COMMUNICATING AIR POLLUTION EXPOSURE: A NOVEL AIR POLLUTION INDEX SYSTEM BASED ON THE RELATIVE RISK OF MORTALITY ASSOCIATED WITH EXPOSURE TO THE COMMON URBAN AIR POLLUTANTS.

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ABSTRACT

The relationship between ambient air pollution and health remains of primary concern. In a typical urban environment, individuals are exposed to a complex mix of 200 or more air pollutant species with a wide range of exposure-response functions and health impacts. Monitoring and modelling may be used to assess pollutant levels, but accurate yet accessible communication of the associated health impacts is problematic. An Air Pollution or Air Quality Index system, a numerical scale indicating the level of air pollution in an area, is widely used for this purpose. The predominant approach employs the relevant national Air Quality Standard (AQS) as a benchmark for calculating the index values, and associates index values with general descriptors indicating the expected health impact. This approach has an element of subjectivity, as setting the AQS may include non-health factors such as the cost of attainment of the standards. The national standards of different countries differ though they are supposedly based on the same underlying epidemiological and controlled exposure data. We propose the use of attributable health risk functions to construct a novel Air Pollution Index System. The proposed system offers a transparent and objective methodology that uses the empirical exposure-response functions, including observed increases of mortality and morbidity attributable to air pollutant exposure. This implies that our index system differs significantly from the systems used in the United Kingdom and the United States of America.

1. INTRODUCTION

Urban air pollution is predominantly the result of pollutant emissions from industrial and domestic fossil fuel combustion, and emissions from petrol (gasoline) and diesel vehicles. Ambient pollutant concentrations, time-averaged over periods ranging from 15 minutes to a year, are the result of primary pollutant emissions from these and other sources, atmospheric transformation processes, including the formation of secondary pollutants, local topographical features and meteorological conditions. Pollutant concentrations may therefore vary with time and location within the urban environment, independently, collinearly or antagonistically to each other. The inhabitants of a typical urban centre may be exposed to several hundred individual chemical species in ambient air. [1]

Adverse health effects may be due to short-term (minutes to several days) exposure to pollutants or prolonged exposure (months to years). Different pollutants may have widely different exposure-response characteristics. The health endpoints associated with exposure to individual air pollutants may include the exacerbation of respiratory symptoms and cardiovascular disease, increased hospital admissions, compromised immune systems, premature death, cancer or impairment of neurological development. [1] The short-term adverse health response may lag the exposure by several hours, up to a period of several days [2]; carcinogens have a latency period of years or decades. Individual susceptibility and the prevalence of health conditions that predispose the exposed population to an adverse response further complicate attempts to accurately estimate the actual site-specific health risk associated with air pollution. [3]

The task of communicating the complex relationship between air pollutant exposure and ill health to the public in a manner that is both simple and accurate is an important albeit difficult aspect of an air pollution information system. [4] An Air Pollution Index (API) (or Air Quality Index, AQI) is a numerical scale, usually colour coded, widely used to relate air pollution exposure data to the risk of short-term adverse health. In practice a subset of air pollutant exposures, consisting of the concentrations of the common air pollutants – sulphur dioxide (SO2), particulate matter (PM), nitrogen oxides (NOx), carbon monoxide (CO) and ozone (O_3) – is used to determine the API. The systems in current use are based on the calculation of an index value for each of the pollutants; in most cases, the API is then considered to be the highest of the individual pollutant index values. The population exposure estimate may be based on monitored (measured) ambient air quality data or modelled values. To promote public access to the information, these indices are usually web-based.

Four key problems have to be addressed in the design of an API system: the selection of pollutant exposure metrics (concentration-averaging time combinations) for inclusion in the index, the selection of appropriate exposure- (health) response functions, a method of assigning each exposure metric value to a common numerical scale (that is, choosing an exposure metric value that corresponds to an index value) and a methodology or algorithm for calculating the overall index value (assuming that this is the ultimate objective) based on the index values of the individual pollutants. There is currently no internationally accepted methodology for setting up an air pollution index system. We propose a novel system based on the Relative Risk of premature mortality due to exposure to the common air pollutants is proposed. This approach systematically addresses the above four key problems.

2. CURRENT PRACTICE

An Internet search was used to survey air pollution index (API) and air quality index (AQI) systems currently in use around the world. A number of countries and territories (including the United Kingdom (UK), the United States of America (USA), Belgium, France, Spain, Finland, Sweden, Canada, Mexico, Australia, New Zealand, Hong Kong, Singapore, Malaysia, Thailand, China, Macau, Indonesia, Taiwan [5]) use an air pollution (or air quality) index, usually applied at the urban (city) scale, to communicate the air quality. These air pollution (or air quality) index systems are a simplified means of communicating the potential health impacts of prevailing air pollution levels. In the majority of examples, the air quality of air pollution index is based on the ambient concentrations of the classical pollutants – SO_2, PM (usually PM_{10}), NO_2, CO and O_3. In a few cases $PM_{2.5}$ is considered in the calculation of the index.

Most of the systems surveyed rely on relating measured (monitored) rather than modelled concentrations of air pollutants to a numerical scale. Current international practice is exemplified through a more detailed discussion of the UK and USA systems.

2.1 The United Kingdom index system

The UK Air Pollution Index system was originally (in 1990) introduced as a four-band system indicating low, moderate, high and very high air pollution levels. In 1997 this system was modified to a 1-10 index scale by breaking each of the low, moderate and high bands into three equal index values (i.e. 1 to 9) with values greater than the high/ very high threshold being designated index 10. [4] The breakpoint value between the 'low' and 'moderate' bands (index values 3 to 4) corresponds to the UK Air Quality Standards; the air quality standards are based on the assessment of adverse health effects of air pollution.

The rationale behind this index system is given as follows:

"When air pollution is LOW (1-3) effects [are] unlikely to be noticed even by those sensitive to air pollution.
When air pollution is MODERATE (4-6) sensitive people may notice mild effects but these are unlikely to need action.
When air pollution is HIGH (7-9) sensitive people may notice significant effects and may need to take action.
When air pollution is VERY HIGH (10) effects on sensitive people, described for HIGH pollution, may worsen." [6]

The UK index system is summarised in Table 1.

Band	Index	Ozone	Nitrogen Dioxide	Sulphur Dioxide	Carbon Monoxide	PM_{10} Particles
		8 hourly or hourly mean*	**Hourly mean**	**15 minute mean**	**8 hour mean**	**24 hour mean**
		µg/m^3	**µg/m^3**	**µg/m^3**	**mg/m^3**	**µg/m^3**
	1	0-32	0-95	0-88	0-3.8	0-16
Low	2	33-66	96-190	89-176	3.9-7.6	17-32
	3	67-99	191-286	177-265	7.7-11.5	33-49
UK Air Quality Standards						
	4	100-126	287-381	266-354	11.6-13.4	50-57
Moderate	5	127-152	382-476	355-442	13.5-15.4	58-66
	6	153-179	478-572	443-531	15.5-17.3	67-74
	7	180-239	573-635	532-708	17.4-19.2	75-82
High	8	240-299	636-700	709-886	19.3-21.2	83-91
	9	300-359	701-763	887-1063	21.3-23.1	92-99
Very High	10	360 or more	764 or more	1064 or more	23.2 or more	100 or more

* For ozone, the maximum of the 8 hourly and hourly mean is used to calculate the index value.

Table 1: Boundaries Between Index Points for Each Pollutant in the UK system.[a]

a. Adapted from the netcen (www.netcen.co.uk) data archive website: http://www.airquality.co.uk/archive/standards.php#std

For each pollutant/ averaging time combination, the lower bound of index value 4 equals the UK Air Quality Standards. The Standards and the index values are based on the recommendations of the Expert Panel on Air Quality Standards. [7] The Standards therefore appear to be the basis for normalizing (providing a relative scale) of the index system.

The index values are associated with colours ranging from green (index value 1) to purple (index value 10).

2.2 The United States of America Environmental Protection Agency (US EPA) system

A uniform air quality index (AQI), originally called the Pollutant Standard Index (PSI) was established in 1976, for use by State and local agencies on a voluntary basis. [8]

The PSI or AQI, as it is currently referred to, includes indices for O_3, PM, CO, SO_2, and NO_2, which relate ambient pollutant concentrations to index values on a scale from 0 to 500. [9] This scale represents a very broad range of air quality, from pristine air to air pollution levels that present "imminent and substantial endangerment to the public". The index is normalized across pollutants by defining an index value of 100 as the numerical level of the primary NAAQS for each pollutant and an index value of 500 as the SHL. Such index values serve to divide the index into categories, with each category being identified by a simple informative descriptor. The descriptors are intended to convey to the public information about how air quality within each category relates to public health, with increasing public health concerns being conveyed as the categories range to the upper end of the scale. [9]

Table 2 summarises the USA index system.

These breakpoints --							**Equal these**	
O_3 (µg/m^3) 8-hour	**O_3 (µg/m^3) 1-hour[1]**	**PM_{10} (µg/m^3) 24h**	**$PM_{2.5}$ (µg/m^3) 24h**	**CO (mg/m^3) 8h**	**SO_2 (µg/m^3) 24h**	**NO_2 (µg/m^3) 24h**	**AQIs**	**Categories**
0-128		0 – 54	0.0 – 15.4	0-5.1	0-90	(2)	0 – 50	Good
130-168		55 – 154	15.5 – 40	5.1-10.9	93-383		51-100	Moderate
			US National Air Quality Standards					
170-208	250-328	155 – 254	41 – 65	11.0-14.4	386-596	(2)	101 – 150	Unhealthy for sensitive groups
210-248	330-408	255 – 354	66 – 150	14.5-17.9	599-809		151 – 200	Unhealthy
250-748	410-808	355 – 424	151–250	18.0-35.3	811-1607		201 - 300	Very unhealthy
	810-1008	425 – 504	251–350	35.4-46.9	1609-2139	239-313	301 – 400	Hazardous
	1010-1208	505 – 604	351–500	47.0-58.5	2141-2671	315-390	401 – 500	Hazardous

Table 2: Breakpoints for the USA Air Quality Index (adapted from [8, 9])

US EPA Footnotes to Table 2:

1. The AQI report may be based on 8-hour ozone values. In some cases the 1-hour O3 index value may be calculated and the maximum of the two reported.
2. NO_2 has no short-term NAAQS and can generate an AQI only above a AQI value of 200
3. 8-hour O_3 values do not define higher AQI values (>=301). AQI values of 301 or higher are calculated with 1-hour O3 concentrations
4. If a different SHL (significant harm level) for PM2.5 is promulgated [in the US], these numbers will change accordingly

For pollutant concentrations within the various bands, the US EPA provides for a linear interpolation procedure to estimate index values between the breakpoints. Thus the exposure-response function is assumed to be linear within the bands.

The index values, descriptors and colours associated with the US EPA AQI system are: index values 0-50 (green) "Convey[s a] positive message about air quality", values 51-100 (yellow) "Convey [a] message that daily air quality is acceptable from public health perspective, but every day in this range could result in potential for chronic health effect; and for O3, convey a limited health notice for extremely sensitive individuals", values 101-150 (orange) convey a "Health message for members of sensitive groups", 150-200 (red) requires a "Health advisory of more serious effects for sensitive groups and notice of possible effects for general population when appropriate", 201-300 (purple) "Health alert of more serious effects for sensitive groups and the general population" and 301-500 and above (maroon) "Health warnings of emergency conditions". [9]

2.3 Comparison of the UK and USA index systems

The UK and USA index systems are attempting to achieve the same objective – the presentation of air pollution (or air quality) data using an index system, but the two systems differ in several respects, making direct comparison difficult. The UK index system has values from 0 to 10, with 10 (designated a 'very high' pollution level) representing all concentrations greater than the upper bound for the 8-9 band; the US system has values from 0 to 500, values in the range 300 to 500 are designated 'hazardous'. Ozone 1h and 8h averages are used in both cases, but these values are used somewhat differently. In the US system, *both* 1h and 8h average ozone concentration values are used to define index values in the range 101 to 300 but in the UK system, *either* the 1h or the 8h concentration value may be used to define the index value. The UK ozone AQS is 100 $\mu g/m^3$ for the 1h or the 8h average value; the US standard is 250 $\mu g/m^3$ for the 1h average and 170 $\mu g/m^3$ for the 8h average. In the cases of SO_2 and NO_2, different time-averaged values are used in the two jurisdictions. The US EPA includes $PM_{2.5}$ in its index system whereas the UK does not.

Only PM_{10} and CO are treated identically. The UK and US Air Quality Standards for CO are essentially the same, 11.6mg/m^3 and 11.0 mg/m^3 respectively. In the UK system the AQS value for PM_{10} is 50 $\mu g/m^3$; in the US system, 150 $\mu g/m^3$, about 3 times higher than the UK value.

The descriptors for similar exposures differ significantly, particularly for PM10. For PM10 (24h average), the UK system designates values in the range 75 to 99 $\mu g/m^3$ as 'high', indicating that "sensitive people may notice significant effects and may need to take action". In the US system, the same PM10 exposure is designated 'moderate', indicating that "daily air quality is acceptable from public health perspective, but every day in this range could result in potential for chronic health effect". For ozone, values in the range 100 to 126 $\mu g/m^3$ would be designated 'good' in the UK system, but 'moderate' in the US system. Although the standards for the two systems are about equal for CO (8h average), values in the range 5.1 to 10.9 $\mu g/m^3$ would be regarded as 'moderate' in the US system, but 'low' in the UK system.

In both the UK and the USA, the overall index and the associated descriptor of the air quality for the day is taken as the highest index value reached by any pollutant of the group that is monitored. Thus, in both systems, if only one pollutant reaches a given band, say the 'moderate band' level of air pollution, the overall descriptor used is 'moderate'. If four pollutants all reach the 'moderate' band air pollution, is again, described as 'moderate'. In the second case, a more significant health effect may however be expected in comparison to the former (Maynard & Coster, 1998). Thus neither system accounts for the additive impact of different air pollutants.

3. AN ALTERNATIVE APPROACH TO THE CONSTRUCTION OF AN API SYSTEM

The context for the alternative air pollution index system proposed in this paper is the development of a predictive air pollution modelling system dubbed the Dynamic Air Pollution Prediction System (DAPPS)[1]. The DAPPS involves the development and integration of the following elements: downscaling of the current numerical urban-scale meteorological prediction to a finer spatial (1.0 km) and temporal resolution (1 hour) and establishing a comprehensive air pollutant emission inventory that includes industrial, motor vehicle, aircraft and domestic emissions, and temporal variations in these emissions. The enhanced meteorological data and the comprehensive emission inventory data are used as inputs into a photochemical dispersion model, the Comprehensive Air Quality Model with Extensions (CAMx), to forecast air pollution fields (spatially resolved air pollutant concentrations) for the forecast meteorology. The DAPPS is intended to address the need for integrated and publicly accessible information on urban scale air pollution, and the communication of the associated potential health impacts through an air pollution index system.

3.1 Methodology for developing the DAPPS Air Pollution Index (API) system

The basic concept of this index is that of using a combination of (DAPPS) modelled pollutant concentrations and published exposure-response functions for a given health endpoint (excess daily mortality) to derive a numerical scale specific to each of the pollutants included in the index system. The factors considered in constructing the API system are: selection of the pollutants and the averaging period(s) (the exposure metric) to be included in the system, the health endpoints and response time of exposure to the air pollutants, the availability of exposure-response relationships for each exposure metric and in relation to the health endpoint and the basis for normalizing the data, including a consideration of the 'toxicological model' for exposure-response to be used, and the relative scale to be used. The later requires a normalised numerical scale to establish an equivalence of harm for different pollutants, with different adverse health effects and exposure-response relationships.

Specific criteria used to screen the pollutant exposure metrics to be included in the API system were: an adverse health response time of less than 3 days, DAPPS predictive modelling capabilities, availability of exposure- (health) response relationships to short-term (<=24 hours) exposure and international practice for similar systems.

In addition to establishing index values for each pollutant exposure metric over the range of interest, the overall method and algorithm(s) used to calculate the final index should consider the viability of including additive or synergistic effects due to simultaneous exposure to multiple pollutants. The number of cases of excess mortality and morbidity due to pollution exposure is a function of the actual number of people exposed and the distribution of vulnerable or sensitive subgroups within the exposed population. If the demographic profile and the health status of the exposed population were known, these factors could be incorporated as modifiers of the API. The DAPPS forecast of air pollution fields, including forecast secondary pollutant concentrations, is the basic input for the API calculations.

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[1] DAPPS is a research project involving a consortium of four South African partners – the CSIR (the lead partner), South African Weather Service, the Peninsula Technikon and SRK Consulting, and is funded by the Department of Arts, Culture, Science and Technology via the National Research Foundation's Innovation Fund.

3.2 Results

3.2.1 Initial screening of possible exposure metrics

Table 3 represents the results of the initial screening of air pollutant metrics.

Pollutant	**SO_2**	**NO_2**	**O_3**	**PM_{10}**	**$PM_{2.5}$**	**CO**
Averaging periods	**1h, 24h**	**1h, 24h**	**1h, 3h, 8h**	**24h**	**24h**	**1h, 8h**

Table 3: Pollutants and averaging periods short-listed for inclusion in the DAPPS API system

The DAPPS is attempting to provide close-to-real-time information on current and short-term future air pollution levels throughout the modelling domain; the Air Pollution Index (or indices) would therefore indicate the likely short-term health impacts this exposure. Pollutants with long-term health effects (benzene, 1,3 butadiene, dioxins/ furans, polycyclic aromatic compounds, lead, etc.) were excluded from the API calculations. This does not preclude the provision of potential health impact information (for example by comparing predicted daily values against guideline values) for pollutants with a latency period of years (carcinogens) or cumulative action (lead) as part of the overall DAPPS system, but these pollutants are not included in the index system. Exposures of less than 1 hour were excluded as this is the minimum time resolution of the DAPPS. All combinations of pollutant and time-averaging periods are to be found in one or other international jurisdiction.

3.2.2 Pollutant exposure-health response relationships

The short-term adverse health effects of exposure to the classical air pollutants are essentially respiratory and cardiovascular. An extensive literature has demonstrated the associations between exposure to the classical pollutants and ill-health endpoints such as increased hospital admissions for respiratory, cardiovascular disease and congestive heart failure, increased asthma attacks, increased acute bronchitis and decreased lung function. Many studies have also shown the associations with increased daily mortality, in total and due to cardiovascular and respiratory causes. [10]

World Health Organisation (WHO) Relative Risk values

The question of the exposure-response relationship for each of the pollutants may be approached from one of two perspectives: a ‘toxicological’ approach that assumes a threshold below which no adverse effects occur or a risk-based approach that assumes the absence of such a threshold, that all exposures carry a degree of risk. [2] The extensive scientific literature on the relationship between exposure to air pollution and health has been reviewed and summarised in a number of WHO publications. [1,3,12] Of the pollutants under consideration for the API (SO_2, NO_2, PM_{10}, $PM_{2.5}$, O_3 and CO), the PM_{10}, $PM_{2.5}$ and O_3 do not have an apparent threshold value below which the risk of adverse health effect is zero. Continuing research indicates that SO_2 and NO_2 may not have threshold values either (WHO, 2000c). Thus any exposure to these pollutants appears to carry a finite risk of an adverse health effect.

The WHO report proposes a procedure for health impact assessment (of air pollution) in the European Region [11], using published Relative Risk factors for SO_2, NO_2, PM_{10}, $PM_{2.5}$ and O_3 for a range of health endpoints, including respiratory and cardiovascular diseases and mortality. Of the health endpoints, ‘Total mortality’ is the only one that is common to all the pollutants and time-averaged values under consideration in developing the DAPPS APIs. Table 4 has been extracted from Annex A of the WHO Health Impact Assessment report. [12]

HEALTH ENDPOINT	Incidence	PM_{10} 24h avg	$PM_{2.5}$ 24h avg	SO_2 24h avg	O_3 8 hr max	O_3 1 hr max	NO_2 daily avg	NO2 1 hr max
	Per 100 000	**RR**	**RR**	**RR**	**RR**	**RR**	**RR**	**RR**
MORTALITY								
Total mortality	**1013**	**1.0074**	**1.015**	**1.004**	**1.0051**	**1.0046**		**1.003**
Cardiovascular Mortality	497	1.008		1.008	1.004	1.004	1.002	1.002
Respiratory Mortality	66	1.012		1.01	1.0126	1.008		

Table 4: Relative Risk (central estimate) of health outcome per 10 $\mu g/m^3$ increase in pollutant concentrations[a] [12]

a: Extracted from the WHO HIA Report, Annex A.

In order to estimate the health impact, the proportion of the health impact (e.g. total mortality) attributable to a given exposure (pollutant-time combination) in a given population may be calculated using:

$$AP = \frac{SUM\{[RR(C) - 1] * p(c)\}}{SUM[RR(c) * p(c)]} \quad (1)$$

where: RR(c) is the relative risk for the health outcome in category c of exposure, p(c) the proportion of the population in category c of the exposure and AP the Attributable Proportion (of the health outcome due to the given exposure).

The estimate of the number of cases (for a given pollution level) is thus clearly dependent on the baseline frequency and the relative risk factors; both these factors may vary from city to city or country to country.

The data given in Table 4 are based on studies in Europe. Baseline incidence and Relative Risk values may be different in regions and/ or different populations, may be different in South African cities and within different areas of a city. This approach to health impact assessment provides a systematic method for estimating the effect of increasing air pollutant exposure, measured using the metric of a concentration-averaging time combination. There is a paucity of epidemiological data for ambient CO concentrations. [12] Swartz [13] quotes two values for the relative risk (daily mortality) per 10 mg/m3 of CO, 8h average, namely 1.04 and 1.05. The average of 1.045 was used. In selecting the unequivocal health endpoint ‘Total mortality’ as a common measure of air pollutant effects, the problem having to establish the equivalent impact of different measures of morbidity (for example, increased asthma attacks vs hospital visits for cardiovascular illness) is avoided.

3.2.3 The DAPPS Air Pollution Index System

The method uses the Relative Risk of daily mortality attributable to exposure to each pollutant/ time averaged value to define index values, and to calculate the air pollutant exposure values corresponding to the same relative risk and index value. The numerical scale (the range of index values) is essentially arbitrary. A range of 0 to 10 was chosen (similar to the UK system), with ‘10’ representing exposures greater than or equal to the values corresponding to ‘10’. The corresponding colour codes range from green to purple (Table 5).

	Pollutant exposure metric ->	PM10, 24h average [µg/m3]	PM2.5, 24h average [µg/m3]	SO2, 24h average [µg/m3]	Ozone, 8h maximum [µg/m3]	Ozone, 1h maximum [µg/m3]	NO2, 1h maximum [µg/m3]	CO, 8h rolling average [mg/m^3]
Relative Risk	**Index value**	**Concentration = (RR-1)/(Excess Risk Factor)**						
1	0	0	0	0	0	0	0	0.0
1.015	1	21	10	38	30	33	51	3.9
1.031	2	41	20	77	60	67	102	7.9
1.046	3	62	30	115	90	**100**	153	11.8
1.061	4	83	40	153	120	133	204	15.7
1.077	5	104	50	192	150	167	256	19.7
1.092	6	124	60	230	180	200	307	23.6
1.107	7	145	70	268	210	233	358	27.5
1.123	8	166	80	307	241	267	409	31.5
1.138	9	186	90	345	271	300	460	35.4
> 1.153	10	**>=207**	**>=100**	**>=383**	**>=301**	**>=333**	**>=511**	**>=39.3**

Table 5: The definition of the DAPPS Air Pollution Index (API) System

3.2.4 Methodology for defining a combined index

Table 5 defines individual indices for each of six pollutant exposure metrics. Except for PM10 and PM2.5 (expected to be strongly correlated), the effect of exposure to each pollutant is independent. Thus, for a given set of exposures, the total excess daily mortality is expected to be the sum of the values associated with exposure to each pollutant. If PM10 or PM2.5 were chosen to represent particulate matter exposure, and the 1h or the 8h average ozone concentration, the overall air pollution index (the API), based on the five pollutants, would have a range of 0 to 50.

4. DISCUSSION

The literature review showed that there is no internationally standardised methodology for constructing air pollution indices. The UK and US systems are similar in concept but differ substantially in implementation. The two systems cannot easily be aligned with each other to form the basis for a South African Air Pollution Index system.

Table 6 presents a comparison between the DAPPS and UK API values. The agreement between the DAPPS index value for O_3 and the UK value of 3 is by design – the DAPPS value was aligned with the UK value at 3. There are significant differences between the two systems for the other pollutants. The differences between the UK and the US systems have already been noted. The DAPPS Index System is self-consistent for the given health endpoint (daily mortality), and is linear with respect to the exposure metric (up to value 9). The UK and US systems are linear over part of the range, but the slopes are not constant.

Index Value: Exposure Measure [ug/m^3]	3 DAPPS	3 UK	6 DAPPS	6 UK	9 DAPPS	9 UK
PM_{10}, 24h average	62	50	124	75	186	100
$PM_{2.5}$, 24h average	30	-	60	-	90	-
SO_2, 24h average	115	-	230	-	345	-
O_3, 8h maximum	90	100	180	180	271	300
O_3, 1h maximum	100	100	200	180	300	300
NO_2, 1h maximum	153	287	307	573	460	700
CO, 8h rolling average	11.8	11.5	23.6	17.4	35.4	23.2

Table 6: Comparison of Proposed DAPPS Air Pollution Index Values for individual pollutants against UK Index Values

5. CONCLUSIONS

The proposed air pollution index system, based on excess mortality associated with exposure to the common air pollutants, provides a transparent, consistent and coherent methodology for deriving the air pollution index values. A combined index that is the sum of the indices of the five common air pollutants (using a single exposure metric for each pollutant) yields a system that is consistent with the epidemiological literature. This avoids the weakness in current systems of using the highest individual index value only to define the overall air pollution index, ignoring the reality of the effect of multiple exposures.

The use of the indices to estimate the health risks (and impacts) of air pollution in a given urban environment requires city specific baseline incidence data and relative risk factors. A more complex index system may be developed to account for morbidity (in addition to mortality), including the observed increasing severity of illness at higher pollution levels, and to account for the population density and vulnerability in pollutant exposed areas.

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