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AIR QUALITY AS RESPIRATORY HEALTH INDICATOR — A CRITICAL REVIEW

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Abstract
As part of the European Public Health project IMCA II validity and practicability of "air pollution" as a respiratory health indicator were analyzed. The definitions of air quality as an indicator proposed by the WHO project ECOEHIS and by IMCA I were compared. The public availability of the necessary data was checked through access to web-based data-bases. Practicability and interpretation of the indicator were discussed with project partners and external experts. Air quality serves as a kind of benchmark for the good health-related environmental policy. In this sense, it is a relevant health indicator. Although air quality is not directly in the responsibility of health policy, its vital importance for the population's health should not be neglected. In principle, data is available to calculate this IMCA indicator for any chosen area in Europe. The indicator is relevant and informative, but calculation and interpretation need input from local expert knowledge. The European health policy is well advised to take air quality into account. To that end, an interdisciplinary approach is warranted. The proposed definition of air quality as a (respiratory) health indicator is workable, but correct interpretation depends on expert and local knowledge.

Key words:
Health indicators, Air quality, Public health, Respiratory health

INTRODUCTION

Air pollution still poses a significant threat to human health and leads to greater morbidity and shorter life expectancy [1–5]. Therefore, in the list of "Environment and Health Indicators" of the WHO-coordinated European project "Development of Environment and Health Indicators for the European Union Countries (ECOEHIS)" [6] indicators on air pollution were included. The final set consisted of 7 core indicators covering emissions of air pollutants, transport-related indicators (passengers transport demand, freight transport demand and fuel consumption), health effects of air pollution (Years of Life Expectancy Lost due to PM exposure), one indicator of indoor air quality, namely policies to reduce environmental tobacco smoke exposure, and one complex indicator of exposure to air pollution. This indicator has two components: population-weighted annual average concentration of particulates (PM10, PM2.5) and ozone (O_3) and exceedance of air quality limit values for nitrogen dioxide and sulfur dioxide (NO_2, SO_2).

Obviously, this exposure indicator is an indicator of environmental quality, not directly of population health, in spite of the fact that air quality does have a fundamental impact on health as well.

As air pollution has, inter alia, a negative impact on respiratory health, the European Public Health project "Indicators for monitoring COPD and asthma in the EU" (IMCA [7]) decided to include one parameter regarding air quality:

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air pollution exposure to: NO_2, SO_2, O_3, PM10, PM2.5 (indicator No. 3.3.1 — physical environment). The definition of this indicator specified two different approaches: (a) Annual average of concentrations in μg/m³ for a specific geographical area; (b) Population-weighted exposure to selected air pollutants (as defined by the ECOEHIS project). Thus, a direct reference to the ECOEHIS definition is provided.

The follow-up project IMCA II [7] was charged with the task to test the practicability of the IMCA set of indicators in pilot studies and/or to study the availability of the necessary data. This paper deals with the aforementioned indicator "air pollution exposure".

METHODS

This paper presents the authors' personal opinion on and an approach towards the air quality indicator as defined by the IMCA project and also reflects on the ECOEHIS definition that is referred to by IMCA. The opinion is based on personal experience with air pollution research, close contact with several European research and public health projects on air quality and with WHO working groups (including the IMCA and ECOEHIS projects), a web-search on data availability, and discussions with international experts.

RESULTS

The following key questions concerning the practicability and validity of the air quality indicator were identified and — as far as possible — answered as well.

Is air quality an indicator of respiratory health?

Undoubtedly, air quality is a determinant of respiratory health, but is it an indicator? The concentration of indicator pollutants is certainly an indicator of environmental status and when this concentration is linked to population exposure, it serves as a good indicator of the health-related environment. However, while ECOEHIS is about environment and health indicators, the IMCA project concerns a subset of health indicators only, namely indicators of respiratory health. Air pollution per se does not inform you directly about population health. Two populations exposed to the same level of air pollution might still differ in their respiratory health status because of their robustness, age distribution, smoking behavior or occupational exposures, to name but a few relevant factors. Nevertheless, better air quality has been shown to improve the health of the exposed groups [8–12]. In this regard air quality is a benchmark test of good health policy. Thus, it is not an indicator of health, but of good health policy, although usually air quality is not within the responsibility of the health agencies. This is true for many areas (including education, economy, social affairs, transport and spatial planning) that are relevant for health and are not controlled by the public health services, but should still be considered in public health [13–17].

Air quality as a health determinant serves as a benchmark test of health policy and in this respect it is indeed a health indicator. But is it an indicator of respiratory health? It is well established that air pollution is detrimental to respiratory health, but its effects are not restricted to the respiratory system [18]. Indeed, the impact of air pollution on the cardiovascular system is much more pronounced [19]. On the other hand, it is not only respiratory exposure that affects the airways. Prominent examples of environmental exposures that reach the airways not via inhalation are arsenic in drinking water (that leads to an increased risk of lung cancer [20]) and maternal smoking during pregnancy where the pollutants reach the embryo via the blood stream, but still cause respiratory impairments [21,22].

Therefore, the connection between air pollution and airways is by no means specific, but from a didactic perspective it makes sense to list respiratory exposures among respiratory health indicators.

Which pollutants should be considered?

IMCA named 5 pollutants: NO_2, SO_2, O_3, PM10, and PM2.5. These are indeed the most important pollutants that are monitored on a routine basis in Europe and worldwide. They represent only a part of the full mixture of pollutants. However, most pollutants share similar sources (e.g., the gaseous oxides of sulfur and nitrogen as well as a substantial part of particulate matter stem from combustion sources, as do carbon monoxide and a range of organic carbon species) and a similar fate through common meteorological conditions (shift of air masses, inversion layers, dilution due to winds and thermal circulation). Therefore, a few indicator pollutants suffice to characterize the overall air quality: (a) the primary pollutant mixture (mostly derived from combustion sources), and (b) the secondary mixture originating from complex atmospheric chemical processes involving primary pollutants and UV-light and yielding ozone and other photochemical species including secondary particles. Both mixtures are represented in this set of parameters. Nevertheless, it should not be forgotten that none of these parameters is fully source-specific and the pollution mixtures from different sources are likely to have a different toxic potential [4].

Why background monitoring stations?

The ECOEHIS definition [6] is based on data from background stations. The EU air quality directive [23] provides a strict definition of different types of monitor locations. These types are indicated in the meta-database in AirBase [24]. Therefore, it is easy to select data from background stations only. But is this data relevant for population exposure and does it serve as an indicator of good local health policy?

Background data is certainly more reliable and represents a wider area than the data from source-specific monitoring stations (industrial sites, road-side stations). For a monitoring station located in the proximity of a strong pollution source even small changes in its location can have substantial impact on the measurement results. This severely affects the comparability and interpretation. The data does not allow estimating the average exposure of a larger area.

However, background concentrations are mostly influenced by geographical and climatic conditions on the one hand, and long-range transport on the other. Local policy has little means to influence these values. How then could they serve as indicators of good policy?

Background levels might be low. But if a high percentage of the population lives close to local pollution sources, this is not informative of the true population exposure. The most important local pollution source in many urban settings is road traffic. This is not only due to the strong contribution of road transport to the overall emissions, but also due to its ground-level production of pollutants and proximity to people's homes. As a consequence, the ECOEHIS project also included indicators of road traffic in the core set of indicators, while IMCA did not. Traffic indicators are necessary to complement the information provided from background stations. In a novel approach, Künzli et al. [25] have suggested "percentage of people living near busy roads" as another indicator. The availability of data to estimate and formalize this indicator has just been assessed in another EU project (Aphekom [26]).

In that way, the indicator "air quality" could still be improved by adding additional parameters, but it is already a great step forward when at least one indicator of air pollution is included in the IMCA list.

How to calculate the annual average of concentrations?

The IMCA indicator 3.3.1 consists of two parts. The first addresses the average regional concentration. It does not explain the methods by which this average is calculated because only the second part refers to the ECOEHIS definition. Nevertheless, it seems reasonable that also for the first part background monitoring data is to be used. Still, the "specific geographical area" on which this indicator is to be applied remains to be defined.

Since this should be an indicator of health policy, it is reasonable to choose as "an area" an administrative entity that is regulated by a common policy, e.g., a state or a similar political unit. However, air pollution is not confined by political borders. Although borders both of air masses and of political units sometimes follow geographical structures like mountain ranges, political borders often are defined for instance by the course of a river which is not relevant for air pollution. In fact, most political entities cover a larger area consisting of parts with different background air pollution levels. It could be assumed that "average" not only refers to temporal, but also to spatial averaging, but it is not clear how this averaging could be done. Monitoring stations are not evenly distributed throughout an area. Therefore, some kind of weighting of the monitoring data is necessary before a "true" average can be calculated. Most likely, this does not refer to weighting based on population numbers because this approach is indicated in the second part of the indicator definition. Weighting should rather be performed on an acreage basis: A monitoring station that provides data representative for a larger area would be attached a stronger weight. There is some expertise necessary and knowledge of the local geographic and meteorological conditions to assess the area for which a single (background) monitoring station is deemed representative.

Alternatively, "areas" could be defined by geographical rather than by political conditions. Then, the "typical" air pollution for instance of a basin, an urban area or a valley could be calculated from all (background) stations operating in this area. This could be done by simply averaging the annual means from each monitor, maybe after excluding the most extreme monitors of the area. In another approach, one monitor could be selected as the most representative one for the area under a study based on the correlation of this monitor with the other ones over time. Data from nearby monitors could be used to fill data gaps.

How to calculate population-weighted exposure to selected air pollutants?

Already the averaging over a specific area poses some problems, as discussed before. Calculating a population-weighted exposure is even more challenging. In Annex 4 of the ECOEHIS report [6] more information with regard to population-weighting is provided:

"Based on measurements at city background monitoring sites or other assessment techniques, the pollution concentration is estimated for a certain area A. The number of people living in this area is required. If this number is not available (e.g., due to insufficient spatial resolution in the population data), the fraction of the urban built-up territory in area A is taken as the estimate of the fraction of the population in a city living in area A. The exposure of rural population may also be estimated using rural monitoring sites or modeling". The details of the computation are described in the same annex:

"For a given population, the exposure to an ambient air pollutant y is calculated as the annual mean concentration measured in the area relevant for that population.

For larger population at regional or national scales, the indicator can be presented as population distribution over a few categories of annual average pollutant levels.

For the purposes of health-relevant assessment at larger areas (big cities, regional, and national scales), the indicator is calculated using the population-weighting as:

$$Exp_y = SUM\ \{(P_i/P) \times C_{yi}\},$$

where:

C_{yi} = annual concentration of pollutant y in sub-population i,

$P = SUM\ (P_i)$ — total population in urban/rural area/region/country".

WHO [6] acknowledges that population-weighting requires "an expert input on a local level. A problem could be linking the population data with the air data, because information on the population covered by the monitoring (is) not always reported". In fact, this approach faces a similar problem as with the "area" approach: the population numbers are again usually provided by political entities, and do not reflect different air masses. Again, it would seem reasonable to select one monitoring station that best represents a given area. Especially in urban areas, there usually operate more than one "background" stations. Nevertheless, not all of them reflect the true background concentration equally well because of the many local sources in urban areas.

In this situation it seems prudent to select the "best" background station based on a comparison of the available monitors. The monitor displaying the highest temporal correlation with the other monitors is likely to be less influenced by specific local sources and, as such, would be deemed most representative of the regional background exposure.

The selection of the population is often based on pragmatic considerations. Although the population in the countryside around the urban centre is usually exposed to the same background concentrations of primary pollutants, a clear demarcation is needed and is often found with the political boarders of the city area.

Since today a high percentage of the population of a country lives in cities and a high percentage of the rest lives in the cities' vicinity exposed to similar background concentrations, an averaging of annual mean background levels of all cities (weighted by the population number of each city) is a reasonably accurate approach to an overall population weighted exposure of such whole country.

This approach is less accurate for secondary pollutants. In the European setting, ozone levels are often highest outside the urban pollution hot-spots because of their fast reduction upon contact with primary pollutants. Therefore, secondary pollutants are often higher in rural areas that are less populated. Neglecting these areas in the estimates might lead to biased results. It seems that of the two approaches proposed by WHO the spatial weighting is better suited for the secondary pollutants, while the population average is more appropriate for the primary pollution mixture.

Is the data reliable?

Even background monitoring stations from the same area report somewhat different concentrations. This shows that even "background" is not as straightforward as it might seem. Obviously, the results from source-specific stations are much more variable and are more strongly influenced by seemingly small local factors, but also "background" is never truly and totally background.

European laws state that limit values are valid practically "everywhere" where people might be exposed. Therefore, also stations in the neighborhood of relevant pollution sources should not report exceedances. This increases the political pressure to select more "appropriate" locations for these monitoring stations. The political pressure on background stations is less severe, but still present. But even without any political intervention and with correct implementation averaging can be misleading. A simple thought experiment serves as an example for that:

Imagine an area with three background and two kerbside stations: Annual mean levels (of PM10) at the 5 stations are listed in Table 1. The left column indicates the situation before a new main road (bypass) was built. This bypass was built to reduce traffic density in the town, but at the same time it led to an overall increase in motorized traffic in the whole area. The bypass was planned in an area that already was in somewhat poorer environmental conditions before the bypass was built. This is indicated by the highest concentration of PM10 among all background stations. Due to the construction of the new road, one former background station suddenly became a kerbside station where annual mean levels of PM10 increased from 24 to 31 $\mu g/m^3$. PM10 concentrations at all other stations remained unchanged. Nevertheless, the average concentration both of the background stations and the kerbside stations of the whole area declined.

Table 1. Annual mean levels of PM10 at 5 monitoring stations before and after the construction of a main road*

Station type	PM10 (μg/m³)	
	before	after
Background	20	20
	22	22
	24	–
Average	22	21
Kerbside	–	31
	39	39
	41	41
Average	40	37

* Concentrations only changed at one station that turned from a background to a kerbside one.

This little (extreme) example illustrates that input from local experts is needed in order to select meaningful data. "Air quality" as an indicator of (respiratory) health cannot be generated automatically from routine monitoring data. Creation and interpretation of the specific indicator needs informed consideration of the local conditions.

Single values, even mean values for one year, are of little relevance. Chance variations must be separated from long-term trends. This can only be achieved by looking at a longer time-series. This also requires some consistency in the measurement technology and in the monitors' location. Even then, the local environment near the monitor can undergo fundamental changes (like these exemplified by the thought experiment described above) invalidating any generalized conclusions.

Where is the data available?

European air pollution monitoring data is stored in AirBase operated by EEA [24]. AirBase allows selection of

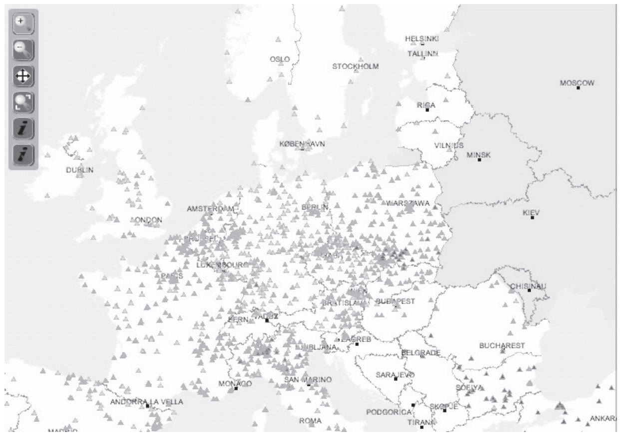

Fig. 1. Example view (screen shot) from AirBase: PM10 annual mean values (indicated by color codes) in 2008 from all background stations.

station type (e.g., a background station), pollutant, and kind of values (e.g., maximal or average value) (Figure 1). Figure 1 also shows clearly that monitoring stations are not evenly distributed. Some areas are subjected to a very dense coverage, while others are only sparsely monitored. Customarily, monitoring is higher in densely populated areas that are more relevant for population weighted-exposure.

CONCLUSIONS

Issues of validity and practicability of the IMCA indicator "3.3.1 Physical environment — air pollution exposure" were discussed. Problems were identified and possible solutions and compromises were suggested. Nevertheless, as for every complex indicator, the suggested approaches do not generate a mathematically exact figure, but only a rough estimate of health-related air quality.

In principle, data is available to calculate this IMCA indicator for any chosen area in Europe. The indicator is relevant and informative, but calculation and interpretation need input from local expert knowledge. This is also acknowledged by WHO on whose definition the IMCA indicator is based. But the detailed annex in the WHO publication might encourage expectations that such an indicator can be calculated after collecting data through a cursory internet search. It is certainly possible to collect necessary data and to calculate some figures, but these would be meaningless and eventually misleading when input from local experts is missing.

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