Geo Factsheet

Number 77

Multiple Hazards in Cities: Examples From London and Mexico City

In this Factsheet we examine the nature of some of the hazards in two large cities, London and Mexico City. Although there are a number of stark contrasts between London and Mexico City, some of the hazards are similar such as air pollution and industrial disasters. Others are place specific: London's low lying estuarine location makes it vulnerable to sea surges and high tides whereas Mexico City's position close to a tectonic boundary make it vulnerable to earthquakes. Other cities where multiple hazards exist include Los Angeles (smog, earthquakes, floods), Athens (smog, earthquakes) and Cairo (air pollution, earthquakes, industrial pollution).

Hazards in London

London has experienced a variety of hazards for a long period of time. Examples (and some measures to manage them) include:

- a Royal Decree in 1306 banned the burning of coal in order to reduce air pollution
- the Great Fire of London in 1666 which burnt over 13 200 homes.
- the Little Ice Age of the seventeenth century which caused the Thames to freeze over.
- the blitz in World War 2 which reduced much of London, especially its industries and residential areas in the densely packed inner city.
- high tides and storm surges
- smog, especially in the 1950s
- the Paddington rail disaster of October 1999.

London is increasingly at risk of storm surges. This is due to a combination of:

- rising sea levels (caused by the greenhouse effect and global warming).
- down-tilting of the south of England (caused by the isostatic uplift of Scotland as a result of the end of the last glacial period).
- long-term subsidence (caused by the weight of buildings on the sediments of London).

As a result, the Thames Barrier was constructed in 1983 to protect London from high tides and storm surges.

Many other hazards are human in origin. Canvey Island is a chemical and oil refining complex on the banks of the Thames Estuary. There is enough flammable material there to kill 18 000 people and one report concluded that it constituted a 'severe public safety hazard'. Other hazards caused entirely by human activity include terrorist attacks, air accidents, and traffic accidents.

Air quality

The traditional London smogs occurred under high pressure conditions whereby low level temperature inversions trapped particulates and sulphur dioxide at low levels. In addition, manufacturing industries and domestic fires spewed out masses of pollutants. One of the worst smogs was between 4th and l0th December 1952.

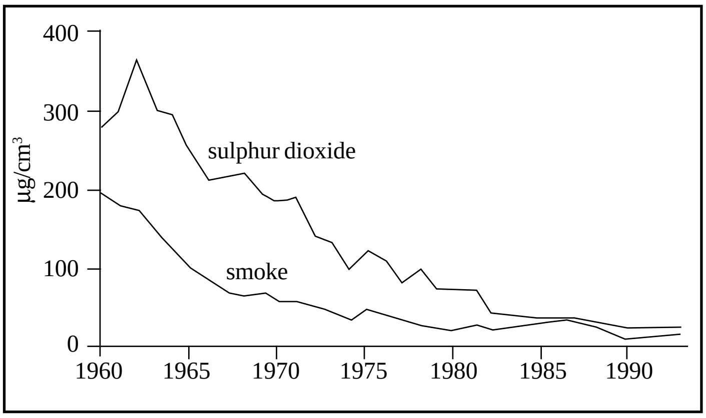
- visibility was down to 5 meters.
- the fog had a pH of 1.6.
- there were nearly 4,000 deaths, especially among the elderly and those with respiratory problems.

Such 'pea-soupers' became rare for a number of reasons:

- the 1956 Clean Air Act banned coal fires and provided financial assistance to households to convert to smokeless fuel;
- many houses converted to oil, gas and electric heating;
- deindustrialisation led to a further reduction in air borne pollution
- legislation reducing the sulphur content of oil to 1% also helped improve air quality.

As a result London's SO_2 concentrations fell from about 300 µg/cm^3 in the mid-1960s to below 50 µg/cm^3 in the 1980s (Fig 1).

Fig 1. Trends in sulphur dioxide and smoke levels in London



In the late 1980s and early 1990s, however, smogs returned. Moreover, the cause was different: cars and other vehicles were now the main source of particulates, carbon monoxide, nitrogen oxides and volatile organic compounds (VOCs). The worst winter smogs to occur in the 1990s were in December 1991. Under cold, high pressure conditions levels of nitrogen dioxide peaked at 423 parts per billion (ppb), more than twice the WHO safe limit of 209 ppb. Over 160 deaths were attributed to the smog. In addition, levels of benzene rose by as much as sevenfold. Similar smogs, although not as intense, occurred in Manchester and Birmingham.

The main reason for this increase in air pollution has been the increase in the number of cars on the road. Improvements to the road network have in turn led to more cars on the roads, and greater concentrations of cars in out of town sites. This is related to an increase in the number of facilities located further from residential areas and suburban centres, such as hospitals, shopping centres and sports complexes. These are much easier to get to by car than by public transport.

The government has attempted to reduce levels of pollution with a variety of methods:

- variable speed limits on the M25 reduce the number and length of traffic jams.
- Red Routes in London, (on which stopping is not permitted) also reduce the amount of exhaust fumes given off.
- pedestrianisation of shopping centres reduces emissions
- the reintroduction of trams, such as between Croydon and Wimbledon.

Nevertheless, there are still a large number of old vehicles in operation emitting large amounts of harmful gases.

Groundwater

During the early part of the century, water levels in the aquifer in North and Central London fell owing to over-abstraction, leaving a large volume of empty aquifer. Since the 1940s abstractions have decreased so that in most parts of London, especially the central area, water levels are now rising. This may pose a threat to foundations and tunnels constructed while levels were lower.

Some parts of London are now at risk from **rising** water levels. The most affected area lies inside the route of the Circle Line tube - west from Tower Hill to Earl's Court, north to Paddington, and east to Liverpool Street. The City, Mayfair and Westminster could be damaged without a plan to pump out groundwater every year. The London Underground and other underground structures such as car parks are most at risk.

London Underground pumps 14 million litres of water from its network each year to cope with flooding. According to the Environment Agency, which has been monitoring London's groundwater since 1991, groundwater levels are rising at about three metres per year compared with 2.5 metres in the early 1990s. In some areas, groundwater in the so-called London Basin is only 40 metres from the surface.

Fig 2. Groundwater problems in the Lower Thames Basin

- Flows in several rivers have been depleted as a result of large groundwater abstractions close to the headwaters or along the river valleys. Worst affected are the rivers Misbourne, Ver, Wey, Pang and the Letcombe Brook.
- Groundwater has been affected by saline intrusions along the River Thames.
- Most sites which have been considered suitable for waste disposal and landfill are quarries located on aquifers, such as sand and gravel quarries overlying the chalk aquifer, as in south Hertfordshire - the waste could pollute drinking water.
- There is continued pressure for redevelopment of former industrial sites, many of which occupy prime locations in urban areas. The land is frequently contaminated and there is often associated groundwater pollution.
- Nitrate concentrations are rising in other parts of the catchment.
- Other chemicals, such as pesticides, are in widespread use across the catchment and the frequency of detection in groundwater has risen.
- Groundwater in some urban areas has been contaminated by leakage from sewers and through widespread usage of chemicals such as solvents.

Contaminated land

The East Thames region has been described as the area where London 'generates its energy and dumps its waste'. The result of this is that much of the land is contaminated. One such area is the Barking Levels. Here the soil and air is contaminated, and the marshes have been used as a dumping ground for industrial waste, and murder victims! One part has been used as a landfill site since Victorian times and there are nearly 60 metres of compressed rubbish.

In places, the land has been contaminated with radon gas, asbestos, fuel ash, lead and cyanide. The Harys Lane Estate by Barking Creek, for example, was built on an old asbestos works and is now suffering from contaminated air. In the nearby Black Lagoon levels of lead are as high as 33 000 ppm in the soil. In addition, gases given off by the old gas works and former industries have been known to ignite spontaneously.

Multiple hazards in Mexico City

Like London, Mexico City experiences many hazards. These include poor air quality, earthquakes, and shortages of water. In addition, there are hazards related to industrial accidents, poverty, and infectious diseases. Mexico City has a population density which exceeds 14 000 people per km^2 in some areas. This intensifies the risk hazard. For example, on 19 November 1984 over 450 people were killed when a gas truck exploded in a liquefied gas storage depot in San Junico suburb. Fires covered an area of just 20 blocks but more than 4,350 people were severely burned in the incident; 30 000 were made homeless and 300 000 people had to be evacuated. As such a small area shows, high density housing increases the numbers at risk from hazards.

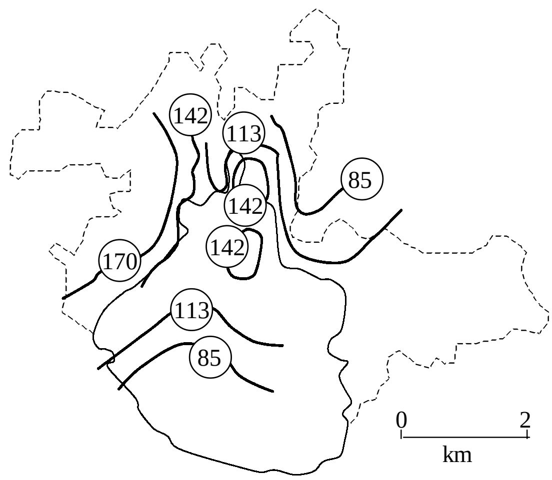
Environmental problems are rife in Mexico City. The concentration of 3.5 million vehicles and 40 000 factories emits 12 000 tons of gaseous waste daily. Smog reduces visibility to about 2 km. The city has the world's highest ozone concentration and one of the highest figures for carbon monoxide. In 1994 air quality (as defined by the World Health Organisation) was acceptable on only 20 days in the year! In addition, there is very little green space in the city.

There is a serious problem caused by the dumping of hazardous waste. There are no legal landfill sites and only five recycling plants in Mexico City. Illegal dumping at Rincon Verde has led to increased risk of diseases in the area, underground fires and pollution of the water table.

Air quality

Mexico City's 20 million inhabitants suffer some of the worst air quality in the world (Fig 3).

Fig 3. Sulphur dioxide levels in Mexico City



- - - Metropolitan Area of Mexico City Boundary

—— Federal District Boundary

(85)— Concentration of SO_2 ($\mu g/m^3$)

The city is surrounded by mountains and experiences frequent temperature inversions. Smogs are common between November and May. In 1992 poor air quality occurred on 192 days, over half of the year. Smogs can be so severe that schools are closed for a month, and industries have to reduce production by up to 75%. It is thought that about 3,000 deaths annually are caused by the smogs.

> ***Exam Hint*** *- Detailed Case Studies are essential for candidates who are aiming for the highest grades. Examiners look for detailed treatment of a range of hazards.*

Mexico City has very poor air quality for a number of reasons:
- its large population size, 20 million people, increasing through migration
- the large number of industries, over 35 000 and 3.5 million cars
- its location in a high altitude basin
- frequent temperature inversions in the winter
- its urban heat island effect
- its latitude (19° North) and altitude (2250 metres) providing plenty of winter sunshine
- because the city is prone to earthquakes people use portable gas cylinders rather than piped gas; leaking gas adds benzene to the atmosphere, and this increases the levels of tropospheric ozone
- because Mexico City is so vast people travel long distances to work - this adds to the volume of pollutants in the atmosphere
- most cars are old, inefficient and not regulated very strictly

The city has high levels of carbon monoxide, lead, PM_{10}s and sulphur dioxide. Air quality is notoriously poor and in 1992 acceptable levels of ozone, PM_{10}s and carbon monoxide occurred on only 8 days!

Mexico City has very high levels of ozone, especially in the south west. During the day air moves towards the south west - this allows sufficient time for photochemical reactions to take place, hence there are very high levels of ozone and petrochemical smog in the south west. The air cannot escape because it is trapped in the basin by the surrounding mountains.

Up to 2 million people suffer diseases caused by air pollution. It is thought that the health costs related to ozone are $100 million a year - and PM_{10}s $800 million a year! The particulate problem is especially acute owing to the dust from the dried bed of the Texcoco Lake to the north east of the city, the large landfill sites surrounding Mexico City, and the urban heating systems.

There have been a number of schemes to reduce air pollution in Mexico City. In 1989 the authorities introduced colour-coded permits to restrict traffic from the city. The scheme reduces the number of vehicles in the city by up to 400 000 a day and has improved air quality by as much as 15%. Drivers face fines of $600 if they break the restriction. In addition, all taxis over 10 years old had to be replaced, and the amount of lead in petrol has been halved. Nevertheless, these schemes are limited by the amount of money available to the government and to individuals. Mexico's foreign debt and the poverty experienced by many people means that many more costly environmentally-friendly policies cannot be implemented.

Hence, lead concentrations remain high, especially in some northern industrial areas where oil companies, cement manufacturers, metal foundries and paper manufacturers are located. Industries tend to be concentrated in the northern areas whereas the more affluent residential areas are in the south and west. However, daytime air flows are frequently from the north east to the south west, transporting the pollution problem to the residential areas.

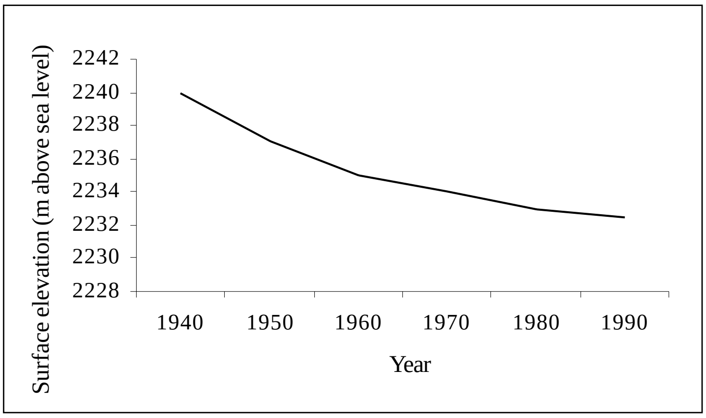
Groundwater

At an urban scale water shortages are acute. Although Mexico City is renowned for its smog, there is a new problem. Residents claim that if they don't die from air pollution they will either die from thirst or from drowning in their own sewage.

The main source of water for Mexico City's 20 million people is an aquifer below the city. However, the aquifer is running dry; the result is that Mexico City is sinking at a rate of 50 cm a decade (Fig 4).

Dangerous cracks in the clay sediments threaten to contaminate the aquifer, which lies just 100 metres below the surface. Mexico City uses 62 cubic metres of water a second. Two-thirds comes from the aquifer The rest, 19 tonnes per second, is pumped from dams 120 km away. The electricity needed to pump the water would support a medium sized town for a day.

Fig 4. Subsidence in Mexico City



Mexico City's demand for water has brought it into conflict with neighbouring states. As Mexico City uses more water there is less available for irrigation. In addition, up to 30% of Mexico City's water is lost through leakages and theft. The solution offered is to meter the use of water and charge residents for what they use. This is likely to be very unpopular and so far the government has resisted moves to introduce meters.

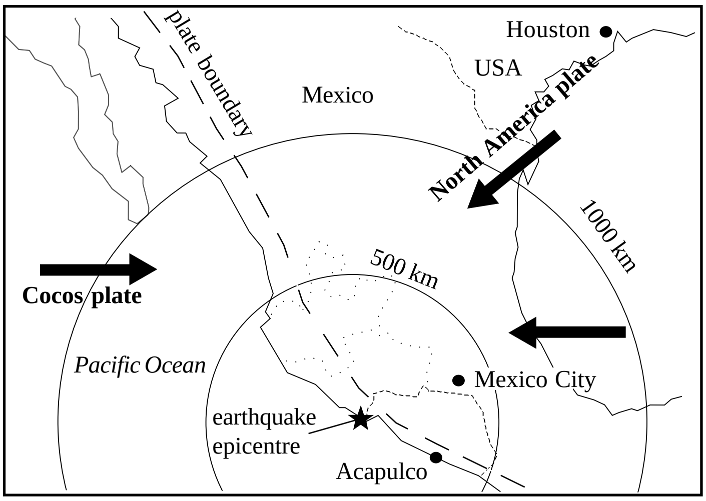
Earthquakes

The earthquake which affected Mexico City in 1985 caused widespread damage along the Pacific Coast, close to the epicentre, but the worst damage occurred in Mexico City. There, over 7 000 people died, 40 000 people were injured, and 30 000 were made homeless. The economic loss was estimated at over $4 billion.

The disaster affected some areas more than others. Buildings on 'susceptible' soils and alluvial (river) deposits are prone to collapse. For example, in the 1957 earthquake in Mexico City 96% of houses damaged were built on the Lake Texcoco sediments. Similarly, most of the damage in the 1985 earthquake was on susceptible sediments on the floor of an old lake bed. When shaken in an earthquake the foundations of structures in these sediments break up, lose strength, or became waterlogged. This is known as liquefaction. This makes them particularly vulnerable to disasters.

The epicentre of the 1985 earthquake was 370 km away from Mexico City (Fig 5). Although there was some damage along the Pacific Coast most of the damage was in Mexico City.

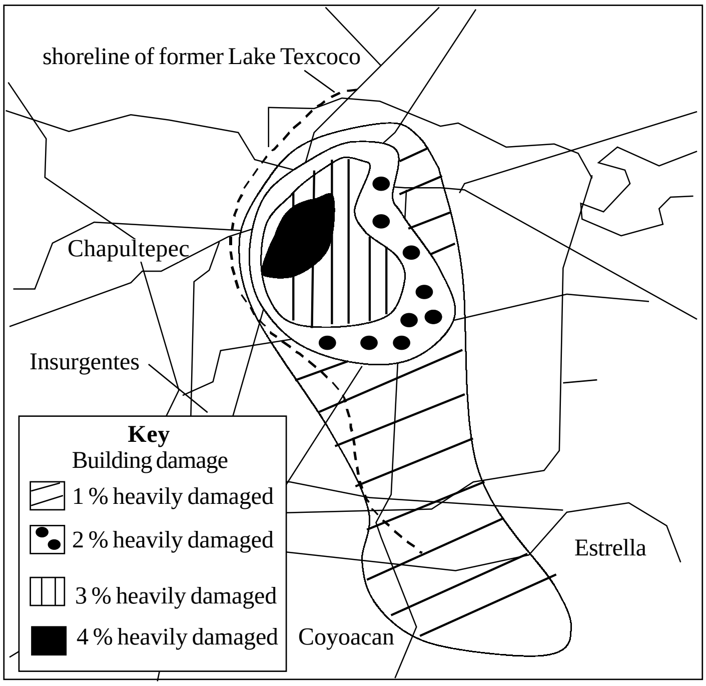
Fig 5. 1985 earthquake



Within Mexico City the effect of the earthquake was concentrated in a very small area. Fewer than 4% of buildings in Mexico City's core were destroyed. The key factors appear to be unstable sediments, high housing densities and poor building structures.

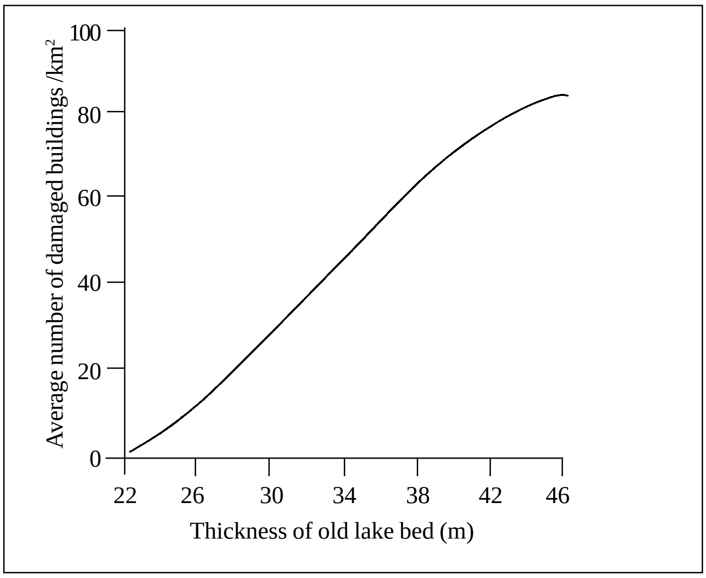
Fig 6. shows the relationship between the percentage of buildings damaged and the unstable sediments of the old lake bed.

Fig 6. Building damage around old lake bed



The thicker the lake sediments the greater the number of buildings damaged (Fig 7). Many of the victims were relative newcomers forced to live in unsafe areas in poorly constructed buildings.

Fig 7. Building damage and lake sediment thickness



Practice Questions

1. How do the causes of smogs in the 1990s compare with the causes of those in the 1950s?
2. Describe the trend of sulphur dioxide levels, as shown in Fig 1. How do you explain this change?
3. Why are groundwater levels in London rising?
4. Briefly explain how groundwater can become contaminated.
5. Describe the relationship between (a) the distribution of lake sediments and the impact of the earthquake (Fig 6), and (b) the thickness of lake sediments and the damage caused (Fig 7).
6. Compare and contrast the environmental hazards experienced in large cities in the developed world with those in the developing world. Use examples to support your answer.

Suggested Answers

1. The 1950s smogs occurred under high pressure conditions whereby low level temperature inversions trapped particulates and sulphur dioxide at low levels. The pea-soupers of the 1950s were largely caused by coal-burning in homes and industries. In addition, manufacturing industries and domestic fires spewed out masses of pollutants. By contrast, in the late 1980s and early 1990s, the cause of smogs had changed. Cars and other vehicles were the main source of particulates, carbon monoxide and nitrogen oxides. The main reason for this increase in air pollution has been the increase in the number of cars on the road. Improvements to the road network have in turn led to more cars on the roads, and greater concentrations of cars in out of town sites. This is related to an increase in the number of facilities located further from residential areas and suburban centres, such as hospitals, shopping centres and sports complexes. These are much easier to get to by car rather than by public transport.
2. London's SO_2 concentrations fell from about 300 g/m^3 in the mid-1960s to below 50 g/m^3 in the 1980s. The improvement in air quality was linked to
   - deindustrialisation which led to a reduction in air borne pollution
   - the 1956 Clean Air Act which provided financial assistance to households to convert to smokeless fuel, and many houses converted to oil, gas and electric heating;
   - legislation reducing the sulphur content of oil to 1% also helped improve air quality.
3. Groundwater levels are rising largely due to reductions in water abstractions. As manufacturing industries have declined, or removed from London, there is much less water taken from the aquifers, hence water levels are rising.
4. Groundwater in some urban areas has been contaminated by leakage from sewers and through widespread usage of chemicals such as solvents. Other chemicals, such as pesticides, are in widespread usage across the catchment and the frequency of detection in groundwater has risen. Rising nitrate concentrations are evident in areas where farming is important. Most sites which have been considered suitable for waste disposal and landfill are quarries located on aquifers, the waste could pollute drinking water. Groundwater has been affected by saline intrusions along the River Thames.
5. The area of highest damage was the old lake bed. Where the lake sediments were thickest the greatest damage occurred. For example, where the lake bed was 46 m thick up to 80 buildings/km^2 were damaged whereas in areas where the lake bed was only 26 m thick the number of buildings damaged was about 20/km^2. This is because lake sediments liquefy when shaken violently and act as a liquid. By contrast on the solid rock fewer buildings were destroyed because the solid rock was able to withstand the shaking forces of the earthquake.
6. There are a number of similarities in the hazards experienced in London and Mexico City, notably air pollution, industrial hazards, and contaminated land. However, there are also many contrasts. London is a developed world city which has deindustrialised. By contrast, Mexico City is in a developing country and is much larger, and is close to a tectonic boundary. Migration continues in Mexico City whereas London has been experiencing counterurbanisation for many years. We have seen that there are many contrasts in the hazards experienced in each city Mexico City is prone to earthquakes and its residents in low quality, high density housing are subjected to many infectious diseases. By contrast, flooding is a threat in London. The ways in which the residents and the authorities cope with the problem depends, in part, on the resources available to them, and also on the pressures created by population growth. London and Londoners, it seems, are better placed to cope with its hazards.

Acknowledgements;
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