Impact assessment of air pollution on health

Capacity Development Program on Air Quality Management and Emission Reduction of PM2.5 for Asian Countries

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Prof. Tze Wai WONG

Adjunct Professor, School of Public Health and Primary Care

The Chinese University of Hong Kong

Background

- Air pollution is an important cause for mortality.
- In the ***2010 study of global burden of diseases***, particulate air pollution accounts for 3.1 million deaths and 3.1% of disability adjusted life years (DALYs) lost globally (Lim et al, 2010).
- Globally, air pollution ranks as the 9th most important risk factor for mortality.
- This problem is especially serious in East Asia, where ambient air pollution is the 4th highest risk factor responsible for disease mortality.

Lim SS, Vos T, Flaxman AD, Danaei G, Shibuya K, Adair-Rohani H, Amann M et al (2012) A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the global burden of disease study 2010. Lancet 380(9859): 2224–2260.

Impact assessment of air pollution on health

- In most developed countries in Europe and North America, it is customary to perform an assessment of the health and economic impact of air pollution.
- A properly conducted, scientifically valid health impact assessment (HIA) and economic impact assessment (EIA) enable policy makers to make the most appropriate choice out of several alternative options.
- The results the HIA and EIA also help to convince the public to accept and participate in the air pollution strategies promulgated.

Definition of HIA

- Health impact assessment (HIA) has been defined as ‘a combination of procedures, methods, and tools by which a policy, programme, or project may be judged as to its potential effects on the health of a population, and the distribution of those effects within the population. HIA identifies appropriate actions to manage those effects’ (WHO, 2002; Lee et al, 2013; Quigley, 2006).

- HIA offers a framework, influenced by policy and regulation, that can be used to assess, justify, and manage projects that may potentially influence public health (Birley, 2011).

Birley, Martin (2011). Health Impact Assessment: Principles and Practice. Abingdon: Earthscan.

Lee JH, Röbbel N and Dora C. Cross-country analysis of the institutionalization of Health Impact Assessment. Social Determinants of Health. Discussion Paper Series 8 (Policy & Practice). Geneva, World Health Organization, 2013.

Quigley, R; den Broeder, L; Furu, P; Bond, A; Cave, B; Bos, R (2006). Health Impact Assessment: International Best Practice Principles. Special Publication Series No. 5. Fargo, USA: International Association for Impact Assessment (IAIA).

World Health Organization (2002). Technical Briefing – Health Impact Assessment: A tool to include health on the agenda of other sectors. Copenhagen: WHO Regional Office for Europe.

HIA and public policy

- There has been increasing international attention on the potential for using HIA as a way to mainstream health into sector policies, as evidenced during the World Conference on Social Determinants of Health (October 2011, WHO) and the United Nations Conference on Sustainable Development (June 2012, WHO).
- Some countries have adopted legislative frameworks and governance mechanisms to consider the impact of policies, programmes or projects on health.
- However, differences in political, socioeconomic and administrative settings lead to substantial variations in the use institutionalization of HIA.

WHO, 2011. *https://apps.who.int/mediacentre/events/meetings/2011/social_determinants_health/en/index.html*
WHO, 2012. *https://www.un.org/en/conferences/environment/rio2012*

HIA and public policy

- Lee et al (2013) compared the institutionalization of HIA in nine (mainly middle- and high-income) countries[1] and the European Union and developed an analytical framework which covers 5 areas:

1. Degree of and Mechanisms for Institutionalization;
2. Political Setting and Context;
3. Framing and Type of HIA;
4. Implementation, Resource requirements and Structures; and
5. Outcomes and Conclusions. In-depth interviews were conducted with policy-makers, experts, public health officials and other stakeholders from and the European Commission (Lee et al 2013)

[1] Australia (South Australia), Canada (Quebec), Finland, Lithuania, the Netherlands, Slovakia, Switzerland, Thailand, the United States of America;

HIA and public policy

- The findings from the interviews showed that *all countries have institutionalized HIA to a certain extent*.

- The degree of institutionalization varied within and across countries; yet there were similarities in the mechanisms used to achieve it (for example through Public Health Acts or establishment of research centres).

- Drivers for the institutionalization of HIA included

1. Recognition of the importance of and need for intersectoral action;
2. Increasing international movement towards health promotion and use of HIA;
3. Support from the health sector;
4. Experiences with the institutionalization of Environmental Impact Assessment (EIA); and
5. Advancement of HIA at the local level.

HIA and public policy

- The key factors enabling institutionalization of HIA were:

1. Legislation (for example inclusion of HIA within Public Health Acts);
2. Political willingness;
3. Involvement of Research communities;
4. Awareness of the Inadequacy of EIA or other assessments in considering health;
5. Capacity and Resources;
6. Availability of international committal documents and tools; and public participation.

HIA and public policy

- Challenges to institutionalization and systematic implementation included:

1. Lack of clarity around methodology and procedures;
2. Narrow definitions of health;
3. Lack of awareness of relevance to other sectors; and
4. Insufficient funding and tools.

Models of Health Impact Assessment

- There are many models of health impact assessment (HIA), although to begin with, these largely fall into two camps (Kemm et al, 2004).

1. The biomedical models mainly examine the underlying mechanisms of health and disease, as related to the influence of the environment; they stem from toxicological and epidemiological knowledge, and tend to involve quantitative analysis and modelling.
2. The broader social models, arising from the social sciences, place more stress on topics such as housing and employment, which also can influence health. By their nature, the analyses used in these models are more qualitative.

- Nowadays, HIAs incorporate aspects of both kinds of model, and may also look at policy, the economy, and other possible health determinants.

The Health Impact Assessment Process

The following is a summary of the HIA process (Kemm et al, 2004; WHO, 2005; Birley, 2011):

1. Screening – determining whether a project *needs* HIA

2. Scoping – setting a framework and goals for the HIA – identifying potential health risks and benefits and affected stakeholders; defining geographical and time boundaries; finding data sources

3. Appraisal / risk assessment – collecting information; finding vulnerable communities; establishing the baseline level of health; assessing and analysing health risks

4. Reporting – prioritising health impacts and suggesting actions to mitigate them; preparing reports and recommendations

5. Dissemination – providing the results of the assessment to stakeholders, including those affected by the proposed project, and supporting the decision-making process

6. Monitoring and evaluation – collecting information and evaluating the impact or outcome of the project

Birley, Martin (2011). Health Impact Assessment: Principles and Practice. Abingdon: Earthscan.

Kemm, John; Parry, Jane; Palmer, Stephen (Eds.) (2004). Health Impact Assessment: Concepts, theory, techniques, and applications. New York: Oxford University Press.

World Health Organization (2005). Health Impact Assessment Toolkit for Cities, Document 1: Vision to Action (Background document: concepts, processes, methods). Copenhagen: WHO Regional Office for Europe.

Health risk assessment of air pollution

- Health impact assessment (HIA) plays an important role in the formulation of air pollution policy and control measures.
- It provides environmental policy makers with quantitative and qualitative information about how any air pollution control policy, strategy, programme or project may affect the health of a community.
- In respect of the health consequences of air pollution levels, HIA aims to elucidate the effects of air pollution currently experienced by the population (*health burden*), and the improvement in health that might be expected through reductions in air pollution (*health impact*).

Burden of disease due to outdoor air pollution

- In the WHO Air Quality Guidelines Global Update Report, the overall estimated burden of disease due to outdoor air pollution may account for approximately 1.4% of total mortality, 0.5% of all disability-adjusted life years (DALYs) and 2% of all cardiopulmonary diseases (WHO 2006).
- Susceptible population subgroups include young children, the elderly and those with chronic heart and lung diseases.
- Certain regions of the world share a higher burden of disease, such as those heavily dependent on coal for fuel and residents of bigger cities exposed to high concentrations of traffic-related pollution.

World Health Organization (2006). Air Quality Guidelines Global Update 2005. World Health Organization Regional Office for Europe, Copenhagen.

Impact of outdoor air pollution on health

- To analyze quantitatively the impact on health of outdoor air pollution in a specific city, region or country, information is needed on:

1. Air pollution concentrations and exposure,
2. Population groups exposed,
3. Background incidence of mortality and morbidity, and concentration–response (CR) functions.
4. Health outcomes: The choice of which health outcomes to include in the assessment may be determined by the strength of available studies, the accessibility of health information, and the importance of the impact from a health and economic perspective.

- Most analyses conducted to date indicate that effects on **mortality**, particularly those relating to **long-term exposure** to air pollutants, tend to dominate the estimated economic effects' (WHO 2006).

World Health Organization (2006). Air Quality Guidelines Global Update 2005. World Health Organization Regional Office for Europe, Copenhagen.

Health risks Estimates and Unit Health Risks associated with Air Pollution

- The association between air pollution and health is well established and the amount of literature on such studies is huge.
- In general, adverse effects on health and survival have been shown on short-term and long-term exposure to different types of air pollutants.
- Different levels of evidence have been established for different health outcomes. Higher risks of mortality and morbidities, in particular, from respiratory and cardiovascular diseases, have been shown on both short- and long-term exposure to air pollution (WHO 2006).

World Health Organization (2006). Air Quality Guidelines Global Update 2005. World Health Organization Regional Office for Europe, Copenhagen.

Health risks Estimates and Unit Health Risks associated with Air Pollution

- Evidence is accumulating that air pollution is also linked to other illnesses – adverse birth outcomes such prematurity, low birth weight as congenital malformations.
- Emerging evidence that long-term exposure to particulates, a key air pollutant in scientific research, might be linked with neurodevelopment in children and cognitive function, and other chronic diseases such as diabetes (WHO 2013).
- Effects on a physiological attribute – lung function, has been well researched in cohort studies in South California (Gauderman et al, 2007, 2015), as well as in many other countries and cities including Hong Kong (Yu et al, 2001; He et al, 2010; Gao et al, 2013).
- However, lung function loss has not been used as a health outcome in HIA due largely to its uncertain impact on specific diseases and survival.

World Health Organization (2006). Air Quality Guidelines Global Update 2005. World Health Organization Regional Office for Europe, Copenhagen.

World Health Organization (2013). Review of evidence on health aspects of air pollution – REVIHAAP Project. Technical Report. World Health Organization Regional Office for Europe, Copenhagen.

Health Outcomes associated with Short-term exposure

- **Mortality**

- Among the ‘criteria air pollutants’ (particulate matters $PM_{2.5}$ and PM_{10}, oxides of nitrogen, ozone and sulphur dioxide), all have been shown to be associated with premature deaths.

- Most of the evidence is from time series studies, where statistical models are constructed to study the association between daily changes in the concentrations of air pollutants and the risk of dying in different populations.

- The earliest time series studies on air pollution and mortality were published in the United States and Europe in the early and mid-1990s.

Mortality associated with Short-term exposure to air pollution

- Time series studies in other countries: e.g., Canada, South Korea and China have been reported. Similar studies in Hong Kong (Wong CM et al, 2001; Wong TW et al, 2002).
- 'Public Health and Air Pollution in Asia' (PAPA) (Wong CM et al. 2010). This multi-city study show that short-term exposure to nitrogen dioxide (NO_2), ozone (O_3), sulphur dioxide (SO_2) and particulate matter with an aerodynamic diameter less than 10 μm (PM_{10}) are statistically significant risk factors for all-cause mortality and deaths from cardiovascular and respiratory causes.
- These findings are broadly consistent with earlier local and overseas studies.
- Many U.S. studies focussed on PM as the underlying "true" cause of mortality, and consider gaseous pollutants like NO_2 to be proxies of PM.

Wong CM, Thach TQ, Chau PYK, Chan EKP, Chung RYN, Ou C-Q, Yang L, Peiris JSM, Thomas GN, Lam TH, Wong TW, Hedley AJ 2010. Part 4. Interaction between Air Pollution and Respiratory Viruses: Time Series Study of Daily Mortality and Hospital Admissions in Hong Kong. In: *Public Health and Air Pollution in Asia (PAPA): Coordinated Studies of Short-Term Exposure to Air Pollution and Daily Mortality in Four Cities.* HEI Research Report 154, Health Effects Institute, Boston, MA.

Wong TW, Tam WS, Yu TS, Wong AHS. Associations between daily mortalities from respiratory and cardiovascular diseases and air pollution in Hong Kong, China. *Occupational and Environmental Medicine* 2002; 59:30-35

Morbidities associated with Short-term exposure to air pollution

- A good account of studies on air pollution and diseases can be found in the Air Quality Guidelines, a Global Update 2005 (WHO 2006).

- In Hong Kong, the first comprehensive study on air pollution and hospital admissions was reported by the author (Wong TW et al, 1999). Hospital admissions for all respiratory and all cardiovascular diseases, as well as specific diseases – chronic obstructive pulmonary diseases (COPD) and heart failure were significantly associated with NO_2, O_3, SO_2 and PM_{10}, while asthma, influenza and pneumonia are significantly associated with three of the four pollutants (i.e., except SO_2).

- More recent studies show similar associations of air pollution with asthma and COPD (Ko et al, 2007).

Ong SG, Liu J, Wong CM, Lam TH, Tam AYC, Daniel L, Hedley AJ. Studies on the respiratory health of primary school children in urban communities of Hong Kong. Science of the Total Environment 1991; 106:121-35.

Ko FWS, Tam WS, Wong TW, Lai CKW, Wong GWK, Leung TF, Ng S, Hui DSC. Effects of air pollution on asthma hospitalization rates in different age groups in Kong Hong. Clinical and Experimental Allergy 2007; 37:1312-1319.

Ko FWS, Tam W, Chan DPS, Wong TW, Tung AH, Lai CKW, Hui DSC. Temporal relationship between air pollutants and hospital admissions for chronic obstructive pulmonary disease in Hong Kong. Thorax 2007; 62:779-784.

Wong TW, Lau TS, Yu TS, Neller A, Wong SL, Tam W, Pang SW. Air pollution and hospital admissions for respiratory and cardiovascular diseases in Hong Kong. Occupational and Environmental Medicine 1999; 56(10):679-683

World Health Organization (2006). Air Quality Guidelines Global Update 2005. World Health Organization Regional Office for Europe, Copenhagen.

Morbidities associated with Short-term exposure to air pollution

- The author (Wong TW et al, 2006) conducted a time series study that demonstrated a significant association between NO_2, O_3, SO_2, PM_{10} and $PM_{2.5}$ and general practitioner (GP) consultations for upper respiratory tract infections (URTI).
- Earlier studies have also reported higher prevalence of respiratory illnesses and bronchial hyperreactivity (BHR) in schoolchildren who live in more polluted districts compared with those in less polluted districts (Ong et al, 1991; Tam et al, 1994; Yu et al, 2001).

Ong SG, Liu J, Wong CM, Lam TH, Tam AYC, Daniel L, Hedley AJ. Studies on the respiratory health of primary school children in urban communities of Hong Kong. Science of the Total Environment 1991; 106:121-35.

Tam AYC, Wong CM, Lam TH, Ong SG, Peters J, Hedley AJ. Bronchial responsiveness in children exposed to atmospheric pollution in Hong Kong. Chest 1994; 106:1056-60.

Wong TW, Tam W, Yu ITS, Wun YT, Wong AHS, Wong CM. Association between Air Pollution and General Practitioner Visits for Respiratory Diseases in Hong Kong. Thorax 2006; 61:585-591.

Yu TS, Wong TW, Wang XR, Song H, Wong SL, Tang JL. Adverse effects of low-level air pollution on respiratory health of school children in Hong Kong. Journal of Occupational and Environmental Medicine 2001; 43:310-16.

Morbidities associated with Short-term exposure to air pollution

- Besides hospital admissions for cardiopulmonary diseases, several respiratory morbidities have been used in HIA in Europe and Australia (Kunzli et al, 1999; Department of Environment and Conservation (NSW), 2005) – the incidence of bronchial asthma attacks, the incidence of acute bronchitis among those aged below 15, the prevalence of chronic bronchitis in adults, and the number of days of restricted activity resulting from air-pollution related illnesses.

- Other effects such as reduced lung function and increased prevalence of respiratory symptoms (e.g., cough) have not been used for health impact assessment (HIA) and economic impact assessment (EIA) , as their economic impacts have not been quantified.

- *Department of Environment and Conservation (NSW). Air Pollution Economics: Health costs of air pollution in the Greater Sydney Metropolitan Region, Sydney 2005.*
- *Künzli N, Kaiser R, Medina S, Studnicka M, Oberfeld G, Horak F. Health costs due to road traffic-related air pollution – an assessment project of Austria, France and Switzerland. Prepared for the Third Ministerial Conference for Environment and Health, London, 1999.*

Unit Health Risks

- Unit risks of air pollution on health have been expressed as relative risks (RR) of developing the disease under study per unit increase in the concentration of an air pollutant.
- For the same diseases and air pollutants, these unit risks often differ quantitatively among studies conducted in different countries / cities, although the ranges of these estimates often overlap.
- In the performance of HIA, it is logical to use local data on unit health risk wherever available. This is because local characteristics in air pollution profile and exposure patterns determine the magnitude of risk, despite the similarities in human response to air pollution.

Table 1: % Excess risk (95% confidence interval) of mortalities and morbidities attributable to a 10 μg/m^3 increase in air pollutant concentration derived from time series studies in Hong Kong

Air pollutant	All-cause mortality (all ages)*	Cardio-vascular mortality*	Respiratory mortality*	Cardio-vascular diseases	Respiratory diseases	Upper respiratory tract infections #
NO_2	1.03 (0.69-1.37)	1.38 (0.75-2.01)	1.41 (0.67-2.15)	*1.00 (0.73-1.26)	*0.75 (0.50 - 1.00)	3.00 (2.00-4.00)
PM_{10}	0.51 (0.23-0.80)	0.63 (0.11-1.16)	0.69 (0.08-1.31)	*0.58 (0.36-0.80)	*0.60 (0.40-0.80)	2.00 (1.60-2.50)
$PM_{2.5}$	0.4097	1.4151	1.0416	0.66 (0.36-0.97)***	0.97 (0.65-1.29)***	2.1 (1.0-3.2)
SO_2	0.91 (0.40-1.42)	1.23 (0.27-2.21)	1.31 (0.21-2.43)	*0.98 (0.53-1.39)	*0.13 (-0.24-0.50)	1.00 (-0.113-1.300)
O_3	0.34 (0.02-0.66)	0.63 (0.04-1.23)	0.36 (-0.33-1.05)	*0.12 (-0.12-0.37) NS	*0.81 (0.58-1.04)	2.50 (1.20-3.80)

* PAPA Study, 2010

*** Qiu et al, 2013

RR of mortality (from long-term follow-up 'cohort' studies)

- For the assessment of the health impact of air pollution, U.S. researchers have focussed on PM as a causative risk factor for all-cause mortality and cause-specific (cardiovascular, pulmonary, and lung cancer) mortalities.
- There are more data on mortality risk from long-term exposure to $PM_{2.5}$ than PM_{10}. Therefore, HIA using $PM_{2.5}$ is preferred by experts in their HIA studies (Kunzli et al, 1999; Fisher et al, 2002; Department of Environment and Conservation (NSW) 2005; COMEAP 2010).

Committee on the Medical Effects of Air Pollution (COMEAP). The Mortality Effects of Long-Term Exposure to Particulate Air Pollution in the United Kingdom. A Report by the Committee on Medical Effects of Air Pollution. Health Protection Agency, United Kingdom 2010. Accessed at: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/304641/COMEAP_mortality_effects_of_long_term_exposure.pdf

Department of Environment and Conservation (NSW). Air Pollution Economics: Health costs of air pollution in the Greater Sydney Metropolitan Region, Sydney 2005.

Fisher GW, Rolfe KA, Kjellstrom T, Woodward A, Hales S, Sturman AP, Kingham S, Petersen J, Shrestha R, King D. Health effects due to motor vehicle air pollution in New Zealand, Report to the Ministry of Transport, Wellington, 2002.

Künzli N, Kaiser R, Medina S, Studnicka M, Oberfeld G, Horak F. Health costs due to road traffic-related air pollution – an assessment project of Austria, France and Switzerland. Prepared for the Third Ministerial Conference for Environment and Health, London, 1999.

RR of mortality (from long-term follow-up 'cohort' studies)

- Dockery et al first published an RR of 1.26 (96% CL: 1.08-1.47), adjusted for smoking and other risk factors, for mortality from fine particulates ($PM_{2.5}$) in the Harvard Six City Study (Dockery et al, 1993).
- Most HIA studies performed in developed countries used the RR reported by Pope et al (2002) in the American Cancer Society cohort study. The RR of all-cause mortality was 1.062 (95% CI: 1.02-1.11). A meta-analysis by WHO also reported an RR of 1.062.

Dockery DW, Pope CA, Xu X, Spengler JD, Ware JH, Fay ME, Ferris BG, Speizer FE. New England Journal of Medicine 1993; 329:1753-59.

Pope CA, Burnett RT, Thun MJ, Calle EE, Krewski D, Ito K, Thurston GD. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. Journal of the American Medical Association 2002; 287(9):1132-41.

RR of mortality (from long-term follow-up 'cohort' studies)

- In a more recent "extended analysis of the American Cancer Society study (Krewski et al, 2009), a slightly higher RR of 1.078 (95% CI: 1.043-1.115) was obtained.
- An HIA study in London by King's College (Walton et al, 2015) used Pope's RR as the unit health risk for assessing the impact of long-term exposure to $PM_{2.5}$.
- The choice of an appropriate RR of all-causes mortality from long-term exposure to $PM_{2.5}$ is important, as the magnitude of this RR influences the overall health impact assessment.
- Compared to the other health endpoints, all-cause mortality is the single most important outcome in terms of health and economic impact.

Krewski D, Jerrett M, Burnett RT, Ma R, Hughes E, Shi Y, Turner MC, Pope CA III, Thurston G, Calle EE, Thun MJ. 2009. Extended Follow-Up and Spatial Analysis of the American Cancer Society Study Linking Particulate Air Pollution and Mortality. HEI Research Report 140. Health Effects Institute, Boston, MA.

Walton H, Dajnak D, Beevers S, Williams M, Watkiss P, Hunt A. Understanding the Health Impact of Air Pollution in London. King College London, 2015. Accessed at: http://www.kcl.ac.uk/lsm/research/divisions/aes/research/ERG/research-projects/HIAinLondonKingsReport14072015final.pdf

Economic Impact Assessment of Air Pollution

- Economic impact assessment (EIA) refers to the valuation of health impacts caused by air pollution.
- EIA is important in air pollution as the latter produces 'external costs' that are not borne by the polluter, but by those whose health and life are being affected.
- Although it is not a legal requirement to conduct EIA in most countries, an economic evaluation of policy options has been required under the U.S. Environmental Protection Agency regulations for rules and regulatory actions that have a "significant impact – those with an annual effect on the economy of $100 million or more (USEPA 2016), or adversely affect in a material way the economy, a sector of the economy, productivity, competition, jobs, the environment, public health or safety, or State, local or tribal governments or communities.
- In many European countries, it is customary to perform EIA studies for major developmental projects.

Economic Impact Assessment of Air Pollution

- THERE ARE TWO APPROACHES (I) COST OF ILLNESS (COI) THAT ASSESSES THE DIRECT MEDICAL COSTS OF ILLNESS, SUCH AS DIAGNOSIS AND TREATMENT FOR THESE ILLNESSES, AND INDIRECT COSTS SUCH AS THE LOSS OF PRODUCTIVITY, AND (II) THE 'WILLINGNESS TO PAY' (WTP) APPROACH, THAT MAKES USE OF SURVEYS TO ASSESS AN INDIVIDUAL'S WILLINGNESS TO PAY TO AVOID SPECIFIED ILLNESSES OR LOSS OF LIFE.
- THE WTP APPROACH HAS BEEN ADOPTED BY THE EUROPEAN AND AUSTRALIAN (SYDNEY) HIA STUDIES, AS IT INCLUDES A COMPREHENSIVE LIST OF VALUES THAT INCLUDE THE DIRECT AND INDIRECT COSTS OF ILLNESS, AND IN ADDITION, OTHER COMPONENTS SUCH AS PAIN AND SUFFERING FROM ILLNESSES, PERCEIVED QUALITY OF LIFE.
- PREMATURE DEATH HAS ALSO BEEN VALUED USING THE 'STATISTICAL VALUE' OF A LIFE LOST AS A UNIT OF MEASUREMENT.
- IN GENERAL, THE VALUATION USING THE WTP APPROACH IS TYPICALLY SEVERAL TIMES HIGHER THAN THAT USING THE COI APPROACH.
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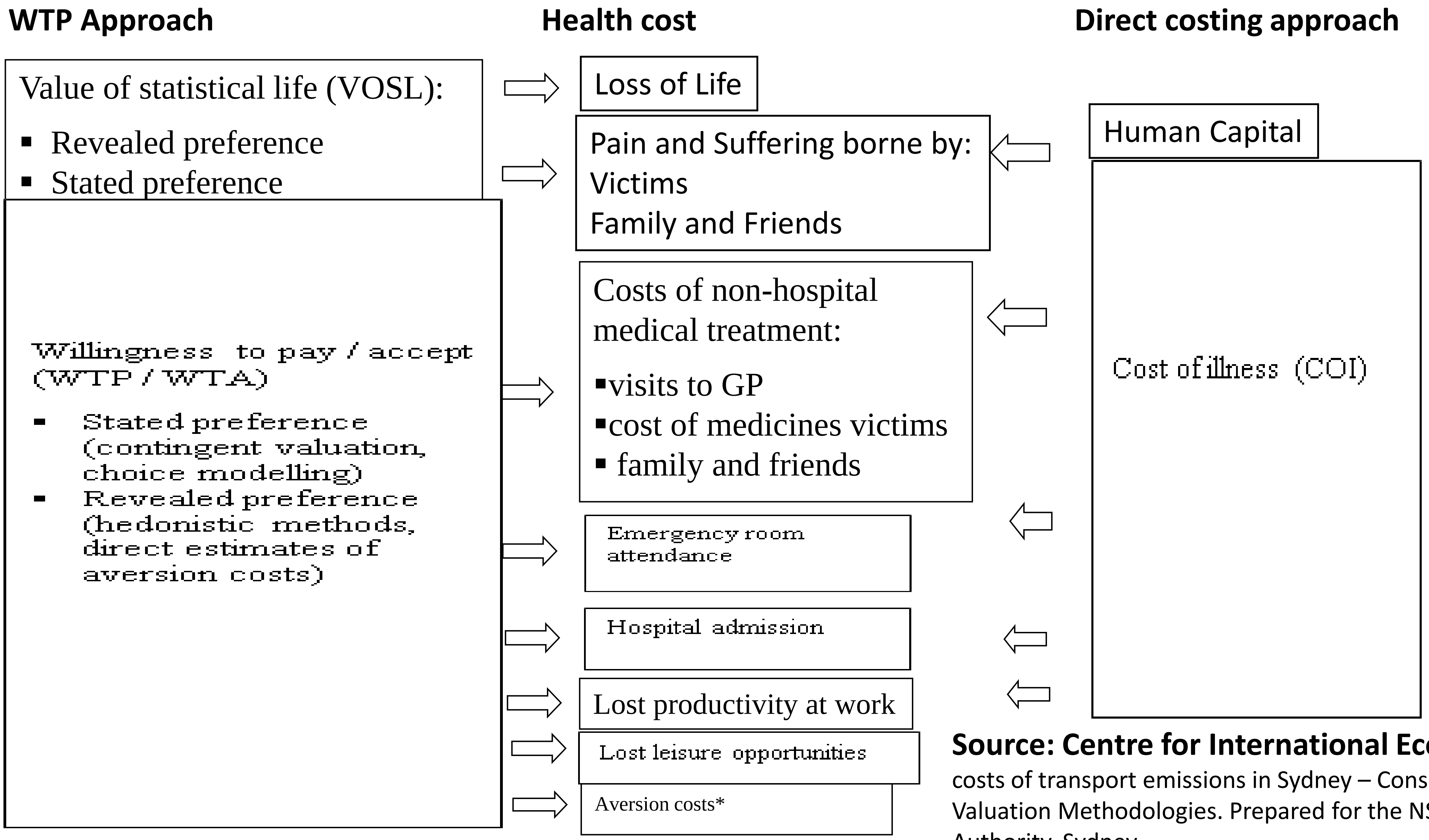
Valuation methodologies and coverage of health costs



* Aversion costs can be associated with both mortality and morbidity effects.

Source: Centre for International Economics, 2001, Health costs of transport emissions in Sydney – Consultancy 2 – Economic Valuation Methodologies. Prepared for the NSW Environmental Protection Authority, Sydney.

Table 2: Economic data relevant to HIA and EIA study in Hong Kong

Service	Fees
Provided by Hospital Authority	
Accident & Emergency	$990 per attendance
In-patient (general hospitals)	$4,680 per day
In-patient (psychiatric hospitals)	$1,940 per day
Intensive care ward/unit	$23,000 per day
High dependency ward/unit	$12,000 per day [N1]
Specialist out-patient (including allied health services)	$1,110 per attendance
General out-patient	$385 per attendance
Derived from survey of doctors (2015)	
Median charge by private general practitioner per consultation	$250 (Range: $120 - $800)

1: The Hospital Authority provides about 90% of all hospital beds in Hong Kong. The rest is provided by the private sector.

Cost of mortality

- Like morbidity, no WTP data are available to estimate the economic costs of premature deaths. However, since VOSL is the single most important item (>90%) in the cost estimate, we have made reference to economic data used by the World Health Organization Regional Office for Europe (WHO, 2015). The baseline VOSL is US$3 million.
- WHO made adjustments in Countries of the European Region, based on their per capita gross domestic product (GDP).
- VOSL ranges from the lowest estimate of US$0.44 (Tajikistan and Uzbekistan) to US$6.28 (Luxembourg) in 2010.
- Data from other countries, such as the U.S. ($10 million), the United Kingdom (US$3.55 million) will also be used as references.
- The Australian EIA study (Department of Environment and Conservation (NSW) 2005) was based on a lower estimate of A$1,004,000 and an upper estimate of A$2,500,000.

COST OF MORTALITY

- VOSL estimates in Asian countries are much lower.
- The average VOSL in China has been estimated as RMB795,000 (Wang & He, 2010).
- In another study by Chen et al (2010), an average value of RMB$1 million (valued in 2006) for premature death, published by World Bank in 2007*, was used.
- In a global review of VOSL (based on earlier studies), the estimated value (in 2000) is US$0.7 million for Taiwan and US$0.8 million for South Korea (Viscusi and Aldy, 2003).

** The World Bank 2007 report made reference to several studies, and used the value reported by Krupnick et al (2006) of RMB1.4 million, based on pooled data from Chongqing and Shanghai, and then adjusted to RMB ! million to reflect income differences between these cities and the rest of China.*

Wang H, He J. The value of statistical life – a contingent investigation in China. Policy Research Working Paper 5421, Washington D C: World Bank, 2010.

World Bank. Cost of pollution in China. Washington D C: World Bank, 2007.

WHO Regional Office for Europe, OECD 2015. Economic cost of the health impact of air pollution in Europe: Clean air, health and wealth, Copenhagen: WHO Regional Office for Europe.

Viscusi WK and Aldy JE. The value of a statistical life: a critical review of market estimates throughout the world. Working Paper 9487, National Bureau of Economic Research, Cambridge MA, 2003.

COST OF MORTALITY

- The VOSL estimates can be considered with reference to the per capita GDP of these countries.
- For example in 2014, the per capital GDP in the U.S. is US$46,405.26; in the U.K., US$40,967.70; Singapore, US$38087.89; Hong Kong's per capita GDP, at US$34,222.29, is 8.89 times that of China, at US$3,865.88.
- If we use the more conservative VOSL estimate of RMB795,000 in China (Wang & He, 2010, World Bank Paper), and adjust this amount by the ratio of per capita GDP of Hong Kong to China (8.89 times), the estimated VOSL for Hong Kong would amount to: 795,000 x 1.19 / 7.75 x 34222.29 / 3,865.88 = US$1,080,620.21 (in 2010 value), assuming an exchange rate (in 2016) of HK$1.19 per RMB, and HK$7.75 per US$.

* THE WORLD BANK 2007 REPORT MADE REFERENCE TO SEVERAL STUDIES, AND USED THE VALUE REPORTED BY KRUPNICK ET AL (2006) OF RMB1.4 MILLION, BASED ON POOLED DATA FROM CHONGQING AND SHANGHAI, AND THEN ADJUSTED TO RMB ! MILLION TO REFLECT INCOME DIFFERENCES BETWEEN THESE CITIES AND THE REST OF CHINA.

COST OF MORTALITY

- An adjustment of the European VOSL to Hong Kong's per capital GDP (relative to EU, at US$30,240.87) would yield an estimate of US$2,650,980 (about 2.5 times the adjusted value using Chen's VOSL and about 2 times that of Wang's VOSL).
- If we use the Taiwan VOSL (US$700,000), the adjusted VOSL for Hong Kong is US$1,071,599. Using South Korea's VOSL of US$800,000, the adjusted VOSL for Hong Kong is US$1,114,480.
- Hence, an estimate of VOSL at US$1 million for Hong Kong, adjusted for per capital GDP, is in line with similar estimates in neighbouring Asian countries.
- We used the adjusted VOSL from the European value of US$2,650,980 as the upper limit, and the adjusted VOSL from Wang's data of US$1,080,620.21 as the lower limit in our EIA. (Both are expressed in 2010 dollar value.)

Table 3: Health outcomes associated with air pollution, source and strength of evidence

Health outcomes		Exposure to air pollution	Evidence*§
Mortality, all cause		Long-term	Sufficient to infer causality §
Cause-specific mortality	Cardiovascular	Short-term	Sufficient to infer causality *§
	Respiratory		Sufficient to infer causality *§
Hospital admissions	Cardiovascular	Short-term	Sufficient to infer causality *§
	Respiratory		Sufficient to infer causality *§
Specific diseases			
Chronic bronchitis	Incidence	Long-term	Suggestive
	Prevalence	Long-term	Insufficient
Bronchitis in children	Incidence	Long-term	Sufficient to infer causality *§
Asthma attacks in children	Prevalence	Short-term	Sufficient to infer causality *§
Asthma attacks in adults	Prevalence	Short-term	Sufficient to infer causality *§
Hospitalization for asthma	Attacks	Short-term	Sufficient to infer causality
Upper respiratory illnesses (URI)	Incidence	Short-term	Sufficient to infer causality
Lung function in children		Long-term	Sufficient to infer causality
Lung growth in children		Long-term	Sufficient to infer causality
Cardiopulmonary fitness (VO_{2max})		Long-term	Highly suggestive
Restricted activity days in adults		Short-term	Sufficient
Sickness absence in adults		Short-term	Sufficient
Low birth weight (LBW), preterm births, intrauterine growth retardation (IUGR) and birth defects		Long-term	Suggestive but inconsistent for LBW, preterm births and IUGR; Limited evidence for birth defects *
Neurodevelopmental deficit in children			Mainly through ingestion, but air pollution also contributes to indirect exposure *
Cognitive defects in adults			Inconclusive §
Childhood leukaemia			Insufficient *
Atherosclerosis		Long-term	Strong supportive evidence from experimental studies §
Diabetes mellitus		Long-term	Suggestive §

* *Effects of air pollution on children's health and development: A review of the evidence. WHO Special Programme on Health and Development, European Centre for Environment and Health, Bonn Office 2005.*

§ Review of Evidence on health aspects for air pollution – REVIHAAP Project, Technical Report, World Health Organization Regional Office for Europe, Denmark, 2013.

Table 4: Estimates of premature mortalities attributed to $PM_{2.5}$ using mortality data in 2012

Health Outcomes	Annual no. of deaths	Unit RR per 10 μg/m³	Annual $PM_{2.5}$ conc.§	Target $PM_{2.5}$ conc.	Change in exp. conc.	RR for 1μg/m³	RR for change in exp. conc.	Attributable fractionΨ	Annual attributable deaths	Remark
All-cause mortality (Hypothetical no.)	100,000	1.06 *	28.6	27.6	1	1.005844	1.005844	0.00581	581	Pope's RR; Assuming a 1 μg/m³ change in $PM_{2.5}$ concentration
All non-external ϕ cause mortality	42,017	1.06 *	28.6	27.6	1	1.005844	1.005844	0.00581	244	Pope's RR; Assuming a 1 μg/m³ change in $PM_{2.5}$ concentration
All non-external cause mortality	42,017	1.02	28.6	27.6	1	1.001982	1.001982	0.001978	83	Lower 95% CL of RR; Assumes a 1 μg/m³ change in $PM_{2.5}$ concentration
All non-external cause mortality	42,017	1.11	28.6	27.6	1	1.010491	1.010491	0.010382	436	Upper 95% CL of RR; Assumes a 1 μg/m³ change in $PM_{2.5}$ concentration
All non-external cause mortality	42,017	1.062 *	28.6	10 φ	18.6	1.005844	1.114471	0.102714	4,316	Pope's RR; Assumes $PM_{2.5}$ changes to 10 μg/m³
All non-external cause mortality	42,017	1.02	28.6	10 φ	18.6	1.001982	1.03752	0.036163	1,519	Lower 95% CL of RR; Assumes $PM_{2.5}$ changes to 10 μg/m³
All non-external cause mortality	42,017	1.11	28.6	10 φ	18.6	1.010491	1.214229	0.176432	7,413	Upper 95% CL of RR; Assumes $PM_{2.5}$ changes to 10 μg/m³
All non-external cause mortality	42,017	1.078 #	28.6	27.6	1	1.007539	1.007539	0.007483	314	Krewski's RR;
All non-external cause mortality	42,017	1.046	28.6	27.6	1	1.004507	1.004507	0.004487	189	Krewski's L95% CL of RR
All non-external cause mortality	42,017	1.115	28.6	27.6	1	1.010945	1.010945	0.010826	455	Krewski's U95% CL of RR
All non-external cause mortality	42,017	1.078 #	28.6	10	18.6	1.007539	1.149929	0.130381	5,478	Krewski's RR;
All non-external cause mortality	42,017	1.046	28.6	10	18.6	1.004507	1.087249	0.080247	3,372	Krewski's L95% CL of RR
All non-external cause mortality	42,017	1.115	28.6	10	18.6	1.010945	1.224422	0.183288	7,701	Krewski's U95% CL of RR

Footnote to Table 4:

- * RR according to Pope et al (2002).
- # RR according to Krewski (2009)
- § $PM_{2.5}$ concentration based on EPD's Air Quality Report (2014)
- Ψ Attributable fraction (AF) = (RR-1)/RR
- φ 2012 mortality data from Census and Statistics Department: All non-external causes of death (42,017) = Total deaths (43,672) - deaths from external cause (1,655)
- φ Assuming a counter-factual of 10 $\mu g/m^3$, the WHO AQG annual concentration for $PM_{2.5}$.

Table 5: Estimates of premature mortalities attributed to NO_2 (assuming a 30% overlap with $PM_{2.5}$ effect using mortality data in 2012

Health Outcomes	Annual no. of deaths	Unit RR* per 10 µg/m^3	Annual NO_2 conc.	Target NO_2 conc.	Change in exp. conc.	RR for 1µg/m^3	RR for change in exp. conc.	Attributable fraction Ψ	Annual attributable deaths	Remark
All non-external ϕ cause mortality	42,017	1.039	52.7	51.7	1	1.003833	1.003833	0.003819	160	RR using HRAPIE recommendation of 30% overlap with $PM_{2.5}$ mortality
All non-external ϕ cause mortality	42,017	1.039	52.7	40$^{\varphi}$	12.7	1.003833	1.049788	0.047427	1,993	(Ditto); Central RR
All non-external cause mortality	42,017	1.022	52.7	40	12.7	1.002179	1.028023	0.027259	1,145	Lower 95% CL of RR
All non-external cause mortality	42,017	1.056	52.7	40	12.7	1.005464	1.071651	0.06686	2,809	Upper 95% CL of RR

* RR using HRAPIE (WHO 2013) recommendation of 30% overlap with $PM_{2.5}$ mortality

Ψ Attributable fraction (AF) = (RR-1)/RR

ϕ 2012 mortality data from Census and Statistics Department: All non-external causes of death (42,017) = Total deaths (43,672) - deaths from external cause (1,655)

$^{\varphi}$ Assuming a counter-factual of 40 µg/m^3, the WHO annual AQG.

Table 6: Estimates of premature mortalities (all non-external cause) attributed to the combined effects of $PM_{2.5}$ and NO_2, using 2012 mortality data

RR used / change in conc.	Annual deaths ($PM_{2.5}$) per 1 μg/m^3	Annual deaths (NO_2)	Annual deaths (combined)
Central RR /	244	160	404
Lower 95% CI	83	91	174
Upper 95% CI	436	228	664
RR used / change in conc.	Annual deaths* ($PM_{2.5}$) for 18.6 μg/m^3	Annual deaths* (NO_2) for 12.7 μg/m^3	Annual deaths* (combined)
Central RR	4,316	1,993	6,309
Lower 95% CI	1,519	1,145	2,664
Upper 95% CI	7,413	2,809	10,222

* Assume counter-factual for $PM_{2.5}$ = 10 μg/m3; NO_2 = 40 μg/m3;

Table 7: Estimates of increased hospital admissions attributed to $PM_{2.5}$ using hospital admission statistics in 2012

Hospital admissions	Annual no. of patients	Unit RR per 10 μg/m³ §	Annual $PM_{2.5}$ conc.	Target $PM_{2.5}$ conc.	Change in conc.	RR for 1 μg/m³	RR for change in exp. conc.	Attributable fraction Ψ	Annual attributable cases	Remark
CVS diseases (Hypothetical)	100,000	1.0066	28.6	27.6	1	1.000658	1.000658	0.000658	66	RR from Qiu et al (2013) §
CVS diseases*	70,934	1.0066	28.6	27.6	1	1.000658	1.000658	0.000658	47	hospital admissions in 2012
CVS diseases*	70,934	1.0036	28.6	27.6	1	1.000359	1.000359	0.000359	25	Lower 95%C L
CVS diseases*	70,934	1.0097	28.6	27.6	1	1.000966	1.000966	0.000965	68	Upper 95%C L
CVS diseases*	70,934	1.0066	28.6	10	18.6	1.000658	1.012311	0.012161	863	Central RR
CVS diseases*	70,934	1.0036	28.6	10	18.6	1.000359	1.006706	0.006662	473	Lower 95%C L
CVS diseases*	70,934	1.0097	28.6	10	18.6	1.000966	1.018117	0.017795	1,262	Upper 95%C L
Respiratory diseases hypothetical	100,000	1.0097	28.6	27.6	1	1.000966	1.000966	0.000965	96	R from Dr. Qiu Hong § (personal communication)
Respiratory diseases*	104,953	1.0097	28.6	27.6	1	1.000966	1.000966	0.000965	101	
Respiratory diseases*	104,953	1.0065	28.6	27.6	1	1.000648	1.000648	0.000648	68	Lower 95%C L
Respiratory diseases*	104,953	1.0129	28.6	27.6	1	1.001283	1.001283	0.001281	134	Upper 95%C L
Respiratory diseases*	104,953	1.0097	28.6	10	18.6	1.000966	1.018117	0.017795	1,868	Central RR
Respiratory diseases*	104,953	1.0065	28.6	10	18.6	1.000648	1.012124	0.011979	1,257	Lower 95% C L
Respiratory diseases*	104,953	1.0129	28.6	10	18.6	1.001283	1.024127	0.023559	2,473	Upper 95% C L
Annual cardiovascular and respiratory admissions attributable to $PM_{2.5}$ (= 863 + 1868)									2,731	Assuming 10 μg/m³ as counter-factual

Footnote to Table 7:

* Based on data on hospital admissions in 2012, Hospital Authority

Ψ Attributable fraction (AF) = (RR-1)/RR

§ RR from Dr. Qiu Hong, School of Public Health, the University of Hong Kong (personal communication)

Table 8: Estimates of increased hospital admissions attributed to NO_2 using hospital admission statistics in 2012

Hospital admissions	Annual no. of patients	Unit RR per 10 μg/m³	Annual NO_2 conc.§	Target NO_2 conc.	Change in exp. conc.	RR for 1 μg/m³	RR for change in exp. conc.	Attributable fractionΨ	Annual attributable cases	Remark
CVS diseases (Hypothetical)	100,000	1.01	52.7	51.7	1	1.000996	1.000996	0.000995	99	2012 hospital data; RR from PAPA study; Annual NO_2 based on EPD 2014 Air Quality Report
CVS diseases*	70934	1.01	52.7	51.7	1	1.000996	1.000996	0.000995	71	(ditto)
CVS diseases*	70934	1.0073	52.7	51.7	1	1.000728	1.000728	0.000727	51	L95%C L
CVS diseases*	70934	1.0126	52.7	51.7	1	1.001253	1.001253	0.001251	89	U95%C L
CVS diseases*	70934	1.01	52.7	40	12.7	1.000996	1.012717	0.012557	891	Central RR
CVS diseases*	70934	1.0073	52.7	40	12.7	1.000728	1.00928	0.009195	652	L95%C L
CVS diseases*	70934	1.0126	52.7	40	12.7	1.001253	1.016029	0.015776	1,119	U95%C L
Respiratory diseases (Hypothetical)	100000	1.0075	52.7	51.7	1	1.000747	1.000747	0.000747	75	CM Wong: PAPA study 2011
Respiratory diseases*	104953	1.0075	52.7	51.7	1	1.000747	1.000747	0.000747	78	(ditto)
Respiratory diseases*	104953	1.005	52.7	51.7	1	1.000499	1.000499	0.000499	52	L95%C L
Respiratory diseases*	104953	1.01	52.7	51.7	1	1.000996	1.000996	0.000995	104	U95%C L
Respiratory diseases	104953	1.0075	52.7	40	12.7	1.000747	1.009535	0.009445	991	Central RR
Respiratory diseases	104953	1.005	52.7	40	12.7	1.000499	1.006354	0.006314	663	L95%C L
Respiratory diseases	104953	1.01	52.7	40	12.7	1.000996	1.012717	0.012557	1,318	U95%C L
Annual cardiovascular and respiratory admissions attributable to NO_2 (= 891 + 991)									1,882	Assuming 40 μg/m³ as counter-factual

* Based on data on hospital admissions in 2012, Hospital Authority

Ψ Attributable fraction (AF) = (RR-1)/RR

Table 9: Estimates of URI consultations to private GPs, attributed to $PM_{2.5}$ using low and high estimates of total GP numbers in 2013

Upper respiratory infections (new cases)	Annual no. of patients	Unit RR per 10 µg/m³	Annual $PM_{2.5}$ conc.	Target $PM_{2.5}$ conc.	Change in exp. conc.	RR for 1µg/m³	RR for change in exp. conc.	Attributable fraction^Ψ	Annual attributable cases	Remark
GP consultations (hypothetical)	1,000,000	1.021	28.6	27.6	1	1.00208	1.00208	0.002076	2,076	Central RR
GP consultations, low estimate*	8,179,735	1.021	28.6	27.6	1	1.00208	1.00208	0.002076	16,982	Central RR
GP consultations, low estimate*	8,179,735	1.01	28.6	27.6	1	1.000996	1.000996	0.000995	8,135	L95%C L
GP consultations, low estimate*	8,179,735	1.032	28.6	27.6	1	1.003155	1.003155	0.003145	25,724	U95%C L
GP consultations, low estimate*	8,179,735	1.021	28.6	10	18.6	1.00208	1.039412	0.037918	310,159	Central RR
GP consultations, low estimate*	8,179,735	1.01	28.6	10	18.6	1.000996	1.01868	0.018337	149,995	L95%C L
GP consultations, low estimate*	8,179,735	1.032	28.6	10	18.6	1.003155	1.060338	0.056904	465,462	U95%C L
GP consultations, high estimate§	21,575,032	1.021	28.6	27.6	1	1.00208	1.00208	0.002076	44,792	central RR
GP consultations, high estimate§	21,575,032	1.01	28.6	27.6	1	1.000996	1.000996	0.000995	21,457	L95% C L
GP consultations, high estimate§	21,575,032	1.032	28.6	27.6	1	1.003155	1.003155	0.003145	67,852	U95% C L
GP consultations, high estimate§	21,575,032	1.021	28.6	10	18.6	1.00208	1.039412	0.037918	818,081	Central RR
GP consultations, high estimate§	21,575,032	1.01	28.6	10	18.6	1.000996	1.01868	0.018337	395,630	L95% C L
GP consultations, high estimate§	21,575,032	1.032	28.6	10	18.6	1.003155	1.060338	0.056904	1,227,712	U95% C L
Mean annual GP consultations for new URI attributable to $PM_{2.5}$ (= 310,159 + 818,081)/2									564,120	Mean of low and high estimates of GP numbers

Table 10: Estimates of URI consultations to private GPs, attributed to NO_2 using low* and high[§] estimates of total GP numbers in 2013

Upper respiratory infections (new cases)	Annual no. of patients	Unit RR per 10 µg/m³	Annual NO_2 conc.§	Target NO_2 conc.	Change in exp. conc.	RR for 1µg/m³	RR for change in exp. conc.	Attributable fraction[Ψ]	Annual attributable cases	Remark
GP consultations (hypothetical)	1,000,000	1.03	52.7	51.7	1	1.00296	1.00296	0.002952	2,952	Central RR
GP consultations, low estimate*	8,179,735	1.03	52.7	51.7	1	1.00296	1.00296	0.002952	24,143	Central RR
GP consultations, low estimate	8,179,735	1.02	52.7	51.7	1	1.001982	1.001982	0.001978	16,182	L95%C L
GP consultations, low estimate	8,179,735	1.04	52.7	51.7	1	1.00393	1.00393	0.003914	32,019	U95%C L
GP consultations, low estimate	8,179,735	1.03	52.7	40	12.7	1.00296	1.038253	0.036844	301,373	Central RR
GP consultations, low estimate	8,179,735	1.02	52.7	40	12.7	1.001982	1.025468	0.024836	203,150	L95%C L
GP consultations, low estimate	8,179,735	1.04	52.7	40	12.7	1.00393	1.051072	0.04859	397,454	U95%C L
GP consultations, high estimate[§]	21,575,032	1.03	52.7	51.7	1	1.00296	1.00296	0.002952	63,679	central RR
GP consultations, high estimate	21,575,032	1.02	52.7	51.7	1	1.001982	1.001982	0.001978	42,682	L95% C L
GP consultations, high estimate	21,575,032	1.04	52.7	51.7	1	1.00393	1.00393	0.003914	84,453	U95% C L
GP consultations, high estimate	21,575,032	1.03	52.7	40	12.7	1.00296	1.038253	0.036844	794,906	Central RR
GP consultations, high estimate	21,575,032	1.02	52.7	40	12.7	1.001982	1.025468	0.024836	535,832	L95% C L
GP consultations, high estimate	21,575,032	1.04	52.7	40	12.7	1.00393	1.051072	0.04859	1,048,333	U95% C L
Annual GP consultations for new URI attributable to PM2.5 (= 301,373 + 794,906)/2									548,140	Mean of low and high estimates of GP numbers

Table 11: Estimates of new URI consultations to GOPCs, attributed to $PM_{2.5}$ in the year 2012-2013

Upper respiratory infections (new cases)	Annual no. of patients	Unit RR per 10 µg/m^3	Annual $PM_{2.5}$ conc.	Target $PM_{2.5}$ conc.	Change in exp. conc.	RR for 1µg/m^3	RR for change in exp. conc.	Attributable fraction$^{\Psi}$	Annual attributable cases	Remark
GOPC consultations (hypothetical)	1,000,000	1.005	28.6	27.6	1	1.000499	1.000499	0.000499	499	Central RR for PM_{10} based on Tam et al, 2014
GOPC new URI consultations *	2,060,813	1.005	28.6	27.6	1	1.000499	1.000499	0.000499	1,028	Central RR for PM_{10}
GOPC new URI consultations *	2,060,813	1.002	28.6	27.6	1	1.0002	1.0002	0.0002	412	L95%C L
GOPC new URI consultations *	2,060,813	1.009	28.6	27.6	1	1.000896	1.000896	0.000896	1,846	U95%C L
GOPC new URI consultations *	2,060,813	1.005	28.6	10	18.6	1.000499	1.00932	0.009234	19,029	Central RR for PM_{10}
GOPC new URI consultations *	2,060,813	1.002	28.6	10	18.6	1.0002	1.003723	0.003709	7,644	L95%C L
GOPC new URI consultations *	2,060,813	1.009	28.6	10	18.6	1.000896	1.016805	0.016527	34,059	U95%C L

[1] In Tam's study, only RR for PM_{10} was available. This is used as a proxy of RR for $PM_{2.5}$ in our HIA study. In general, RR for PM_{10} is slightly lower in magnitude than that for $PM_{2.5}$.

[2] No. of new URI consultations based on the same assumption as for private GP consultations, with 78% of consultations being new cases, and 46.9% of all GOPC cases are URI.

* Based on annual GOC consultation of 5,633,407 in 2012-13, assuming 78% are new cases, and 46.9% are URI. $^{\Psi}$ Attributable fraction (AF) = (RR-1)/RR

Table 12: Estimates of new URI consultations to GOPCs, attributed to NO_2 in the year 2012-2013

Upper respiratory infections (new cases)	Annual no. of patients	Unit RR per 10 µg/m³	Annual NO_2 conc.	Target NO_2 conc.	Change in conc.	RR for 1µg/m³	RR for change in exp. conc.	Attributable fraction$^{\Psi}$	Annual attributable cases	Remark
GOPC consultations (hypothetical)	1,000,000	1.01	52.7	51.7	1	1.000996	1.000996	0.000995	995	Central RR based on Tam et al, 2014
GOPC new URI consultations *	2,060,813	1.01	52.7	51.7	1	1.000996	1.000996	0.000995	2,050	Central RR based on Tam et al, 2014
GOPC new URI consultations *	2,060,813	1.006	52.7	51.7	1	1.000598	1.000598	0.000598	1,232	Lower 95% C L
GOPC new URI consultations *	2,060,813	1.013	52.7	51.7	1	1.001292	1.001292	0.001291	2,660	Upper 95% C L
GOPC new URI consultations *	2,060,813	1.01	52.7	40	12.7	1.000996	1.012717	0.012557	25,878	Central RR based on Tam et al, 2014
GOPC new URI consultations *	2,060,813	1.006	52.7	40	12.7	1.000598	1.007626	0.007568	15,597	Lower 95% C L
GOPC new URI consultations *	2,060,813	1.013	52.7	40	12.7	1.001292	1.016539	0.01627	33,529	Upper 95% C L

* Based on annual GOC consultation of 5,633,407 in 2012-13, assuming 78% are new cases, and 46.9% are URI.

$^{\Psi}$ Attributable fraction (AF) = (RR-1)/RR

Table 13: Estimated years of life lost per 10 $\mu g/m^3$ change in $PM_{2.5}$ concentration

Age	No. of deaths	Attributable fraction	No. of attributable deaths	Life Expectancy	Expected Years of life lost
0	137	0.056604	7.754717	83.6	648.2943
1-4	33	0.056604	1.867925	78.9	147.3792
5-9	30	0.056604	1.698113	74	125.6604
10-14	24	0.056604	1.358491	69	93.73585
15-19	63	0.056604	3.566038	64	228.2264
20-24	135	0.056604	7.641509	59.1	451.6132
25-29	148	0.056604	8.377358	54.2	454.0528
30-34	235	0.056604	13.30189	49.3	655.783
35-39	367	0.056604	20.77358	44.5	924.4245
40-44	612	0.056604	34.64151	39.7	1375.268
45-49	986	0.056604	55.81132	35	1953.396
50-54	1,573	0.056604	89.03774	30.4	2706.747
55-59	2,185	0.056604	123.6792	26	3215.66
60-64	2,620	0.056604	148.3019	21.7	3218.151
65-69	2,626	0.056604	148.6415	17.9	2660.683
70-74	3,743	0.056604	211.8679	14.2	3008.525
75-79	6,172	0.056604	349.3585	11	3842.943
80-84	7,713	0.056604	436.5849	8.7	3798.289
85+	14,489	0.056604	820.1321	8.7	7135.149
Total	43,891		2,484.396		36,643.98
				Average per person	14.75 (years)

If the loss of life is borne only by those who suffered from premature deaths, the average loss of life expectancy is 14.75 years. IF WE ASSUME THE LOSS OF LIFE YEARS IS TO BE EQUALLY BORNE BY THE HONG KONG POPULATION (7,070,388), THE AVERAGE "SHORTENING OF LIFE EXPECTANCY" FOR AN INDIVIDUAL WITH A LIFE EXPECTANCY OF 82 YEARS (AVERAGED FOR BOTH GENDERS) WOULD BE QUITE SMALL, AT ABOUT 3.5 DAYS. THE REALITY IS PROBABLY IN BETWEEN – SOME PEOPLE DIE MUCH EARLIER, AND SUFFER FROM A SIGNIFICANT SHORTENING OF LIFE EXPECTANCY, WHILE OTHERS ARE LESS AFFECTED, WITH MUCH SMALLER SHORTENING OF LIFE EXPECTANCY.

Economic impact assessment

- The economic impact for 244 estimated deaths (based on 2012 mortality statistics) that may be attributed to a 1 μg/m³ change in $PM_{2.5}$ is US$701,302,204 (95% CI: US$283,795,357 – US$1,253,149,713), using the higher VOSL estimate, and US$285,872,210 (95% CI: US$97,340,285 – US$510,822,118) , using the lower estimate.
- Hence, the estimated annual economic impact of premature deaths ranges from about US$97 million to US$1.25 billion, or HK$754 million to HK$9.71 billion, using an exchange rate of HK$7.77 per US$.
- When a counter-factual for $PM_{2.5}$ of 10 μg/m³ against the annual mean concentration of 28.6 μg/m³ is used in the estimate, the corresponding values are: US$12,398,264,788.05 (95% CI: US$4,365,109,577.69 – US$21,296,650,955.69) for the higher VOSL, and US$5,053,911,607.84 (95% CI: $1,779,352,057.83 – $8,681,165,736.75) using the lower VOSL estimate.
- The range of estimates, therefore, is from about US$1.78 billion to US$21.3 billion, or HK$13.8 billion to HK$165.5 billion.
- It should be noted that all the above figures reflect an economic impact on an annual basis.

Economic impact assessment

- The independent effects of NO_2 on premature mortality have also been evaluated.
- The economic impact for a 1 $\mu g/m^3$ change in NO_2 is US$479,083,129 (95% CI: US$272,726,443 – US$681,758,763) for the higher VOSL estimate, and $195,288,923.75 (95% CI: US$111,171,632 – US$277,905,706) for the lower VOSL estimate.
- Hence the range of estimates is from US$111,171,632 to US$681,758,763.
- In HK dollar values, the estimate of economic impact range from HK$864 million to HK$5.297 billion.
- When a counter-factual for NO_2 of 40 $\mu g/m^3$ against the annual mean concentration of 52.7 $\mu g/m^3$ is used in the estimate, the corresponding values are: US$5,950,273,911.94 (95% CI: US$3,419,919,870.48- US$8,388,362,116.30) for the higher VOSL estimate, and $2,425,513,481.72 (95% CI: US$1,394,063,849- US$3,419,352,740) for the lower VOSL estimate.
- The overall range of economic impact is US$1,394,063,849 to US$8,388,362,116. The equivalent values are: HK$10.83 billion and HK$65.18 billion.

Economic impact assessment

- The combined effects of $PM_{2.5}$ and NO_2, assuming a 30% overlap (WHO 2013a ,b) are presented in Table 14:

Table 14: Economic impact of premature mortality attributable to the combined effects of $PM_{2.5}$ and NO_2, using VOSL and the loss of productivity approaches

RR (per 10 µg/m³)	Change in conc. (µg/m³)		No. of attributable deaths	VOSL-Europe* (US$)	VOSL-China§ (US$)	Unit productivityφ loss (US$)
	$PM_{2.5}$	NO_2				
Central	1	1	411	$1,180,385,333.41	$481,161,133.45	$1,555,203.56
Lower 95%	1	1	178	$511,521,799.99	$208,511,917.34	$673,949.85
Upper 95%	1	1	674	$1,934,908,475.44	$788,727,823.72	$2,549,317.13
Central	18.6	12.7	6,387	$18,348,538,699.99	$7,479,425,089.57	$24,174,912.95
Lower 95%	18.6	12.7	2,710	$7,785,029,448.17	$3,173,415,906.83	$10,257,078.90
Upper 95%	18.6	12.7	10,333	$29,685,013,071.99	$12,100,518,476.44	$39,111,158.58

Economic impact assessment

- The economic impact on premature mortality for a 1 $\mu g/m^3$ change in NO_2 and $PM_{2.5}$ is US$1,180,385,333 (95% CI: $511,521,800 - $1,934,908,475), according to the higher VOSL estimate, and US$481,161,133 (95% CI: $208,511,917.34 - $788,727,824) from the lower VOSL estimate.

- The range of the combined effects, using the lower 95% confidence limit of RR and the lower VOSL and the upper 95% confidence limit of RR and the higher VOSL, is from US$208,511,917 to US$1,934,908,475, or HK$1.62 billion to HK$15.03 billion.

- The economic impact on premature mortality for a 18.6 $\mu g/m^3$ change in $PM_{2.5}$ and a 12.7 $\mu g/m^3$ change NO_2 is about 20 times higher than the unit change, at $18,348,538,700 (95% CI: $7,785,029,448.17 - $29,685,013,071.99) for the higher VOSL estimate, and $7,479,425,089.57 (95% CI: $3,173,415,907 - $12,100,518,476) for the lower VOSL estimate.

Note: A fundamental methodological issue in developing the HIA tool is whether a single pollutant or multiple pollutants should be used in the model.

Economic impact assessment

- The range of the combined effects, using the lower 95% confidence limit of RR and the lower VOSL and the upper 95% confidence limit of RR and the higher VOSL, is from US$208,511,917 to US$1,934,908,475, or HK$1.62 billion to HK$15.03 billion (for a 1 μg/m^3 change in NO_2 and $PM_{2.5}$).
- As before, the productivity loss ranges from 0.13% to 0.3% of the economic impact using VOSL estimates.
- When a counter-factual for $PM_{2.5}$ of 10 μg/m^3 against the annual mean concentration of 28.6 μg/m^3 is used in the estimate, the corresponding values are: US$18,348,538,699.99 (95% CI: US$7,785,029,448 - US$29,685,013,072) for the higher VOSL estimate, and $7,479,425,089.57 (95% CI: US$3,173,415,907 - US$12,100,518,476) for the lower VOSL estimate.
- The overall range of economic impact is US$3,173,415,907 to US$29,685,013,072.

Note: A fundamental methodological issue in developing the HIA tool is whether a single pollutant or multiple pollutants should be used in the model.

Productivity loss from premature mortality

- Is calculated by assuming a median monthly income among the working population.
- Since most deaths occur in the elderly population, the productivity loss attributable to air pollution is relatively small compared to the VOSL.

Cost of illness (COI) estimate

- Cost of hospitalization
- Productivity loss from hospitalization
- Cost of GP and GOPC consultations
- Productivity loss from GP and GOPC consultations

Total economic impact

- The total economic impact of air pollution-related visits for URI by air pollutant is summarized in Tables 15-17.
- For a 1 $\mu g/m^3$ change in $PM_{2.5}$, the total direct cost of illness (both GP visits and GOPC visits) ranges from HK$2.19 million – 17.67 million.
- For a 1 $\mu g/m^3$ change in NO_2, the direct cost ranges from $4.52 – 23.13 million.
- The productivity loss ranges from HK$3.41 – 27.88 million for 1 $\mu g/m^3$ change in $PM_{2.5}$ and 6.96 – 34.88 for 1 $\mu g/m^3$ change in NO_2.
- The combined value of COI and productivity loss ranges from HK$5.62 – 45.54 million for 1 $\mu g/m^3$ change in $PM_{2.5}$ and HK$11.48 – 56.97 for 1 $\mu g/m^3$ change in NO_2.
- When the costs are estimated by the counter-factuals of the 2 pollutants, the range of the total COI ranges from HK$40.44 – 320.04 million for PM2.5, and HK$56.79 – 274.99 million for NO_2.
- The productivity loss estimated by the counter-factuals ranges from HK$63.06 – 504.70 for $PM_{2.5}$ and HK$87.50 – 432.74 million for NO_2.
- The total economic impact for $PM_{2.5}$ ranges from HK$216.54 – 824.75 million, while that for NO_2 ranges from HK$216.49 – 707.74 million.

Table 15: Total economic impact of air pollution-related GP visits for URI by air pollutant

	Cost of GP visits (million HK$)						**Productivity loss from GP visits (million HK$)**						**Total economic impact of GP visits (million HK$)**					
Pollutant	$PM_{2.5}$		NO_2		Both		$PM_{2.5}$		NO_2		Both		$PM_{2.5}$		NO_2		Both	
Change in conc.	$1\mu g/m^3$	$18.6\ \mu g/m^3$	$1\mu g/m^3$	$12.7\ \mu g/m^3$	$1\mu g/m^3$	$18.6\ \mu g/m^3$ $PM_{2.5}$ & $12.7\ \mu g/m^3$ NO_2	$1\mu g/m^3$	$18.6\ \mu g/m^3$	$1\mu g/m^3$	$12.7\ \mu g/m^3$	$1\mu g/m^3$	$18.6\ \mu g/m^3$ $PM_{2.5}$ & $12.7\ \mu g/m^3$ NO_2	$1\mu g/m^3$	$18.6\ \mu g/m^3$	$1\mu g/m^3$	$12.7\ \mu g/m^3$	$1\mu g/m^3$	$18.6\ \mu g/m^3$ $PM_{2.5}$ & $12.7\ \mu g/m^3$ NO_2
Lower estimate of GP no.																		
Central RR	4.24	77.54	6.04	75.34	10.28	152.88	6.79	124.06	9.66	120.55	16.45	244.61	11.04	201.60	15.69	195.89	26.73	397.49
Higher estimate of GP no.																		
Central RR	11.20	204.52	15.92	198.73	27.12	403.25	17.92	327.23	25.47	317.96	43.39	645.19	29.11	531.75	41.39	516.69	70.50	1,048.44

Table 16: Total economic impact of air pollution-related GOPC visits for URI by air pollutant

	Cost of GOPC visits (million HK$)						Productivity loss from GOPC visits (million HK$)						Total economic impact of GOPC visits (million HK$)					
Pollutant	$PM_{2.5}$		NO_2		Both		$PM_{2.5}$		NO_2		Both		$PM_{2.5}$		NO_2		Both	
Change in conc.	1μg/m³	18.6 μg/m³	1μg/m³	12.7 μg/m³	1μg/m³	18.6 μg/m³ $PM_{2.5}$ & 12.7 μg/m³ NO_2	1μg/m³	18.6 μg/m³	1μg/m³	12.7 μg/m³	1 μg/m³	18.6 μg/m³ $PM_{2.5}$ & 12.7 μg/m³ NO_2	1 μg/m³	18.6 μg/m³	1μg/m³	12.7 μg/m³	1μg/m³	18.6 μg/m³ $PM_{2.5}$ & 12.7 μg/m³ NO_2
Central RR	0.400	7.33	0.79	9.96	1.19	17.29	0.41	7.61	0.82	10.64	1.23	18.25	0.81	14.94	1.61	20.60	2.42	35.54

Table 17: Total economic impact of air pollution-related GP and GOPC visits for URI by air pollutant

	Total cost: GP + GOPC visits (million HK$)						Total productivity loss: GP + GOPC visits (million HK$)						Total economic impact of GP visits + GOPC visits (million HK$)					
	$PM_{2.5}$		NO_2		Both		$PM_{2.5}$		NO_2		Both		$PM_{2.5}$		NO_2		Both	
Change in conc.	1μg/m³	18.6 μg/m³	1μg/m³	12.7 μg/m³	1μg/m³	18.6 μg/m³ $PM_{2.5}$ & 12.7 μg/m³ NO_2	1μg/m³	18.6 μg/m³	1μg/m³	12.7 μg/m³	1 μg/m³	18.6 μg/m³ $PM_{2.5}$ & 12.7 μg/m³ NO_2	1 μg/m³	18.6 μg/m³	1μg/m³	12.7 μg/m³	1μg/m³	18.6 μg/m³ $PM_{2.5}$ & 12.7 μg/m³ NO_2
Lower estimate of GP no.																		
Central RR	4.64	84.87	6.83	85.30	11.47	170.17	7.20	131.61	10.48	131.19	17.68	262.86	11.85	216.54	17.30	216.49	29.15	433.03
Higher estimate of GP no.																		
Central RR	11.6	211.85	16.71	208.69	28.31	420.54	18.33	334.84	26.29	328.60	44.62	663.44	29.92	546.69	43.00	537.29	72.92	1,083.98

Summary of health impact assessment (HIA)

- A key message is:
- Air pollution exerts a significant health impact on Hong Kong's residents.
- A unit change in $PM_{2.5}$ concentration ($1\mu g/m^3$) is causally associated with 244 premature deaths in Hong Kong, and
- A reduction from the annual mean $PM_{2.5}$ concentration ($28.6\ \mu g/m^3$ in 2012) to the WHO air quality guideline (AQG) level ($10\ \mu g/m^3$) is estimated to prevent 4,316 premature deaths (95% confidence limit: 1,519 – 7,413).
- Using a life-table approach, a $10\ \mu g/m^3$ change in $PM_{2.5}$ concentration is associated with a loss of 2,484 lives and a total of 36,644 life years (about 15 years lost per premature death).

Summary of health impact assessment (HIA)

- Estimates based on NO_2, which is now recognized to exert an independent effect (assuming 30% overlap with $PM_{2.5}$ effects) on mortality gives 2,071 (95% CI: 1,190 – 2,920) additional deaths , based on a reduction of NO_2 level from 52.7 $\mu g/m^3$ to the WHO AQG of 40 $\mu g/m^3$.
- The combined effects of these two air pollutants therefore are responsible for an annual death toll of 6,387 (95% CI: 2,709 – 10,333) using the same counter-factuals.

Implications of HIA findings

- We have shown that using internationally accepted unit risk estimates, the burden of air pollution on health in Hong Kong is substantial.
- The number of premature deaths attributable air pollution ($PM_{2.5}$ and NO_2 combined) is 6,387 or 14.6% of 43,672 deaths in 2012.
- This is not as high as ‘death tolls’ published in other HIA studies that use anthropogenic $PM_{2.5}$ as a measure of health burden.
- In those scenarios, the counter-factuals are non-anthropogenic $PM_{2.5}$, which is substantially lower than 10 $\mu g/m^3$, the counter-factual that we use in this study.

Implications of HIA findings

- Compared to premature mortality, the assessment of life years lost has been considered as a more appropriate indicator of the adverse effect of air pollution on survival (COMEAP 2010).
- The reason is that the assessment of life years represents not only the loss of life, but the extent of shortening of life expectancy in different ages affected by air pollution.
- However, the drawback of expressing health impact in terms of the numbers of life years lost is that this is not a easy-to-comprehend concept, compared to the number of premature deaths. For example, it is difficult for a policy maker to decide whether a certain number of life years lost is too high or not.

Implications of HIA findings

- The health impact on hospital admissions for cardio-respiratory diseases is also substantial.
- Compared to premature mortality, hospital admissions attributable air pollution is 1.55% of all hospital admissions (about one-tenth the percentage attributed to premature mortality). This can be explained by the fact that the RR used for short-term exposure to air pollution is one order of magnitude lower than the RR used for assessing mortality from long-term exposure to air pollution.
- No unit risk of hospital admissions for *long-term* exposure to air pollution is available in the literature.

Limitations of HIA findings

- Our HIA results are based on health outcomes for which relevant data are available.
- For specific health outcomes that have been assessed in other HIA studies, such as the prevalence of asthma, the incidence and prevalence of chronic obstructive pulmonary disease, acute bronchitis, and lost days from work, we could not find the corresponding incidence and prevalence data, or data related to the costs of medical treatment of these conditions.
- Hence, our HIA is a conservative assessment that has omitted the above health conditions that are generally recognized to be causally associated with air pollution.
- Our estimates of hospitalizations do not include private hospital data, although private hospitals only constitute about 10% of hospital beds in Hong Kong.

Summary of EIA

- We estimated that the annual economic impact of premature mortality attributable to a 1 $\mu g/m^3$ change in $PM_{2.5}$ ranges from HK$754 million to HK$9.71 billion, while that attributable to a counter-factual of 10 $\mu g/m^3$ in $PM_{2.5}$ concentration (from 28.6 $\mu g/m^3$) ranges from HK$13.8 billion to HK$165.5 billion.
- The economic impact is huge, even without taking into account the independent effect of NO_2 on mortality.
- The economic impact attributed to for a 1 $\mu g/m^3$ change in NO_2 ranges from HK$864 million to HK$5.297 billion.
- When these figures are combined, the total economic impact ranges between HK$1.62 billion and 15 billion.
- These estimates vary widely because they range between the lowest value of statistical life (VOSL) using the lower 95% confidence limit of the RR, and the highest value of the VOSL, using the upper confidence limit of the RR.
- The corresponding values, using the same counter-factuals as before, range between HK$24.7 billion and HK$230.7 billion.

Summary of EIA

- By contrast, the estimated losses of productivity from the loss of lives are much smaller, ranging from HK$2,444,614 (using lower 95% CI of RR) to HK$12,828,841 (using upper 95% CI of RR), per 1 $\mu g/m^3$ change in $PM_{2.5}$.
- Expressed as the counter-factuals used, the values are from HK$44.7 million to HK$218 million, less than one percent of the lower VOSL estimate at the lower 95% CI of RR.
- Productivity loss from hospital illnesses is likewise small, at about HK$3 million per year.

Summary of EIA

- The direct COI from hospital illnesses at HK$51.7 million is 0.2% of the VOSL using the lower VOSL estimates and lower 95% CI of the RR, and the estimated productivity loss from hospital admissions (both cardiovascular and respiratory illnesses) is $4.4 million (about 8.5%).
- The annual COI for private GP consultations for URI ranges from a low estimate (low GP numbers and lower 95% CI of RR) of HK$51 million to a high of HK$262 million (high GP numbers and upper 95% CI of RR).
- The central estimate (central RR) is HK$75.3 million (low GP number) to HK$198.7 million (high GP number).
- All the estimates are higher than hospital COI, except for the lowest estimate (low GP no. and L95% CI of RR).
- Also, the productivity losses from the URI are about 50 – 60% higher than the COI.
- The COI of GOPC visits for URI is much lower, at HK$7.3 million (range: $2.94 million to $13.11 million), with almost equivalent values of productivity losses (because the unit cost for GOPC is much higher than the GP charges).

Implications of EIA findings

- The economic impact assessed by direct cost of illness (COI) is a small sub-set of the total economic impact, which is generally regarded by health economists to be best assessed by the ‘willingness-to-pay’ (WTP) methodology.
- Economic impact assessment (EIA) reports in Europe, Australia and New Zealand have shown clearly that direct COI is but a fraction of the economic impact using the WTP approach.
- The COMEAP (2010) suggests that COI results are likely to mislead policy makers, the public and the polluters by grossly under-estimating the true cost of air pollution.
- The major drawback using the WTP approach, however, is the lack of local data, which are essential in producing valid results, as WTP varies widely between communities, owing to the diversity of their culture, and socioeconomic conditions.

Limitations of EIA findings

- The most critical comments about economic valuation results from non-health economists are on the validity of WTP estimates.
- Their arguments are that since WTP values are based on hypothetical situations, it is impossible to valuate one's life or one's health.
- Yet, after decades of research into the methodology, health economists have found that the WTP values in general reflect the COI plus other attributes not otherwise assessed, such as opportunity costs of being healthy.
- WTP has been used extensively in the valuation of life and health. Clearly, life cannot be worthless after a person supposedly stops his / her economic productivity. This is even less so if the subject (and not a disconnected economist) is asked to value his / her own life.

Limitations of EIA findings

- In our study, the problem is not with the VOSL approach, but with the actual valuation placed on a life.
- This is partly circumvented by the use of the WHO statistics (WHO 2015) and World Bank data (Wang et al, 2010), for which we adjust the VOSL by the per-capita GDP of Hong Kong, against the VOSL estimates in China and WHO European Region.
- The limitation of COI is its incompleteness, while the limitation of WTP is the absence of local WTP data on morbidity and VOSL.
- We consider that the adjusted VOSL is a reasonable approach, but the lack of WTP data on hospital illnesses and minor URI is a major limitation of our EIA.
- We believe the presence of local WTP data would give a more realistic estimate of health and morbidity than the COI approach alone.

Future uses of findings in this study

- The HIA and EIA studies that we have conducted have illustrated that we have a great need for better and more comprehensive data for a more accurate assessment.
- An HIA and EIA that grossly under-estimate the "true" situation will do more harm than good.
- Our findings agree with those in international HIAs and EIAs in that premature mortality is the predominant health and economic impact, and the magnitude of the HIA and EIA clearly shows air pollution exerts a heavy toll on health and the economy.
- This is in agreement with findings by the WHO Global burden of Disease Project (Lim et al, 2010) that ambient air pollution is one of the major, yet preventable risk factor to ill-health.

Future uses of findings in this study

- The present study has two values. First, it shows the burden of air pollution is high, and second, it enables the policy maker to assess the health impact and cost-benefit of an air quality improvement policy or strategy.
- This evidence-based environmental policy is the direction that most developed countries are taking in recent years, and we must not lag behind.
- Regular updating of diseases to be included in HIA is necessary in the light of up-to-date scientific evidence.
- Some possible effects of air pollution that are under research, such as the impairment of cognitive functions of adults and neurodevelopmental deficit of children , would radically change the HIA results if evidence for a causal-relationship is strengthened.
- Likewise, updating of exposure response functions, exposure data, local health data (hospital admissions and mortality, disease prevalence data and economic data) are necessary to ensure the validity of our study over time.

Conclusion

- After an extensive literature review of health and non-health effects of air pollution, we have performed a health and economic impact assessment (HIA, EIA) of air pollution in Hong Kong, taking 2012 data as an example.
- Our approach in HIA is based on studies in Europe, Australia and the U.K., with necessary modifications owing to the lack of local health and economic data.
- Our findings are in agreement with that from other studies – that air pollution exerts a heavy toll on health and the economy.

Conclusion

- We have developed a worksheet to quantify the health and economic impacts.
- This worksheet can be used to estimate the burden of air pollution and the benefits of air pollution control.
- By using different air quality data that may be derived from modelling assumptions, the output from this worksheet will enable us to predict (with a fairly wide range, in the case of EIA) the benefits of air pollution control.
- This will enable the use of cost-benefit analysis of different options, and represent an evidence-based approach in policy decision that has hitherto been based on empirical data.