Title: AIR QUALITY MONITORING SYSTEM

Abstract: Methods for relating air quality data which are temporally and spatially resolved, to the temporal and/or spatial location of an individual or group of individuals are disclosed. Also disclosed are applications of the method and data obtained to such end uses as prediction of an individual’s future health and calculation of health insurance premiums for an individual for example.
AIR QUALITY MONITORING SYSTEM

Field of the Invention
The invention relates to air quality monitoring. More particularly but not exclusively it relates to the monitoring of air quality over a geographic area, storage of this data over time, and use of this temporal and spatial data in downstream applications.

Background
An individual’s respiratory health is a function of both their genetic disposition (as may be determined by medical tests) and their environmental exposure. One component of the environment is the exposure of an individual to airborne pollutants, both outdoors (such as pollutants arising from car emissions) and indoors (pollutants arising from photocopiers in the workplace, for example).

Currently air pollution represents a health risk that is not estimated with any degree of accuracy, particularly at the level of an individual or a corporation.

Public health organizations use monitors to measure air pollution, but only employ detectors at a few sites across a given city. Measurements obtained do not accurately represent the levels to which a particular individual is exposed to specific pollutants. For example, it has been shown that pollutant concentrations can vary significantly between sites that are spatially quite close (eg each side of road, between street level and 12th story in a building, two sides of a hill etc) due to air flow patterns and pollutant source distributions (Croxford B, Penn Am Hillier B, Spatial Distribution of Urban Pollution: Civilizing Urban Traffic, Science of the Total Environment Vol 189/190 (1996)). Indoor air quality can also vary dramatically due to the presence of pollutant sources such as photocopiers (ozone emissions (DEW, UCL)) and air-conditioning (solvents, fungi, bacteria etc).

More recently, with the decreasing cost of gas pollutant sensor technology and the advent of widespread wireless communication networks it is becoming possible for an air pollution monitoring network to be established on a street by street basis at relatively low cost. Such a system will allow a much more accurate profile of pollutant levels across a geographic region.

There is prior art in existence which attempts to monitor certain health factors over time in a given location. For example remote monitoring of the conditions a group of employees may be working under is disclosed in US 4,347,568 (Giguere et al), whilst other disclosures
include correlation of the level of some environmental parameter (such as ambient soot concentrations at a site in city) and a public health indicator (such as hospital bed admissions for respiratory illness). However these correlations are not specific to an individual, but averaged since the data manipulations assume (incorrectly) an entire group of individuals to have either equal susceptibility or equal exposure or both.

Prior art also exists attempting to link an individual’s health risk assessment to mortality or to “wellness”. For example US 5,937,387 (Summerrell et al) discloses a method of estimate the “wellness” of an individual through a number of input criteria (obtained by asking questions of the individual) whilst US 6,059,724 (Campbell et al) discloses a computer system for predicting the future health of individuals particularly in respect of predicting the onset of a particular disease.

Further, some have disclosed the use of certain health related factors in estimation of the future health of an individual and particularly with respect to the risk that individual presents to an insurance provider (US 4,975,840, de Tore et al; and US 5,937,387).

Healthcare insurance hitherto has been based solely on the perceived medical condition of an individual and some lifestyle behaviours (as indicated by the potential insuree, in a response to the provider). The environmental pollutant exposure of such individuals has not previously been relied upon. Hence, health risk estimates for respiratory illnesses, for example, are likely to be inaccurate.

Object of the Invention

It is an object of the invention to provide an historical database of spatially resolved gas pollutant or air quality data and/or a method of compiling the same.

It is an additional or alternative object to correlate historical gas pollutant or air quality data with the present, past or future health of an individual.

It is an additional or alternative object to correlate historical gas pollutant or air quality data with the risk an individual present to an insurance provider.

It is an additional or alternative object to provide a healthcare insurance provider with an additional or improved risk estimation means.

It is an additional or alternative object to provide town planners or other bodies with a planning tool.
It is an additional or alternative object to at least provide researchers or insurance providers or the public with a useful alternative to their existing risk assessment criteria.

5 Statements of the Invention
According to a first aspect of the invention there is provided a database of air quality data,
wherein the database includes a plurality of, or continuous, air quality data records derived from air quality readings taken or observed at a plurality of times or continuously, and at individual recording sites distributed over a plurality of geographic and/or spatial locations, and wherein the air quality data stored in the database is temporally and spatially resolved.

Preferably the air quality data correlates with the spatial and temporal locations of a specific individual or group of individuals.

Preferably the air quality readings have been taken or observed at regular intervals.
Preferably or alternatively the air quality readings may be taken or observed at, or over, a predetermined sample time, the predetermined sample time being relevant to the character or nature of a particular recording site (for example, during the day if an inner city or vocational site; or during the night, if a residential site), or the presence or absence of an individual or group of individuals.
Preferably each air quality record includes air quality data pertaining to levels of one or more of carbon monoxide, sulfur dioxide, nitrogen dioxide, nitric oxide, ozone, hydrocarbons, toluene, benzene, volatile organic compounds, particulates, PM10, PM2.5, chlorine, hydrogen sulfide, ammonia, terpenes, pollens, formaldehyde, paraphdehyde, carbon dioxide, humidity, relative humidity (as a proxy for dust mite populations).
Preferably the air quality records may be employed to calculate an air quality index for a defined location, the air quality index being a numerical indicator of air quality.
More preferably the database will include temporal and spatial air quality indices.
Preferably each defined location may contain one or more recording sites.
Preferably the air quality index will reflect the presence of one or more of carbon monoxide, sulfur dioxide, nitrogen dioxide, nitric oxide, ozone, hydrocarbons, toluene, benzene, volatile organic compounds, particulates, PM10, PM2.5, chlorine, hydrogen sulfide, ammonia, terpenes, pollens, formaldehyde, paraphdehyde, carbon dioxide, humidity, relative humidity (as a proxy for dust mite populations).
Preferably the air quality data and/or air quality record and/or air quality indices may be relevant to and/or used by one or more individuals/entities/companies.
Preferably a computer program is used to calculate, or to facilitate calculation of the air quality index.

Preferably the database may also contain pollutant particulate information relevant to one or more of the recording sites. Preferably the pollutant particulates may include soot, smog and/or smoke.

Preferably the database may also contain data relating to UV light and/or sunlight hours recorded at the recording sites.

According to a second aspect of the invention there is provided a method of compiling an air quality database of air quality data, comprising the steps of:

-observing or taking individual air quality readings at each of a plurality of recording sites distributed over geographic and/or spatial locations, at a recording time tn (tn = t1,t2,.....),

-creating an air quality data record in the database to reflect the air quality at each recording site at each recording time tn,

such that the air quality data stored in the air quality database is temporally and spatially resolved.

Preferably the location and time of each individual air quality reading correlates with or may be relevant to the spatial and temporal locations of a specific individual or group of individuals.

Preferably the air quality readings may be taken or observed at regular intervals. Alternatively the air quality readings may be continuously taken or observed.

Preferably each air quality record includes air quality data pertaining to levels of one or more of carbon monoxide, sulfur dioxide, nitrogen dioxide, nitric oxide, ozone, hydrocarbons, toluene, benzene, volatile organic compounds, particulates, PM10, PM2.5, chlorine, hydrogen sulfide, ammonia, terpenes, pollens, formaldehyde, paraldehyde, carbon dioxide, humidity, relative humidity (as a proxy for dust mite populations).

Preferably the air quality data and/or air quality record and/or air quality indices may be relevant to and/or used by one or more individuals/entities/companies.

Preferably the air quality data is taken or observed using a network of air pollution sensors.

Preferably the air pollution sensors are located in rural and/or urban sites. More preferably the air pollution sensors are located in indoor and/or outdoor sites.

Preferably readings are further taken and recorded to reflect relative humidity and/or UV light recorded at the recording sites.

Preferably the air pollution sensor network is linked via radio, internet or phone to a central data storage facility such as a computer.
According to a third aspect of the invention there is provided a method of preparing a pollutant exposure profile for a particular air quality recording site comprising or including the steps of:
- compiling an air quality database of air quality data as previously described
- interpretation of, or presenting the air quality data records of the database to reflect the pollution profile of the recording site over time.

Preferably the pollution profile reflects the level of one or more of carbon monoxide, sulfur dioxide, nitrogen dioxide, nitric oxide, ozone, hydrocarbons, toluene, benzene, volatile organic compounds, particulates, PM10, PM2.5, chlorine, hydrogen sulfide, ammonia, terpenes, pollens, formaldehyde, paraldehyde, carbon dioxide, humidity, relative humidity (as a proxy for dust mite populations), present at the particular air quality recording site over time.

Preferably the pollutant exposure profile may be relevant to and/or used by one or more individuals/entities/companies.

Preferably the pollutant exposure profile may be numerical and/or graphical or any other representation.

Preferably the pollution profile may also indicate UV light levels and/or sunlight hours recorded at the recording sites.

Preferably a computer program is used to prepare, or to facilitate preparation, of the pollutant exposure profile.

According to a fourth aspect of the invention there is provided a pollutant exposure profile for a particular air quality recording site comprising or including a representation of historical air quality for the recording site, prepared according to the abovementioned method.

According to a fifth aspect of the invention there is provided a method for determining an individual pollutant exposure profile relevant for a particular individual/entity/corporation including the steps of:
- identifying the location of the particular individual/entity/corporation (according to residential/vocational geographic or otherwise location),
- preparing the pollutant exposure profile as described previously for substantially the identical location,
- correlating the pollutant exposure profile for the location with the amount of time the particular individual/entity/corporation spends substantially within or proximate to the location.
Preferably the individual pollution profile reflects the level of one or more of carbon monoxide, sulfur dioxide, nitrogen dioxide, nitric oxide, ozone, hydrocarbons, toluene, benzene, volatile organic compounds, particulates, PM10, PM2.5, chlorine, hydrogen sulfide, ammonia, terpenes, pollens, formaldehyde, paraldehyde, carbon dioxide, humidity, relative humidity (as a proxy for dust mite populations) present at the particular air quality recording site over time.

Preferably the pollutant exposure profile may be numerical and/or graphical or any other representation.

Preferably the pollutant exposure profile may also contain data relating to UV light and/or sunlight hours recorded at the recording sites.

Preferably or alternatively the pollutant exposure profile may be taken or observed at, or over, a predetermined sample time, the predetermined sample time being relevant to the character or nature of a particular recording site (for example, during the day if an inner city or vocational site; or during the night, if a residential site).

Preferably a computer program is used to determine, or to facilitate determination of the individual pollutant exposure profile for the particular individual/entity/corporation.

Preferably the individual pollution profile is calculated according to

\[ EP_{x,t,i} = \sum_{x=x_1}^{x_2} \sum_{t=t_1}^{t_2} C_i \]

where

- \( EP_{x,t,i} \) = exposure of person p to pollutant i at location x for period t
- \( C_i \) = concentration of pollutant i at time t and position x
- \( t_1, t_2 \) = time of measurement
- \( dt \) = increment between measurements for pollutant i.

According to a sixth aspect of the invention there is provided a method for determining a health index for a particular individual including the steps of:

- determining the individual pollutant exposure profile for the individual, as previously described,
- compiling personal information concerning the health of the individual
- correlating the individual pollutant exposure with the personal information of the individual to provide the health index of the individual.

Preferably the personal information includes any genetic susceptibility of the individual.

Preferably a computer program is used to determine, or to facilitate determination of a health index for a particular individual.
According to a seventh aspect of the invention there is provided a **method for estimating the risk of the onset of a respiratory illness for an individual**, including the steps of:
- determining the health index of an individual, as previously described,
- using the pollution exposure profile of the particular location to predict future air quality at that particular location,
- correlating the predicted future air quality with the health index of the individual to estimate the risk on the onset of a respiratory illness.

Preferably the illnesses of interest may include asthma, and/or lung cancer.
- Preferably the risk of onset of the illness may be correlated with the place or residence and/or vocation of the individual.
- Preferably a computer program is used to determine, or to facilitate determination of the risk of the onset of a respiratory illness for an individual.

According to an eighth aspect of the invention there is provided a **method of determining a health risk factor for a particular individual** including the steps of:
- determining the individual pollutant exposure profile for the individual, as previously described,
- determining the health index of the individual, as previously described,
- taking into consideration any relevant epidemiological studies and/or results and/or correlations
- calculating the health risk factor for the individual.

Preferably the epidemiological studies/results/correlations may relate to respiratory illnesses including asthma, or lung cancer.

Preferably the health risk factor for an individual may be used by a health care provider or health care insurer to quantify or estimate the insurance risk of the person, due to their present and/or historical and/or future exposure to pollutants.

Preferably the health risk factor may be correlated with the place or residence and/or vocation of the individual.

Preferably a computer program is used to determine, or to facilitate determination of the health risk factor for a particular individual.

According to a ninth aspect of the invention there is provided a **computer program** substantially as previously described.
According to a tenth aspect of the invention there is provided a method of assessing the risk (to provide a risk assessment) presented by one or more air pollutants to the respiratory health of an individual comprising or including the steps of:

a) in respect of one or more air pollutants, obtaining a pollutant exposure profile according to the method as described in claim 18, for a site or relevance to the individual,

b) collecting respiratory health data of the individual, including time and duration of a respiratory illness, and

c) calculating a personal dose-response curve for the individual, using

$$ R_{p_i} = f_{p_i}(E_{p_i}) $$

where

$ R_{p_i} $ is the response of a person to exposure to pollutant $ i $

$ E_{p_i} $ is the measured exposure of a person to pollutant $ i $

$ f_{p_i}() $ is the function that relates a person’s response to exposure to pollutant $ i $.

d) using the personal dose-response curve to directly or indirectly estimate the health risk to that person of the particular location.

Preferably said one or more air pollutants are indoor pollutants and the particular location is an indoor location.

Preferably said one or more air pollutants is one or more of carbon monoxide, sulfur dioxide, nitrogen dioxide, nitric oxide, ozone, hydrocarbons, toluene, benzene, volatile organic compounds, particulates, PM10, PM2.5, chlorine, hydrogen sulfide, ammonia, terpenes, pollen, formaldehyde, paraldehyde, carbon dioxide, humidity, relative humidity (as a proxy for dust mite populations).

According to an eleventh aspect of the present invention there is provided a method of calculating a health insurance premium for an individual comprising or including the steps of:

a) assessing the risk presented by one or more air pollutants to the respiratory health of the individual as claimed in any one of claims 41 to 43,

b) using the risk assessment as a weighting factor to calculate the premium.

Accordingly to a twelfth aspect of the present invention there is provided a method of identifying a building with the potential to pose a respiratory health risk to one or more building occupants comprising or including the steps of:

a) collection of air pollution concentration data for one or more air pollutants from a one or more sensors located in the building, and

b) undertaking a health risk assessment substantially as claimed in claim 41, according on one or more of the building’s occupants.
In a thirteenth aspect of the present invention consists of a method of identifying potential rooms, offices or areas in a building which may have a detrimental effect on worker productivity rates due to poor air quality comprising or including the steps of:

a) collecting air pollutant exposure data specific to locations of workers in the building via a plurality of sensors located in the building;
b) compiling a database of air pollutant data which is temporally and/or spatially resolved
c) correlating worker productivity with the air pollutant exposure data to analyse the offices and rooms in a building according to their propensity to have a detrimental effect on worker productivity due to poor wellness suffered as a result of poor indoor air quality.

Preferably the database compilation occurs via connection of the plurality of sensors to a computer data storage device or database via a packet switched network or over a circuit switched network.

DESCRIPTION OF THE FIGURES

Figure 1: Example pollutant- dose-response correlation for an individual.

DETAILED DESCRIPTION

A. The Network of Air Pollution Sensors

A sensor network is employed consisting of a distributed network of monitors in one or more of rural and urban, indoor and outdoor sites that measure the local concentrations of individual pollutants.

Gas sensor technology based on gas sensitive semi-conducting metal oxides, infra-red spectroscopy, electrochemical devices, colorimetric devices etc could be used to detect gases at specific locations in both outdoor and indoor, urban and rural environments for the purpose of quantifying an individuals pollutant exposure profile.

UV and meteorological detectors, including relative humidity for example, could also be incorporated into the network to provide such data as a function of location.

Ideally therefore, the sensor network is made up of a plurality of in-expensive air pollution sensors that are linked via radio, internet or phone to a central data storage facility such as a computer. The network collects individual-centric data ie, the pollutant concentration data at a time and place in which an individual is located, ie at home and at work or school. Air pollutants that are measured include SO$_2$, CO, O$_3$, Volatile organic compounds, volatile aldehydes, formaldehyde, humidity, NO$_2$, NO, chlorine, ammonia, hydrogen sulfide,
hydrocarbons, benzene, relative humidity (a proxy for dust mite populations), dust (PM2.5 or PM10) etc.

B. Pollution Index for a Site
As part of the invention the establishment of, and tracking of changes within, a grading system of air quality for each of the sites as a function of the average local pollution level will be calculated and housed within the database. The grading system may be in a number of forms without departing from the scope of the invention. For example it may be a 1-10 pollution index (1 being low ambient pollution, 10 being high). This grading system may not be linear as there may be a threshold level for a pollutant below which there is no measurable effect on an individual’s health.

Laboratory studies have shown that pollutants can act in synergy with other factors eg high ozone levels, to increase sensitivity of an asthma sufferer to house dust (Charles Popper et al., University of Davis). Such findings and correlations may be taken into account within the calculation of the pollution index (or in any other embodiment of the invention).

C. Database of Pollutant Data
The database of the invention is a time-resolved, and spatially/geographically-resolved database including pollutant levels for each site. The main pollutants incorporated are carbon monoxide, sulfur dioxide, nitrogen dioxide, nitric oxide, ozone, hydrocarbons, toluene, benzene, volatile organic carbons, particulates, PM10, PM2.5, chlorine, hydrogen sulfide, ammonia, terpenes, although additional pollutants or other factors may be measured or incorporated without departing from the scope of the invention.

The database may be made available over the world wide web or a mobile phone network to enable consumers to make informed choices about their behaviour (eg not going for a run because pollution levels are too high).

The database or pollution index may be used by medical agencies and research groups to assess the effect of pollution on health thereby improving our understanding of the health effects of pollutants. Thus this concept is a research tool.

D. Pollutant Exposure Profile
The pollutant exposure profile will provide an historical profile of levels of pollutants or other measured or observed species for a particular site. It will be appreciated that such
historical data may be presented in any one of a number of ways without departing from
the scope of the invention. For example, presentation may be graphical, numerical or
combined.

Specifically, in one preferred form, information collected is $C_i$ (ambient air concentration
of pollutant i) and t (time of measurement) at each of the places the person (p) is located.

The database stores personal pollution exposure data and personal medical history. It can
be used to determine the health index for a particular individual. The personal exposure is
calculated as the sum of the concentrations of pollutants measured, integrated over the
measurement time for each place in which the person is located. The personal exposure
(Ep) to pollutant i is calculated by the equation below:

\[ Ep_{x,t,i} = \sum_{x=x_1}^{x_n} \sum_{t=t_1}^{t_n} C_i \]

where

- $Ep_{x,t,i}$ = exposure of person p to pollutant i at location x for period t
- $C_i$ = concentration of pollutant i at time t and position x
- $t_n$ = time of measurement
- $dt$ = increment between measurements for pollutant i

The total exposure of a person (p) at a location for a given period is calculated as the sum
of exposures to individual pollutants.

\[ EP_{x,t,\text{total}} = \sum_{i=1}^{n} Ep_{x,t,i} \]

The exposure (Ep) can be averaged over a time period as required such as daily, weekly,
monthly or yearly giving average daily, weekly or yearly doses.

**E. Individual's Health Index**

Medical test data for an individual which describes the genetic susceptibilities of the
individual to atmospheric pollutants are incorporated to calculate the individual health
index.

Medical and laboratory tests eg allergy tests, published toxicity data (USDHHS) and
epidemiological data can be used to establish the correlation between exposure to
pollutants and illness for a given individual.
For any individual a health risk calculation could be made based on the individuals genetic make-up and their work and home locations.

The invention enables the reliability and accuracy of the health risk calculation to improve with time due to:

(a) the increase in the accuracy of the exposure data of an individual from an increase in the number of monitors in the environment.

(b) an improvement in the number of genetic tests for susceptibility to pollutants.

F. Estimating Risk of Onset of Illness

The health index of the individual is used, with known factors relating to particular illnesses (particularly respiratory), to predict the onset of a particular illness. This may be used to inform an individual that "given your predisposition to an illness, your history in this particular air quality location, and the historical air quality profile of this location, if you don't move workplace or residence you are likely to develop..." for example.

G. Health risk factor for a particular individual

The individual exposure profile for a person is used in conjunction with their medical condition and epidemiological studies to give a method of determining the effect of an individual's work and home locations on their health due to the atmospheric environment to which they are exposed. This would then provide a way of accurately determining the health risk of an individual for insurance and healthcare purposes.

An algorithm that calculates the health risk of an individual given his/her genetic susceptibilities and the pollution index of the individuals home and work environments is used. This algorithm could be embodied in software without departing from the scope of the invention, that takes input of an individuals susceptibility and work/home address and outputs a risk assessment and/or insurance premium.

Our invention will enable this health risk to be assessed for an individual or corporation.

For example, exposure-response data is available from prior art for example from the Environmental Protection Agency, US and Agency for Toxic Substances and Disease Registry, US and based on toxicological and epidemiological studies. The relationship between exposure and response is defined by a function:
\[ R_{p_i} = f_{p_i}(E_{p_i}) \]

where

- \( R_{p_i} \) is the response of a person to exposure to pollutant \( i \)
- \( E_{p_i} \) is the measured exposure of a person to pollutant \( i \)
- \( f_{p_i}() \) is the function that relates a person's response to exposure to pollutant \( i \)

The function \( f() \) is specific to a pollutant, a person, and a measurement interval. Prior art has established function \( f() \) for a number of pollutants for the general population (for example, "Breath Taking: Premature Mortality due to Particulate Air Pollution in 239 American Cities" - a May 1996 report by the Natural Resources Defense Council) however these fail to take into account an individual’s susceptibility or response to a particular pollutant. The method thus describes a means by which an individual can determine which pollutants they are particularly affected by.

By collecting the personal health history of an individual it is possible to develop the dose-response correlation (ie the \( f() \) function) specific to the individual. This can then be used to specify pollutant minimum risk levels (MRL) for the individual which defines \( f() \) pollutant level without appreciable risk to the individual (see Figure 1).

The MRL can then be used by the individual to make choices about the places they live and the identification and positioning of pollutant sources within their indoor environment.

H. Other downstream applications

The air quality database could also be used to detect fugitive emissions and enable the source to be accurately located, the emissions stopped and party fined for non-compliance. Pollution/meteorological data could be used to remotely cause an action eg closing a greenhouse window due to the wind-carry of herbicide from a neighbouring farm.

Corporations may use the pollution index to make informed choices about their indoor air quality and therefore manage their employee healthcare.

Individuals, schools, and corporations may use the database of pollution levels at locations and or the pollution index to make informed choices about where they may wish to live, work or be located.
EXAMPLES

Example 1.
Semiconducting metal oxide gas sensors sensitive to ozone and volatile organic compounds (VOC) are interfaced to two PCs via RS232 cables. One PC installed in the home and one in the place of work (office), respectively, of a person. The PCs are then be connected to the internet and the data collected by the sensors obtained from the PCs by a remote computer via the internet.

The concentration of ozone and VOCs are thus measured and the total dose of these pollutants that the person was exposed to calculated over a period of 3 months. During that time the person is able to keep a record of asthma attacks, recording time, place, severity of attack on a scale of 1 to 5 and duration. This database of dose-response data is then be used to calculate an individual's dose-response function and minimum risk level.

A plot of number of asthma attacks or severity of asthma attack versus ozone dose per day may show a correlation that would allow a personal dose-response curve to be created that would indicate the minimum risk level (MRL) specific for the person.

The database of ozone concentrations might indicate that the office environment exceeded this MRL when the printer was used for extended periods which increased the persons risk of asthma. Removal of the printer from the office would therefore reduce the asthma attacks of the person.

Example 2.
A dose-response curve for ozone is developed for a person using the procedure described in Example 1 and a minimum risk level (MRL) established. The total exposure data obtained by the sensor network and database described in Example 1 is then used to determine whether the person's MRL was exceeded during a given time period. This information is then be used by an health insurance company to set the price of premiums or level of rebates thus encouraging a person with a susceptibility to ozone-induced asthma to choose to live in an environment with low ozone levels to reduce their incidence of asthma.

Example 3.
A dose-response curve for one or more of formaldehyde, sulfur dioxide, carbon monoxide, carbon dioxide etc is developed for a person as in Example 1 and used in a similar way in Example 2.

Example 4.
A plurality of sensors that detect one or more of SO$_2$, CO, O$_3$, Volatile organic compounds, volatile aldehydes, formaldehyde, humidity, NO2, NO, chlorine, ammonia, hydrogen sulfide, hydrocarbons, benzene, relative humidity (a proxy for dust mite populations) or dust, are distributed through a building and connected via a wired or wireless network to a computer or computers that may be located in the building or elsewhere such that the ambient air concentrations of the gas or gases are recorded in a database.

The database also specifies the place and time of the gas concentration reading. The database is used to establish the dose of the gas or gases that the inhabitants of the building are exposed to. This dose is compared to the minimum risk levels, established by a procedure outlined in Example 1, of each inhabitant. If the dose of a gas exceeds the MRL of an individual or individuals in a particular location (office or room) then they and/or the building owner may be notified to take remedial steps.
CLAIMS

1. A **database of air quality data** wherein the database includes a plurality of, or continuous, air quality data records derived from air quality readings taken or observed at a plurality of times or continuously, and at individual recording sites distributed over a plurality of geographic and/or spatial locations, and wherein the air quality data stored in the database is temporally and spatially resolved.

2. A database as claimed in claim 1 wherein the air quality data correlates with or is relevant to the spatial and temporal locations of a specific individual or group of individuals.

3. A database as claimed in claim 2 wherein the air quality readings may be taken or observed at, or over, a predetermined sample time, the predetermined sample time being relevant to the character or nature of a particular recording site, or to the presence of absence of an individual or group of individuals.

4. A database as claimed in claim 3 wherein each air quality record includes air quality data pertaining to levels of one or more of carbon monoxide, sulfur dioxide, nitrogen dioxide, nitric oxide, ozone, hydrocarbons, toluene, benzene, volatile organic compounds, particulates, PM10, PM2.5, chlorine, hydrogen sulfide, ammonia, terpenes, pollens, formaldehyde, paraldehyde, carbon dioxide, humidity, relative humidity.

5. A database as claimed in claim 4 wherein the air quality records are employed to calculate an **air quality index** for a defined location, the air quality index being a numerical indicator of air quality.

6. A database as claimed in claim 5 wherein the air quality index will reflect the presence of one or more of carbon monoxide, sulfur dioxide, nitrogen dioxide, nitric oxide, ozone, hydrocarbons, toluene, benzene, volatile organic compounds, particulates, PM10, PM2.5, chlorine, hydrogen sulfide, ammonia, terpenes, pollens, formaldehyde, paraldehyde, carbon dioxide, humidity, relative humidity in the air at the time of the reading.

7. A database as claimed in claim 6 wherein the air quality data and/or air quality record and/or air quality indices may be relevant to and/or used by one or more individuals/entities/companies.
8. A database as claimed in claim 7 wherein a computer program is used to calculate, or to facilitate calculation of the air quality index.

9. A database as claimed in claim 8 wherein the database further contains one or both of UV light, and/or sunlight hours relevant to one or more of the recording sites.

10. A method of compiling an air quality database of air quality data, comprising the steps of:
- observing or taking individual air quality readings at each of a plurality of recording sites distributed over geographic and/or spatial locations, at a recording time \( t_n = t_{1}, t_{2}, \ldots, \).
- creating an air quality data record in the database to reflect the air quality at each recording site at each recording time \( t_n \), such that the air quality data stored in the air quality database is temporally and spatially resolved.

11. A method as claimed in claim 10 wherein the location and time of each individual air quality reading correlates with our may be relevant to the spatial and temporal locations of a specific individual or group of individuals.

12. A method as claimed in claim 11 wherein each air quality record includes air quality data pertaining to levels of one or more of carbon monoxide, sulfur dioxide, nitrogen dioxide, nitric oxide, ozone, hydrocarbons, toluene, benzene, volatile organic compounds, particulates, PM10, PM2.5, chlorine, hydrogen sulfide, ammonia, terpenes, pollens, formaldehyde, paraldehyde, carbon dioxide, humidity, relative humidity.

13. A method as claimed in claim 12 wherein the air quality data and/or air quality record and/or air quality indices may be relevant to and/or used by one or more individuals/entities/companies.

14. A method as claimed in claim 13 wherein the air quality data is taken or observed using a network of air pollution sensors located in rural and/or urban sites.

15. A method as claimed in claim 14 wherein the air pollution sensors are located in indoor and/or outdoor sites.
16. A method as claimed in claim 15 wherein further readings are recorded to reflect one or both of UV light, and/or sunlight hours recorded at the recording sites.

17. A method as claimed in claim 16 wherein the air pollution sensor network is linked via radio, internet or phone to a central data storage facility such as a computer.

18. A method of preparing a pollutant exposure profile for a particular air quality recording site comprising or including the steps of:
   - compiling an air quality database of air quality data substantially according to the method claimed in any one of claims 10 to 17,
   - interpretation of, or presenting the air quality data records of the database to reflect the pollution profile of the recording site over time.

19. A method as claimed in claim 18 wherein the pollution profile reflects the level of or one or more of carbon monoxide, sulfur dioxide, nitrogen dioxide, nitric oxide, ozone, hydrocarbons, toluene, benzene, volatile organic compounds, particulates, PM10, PM2.5, chlorine, hydrogen sulfide, ammonia, terpenes, pollens, formaldehyde, paraldehyde, carbon dioxide, humidity, relative humidity, present at the particular air quality recording site over time.

20. A method as claimed in claim 19 wherein the pollutant exposure profile may be relevant to and/or used by one or more individuals/entities/companies.

21. A method as claimed in claim 20 wherein the pollutant exposure profile may be numerical and/or graphical or any other representation.

22. A method as claimed in claim 21 wherein the pollution profile may also indicate one or both of UV light, and/or sunlight hours recorded at the recording sites.

23. A method as claimed in claim 22 wherein a computer program is used to prepare, or to facilitate preparation, of the pollutant exposure profile.

24. A pollutant exposure profile for a particular air quality recording site comprising or including a representation of historical air quality for the recording site, prepared according to the method as claimed in any one of claims 13 to 23.

25. A method for determining an individual pollutant exposure profile relevant for a particular individual/entity/corporation including the steps of:
identifying the location of the particular individual/entity/corporation (according to residential/vocational geographic or otherwise location),

- preparing the pollutant exposure profile substantially according to the method as claimed in any one of claims 18 to 23, for substantially the identical location,

- correlating the pollutant exposure profile for the location with the amount of time the particular individual/entity/corporation spends substantially within or proximal to the location.

26. A method as claimed in claim 25 wherein a computer program is used to determine, or to facilitate determination of the individual pollutant exposure profile for the particular individual/entity/corporation.

27. A method as claimed in any one of claims 25-26 wherein the individual pollution profile is calculated according to:

\[ Ep_{x,t,i} = \sum_{x=x_t}^{x_{t+1}} \sum_{t_{t-1}}^{t_t} C_i \]

where

- \( Ep_{x,t,i} \) = exposure of person \( p \) to pollutant \( i \) at location \( x \) for period \( t \),
- \( C_i \) = concentration of pollutant \( i \) at time \( t \) and position \( x \),
- \( t_n \) = time of measurement,
- \( dt \) = increment between measurements for pollutant \( i \).

28. A method for determining a health index for a particular individual including the steps of:

- determining the individual pollutant exposure profile for the individual, substantially according to the method as claimed in any one of claims 25 to 27,
- compiling personal information concerning the health of the individual,
- correlating the individual pollutant exposure with the personal information of the individual to provide the health index of the individual.

29. A method as claimed in claim 28 wherein the personal information includes any genetic susceptibility of the individual.

30. A method as claimed in claim 29 wherein a computer program is used to determine, or to facilitate determination of, a health index for a particular individual.
31. A method for estimating the risk of the onset of a respiratory illness for an individual, including the steps of:
   - determining the health index of an individual, substantially according to the method as claimed in any one of claims 28 to 30,
   - using the pollution exposure profile of the particular location to predict future air quality at that particular location,
   - correlation the predicted future air quality with the health index of the individual to estimate the risk on the onset of a respiratory illness.

32. A method as claimed in claim 31 wherein the illnesses of interest includes asthma and/or lung cancer.

33. A method as claimed in claim 32 wherein the risk of onset of the illness may be correlated with the place or residence and/or vocation of the individual.

34. A method as claimed in claim 33 wherein a computer program is used to determine, or to facilitate determination, of the risk of the onset of a respiratory illness for an individual.

35. A method of determining a health risk factor for a particular individual including the steps of:
   - determining the health index of the individual, substantially according to the method as claimed in any one of claims 28-30,
   - taking into consideration any relevant epidemiological studies and/or results and/or correlations,
   - calculating the health risk factor for the individual.

36. A method as claimed in claim 35 wherein the epidemiological studies/results/correlations relate to respiratory illnesses such as asthma, or lung cancer.

37. A method as claimed in claim 35 or 36 wherein the health risk factor for an individual is used by a health care provider or health care insurer to quantify or estimate the insurance risk of the person, due to their present and/or historical and/or future exposure to pollutants.

38. A method as claimed in claim 37 wherein the health risk factor is correlated with the place or residence and/or vocation of the individual.
39. A method as claimed in claim 38 wherein a computer program is used to determine, or to facilitate determination of the health risk factor for a particular individual.

40. A **computer program** substantially as previously described in any one of claims 8, 23, 26 or 34.

41. A **method of assessing the risk (to provide a risk assessment) presented by one or more air pollutants to the respiratory health of an individual** comprising or including the steps of:
   a) in respect of one or more air pollutants, obtaining a pollutant exposure profile according to the method as described in claim 18, for a site or relevance to the individual,
   b) collecting respiratory health data of the individual, including time and duration of a respiratory illness, and
   c) calculating a personal dose-response curve for the individual, using

   \[ Rp_i = f_{p_i}(Ep_i) \]

   where
   \( Rp_i \) is the response of a person to exposure to pollutant \( i \)
   \( E_{pi} \) is the measured exposure of a person to pollutant \( i \)
   \( f_{p_i}(\cdot) \) is the function that relates a person’s response to exposure to pollutant \( i \)
   d) using the personal dose-response curve to directly or indirectly estimate the health risk to that person of the particular location.

42. A method as claimed in claim 41 wherein the one or more air pollutants are indoor pollutants and the particular location is an indoor location.

A method as claimed in claim 45 wherein the one or more air pollutants is one or more of carbon monoxide, sulfur dioxide, nitrogen dioxide, nitric oxide, ozone, hydrocarbons, toluene, benzene, volatile organic compounds, particulates, PM10, PM2.5, chlorine, hydrogen sulfide, ammonia, terpenes, pollens, formaldehyde, paraldehyde, carbon dioxide, humidity, relative humidity.

43. A **method of calculating a health insurance premium for an individual** comprising or including the steps of:
   a) assessing the risk presented by one or more air pollutants to the respiratory health of the individual as claimed in any one of claims 41 to 43,
   b) using the risk assessment as a weighting factor to calculate the premium.
44. A **Method of identifying a building with the potential to pose a respiratory health risk to one or more building occupants** comprising or including the steps of:
   a) collection of air pollutant concentration data for one or more air pollutants from a one or more sensors located in the building, and
   b) undertaking a health risk assessment substantially as claimed in claim 41, on one or more of the building's occupants.

45. A **method of identifying potential rooms, offices or areas in a building which may have a detrimental effect on worker productivity rates** due to poor air quality comprising or including the steps of:
   a) collecting air pollutant exposure data specific to locations of workers in the building via a plurality of sensors located in the building;
   b) compiling a database of air pollutant data which is temporally and/or spatially resolved
   c) correlating worker productivity with the air pollutant exposure data to analyse the offices and/or rooms in a building according to their propensity to have a detrimental effect on worker productivity due to poor wellness suffered as a result of poor indoor air quality.

46. A method as claimed in claim 46 wherein the database compilation occurs via connection of the plurality of sensors to a computer data storage device or database via a packet switched network or over a circuit switched network.
Figure 1
# INTERNATIONAL SEARCH REPORT

**International application No.**

PCT/NZ02/00012

## A. CLASSIFICATION OF SUBJECT MATTER

Int. Cl.: G06F 19/00; A61B 5/08

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPAT, USPTO, EPO: air, quality, pollution, database, temporal, spatial

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

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<th>Category*</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
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<td>US 5,831,876 A (ORR et al.) 03 November 1998</td>
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<td>See the whole document with particular reference to the abstract and column 1, lines 62 - column 2, line 52.</td>
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<td>WO 00/65996 A1 (NOKIA CORPORATION) 09 November 2000</td>
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<td>See the whole document with particular reference to the abstract, figs. 1-3 and pages 4,5.</td>
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<td>Y</td>
<td>WO 00/37933 A1 (RAYTHEON COMPANY) 29 June 2000</td>
<td>1,2,3,10,11</td>
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<td>See the whole document with particular reference to the abstract and page 4, line 30 - page 5, line 13.</td>
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*Note:* For "Y" indications, WO 00/37933 and WO 00/65996 can be individually combined with US 5,831,876

[X] See patent family annex

Further documents are listed in the continuation of Box C

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Date of the actual completion of the international search: 18 April 2002

Date of mailing of the international search report: 30 APR 2002

Name and mailing address of the ISA/AU

AUSTRALIAN PATENT OFFICE
PO BOX 200, WODEN ACT 2606, AUSTRALIA
E-mail address: pct@ipaaustralia.gov.au
Facsimile No. (02) 6285 3929

Authorized officer

SERINEL SAMUEL

Telephone No: (02) 6283 2382

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