

<b>ATTRIBUTABLE CHANGE IN ATMOSPHERIC POLLUTANT CONCENTRATIONS</b>	
<b>GENERAL CONSIDERATIONS</b>	
<i>Issues</i>	Respiratory diseases
<i>Type of indicator</i>	Health outcome
<i>Rationale</i>	<p>Action to reduce children's exposure to ambient air pollution can take many forms. Common policy tools include air quality standards, emissions limits, environmental taxes, subsidies for clean technologies, land use planning, and controls on polluting fuels, products or processes. Which is the most appropriate is likely to vary from one place (and one time) to another, depending on the types and sources of pollution concerned, and the policy, socio-economic and environmental context. How effective any measure is will also depend on how well it is implemented and enforced. Indicators that simply describe the existence or scope of specific policy actions are, therefore, likely to give only a partial picture of the success or otherwise of intervention. More useful is to measure the effects of these measures. One way of doing this is to monitor changes in health outcome. Since many factors other than air pollution affect rates of respiratory illness, however, effects of intervention are often difficult to detect. They may also not become apparent for many years. A more sensitive and earlier indication of the effectiveness of policy intervention is thus given by monitoring the changes in ambient air pollution concentrations that can be attributed to policy intervention.</p>
<i>Issues in indicator design</i>	<p>A number of design issues have to be addressed in developing this indicator. Probably the most important is the choice of pollutant(s). Many different pollutants may affect respiratory health, including fine particulates, nitrogen oxides (NO<sub>x</sub>, NO<sub>2</sub>), sulphur dioxide (SO<sub>2</sub>) and ozone (O<sub>3</sub>). Which is the most important may vary, depending on the character of pollution sources (e.g. the level of industrialization, the road vehicle mix). Choosing only one pollutant may therefore be limiting – though in general terms fine particles are probably the most important and possibly give the best general marker. Where possible, however, it is better to design this indicator to measure changes in all the relevant pollutants. This has the particular advantage of ensuring that pollutant substitution (i.e. increases in one pollutant as a result of a reduction in emissions of another) does not lead to spurious improvements in the indicator. In this case, some form of pollutant index needs to be developed.</p> <p>A second problem concerns the availability of data. Monitoring networks for air pollutants are sparse in most countries, and are rarely fully representative of population exposures. Differences also occur, both from country to country and from one city or region to another, in the types of pollutants measured and the monitoring techniques used. This can make comparisons between different areas difficult. Ideally, the indicator should reflect the availability and quality of the monitored data.</p> <p>A third design question is the averaging period to be used. In most cases, the annual average concentration (calculated by averaging daily or hourly values across the whole year) is the most appropriate. Where strong seasonal or shorter term variations in pollution occur, however, it may be more meaningful to use different averaging periods, or to design the indicator in terms of the peak concentrations, or number of days exceeding a specified threshold.</p>

	<p>Finally, there is the issue of how to assess the attributable component of any change in air pollution concentrations. Not all the changes that occur can necessarily be attributed to intervention; in some cases, intervention may be having a bigger effect than immediately apparent, because – without it – air pollution would have got much worse. The real need is thus to compare changes in air pollutant concentrations after intervention with those that would have occurred without the intervention. This can be done in one of two ways: either by extrapolating pre-intervention trends to the period after intervention, and calculating the difference; or by comparing difference before and after intervention in ‘target’ areas where the policy is implemented, with matched ‘control’ areas where no intervention has occurred.</p>
<b>SPECIFICATION</b>	
<i>Definition</i>	Attributable annual change in average annual concentrations of PM <sub>10</sub> , SO <sub>2</sub> , NO <sub>2</sub> and O <sub>3</sub>
<i>Terms and concepts</i>	<b>Average annual pollutant concentration:</b> the mean concentration of the specified pollutant averaged over a year; adjustment may be necessary in computing the average to take account of gaps in the data, or discontinuities in monitoring.
<i>Data needs</i>	Daily (or hourly) concentrations of PM <sub>10</sub> , SO <sub>2</sub> , NO <sub>2</sub> and O <sub>3</sub> for the base year and current (or latest) year at a representative sample of monitoring stations.
<i>Data sources, availability and quality</i>	Data on air pollutant concentrations are usually obtainable from national or municipal monitoring networks. The range of pollutants measured, their exact definition, monitoring techniques and protocols and siting characteristics may all vary, however so, data may need to be screened to identify the most representative sites. Where possible, sites reflecting residential areas, or other areas in which children may be expected to receive significant exposures, should be selected. Information on the completeness of data capture (e.g. numbers of valid measurements) should also be collected and used to ensure that the data provide reliable estimates of the mean annual concentration.
<i>Level of spatial aggregation</i>	Municipality or region
<i>Averaging period</i>	Annual
<i>Computation</i>	<p>The indicator is computed as the additional change in air pollution (as a percentage) over and above that which would have occurred without intervention. This is achieved by finding the difference between the standardized pollutant concentrations after intervention and the projected concentrations based on a ‘no-intervention’ scenario. Four steps are involved in the process of indicator development.</p> <p>First, a standardized measure of the air pollutant concentration across all sites (<math>P_{mean,y}</math>) in each year should be computed for each pollutant. If appropriate, sites may be weighted in this process according to their geographical representativeness (e.g. to avoid over-influence from local clusters of sites), as follows:</p> $\sum [(W_{site_i} * P_{days_i} / N_{days}) / N_{site}]_y$ <p>where: <math>W_{site_i}</math> is the weight given to site (default = 1);  <math>P_{days_i}</math> is the daily concentration of the pollutant at site <math>i</math>;  <math>N_{days_i}</math> is the number of days for which monitoring is available at site <math>i</math>;  <math>N_{site}</math> is the number of sites</p> <p>The trend in annual standardized concentrations should then be computed for the pre-intervention period for each pollutant. This is best done using</p>

	<p>regression analysis methods (as available in most statistical packages and spreadsheets such as Excel). This provides a formula that can be used to predict concentrations in the post-intervention period. If no trend is observable (i.e. if the association with time is statistically not significant at the 95% level), then the arithmetic average from the pre-intervention period should be used. Alternatively, it may be possible to derive a trend 'by eye' by graphing the data as a scattergram and interpolating a trend line. Whichever method is used, attention should be paid to the nature of the relationship; in the event of a strongly non-linear trend, for example, an appropriate curvilinear trendline should be fitted, either by transforming the data or by using polynomial curve-fitting functions.</p> <p>Using the fitted trend, standardized concentrations for each pollutant for the period after policy intervention should then be calculated, by projection of the trendline. Values for each year since intervention should be computed.</p> <p>Finally, the monitored standardized concentrations are compared with the projected concentrations and the differences calculated. The indicator is expressed as the percentage difference, compared with the projected concentrations, as follows:</p> $100 * \frac{\sum [Pmean_{post} - Pmean_{proj}]_x}{\sum [Pmean_{proj}]_x} / Npoll$ <p>where: <math>Pmean_{proj}</math> is the projected mean annual standardized concentration of the pollutant based on extrapolation from the pre-intervention concentrations;  <math>Pmean_{post}</math> is the mean annual concentration of pollutant in the post-intervention year;  <math>x</math> is the pollutant;  <math>Npoll</math> is the number of pollutants.</p>																																																
Units of measurement	Percentage change																																																
Worked example	<p>Assume that the indicator is being computed on the basis of three pollutants (PM<sub>10</sub>, NO<sub>2</sub> and SO<sub>2</sub>). Assume that the annual concentrations of these in the five years before, and the five years after policy intervention were as shown in the Table below:</p> <table border="1" data-bbox="440 1203 1247 1696"> <thead> <tr> <th>Year</th> <th>SO2</th> <th>PM10</th> <th>NO2</th> </tr> </thead> <tbody> <tr><td>1994</td><td>35</td><td>50</td><td>60</td></tr> <tr><td>1995</td><td>28</td><td>53</td><td>62</td></tr> <tr><td>1996</td><td>32</td><td>48</td><td>70</td></tr> <tr><td>1997</td><td>30</td><td>52</td><td>66</td></tr> <tr><td>1998</td><td>25</td><td>49</td><td>70</td></tr> <tr><td>Intervention</td><td></td><td></td><td></td></tr> <tr><td>2000</td><td>24</td><td>44</td><td>70</td></tr> <tr><td>2001</td><td>20</td><td>47</td><td>63</td></tr> <tr><td>2002</td><td>16</td><td>38</td><td>60</td></tr> <tr><td>2003</td><td>25</td><td>45</td><td>64</td></tr> <tr><td>2004</td><td>18</td><td>35</td><td>58</td></tr> </tbody> </table> <p>When analysed using regression analysis, the relationships with year are as follows:  SO<sub>2</sub>: <math>Pmean_{proj} = 3622.8 - 1.8 * Year</math></p>	Year	SO2	PM10	NO2	1994	35	50	60	1995	28	53	62	1996	32	48	70	1997	30	52	66	1998	25	49	70	Intervention				2000	24	44	70	2001	20	47	63	2002	16	38	60	2003	25	45	64	2004	18	35	58
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	<p>PM<sub>10</sub>: <math>P_{mean_{proj}} = 50.4</math> (no statistical trend = average of <math>P_{mean_{pre}}</math>)</p> <p>NO<sub>2</sub>: <math>P_{mean_{proj}} = -4724.8 + 2.4 * Year</math></p> <p>When used to predict concentrations in the five post-intervention years these give the following estimates:</p> <table border="1" data-bbox="423 367 779 619"> <thead> <tr> <th>Year</th> <th>SO<sub>2</sub></th> <th>PM<sub>10</sub></th> <th>NO<sub>2</sub></th> </tr> </thead> <tbody> <tr> <td>2000</td> <td>24.6</td> <td>50.4</td> <td>72.8</td> </tr> <tr> <td>2001</td> <td>22.8</td> <td>50.4</td> <td>75.2</td> </tr> <tr> <td>2002</td> <td>21.0</td> <td>50.4</td> <td>77.6</td> </tr> <tr> <td>2003</td> <td>19.2</td> <td>50.4</td> <td>80.0</td> </tr> <tr> <td>2004</td> <td>17.4</td> <td>50.4</td> <td>82.4</td> </tr> </tbody> </table> <p>The actual values are then subtracted from these projections to give the differences, year by year:</p> <table border="1" data-bbox="423 703 779 955"> <thead> <tr> <th>Year</th> <th>SO<sub>2</sub></th> <th>PM<sub>10</sub></th> <th>NO<sub>2</sub></th> </tr> </thead> <tbody> <tr> <td>1999</td> <td>-0.6</td> <td>-6.4</td> <td>-2.8</td> </tr> <tr> <td>2000</td> <td>-2.8</td> <td>-3.4</td> <td>-12.2</td> </tr> <tr> <td>2001</td> <td>-5.0</td> <td>-12.4</td> <td>-17.6</td> </tr> <tr> <td>2002</td> <td>5.8</td> <td>-5.4</td> <td>-16.0</td> </tr> <tr> <td>2003</td> <td>0.6</td> <td>-15.4</td> <td>-24.4</td> </tr> </tbody> </table> <p>These differences are then summed for each pollutant, to give the total difference over the five years, and divided by the sum of the projected concentrations for the same five years. The resulting values are then summed and converted to a percentage. For SO<sub>2</sub>, PM<sub>10</sub> and NO<sub>2</sub>, respectively, this gives:</p> $100 * [(-2/105) + (-43/252) + (-73/388)] = -12.6\%$ <p>i.e. a 12.6% reduction in expected air pollution concentrations.</p>	Year	SO <sub>2</sub>	PM <sub>10</sub>	NO <sub>2</sub>	2000	24.6	50.4	72.8	2001	22.8	50.4	75.2	2002	21.0	50.4	77.6	2003	19.2	50.4	80.0	2004	17.4	50.4	82.4	Year	SO <sub>2</sub>	PM <sub>10</sub>	NO <sub>2</sub>	1999	-0.6	-6.4	-2.8	2000	-2.8	-3.4	-12.2	2001	-5.0	-12.4	-17.6	2002	5.8	-5.4	-16.0	2003	0.6	-15.4	-24.4
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<i>Interpretation</i>	<p>This indicator can be interpreted as a measure of the change in ambient air pollution as a result of policy and other interventions. A positive value for the indicator implies that these interventions are failing to improve air quality; a negative value implies that these interventions are succeeding in improving air quality.</p> <p>For several reasons, however, such interpretations need to be interpreted with care. One reason is that policy interventions are not the only factor that may influence changes in ambient air pollution levels: short term variations in economic activity and year to year changes in weather conditions may also be important. Use of a control zone to standardize the indicator, and averaging over several years, help to minimize these effects but residual may still exist. Changes in the distribution of monitoring stations within the network also need to be taken into account, as do changes in measurement methods and the issues of data quality.</p>																																																
<i>Variations and alternatives</i>	<p>Where policies have been introduced in only part of the area of interest, this indicator can be refined by comparing trends before and after intervention in the intervention area (i.e. where the policy has been applied) with trends before and after intervention in a matched control area (one with similar pollution characteristics but in which the policy has not been applied).</p> <p>The indicator can also be formulated in terms of average population of exposure. This has the advantage of providing a measure which is more directly targeted at the risks to children's health. It requires calculating a</p>																																																

	<p>population-weighted measure of exposure by intersecting the monitored data with data on population distribution. The problem with this approach is that there may be large uncertainties in the assumptions about, or models of, pollution patterns. These may more than outweigh the year-to-year variations in ambient pollution levels.</p> <p>Another alternative is to measure the indicator in terms of emissions rather than ambient concentrations. This has the advantage of providing an even earlier warning of the effects of intervention. However, it suffers from the disadvantage that many emissions, especially those from large combustion sources, may not contribute to local pollution or exposures, but instead be dispersed in the high atmosphere. It therefore tends to accentuate industrial areas rather than residential areas as the main sources of concern.</p> <p>In addition, the different pollutants can be weighted according to their relative toxicity.</p>
<i>Examples</i>	None known
<i>Useful references</i>	WHO Healthy Cities Air Management Information System (AMIS): <a href="http://www.who.int/environmental_information/Disburden/Articles/schwela.pdf">http://www.who.int/environmental_information/Disburden/Articles/schwela.pdf</a>