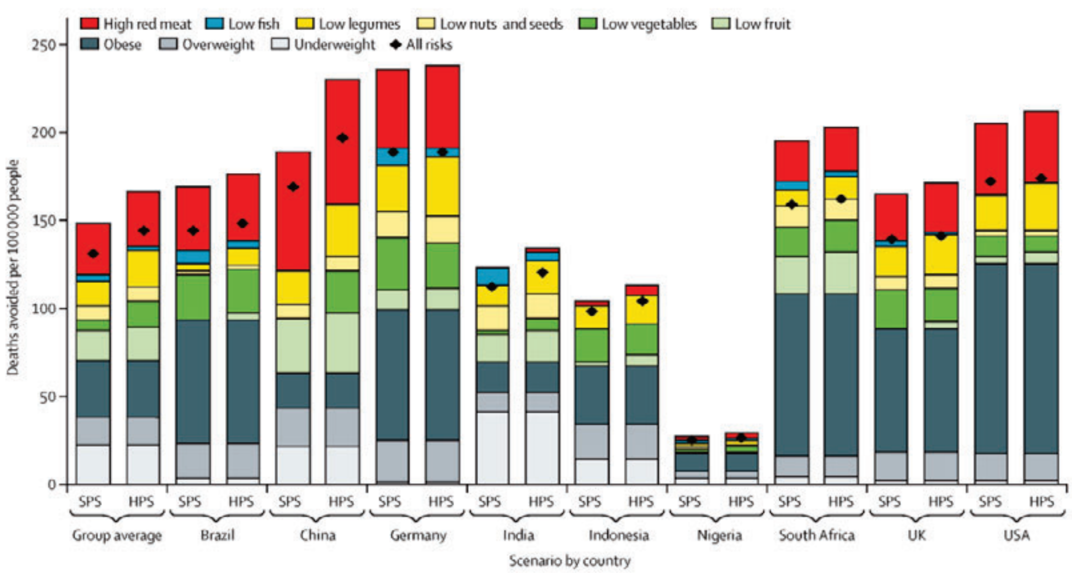
- If designed and implemented appropriately, sustainable food and agriculture policies could encourage people to eat a calorie-balanced diet rich in plant-based nutrition.
- Sustainable travel and transport policies could encourage people to walk or cycle instead of using their cars.

Hamilton et al. (2021) estimated the potential deaths that could be avoided if these health benefits are achieved.

Figure 28 illustrates the diet-related deaths that could be avoided. The x-axis shows two scenarios for various countries: a sustainable pathway scenario (SPS) that is broadly equivalent to the 2015 Paris Agreement and a more optimistic "health in all climate policies" scenario (HPS). Each bar shows the deaths avoided per 100,000 population, color-coded to represent the key dietary risks. Because individuals may be subject to more than one risk, the total deaths avoided per 100,000 population is marked by the black diamond near the top of each bar.

Results are not provided for Hong Kong, but for the SPS scenario in China, Hamilton et al. (2021) estimate around 170 deaths per 100,000 population could be avoided. If Hong Kong were to achieve this level, nearly 13,000 deaths would be avoided based on a population of 7.5 million.[20]

Figure 28: Number of deaths avoided attributable to dietary risks in the year 2040, relative to the current pathway scenario, per 100,000 population; see Hamilton et al. (2021) for full description

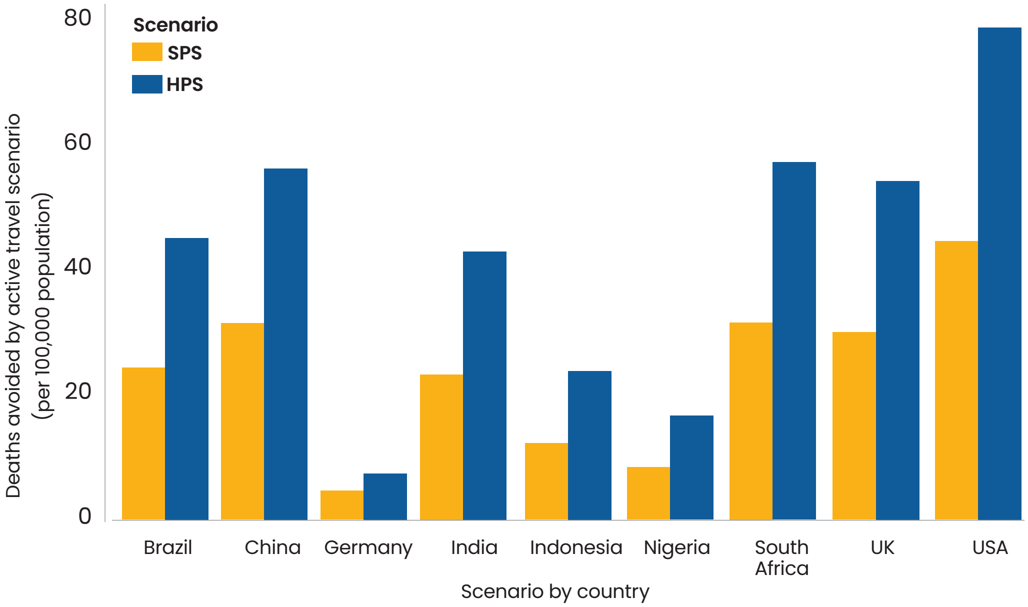


Extracted from Hamilton et al. (2021), available under CC BY 4.0. No changes have been made.

Figure 29 shows the deaths that could be prevented if active travel (walking and cycling) were increased. Again, the x-axis shows the two SPS and HPS scenarios for various countries. The bars show the deaths that could be avoided per 100,000 population in each scenario.

For China, in the SPS scenario, Hamilton et al. (2021) estimate that around 30 deaths per 100,000 population could be avoided. If Hong Kong could achieve this level, it would correspond to over 2,000 avoided deaths for a population of 7.5 million.

Figure 29: Number of deaths avoided in the year 2040 under the SPS and the HPS per 100,000 population, relative to the current pathway scenario; see Hamilton et al. (2021) for full description



Hamilton et al. (2021) suggest that transition risks have the potential for a much larger positive impact compared to the relatively modest negative impact from physical risks. However, they would require widespread behavioral change at the general population level, as well as significant investment in infrastructure – such as making cycling in Hong Kong safer and more appealing.

Caveats and other considerations

Climate science has improved significantly over recent decades, but significant uncertainty remains. Some impact estimates are not available for Hong Kong in the academic literature, and we have had to infer what they might be, based on the information available. That said, even doubling the impacts of each risk to account for uncertainty would still lead to a relatively modest overall physical impact: A 2% increase in annual population mortality in 2050 is equivalent to an 8-basis-point reduction in annual mortality improvements over that 25-year period.

Most research on the impact of climate change on mortality does not allow for the adaptation we will likely see as society works to lessen the impacts of these negative risks. Note that scope for adaptation against climate-related physical risks is generally greatest for higher socioeconomic groups.

We have concentrated on the direct mortality impacts of physical risks in this paper, but these physical risks could cause new-onset morbidity, potentially leading to negative mortality outcomes in the future. An example of this would be the negative mental health consequences of extreme weather events, such as flooding for those who lose their homes or livelihoods and are displaced.

Severe weather events that do not have a significant direct mortality impact can still create significant negative economic outcomes and severely damage infrastructure, both of which could lead to negative health consequences and, ultimately, higher mortality.

We have considered a “middle of the road” emissions scenario over the period to 2050. Over longer periods and in higher emissions scenarios, the mortality impact could be greater.

We have considered each physical risk in isolation, but reality is more complex and interactions between risks increases uncertainty. There is also the risk of reaching climate tipping points, which could lead to a self-reinforcing cycle of increased greenhouse gas emissions and warming.

Some of the actions that have led to climate change, such as deforestation, bring humans and animals closer into contact, which increases the risk of zoonotic disease transmission and the likelihood of future pandemics.

Conclusion

This paper set out to review the academic literature to assess climate change’s potential impact on future mortality in Hong Kong by 2050 under the SSP2-4.5 “middle of the road” emissions scenario.

For those physical risks where the change could be estimated, the overall impact was relatively modest, with annual population deaths potentially increasing by around 1% in 2050. In addition, this impact would be reduced by adaptation measures taken to mitigate these physical risks. This result may be counter to expectations of a more significant impact, although we need to recognize the uncertainties involved.

Beyond the modest negative mortality impact from physical risks, there is the potential for a significant positive effect on population health by implementing suitable transition policies covering food/agriculture and travel/transport. These could significantly reduce future annual population deaths. However, such health benefits are likely to be difficult to achieve, given that they require population behavior change and significant infrastructure investments.

The modest negative mortality impact from physical risks in Hong Kong outlined in this paper does not absolve society from taking action – both in Hong Kong and globally – to limit greenhouse gas emissions and future climate change impacts. Climate change remains a significant risk factor and a priority issue that must be addressed through collective action at the governmental, corporate, and individual levels. The insurance industry has an opportunity to play a leadership role in combating the climate crisis by promoting awareness, providing education, and inspiring, motivating, and incentivizing populations to modify behaviors in ways that will benefit their own health and the planet’s health.

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Limitations

The information provided in this paper is intended for general discussion and education purposes only and should not be relied upon for making specific decisions. The potential change in annual population deaths in 2050 under a 1°C warming scenario is based on the assumptions specified, and different assumptions would give rise to different results.

RGA has made all reasonable efforts to ensure that the information provided in this publication is accurate at the time of inclusion and accepts no liability for any inaccuracies or omissions. Figure 27 acknowledgement

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We thank the projection authors for developing and making the sea-level rise projections available, multiple funding agencies for supporting the development of the projections, and the NASA Sea-Level Change Team for developing and hosting the IPCC AR6 Sea-Level Projection Tool.

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