Good term paper on meteorology: how weather affects pollution in major cities

Environment, Pollution

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Introduction

This term paper explores the issue of weather affecting pollution in major cities. In a major city, where there can be a higher proportion of pollution sources in a relatively small geographical area, the effects are likely to be more distinct and concentrated.

Whilst there are several causes of air pollution, it is known that the air quality at any given time can be affected by the prevailing weather conditions. For example, strong winds can rapidly transport pollutants released into the air great distances from the originating source. Conversely, in conditions when there is very light wind or in still air, the pollutants are likely to accumulate close to the points of release. Rainfall can have the effect of refreshing the environment, or adding pollution to it, depending on the amount of pollutants suspended in the rain clouds, or in the air above ground level. (“ How does weather affect air pollution?” n. d.).

Gases and Fine Particulates

Weather-influenced air pollution can include both the transport and the formation of pollutants. Additionally variations in the weather can influence the production of biogenic pollutants such as pollen, and anthropogenic pollutants – e. g. pollutions produced due to increased demands for energy production. (“ Working Group II: Impacts, Adaptation and Vulnerability: 9. 6. Air Pollution.” n. d.).

The problem of air pollution is particularly serious in densely populated cities, and especially the cities of developing countries. As an example, it is reported that almost 40, 000 people per annum in India meet an early death due to air pollution. (Brandon 1998 p. 2).

The Six Standard Air Pollutants. With respect to urban populations, studies of these pollutants (“ sulfur dioxide (SO2), ozone (O3), nitrogen dioxide (NO2), carbon monoxide (CO), lead, and particulates”), have indicated that in some cases their health impact is greater when the weather is hot. An example is that the effects of SO2 on mortality including cardiovascular mortality were greater in summer than in winter. These findings were in respect of three studies: Valencia and Barcelona in Spain, and Rome in Italy. However, and conversely, another study in Philadelphia, US, found that SO2-related adverse health impacts were greatest in the spring, autumn and winter.

Other studies – based on hospital admissions in a number of cities – found that daily increases in air pollution-related morbidity / mortality rates were linked to high ozone (O3) levels during hot weather. (“ Working Group II: Impacts, Adaptation and Vulnerability: 9. 6. Air Pollution.” n. d.).

Radon Gas. The inert but radioactive gas radon is a known pollutant. It is emitted from the ground in amounts that are affected by variations in the weather. Those variations include precipitation and the barometric pressure, and – to a much lesser extent – the ambient temperature and, possibly, the wind, too. Furthermore, the soil type has a direct bearing on the response to weather variations. Seasonal weather variations are the principal causes of changes in radon emissions, which can differ in magnitude by up to 10 times as a consequence. Precipitation is the most significant cause of emissions increase, followed by an inverse relationship between barometric pressure and emissions (i. e. radon emissions increase as barometric pressure falls). Temperature changes and the effects of wind have a far smaller and less quantifiable effect on radon emissions. (Schumann, Owen & Asher-Bolinder 1988).

Climate Change Effects: Forest Fires

One anticipated effect of climate change resulting in hotter, dryer weather is an increase in the numbers of forest fires and heath or grassland fires. The air pollution produced as a consequence has the potential to impact on health of people even at some distance. Previous major fires of that nature have produced increases in cases of respiratory and eye problems. In one instance in Malaysia, there was a reported “ two- to three-fold increase in outpatient visits for respiratory disease and a 14% decrease in lung function in school children.” Another case in Brazil resulted in “ a 20-fold increase in outpatient visits for respiratory disease.” In Florida, there were links between similar fires and “ significant increases in emergency department visits for asthma (91%), bronchitis (132%), and chest pain (37%).” In contrast, following a study of bushfires in the area of the city of Sydney, Australia, there were no increases in admissions to hospitals for asthma problems. (" Working Group II: Impacts, Adaptation and Vulnerability: 9. 6. Air Pollution." n. d.).

Future Air Quality Changes

It is known that the weather is a major factor in both the dispersal and the local concentrations of airborne pollutants. One significant effect is when a large, high-pressure weather system creates an inverted temperature profile, thereby trapping those pollutants immediately above the surface of the Earth. It is difficult to precisely quantify the predicted effects of anticipated climate change on urban environments. However, it is expected that " any increase in anti-cyclonic conditions in summer would tend to increase air pollution concentrations in cities." (" Working Group II: Impacts, Adaptation and Vulnerability: 9. 6. Air Pollution." n. d.).

A major study undertaken by Health Canada set out to determine the (combined and independent) effects of " extreme weather and air pollution on human health." (McKeown, 2005 p. 1).

The approach used was to categorize the weather types synoptically (i. e. in summary form), in order to evaluate serious adverse health outcomes against extremes of weather (hot or cold) coupled with various air pollutants. The study covered four major cities (" Montreal, Ottawa, Toronto and Windsor") in the south-central part of Canada. This extract focuses on Toronto. Data from North American and Canadian archive sources were analysed, including " models of climatological, weather, air pollution and mortality data, making use of a suite of climatological, meteorological and statistical techniques.” (McKeown, 2005 p. iii).

Acute Mortality from Extreme Weather and Air Pollution. Study findings for the city of Toronto were the result of analysis of data from the years 1954 to 2000. Mortality figures were 120 excess deaths due to hot weather, 105 due to cold weather, and 822 due to air pollution. Comparing those figures with equivalent data for just one year – 1999 – the numbers for that year for air pollution were 695 as determined by Toronto Public Health (in 2004), and 705 in this study. Those figures indicate that air pollution was more severe in the earlier years covered by the study (McKeown, 2005 p. iii).

Projected Future Effects of Climate Change. Based on a projection of an increase of air pollution of 32 percent by 2080, it is expected that the numbers of “ Low” pollution days will be reduced and the numbers of “ High” pollution days will substantially increase. Also, because climate change predictions suggest there will be four times more hot weather warnings than now, there could be three times the current rate of heat-related deaths (rising from a yearly total of 120 to 360). Conversely, deaths associated with extreme cold could fall by the same factor; i. e. from 105 to 35 yearly. A further negative effect of climate change could be up to 30 percent more deaths related to air pollution in Toronto in the 2080s. The number could increase from the current 822 to circa 1070 each year. Bringing all those projections together could mean that the deaths in Toronto associated with extreme weather and air pollution could increase to an annual figure of 1465. Note that none of these figures takes account of other factors such as population growth, and they are likely to be on the low side of actual values

(McKeown, 2005 p. iv).

This case study looks at Mexico City – once one of the world's cleanest cities, but which has become one of the world's most polluted places. Figure 1 in the Appendix shows a tabulation of the world's most polluted cities, illustrating that Mexico City tops the table for four of the six major air pollutants, with either heavy or serious levels for all six. The referenced study by Yip and Madl (updated 2002) mentions that the city was the setting for novelist Carlos Fuentes' 1959 novel entitled " Where the air is clear." Unfortunately, whereas the 1940s visibility there was circa 100 km, these days pollution has reduced that figure often to the order of just 1. 5 km. Part of the problem is that Mexico city – although at circa 2240 meters above sea level – sits in a natural " bowl" flanked by mountains on two sides rising to a further 1, 000 meters. On windless days this topography can cause the pollutants to be trapped, creating the concentration of pollution that results in extremely poor visibility. Figure 2 in the Appendix shows typical contrasting views of the city on windy and windless days (Yip & Madl, updated 2002).

Within that natural basin known as the Valle de Mexico, circa 21 million people (more than a fifth of the country's total population) live in the metropolitan area of Mexico City – one of the world's largest, and located in a seismically active zone. The metropolitan area of the city is increasing at more than three percent each year, and is home to over three million vehicles traversing its streets on a daily basis.

Daily Air Circulations. According to the Yip & Madl paper, there is typically a daily cycle of complex air circulations in Mexico City, (as illustrated in Figure

3 in the Appendix, where there are representations of three phases of the circulations). They are indicated as " Early Morning", Noon", and " Late Afternoon." However, certain weather conditions can cause the emissions produced the previous day to remain trapped, and become combined with those generated during the current day. In these frequently-occurring times of inversion, the early morning situation prevails throughout the entire day, preventing the " old" air being exchanged with " new." (Yip & Madl, updated 2002).

Reduced Oxygen Levels. Due to Mexico City's elevated position (2, 240 meters above sea level) the partial oxygen pressure is just 160 mb, compared with the sea level value of 213 mb. That can have several effects on the population – both directly and indirectly. To breathe at this altitude requires a greater number of red blood cells. Further, the viscosity of the blood is significantly affected. Indirect effects include the altered combustion process. The reduced oxygen levels means that combustion produces less nitrogen oxide, but increases other emissions, including carbon monoxide (CO), various hydrocarbons, and VOCs (volatile organic compounds). (Yip & Madl, updated 2002).

Mexico City Climate. Despite being at high altitude, Mexico City's latitude means that it enjoys a year-round temperate climate. In the winter, persistent high pressure over the adjacent Pacific Ocean results in an air flow from the north over Mexico City that encourages the formation of an inversion zone. Emissions from the industrial areas on the city's northern outskirts become trapped in the city's metropolitan area, combining with the emissions generated by the huge numbers of motor vehicles operating in the city on a daily basis. During the summer months, the combined effect of more sunny days and a stronger airflow from the south helps clean the atmosphere. However, local conditions in the valley help to push air away from the valley's northern end in a southerly direction. Mitigating factors are that the periods of intense sunshine help to raise the air masses, and the rains provide a washing effect for the area. (Yip & Madl, updated 2002).

Mexico City's pollution levels regularly exceed the accepted maxima for air quality. The country's industry is largely powered by fossil fuels. Their incomplete combustion in the reduced-oxygen atmosphere releases primary pollutants into the air, causing irritation to eyes and throat, and in severe cases premature death. They also contribute to global warming. Sunlight acts on these primary pollutants, which react to produce secondary pollutants, helping to form the frequently-occurring brown haze or smog.

Taking the various pollutants in order of their relative amounts in Mexico City, the internal combustion engine exhausts are responsible for 74 percent, followed by natural sources (12 percent), services (10 percent), and industry just three percent. (Yip & Madl, updated 2002).

Air Quality Statistics. Data on air quality in Mexico City's metropolitan area is provided by IMECA (" Indice Metropolitano de la Calidad del Aire"). Their standards are formulated such that any values above 100 " are considered a threat to human health." The following Table is extracted from the Yip & Madl paper:

In 1996, at least some of the standards were exceeded on 333 days (91 percent), and for 20 percent of the days the levels were double the accepted standard. On 71 days values of over 200 were recorded, and on five days the values rose to as high as 250. The paper's authors blame the relative lack of progress in dealing with these pollution problems on a combination of " private interests, corruption, indulgence, ineptitude and decisions more political than scientific." (Yip & Madl, updated 2002).

Other Weather-Linked Air Pollution Events

London, England, December 1952. A persistent smog coupled with low winter temperatures caused a persistent smog, exacerbated by the thousands of open coal fires used by the London population to heat their homes. The resultant massive air pollution caused many deaths from either respiratory or cardiovascular problems. In the week ending 6 December around 2, 000 died (normal for that time of the year in those days). However, the following week there were almost 5, 000 fatalities. It was as a result of this smog that Britain passed a series of Clean Air Acts in the subsequent decade. (Wilson, n. d.).

Liege, Belgium, December 1930. A persistent fog combined with a time of very light winds, temperatures just above freezing, and an anticyclone in the Meuse Valley close to Liege, caused a temperature inversion close to the ground. That prevented the smoke and fumes from factory chimneys escaping into the upper air. Many of the local villagers exhibited respiratory disease symptoms, and over 60 of them died. (Wilson, n. d.).

Volcanic Pollution. There have been a number of instances of volcanic eruptions causing air pollution great distances away from the source. One eruption that occurred very recently originated at the Holuhraun volcano in

Iceland, beginning in late August of this year. As of September 29th, the sulphur dioxide emissions had reached as much as 60, 000 tons a day, and had averaged 20, 000 tons daily since its beginning. To put those figures into perspective, all of the European SO2 emissions, from all sources (" industries, energy production, traffic and house heating, etc.") combine to give a daily total of 14, 000 tons. Due to that and other Icelandic volcanic events, people in Iceland have been experiencing eye and throat problems and headaches, and the effects have been felt even by people in Norway, 800 miles distant (Jasper, 2014).

Conclusions

Air pollution is a serious health problem, as well contributing to climate change / global warming. Research has shown that weather affects the amounts of pollution, generally causing increases of pollutants as the temperatures rise. The pollution is likely to be more concentrated in cities, due to the combination of industry, road traffic and other sources, affecting greater numbers of people because of the density of city populations. In certain climatic conditions, especially where the topography is a contributory factor, pollution can reach severe levels, as has been reported in respect of Mexico City in this paper. Natural events like wildfires (usually after long dry periods), or volcanic activity can also cause major air pollution, which can affect city populations at great distances from the source.

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Appendix

Figure 1: Table of the World’s Most Polluted Cities

(Source: Yip, Maricela & Madl, Pierre. (2002). “ Air Pollution in Mexico City.”)

Pollutants Key:

SO_2 = Sulfur Dioxide

Pb = Lead

CO = Carbon Monoxide

NO_2 = Nitrogen Oxide

O_3 = Ozone

Figure 2: Comparison Between Mexico City Visibilities on Windy and Still Air Days

(Source: Yip, Maricela & Madl, Pierre. (2002). “ Air Pollution in Mexico City.”)

Figure 3: Mexico City Daily Meteorological Processes

(Source: Yip, Maricela & Madl, Pierre. (2002). “ Air Pollution in Mexico City.”)