Trends in the effects of ambient PM 2.5 concentration on mortality risk in Hong Kong, China

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Abstract

Background

Associations between levels of various types of airborne particulate matter such as ambient PM$_{2.5}$ and short-term mortality risk have been studied extensively. A metric called daily exceedance concentration hours (DECH) has been proved useful with respect to better modeling and understanding of acute mortality risk associated with pollution in southern Chinese cities. Notably however, it is unclear whether the strength of the association is time-dependent. The current study investigated this using a comprehensive dataset acquired in Hong Kong spanning from 1999 to 2019. The methodology and modeling employed were similar to those used in prior studies.

Methods

Generalized additive models with quasi-Poisson distribution links were fitted to varying periods of an overall time series. These models were then examined to identify changes in implied effects on mortality risk over time.

Results

The replicated methodology of prior studies resulted in fairly consistent, but much reduced relative effects of DECH levels on mortality risk across the disease groups. The model remained significant with the inclusion of newer datasets. When applying the model to sliding time-windows of data, the effective risk of mortality remained relatively constant despite significantly changing levels of pollutants, especially with regard to mortality risk among cardiovascular diseases. Modelling other cause groups using DECH metrics yielded similar results to those acquired using other air pollution variables.

Conclusion

The results of the study support the use of DECH as a mortality risk factor, particularly with respect to cardiovascular diseases, and the size of the association is fairly consistent.

1. Introduction

Numerous studies indicate that PM$_{2.5}$ is strongly associated with all-cause and specific-cause mortality (Franklin et al., 2007; Apte et al., 2015), but few reports mention whether the strength of associations between air pollution metrics and mortality rates are time-dependent. There are two possibilities. Either the size of an association is consistent, then one can use it with confidence to inform policymaking; or the size of an association is time-dependent, in which case identifying the mechanisms involved in
variations would be informative. A recent study conducted by Lin et al. (2017a) introduced a new air pollution metric, “daily exceedance concentration hours” (DECH).

All conventional measures of air pollution concentration have trended down significantly in recent years (Fig. 1). This includes the novel DECH metric. Intuition suggests that if DECH is a major indicator and cause of acute circulatory-cause mortality, as these levels decline over time the contributing risk of DECH should also decline. Most previous studies investigating air pollution and health hazards have focused on all-cause, circulatory-cause, or respiratory-cause mortality, but in recent years more attention has been paid to mental, nervous system, and skin-related diseases (Dales & Cakmak, 2016; Genc et al., 2012; Kim et al., 2016). Given that the quantitative association between these specific-cause mortalities and PM$_{2.5}$ is vague, a mathematical model using real-life data is necessary to fill the research gap.

In the current study DECH and other variables were used to model all-cause and specific-cause mortality from 1999 to 2019 with time windows of different lengths, to investigate the sizes of associations between air pollution metrics and specific-cause mortality rates. The results of the study are organized into four sections; (A) replicating the methods of prior studies, (B) extending those methods to new data, (C) further exploring the conclusions of prior studies, and (D) applying models and the DECH metric to other diseases.

2. Methods

Data sources were used to gather daily information on mortality, air pollution, weather, hospital admissions for influenza, and public holidays in Hong Kong. All data were indexed daily to form a time series from 01 January 1999 to 30 November 2019. All data processing and analyses were performed using the statistical computation language R, and models were generated using the ‘mgcv’ package.

2.1. Mortality

Mortality data were obtained from the death registry supplied by the Census and Statistics Department of Hong Kong. Data were filtered over three cause groups; all diseases, circulatory diseases, and respiratory diseases. Data from 01 January 1999 to 31 December 2000 were acquired, and cause of death was differentiated in accordance with the International Classification of Diseases (ICD) version 9. All deaths were filtered by numeric codes ranging from 001–799, deaths from circulatory diseases were filtered via codes 390–459, and deaths from respiratory diseases were filtered via codes 460–519. Data from 01 January 2001 to 31 December 2016 were differentiated in accordance with the ICD-10, therefore all deaths were filtered by numeric codes ranging from A00–R99, deaths from circulatory diseases were filtered via codes I00–I99, and deaths from respiratory diseases were filtered via codes J00–J99 (Lin et al., 2017a). Three more cause groups based on conditions commonly considered to be associated with air pollution were also incorporated into the current study; mental and behavioral conditions (Dales & Cakmak, 2016; Ho et al., 2020), diseases of the nervous system and sense organs (Calderón-Garcidueñas et al., 2015; Genc et al., 2012), and diseases of the skin and subcutaneous tissue (Kim et al., 2016). ICD-
10 codes F00–F99 and ICD-9 codes 290–319 were used to filter deaths associated with mental conditions. ICD-10 codes G00–G99 and ICD-9 codes 320–389 were used to filter deaths associated with diseases of the nervous system. ICD-10 codes L00–L99 and ICD-9 codes 680–709 where used to filter deaths associated with skin diseases.

2.2. Air pollution

Hourly air pollution data including PM$_{2.5}$ levels were obtained from the Hong Kong Environmental Protection Department. Only 4 of 19 weather stations collected PM$_{2.5}$ levels before 2004, but more weather stations began to monitor PM$_{2.5}$ levels after that time. By the end of 2019 a total of 16 weather stations across Hong Kong were monitoring PM$_{2.5}$ levels. In the present study daily average pollution levels were calculated using all the data available for each given timepoint. In accordance with many prior studies (Lin et al., 2017a; Lin et al., 2017b), daily mean and daily peak PM$_{2.5}$ concentrations were calculated. Daily meteorological data such as mean temperature (degrees Celsius) and relative humidity (percentage) were also collected. Daily data from all available stations where averaged to obtain daily means.

2.3. Influenza hospital admissions

Influenza hospital admissions data were obtained from the Hong Kong Department of Health's Centre for Health Protection. These data record the weekly influenza admissions totals. In accordance with Qiu et al. (2012) an “outbreak” week was defined as a week exceeding the 75th percentile of admissions for all weeks in that year. Notably the Centre for Health Protection has stated that “Since Feb 10, 2014, Public Health Laboratory Services Branch has adopted new genetic tests … this transition … may bring about increases in detection of and percentage positive for influenza viruses” (CHP, 2014: 2).

2.4. DECH metric

As initially proposed by Lin et al. (2017c) the DECH metric is defined as “daily concentration hours > 25 µg/m$^3$ … [where] for example, an hour with a mean concentration of 28.5 µg/m$^3$ contributes 3.5 concentration-hours to the daily total; and hours with average concentration lower than 25 µg/m$^3$ contribute zero … to the daily total”. The boundary of 25 µg/m$^3$ was chosen by Lin et al. (2017c) based on guidelines published by the World Health Organization (2006). DECH values were calculated for each day on a per-station basis, then the mean DECH of all available stations was used to define the DECH for that day over the region.

2.5. Statistical model

A model was generated then applied to different segments of the time series data. In an effort to maximize consistency and reproducibility, a generalized additive model (GAM) with an expected quasi-Poisson distribution was generated in accordance with Lin et al. (2017c). The aim of this model was to relate the discrete variable of daily circulatory mortality (count) to PM$_{2.5}$ concentrations. By finding the
coefficient on the DECH term for the model, a relative mortality risk effect percent relationship to changes in DECH PM$_{2.5}$ levels can be calculated.

The specific statistical model is as follows, where the time series Y is indexed by day, and hence $E[Y_t]$ gives the expected daily cardiovascular mortality at day t:

$$
\log(E[Y_t]) = \beta_1 \ast \text{DECH}(-l) + s(t, df = 6) + s(MT_0, df = 6) \\
+ s(MT_{1-3}, df = 6) + s(MRH_0, df = 3) \\
+ \beta_2 \ast \text{INFL} + \beta_3 \ast \text{DOW} + \beta_4 \ast \text{PH} + \alpha
$$

DECH is the mean daily measure described in section 2.4 for PM$_{2.5}$ concentration lag 3 days. DECH(-l) is lagged l day from t as described in Lin et al. (2017c), where acute mortality occurs between hours and days from initial exposure to elevated levels. MT is the mean temperature (degrees Celsius) at lag 0, and MT1-3 is a moving average of MT from days lag 1 through 3. This parameter was chosen for similar reasons as DECH being lagged 3 days. MRH is mean relative humidity (%) at lag 0. INFL is a dummy variable that takes the value of 1 when the given day at t is contained within a week designated as an “outbreak” as described in section 2.3. above. DOW refers to day of the week, a dummy variable ranging from 0 to 6 from Monday through Sunday. PH is a dummy variable indicating a public holiday on the present day, where 0 indicates no holiday and 1 indicates a holiday (including Sunday, as defined by the Hong Kong government). The temporal index t was included to account for the clear trend and seasonality described in section 1.1. above, and $\alpha$ is a random error term. The model incorporates smoother functions as penalized regression splines; $s()$. Degrees of freedom were chosen in accordance with standards described in Lin et al. (2017c) and Tian et al. (2013).

### 2.6. Model DECH lags

In the above model, DECH lag l was 2 days when applied to all mortalities, 3 days when applied to circulatory system mortalities, and 2 days when applied to respiratory system mortalities. These lag days were differentiated to match the significance figures identified and used by Lin et al. (2017c). For the newly added cause groups, 1 day lag was applied to mental condition mortalities and nervous system mortalities, and 0 day lag was applied to skin mortalities (Ho et al., 2018).

### 2.7. Model objectives

The data sources and model were carefully constructed to replicate the methods described in Lin et al. (2017c). That study incorporated three models over the mortality groups; all cause, circulatory system, and respiratory system ranging from 1998–2011. The data used in the current study spanned from 1999–2019, facilitating testing and validation of the results over a more comprehensive scale. Three additional mortality groups were also incorporated into the current study; mental and behavioral, nervous system and sense organs, and skin. Notably the lack of 1998 data is due to fine suspended particulate (FSP) data not being available from the Environmental Protection Department for that year. It is unclear how other reports were able to include this data.
Part A of this study aimed to directly replicate results reported by Lin et al. (2017c) within the same time series, and Part B aimed to investigate validity beyond the fitted time series. In Part B the 13-year model in Part A was fitted on a sliding window basis starting in 1999, extending through 2007, and ending in years 2011 and 2019, generating 9 models to test the significance of the model on newer and out-of-sample data (data from 2012–2019). In Part C, to test shorter term changes in DECH, models were fitted to 4-year periods on a sliding window basis starting from 1999 and ending in 2019 inclusive, yielding fitted models across mortality groups for time series beginning with the year range 1999–2002, and extending to the year range 2016–2019. In Part D three additional models were incorporated, derived from the mortality groups mental and behavioral, nervous system and sense organs, and skin using 5-year periods on a sliding window basis starting from 1999 and ending in 2019 inclusive. This resulted in fitted models across mortality groups for time series with year ranges beginning at 1999–2003, and extending to 2015–2019.

3. Results

3.1. Part A: Replicating results

For data ranging from 1999–2011, fitting the model described in Section 2 over all-cause, circulatory-cause, and respiratory-cause mortality groups generated the DECH coefficients shown in Table 1. The interquartile range (IQR) for hourly DECH measurements was 508.55 µg/m$^3$ throughout the period. This contrasts with the IQR of 565 µg/m$^3$ throughout 1998–2011 in Lin et al. (2017c). The DECH coefficients were multiplied by this IQR to generate relative effect percentages for an hourly IQR increase in DECH concentration. Confidence intervals associated with the effect were determined by multiplying the standard error by 1.96. In Table 2 results reported by Lin et al. (2017c) are compared with results generated in the current study, including adjusted relative effect percentages using the Lin IQR value. Ratios of the current study’s coefficients to Lin et al.’s (2017c) coefficients are also presented to neutralize any IQR issue by comparing ratios across groups.

| Coefficient | Std. Error | Significance (Pr>|t|) |
|-------------|------------|------------------------|
| ALL DISEASES | 1.763e-05  | 4.871e-06              | 0.000298               |
| CIRCULATORY | 2.825e-05  | 8.863e-06              | 0.00145               |
| RESPIRATORY | 2.155e-05  | 1.104e-05              | 0.0511                |
### Table 2
Relative effect percentage comparison of fitted models.

<table>
<thead>
<tr>
<th>Relative Effect %</th>
<th>All Diseases</th>
<th>Circulatory</th>
<th>Respiratory</th>
</tr>
</thead>
<tbody>
<tr>
<td>Our Results (IQR 508.55)</td>
<td>0.90 (0.40, 1.39)</td>
<td>1.44 (0.53, 2.34)</td>
<td>1.10 (-0.03, 2.22)</td>
</tr>
<tr>
<td>Our Results (IQR 565)</td>
<td>1.00 (0.45, 1.55)</td>
<td>1.60 (0.59, 2.60)</td>
<td>1.22 (-0.03, 2.46)</td>
</tr>
<tr>
<td>Lin Results (IQR 565)</td>
<td>1.65 (1.05, 2.26)</td>
<td>2.01 (0.82, 3.21)</td>
<td>1.41 (0.34, 2.49)</td>
</tr>
<tr>
<td>Ratio (Our / Lin)</td>
<td>55%</td>
<td>72%</td>
<td>78%</td>
</tr>
</tbody>
</table>

### 3.2. Part B: Extending the model

To explore the validity of the model using other intervals and beyond the original sample data (1999–2011) a windowed approach was used to compute several models on a rolling basis. The values of the DECH coefficients for a given window’s model are shown in the following figures, with 0.05 significance level confidence intervals for each coefficient plotted above and below in red. Fitting on 13-year intervals of data, the sliding window generated 9 models ending in years 2011, 2012, 2013, 2014, 2015, 2016, 2017, 2018, and 2019. Coefficient values for each mortality group are shown in Fig. 2, and reference data for the plotted figures are presented in Tables S1 and S2. In the 13-year windowed models the DECH coefficients for all-cause and circulatory-cause cases reached significance at the 0.05 level for all windows, but respiratory models did not reach significance in the vast majority of cases.

### 3.3. Part C: Extending the model to short-term intervals

Using a sliding window with 4-year intervals, models were fitted to identify short-term changes. DECH coefficients for each mortality group are shown in Fig. 3, and reference data for the plotted figures are shown in Table S3. Multiplying each coefficient by the window’s DECH IQR as in Part A, the relative effect percentages across each mortality group are shown in Fig. 4. Reference data for the plotted figures are shown in Table S4.

### 3.4. Part D: Applying the model to other cause groups

The same independent variables fitting the model described in section 2 were applied to data pertaining to mental, nervous, and skin diseases, which are commonly considered to be related to air pollution. A 5-year sliding window was applied to these models. The DECH coefficients for each window’s model are shown in the following figures, with 0.1 significance level confidence intervals for each coefficient plotted above and below in red. Models that reached significance at the 0.05 level are indicated by “*” in Table 3.
Table 3

Indication of significance of each fitted model's DECH coefficient at the 0.05 level. "*" indicates that the model term reached significance.

<table>
<thead>
<tr>
<th>Window Year End</th>
<th>All</th>
<th>Circulatory</th>
<th>Respiratory</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2003</td>
<td></td>
<td>*</td>
<td>*</td>
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<tr>
<td>2004</td>
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<td>*</td>
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<td>2005</td>
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<td>*</td>
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<td>2006</td>
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<td>2007</td>
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<td>2008</td>
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<td>2009</td>
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<td>2010</td>
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<tr>
<td>2011</td>
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<td>*</td>
<td>*</td>
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<tr>
<td>2012</td>
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<tr>
<td>2013</td>
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<td>2014</td>
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<td>2015</td>
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<td>2016</td>
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<tr>
<td>2017</td>
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<td>*</td>
<td></td>
</tr>
<tr>
<td>2018</td>
<td></td>
<td>*</td>
<td></td>
</tr>
<tr>
<td>2019</td>
<td></td>
<td>*</td>
<td></td>
</tr>
</tbody>
</table>

A general summary of the time series data used is provided in Table 4 below.
Table 4
Basic information about the time series data.

<table>
<thead>
<tr>
<th>Variable</th>
<th># Days</th>
<th>Mean +/- SD</th>
<th>Min</th>
<th>1st Q</th>
<th>Median</th>
<th>3rd Q</th>
<th>Max</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily Mortality</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All diseases</td>
<td>7639</td>
<td>93.2 +/- 16.7</td>
<td>44</td>
<td>81</td>
<td>92</td>
<td>104</td>
<td>171</td>
</tr>
<tr>
<td>Circ.</td>
<td>7639</td>
<td>20.39 +/- 5.66</td>
<td>3</td>
<td>17</td>
<td>20</td>
<td>24</td>
<td>54</td>
</tr>
<tr>
<td>Resp.</td>
<td>7639</td>
<td>20.82 +/- 7.94</td>
<td>3</td>
<td>15</td>
<td>20</td>
<td>26</td>
<td>68</td>
</tr>
<tr>
<td>Ment.</td>
<td>7639</td>
<td>1.75 +/- 1.77</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>Nerv.</td>
<td>7639</td>
<td>0.79 +/- 0.90</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Skin.</td>
<td>7639</td>
<td>0.49 +/- 0.73</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>6</td>
</tr>
<tr>
<td>Air Pollution</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PM$_{2.5}$ DECH</td>
<td>7638</td>
<td>297 +/- 369</td>
<td>0</td>
<td>29.8</td>
<td>144.0</td>
<td>448.2</td>
<td>3355.5</td>
</tr>
<tr>
<td>PM$_{2.5}$</td>
<td>7638</td>
<td>33 +/- 19.4</td>
<td>4.5</td>
<td>18.4</td>
<td>28.6</td>
<td>44.0</td>
<td>172.0</td>
</tr>
<tr>
<td>Weather</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature (C)</td>
<td>7638</td>
<td>24 +/- 5</td>
<td>5</td>
<td>20</td>
<td>25</td>
<td>28</td>
<td>32</td>
</tr>
<tr>
<td>Rel. Humidity (%)</td>
<td>7638</td>
<td>78 +/- 10</td>
<td>27</td>
<td>74</td>
<td>79</td>
<td>85</td>
<td>99</td>
</tr>
</tbody>
</table>

4. Discussion

4.1 Part A

Part A results in section 3.1 are generally consistent with Lin et al. (2017c). All three mortality groups’ models reached significance of the DECH term for their given lag, and the relative difference between mortality groups followed a similar pattern, i.e., the DECH coefficient for all-cause was much lower than that for circulatory-cause, and respiratory-cause was somewhat lower than that for circulatory-cause but greater than that for all-cause.

While the circulatory and respiratory coefficient ratios were consistent with Lin et al.’s (2017c) (respective ratios of 72% and 78%), the all-cause coefficient was 55%, far less than the aforementioned circulatory and respiratory ratios. Further, all of the DECH coefficients indicated lower relative effect percentages, and it is unclear what the source of this large divergence between the two result sets could be because the vast majority of underlying data and modeling techniques used in the two studies were the same. The omission of 1998 weather data as described in section 2.7 is a clear difference, however this is not believed to have had a strong effect due to the model's use of penalized splines to account for long-term trends.
4.2. Part B

When extending the model to years of data out-of-sample in Part A, significance of the DECH coefficients was reached for all-cause and circulatory-cause groups for all windows. The coefficients in these groups were also fairly stable across windows. Notably circulatory-cause coefficients exhibited an increasing trend. This coefficient trend was neutralized by a rapidly lowered DECH IQR in recent years due to decreased air pollutants. Respiratory models did not reach significance in many cases, which is somewhat consistent with the weaker results reported throughout literature.

4.3. Part C

The motivation to model based on a short-term interval such as 4 years was to investigate potential changes in relationships between FSP levels and mortalities in recent years compared to a decade prior where various measures of FSP clearly declined; principally from 2006 to 2019. In the present study most DECH coefficients derived from shorter-term respiratory models did not reach significance, whereas the majority of circulatory-cause and all-cause DECH coefficients were significant, especially those derived from models fitted towards the end of the timeline. No models had significant DECH coefficients in the windows ending in 2002, 2007, 2012, or 2013 and there was a clear outlier in the trend associated with the window ending in 2011. Further investigation is needed to determine what led to this strong inconsistency.

Consistent with expectations, all-cause and circulatory-cause mortality were significantly related to elevated DECH levels, and there was an increasing trend in windows ending in years after 2011—which were above levels of the significant models ending in years 2008–2011. While circulatory-cause mortality exhibited a stable relative effect in later years despite increasing coefficients, this was due to simultaneously decreasing DECH IQRs, and is generally consistent with results presented by Lin et al. (2017c). This indicates that DECH is a novel component of mortality risk, and the model presents a constant level of relative effect of DECH despite changing levels of pollution.

4.4. Part D

In extensions of the model investigating three more disease groups, there were no significant DECH coefficients for any time windows with respect to diseases of the nervous system and sense organs, or skin and subcutaneous tissue. Those results are consistent with a previous study reported by Ho et al. (2018) using Poisson regression models and hazy days as a predictor. For some recent time windows, there were some associations between DECH and deaths associated with mental and behavioral problems, which is consistent with a study reported by Ho et al. (2020) that focused on associations between dementia mortality and environmental pollution. One possible reason for the association between DECH and mental-cause mortality in recent years is that society is paying more attention to mental and behavioral problems, and deaths related to mental health may have been misclassified in the past. In the mortality dataset there were more than 1000 deaths per year related to mental diseases after 2014, whereas there were less than 500 per year before 2009.
Compared to the circulatory-cause and respiratory-cause groups, which were included in the previous study, mental, nervous, and skin disease groups had lower daily death counts. The median of those three groups was to 1 or 0. Zero inflation can cause inaccuracy in quasi-Poisson models.

5. Conclusion

The current study builds on the incremental work of several researchers, principally that of Lin et al. (2017c). Methods described by Lin et al. (2017c) were replicated, and similar but much weaker effects of DECH levels on mortality risk were identified. There was also evidence to support the use of DECH as a mortality risk factor, specifically with regard to circulatory diseases. Despite the downward trend in air pollution in recent years, relative effects between mortality rate and DECH have remained stable. The methods were applied to other diseasespecific mortality risks, and the results obtained were consistent with other studies.

Declarations

Ethics approval and consent to participate

Not applicable

Availability of data and materials

The death registry supplied by the Census and Statistics Department of Hong Kong. All other data are available online.

Consent for publication

Not applicable.

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None.

Conflict of interests

All authors declared no competing interests. The funding agencies had no role in the design and conduct of the study; collection, management, analysis, and interpretation of the data; preparation, review, or approval of the manuscript; or decision to submit the manuscript for publication.
Author’s contributions

All authors conceived and conducted the research and wrote the draft. All authors critically revised the manuscript, and all authors approved the submission.

References


Figures

![Smoothed Daily Air Pollution (1999-2019) (SMA 180 Days)](image)

Figure 1
Simple moving average applied to daily mean and peak PM$_{2.5}$ concentrations and daily mean DECH indicating a trend of improved air quality in Hong Kong in recent years. Compared to the daily mean PM$_{2.5}$, the daily mean DECH better captures variations in air pollution within a day.

**Figure 2**

DECH coefficients across mortality groups for 13-year sliding window fitted models. DECH IQRs associated with later sliding windows were dramatically lower, consistent with results shown in Figure 1. The DECH coefficients for all-cause and circulatory-cause groups reached the 0.05 level of significance for all windows. The respiratory models did not reach significance in the vast majority of cases. The DECH coefficients in circulatory-cause groups exhibited an increasing trend, while in all-cause groups they remained nearly unchanged.
Figure 3

DECH coefficients across mortality groups for 4-year sliding window fitted models. With a narrower time window the DECH IQR peak occurred during 2004–2007. The respiratory models did not reach significance in the vast majority of cases, whereas all-cause and circulatory-cause groups reached significance in the majority of cases.
Figure 4

DECH coefficients across mortality groups for 5-year sliding window fitted models. With a narrower time window the DECH IQR peak occurred during 2004–2007. The respiratory models did not reach significance in the vast majority of cases, whereas all-cause and circulatory-cause groups reached 0.05 significance in the majority of cases.
Figure 5

DECH coefficients across the new cause groups for 5-year sliding window-fitted models with 0.1 significance level confidence intervals. For time windows started after 2010 circulatory-cause groups reached the 0.1 level of significance in the majority cases, whereas there were no clear associations between DECH level and nervous-cause mortality or skin-cause mortality in any time windows.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- appendix.doc