Disability Adjusted Life Years (DALYs) as an integrated IAQ metric of harm

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Thought experiment

Perfectly mixed pollutant. Two people. Different activities. Different ages.
Which person is harmed the most?

8 years old

80 years old
“…the committee chair [of ASHRAE Standard 62-1989 (ASHRAE, 1989)] noted that the minimum ventilation requirement of 7.5 L/s per person is based on body odour control (Janssen 1989). This minimum was increased to 10 L/s per person in many building types to account for contaminants other than human bioeffluents, such as building materials and furnishings, though no specific methodology for determining the increase is noted.”

Thinking about IAQ

Section 2

How do we advance?

**Measurements**

- **Perceived air quality**
  - Good as a rule of thumb but not as a population-scale generic metric. Has limitations: Can’t smell CO, for example.

- **Ratings systems**
  - Helpful to someone sensitive to specific contaminants, and/or home buyers.

- **Sub-indices**
  - Measure range of pollutants to gain a comprehensive picture. Combine all indices into a single measure. E.g. TVOC

- **Exposure limit values**
  - Ratios of maximum concentration to their respective ELV concentrations give a quick indication of risk, where a ratio \( \ll 1 \) might be acceptable but one approaching or exceeding unity may be problematic.

(As discussed by AIVC Workshop on IAQ Metrics in 2017, 3 articles, and IEA Annex 68)
### How do we advance?

<table>
<thead>
<tr>
<th>Pollutant</th>
<th>Indoor/occupational</th>
<th>Threshold By</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Value</td>
<td>Exposure Time</td>
</tr>
<tr>
<td>Particulate matter (PM$_{2.5}$)</td>
<td>25 µg/m$^3$</td>
<td>24 hrs</td>
</tr>
<tr>
<td></td>
<td>35 µg/m$^3$</td>
<td>24 hrs</td>
</tr>
<tr>
<td></td>
<td>65 µg/m$^3$</td>
<td>24 hrs</td>
</tr>
<tr>
<td></td>
<td>Guideline WHO</td>
<td>Standard US EPA</td>
</tr>
<tr>
<td></td>
<td>Standard ASHRAE</td>
<td></td>
</tr>
<tr>
<td>Sulphur Dioxide (SO$_2$)</td>
<td>0.012 ppm</td>
<td>1 year</td>
</tr>
<tr>
<td></td>
<td>0.030 ppm</td>
<td>1 year</td>
</tr>
<tr>
<td></td>
<td>Guideline WHO</td>
<td>Standard US EPA</td>
</tr>
<tr>
<td>Nitrogen Dioxide (NO$_2$)</td>
<td>0.1 ppm</td>
<td>1 hrs</td>
</tr>
<tr>
<td></td>
<td>1 ppm</td>
<td>15-min</td>
</tr>
<tr>
<td></td>
<td>Standard NIOSH/US EPA</td>
<td></td>
</tr>
<tr>
<td>Ozone (O$_3$)</td>
<td>200 µg/m$^3$</td>
<td>8 hrs</td>
</tr>
<tr>
<td></td>
<td>120 µg/m$^3$</td>
<td>8 hrs</td>
</tr>
<tr>
<td></td>
<td>Guideline WHO</td>
<td>ELV/Standard OSHA/US EPA</td>
</tr>
</tbody>
</table>

### Metrics: remarks

- Some standards regulating IAQ rely on non-health based metrics, including carbon dioxide concentrations in indoor spaces and, perception of IAQ.
- Although threshold-based values are useful, they provide insufficient information with which to make any but the most basic judgments (above or below a threshold).
- CO$_2$ concentrations, perception, and threshold-based metrics are considered helpful, however, in a cursory way.
- The well-being of individuals is address considering two parameters: mortality & morbidity. Any single summary measure of health and well-being needs to account for both these aspects, in this case, HALYs are a more robust metric over threshold values.
Health adjusted life years

Section 3

Health Adjusted Life Years (HALY)

HALY: population health summary measures typically used in estimates of the burden of disease. They measure the combined effects of mortality and morbidity in populations, allowing for comparisons across illnesses or interventions as well as between populations. **YLL:** years of life lost; **YLD:** years of life with disability.
**Quality Adjusted Life Years (QALY)**

<table>
<thead>
<tr>
<th>QALY</th>
<th>DALY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measures the quality of life in health gain</td>
<td>Measures health loss in the quality of life</td>
</tr>
<tr>
<td>Accounts for healthy years lived</td>
<td>Accounts for lost of healthy years</td>
</tr>
<tr>
<td>QA quality of life / DA morbidity</td>
<td>LY quantity of life</td>
</tr>
<tr>
<td>LY quantity of life</td>
<td>LY mortality</td>
</tr>
<tr>
<td>Not for specific health outcomes</td>
<td>Measure for specific health outcomes</td>
</tr>
<tr>
<td>Allows to measure the effectiveness of intervention by increasing quality of life</td>
<td>Allows to measure the effectiveness of intervention at reducing the disease burden due to a condition</td>
</tr>
<tr>
<td>Cost to health: Has been allocated to economic values at the national level (i.e. UK)</td>
<td>Cost to health: Has not been allocated to economic values at the national level</td>
</tr>
<tr>
<td>Uses life tables; Can account for discount rates; Can account for age-adjustment</td>
<td></td>
</tr>
<tr>
<td>Do not consider comorbidity (an individual experiencing multiple illnesses)</td>
<td></td>
</tr>
</tbody>
</table>

**Quality Adjusted Life Years (QALY)**

**QALY = length of life years × quality of life**

Provide a comprehensive measure of health in social well-being and physical health dimensions by combining both quantity and quality of life.
A decision can be taken on the relative success of different treatments (£20,000–£30,000 per QALY is suggested by NICE to be the limit for an intervention to be cost-effective).


Quality Adjusted Life Years (QALY): example

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Cost (£)</th>
<th>QALYs</th>
</tr>
</thead>
<tbody>
<tr>
<td>Treatment A gives 2 years of life with a utility value 0.5</td>
<td>1000</td>
<td>2 years × 0.5 = 1</td>
</tr>
<tr>
<td>Treatment B gives 4 years of life with a utility value 0.9</td>
<td>1500</td>
<td>4 years × 0.9 = 3.6</td>
</tr>
<tr>
<td>∆AB</td>
<td>500</td>
<td>2.6</td>
</tr>
<tr>
<td>Ratio</td>
<td>500 £</td>
<td>192 £ per QALY gained</td>
</tr>
</tbody>
</table>

Disability Adjusted Life Years (DALY)

DALY

Disability Adjusted Life Years is a measure of overall disease burden, expressed as the cumulative number of years lost due to ill-health, disability or early death

YLD = Years Lived with Disability

YLL = Years of Life Lost

One DALY = one lost year of healthy life
Disability Adjusted Life Years (DALY)

- **Birth**
- **Incidence of disease**
- **Actual death from disease**
- **Time of death**

Life years lived in full health
Life years lived with disability
Life years lost due to premature death

**YLL**
**YLDs**
**DALY**

**QALY**

Disability Adjusted Life Years (DALY): a simplified example

**Onset Diabetes:**

- **without any treatment**
  - **DALY = 31 years**

**Onset Diabetes:**

- **with treatment**
  - **DALY = 25.4 years**

**Adverted DALYs = 5.6 years**

A value can be proposed on the relative success of the hypothetical treatment (£ per aDALY; limit for an intervention to be cost-effective)
Remarks on QALYs & DALYs

- DALY
  - Is still a methodological and thought experiment.
  - Used as the preferred metric to estimate health impacts in the Global Burden of Disease studies.

- QALY
  - UK, Ireland and Thailand have explicit Cost-Effective Thresholds per QALY.
  - Sweden, Portugal, Poland, Norway, the Netherlands, Hungary, South Korea, Japan, Hungary, the Czech Republic, Canada, Brazil, Belgium and Australia use not-official Cost-Effective Thresholds per QALY.
  - A general cost-effectiveness (C/E) threshold is stated in the literature as 100,000$ USD per QALY.
  - WHO 1 – 3 GDP per capita.

(Cameron et al., 2018 - doi.org/10.1080/16549716.2018.1447828)

DALY impact assessment of indoor air quality

- Lawrence Berkeley Laboratories and the AIVC (see AIVC TN68).
- Reviewed 77 studies reporting on indoor air pollutant concentrations in the U.S. and other countries with similar lifestyles, such as the UK.
- Considered 267 chemical air pollutants in total.
- Calculated the annual health impact of pollutants considering the total intake in houses in addition to intake in other environments.
- The in-house inhalation of air with the mean exposure from the studies was considered relative to a theoretical case of no inhalation.
- The inhalation is weighted to the U.S. population and so there would be differences for other populations, but there are likely to be some similarities in other countries, such as the UK, that have similar lifestyles.
Disability Adjusted Life Years (DALY): An impact assessment approach for indoor air quality

Commonly found indoor air pollutants.

Note the magnitude of confidence intervals

~500 DALY  ~10 DALY  ~5 DALY

Summary

Section 4
Perfectly mixed pollutant. Two people. Different activities. Different ages.

**Which person is harmed the most?**

8 years old

80 years old

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In a household. Perfectly mixed pollutant: PM\textsubscript{2.5}. 1 year of exposure.

Onset of disease: Asthma for 1 year; then death.
Life expectancy 80 and 82.5 years, male and female.

\[
D\text{ALY}_{PM_{2.5}} = (1 \times 0.2) + (80 - 9) \quad D\text{ALY}_{PM_{2.5}} = (1 \times 0.2) + (82.5 - 81)
\]

\[
D\text{ALY}_{PM_{2.5}} = 71.2 \text{ years} \quad D\text{ALY}_{PM_{2.5}} = 4.4 \text{ years}
\]

8 years old (male) 80 years old (female)
What next for health based metrics?

- Annex 86 and ASHRAE 62 are beginning the transition but...
- They’re still some way off being useful and accepted as best practice
- They must be robust to avoid litigation
- They must be combined with appropriate diagnostics
- They must not be a barrier to innovation
- They must also consider energy
- How/can/should we consider mental health?
- Sanctions for non-compliance must be defined and methods of identification derived
- It will require multidisciplinary study and collaboration
- We must involve stakeholders to ensure their support

End

Disability Adjusted Life Years (DALYs) as an integrated IAQ metric of harm