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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

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The olfactory paradigm

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The Olfactory Paradigm

"…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."

Persily, A. 2006. What we Think we Know about Ventilation. *International Journal of Ventilation* 5(3): 275-290.

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Thinking about IAQ

Section 2

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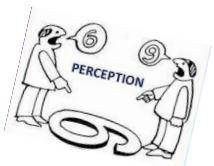
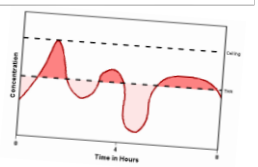
How do we advance?

(As discussed by AIVC Workshop on IAQ Metrics in 2017, 3 articles, and IEA Annex 68)

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 ≪1 might be acceptable but one approaching or exceeding unity may be problematic.





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How do we advance?

Pollutant		Indoor/occupational		Threshold	By
		Value	Exposure Time		
Criteria pollutants	Particulate matter ($PM_{2.5}$)	25 µg/m³	24 hrs	Guideline	WHO
		35 µg/m³	24 hrs	Standard	US EPA
		65 µg/m³	24 hrs	Standard	ASHRAE
	Sulphur Dioxide (SO_2)	0.012 ppm	1 year	Guideline	WHO
		0.030 ppm	1 year	Standard	US EPA
	Nitrogen Dioxide (NO_2)	0.1 ppm	1 hrs	Guideline	WHO
		1 ppm	15-min	Standard	NIOSH/US EPA
	Ozone (O_3)	200 µg/m³	8 hrs	ELV/Standard	OSHA/US EPA
		120µg/m³	8 hrs	Guideline	WHO

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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.

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Health adjusted life years

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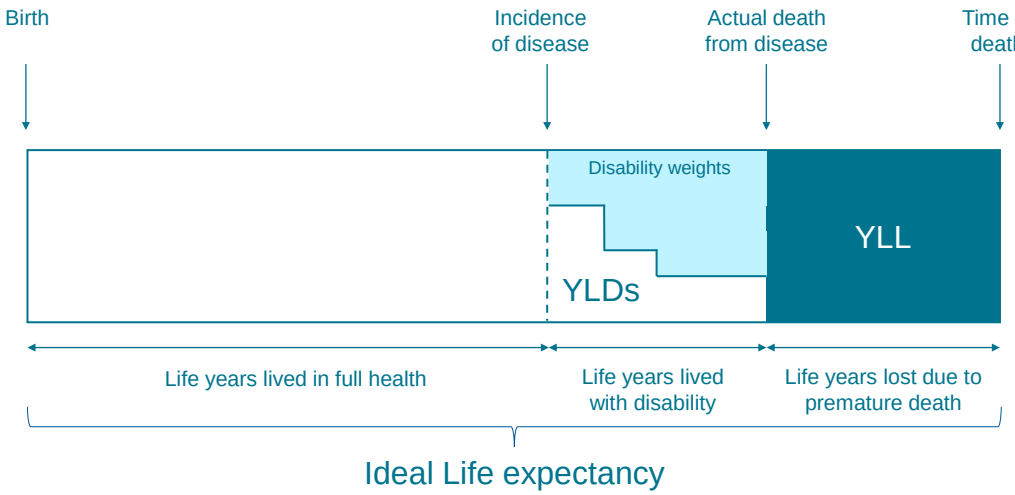
Health Adjusted Life Years (HALY)



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.

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Health Adjusted Life Years (HALY)

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

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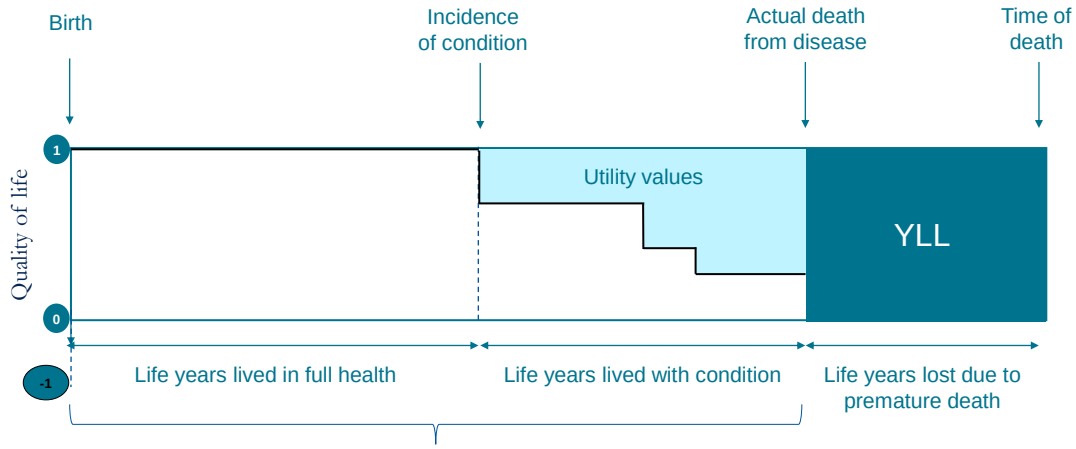
Quality Adjusted Life Years (QALY)



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.

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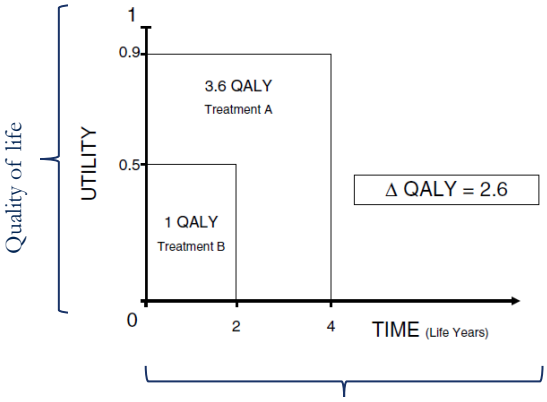
Quality Adjusted Life Years (QALY): example

Treatment	Cost (£)	QALYs
Treatment A gives 2 years of life with a utility value 0.5	1000	2 years×0.5 = 1
Treatment B gives 4 years of life with a utility value 0.9	1500	4 years×0.9= 3.6
ΔAB	500	2.6
Ratio	$\frac{500\ £}{2.6\ QALYs} = 192\ £\ per\ QALY\ gained$	

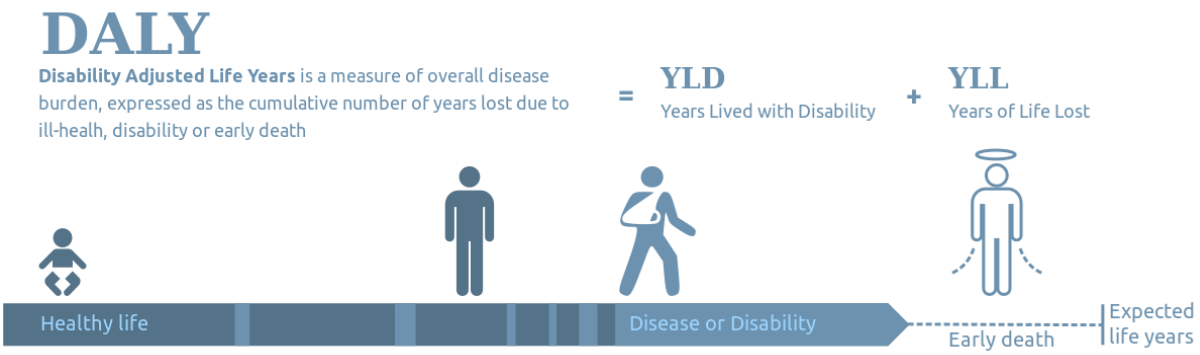


- A decision can be taken on the relative success of different treatments (£20,000-£30,000 per QALY is suggested by NICE to be the limit for an intervention to be cost-effective)

https://en.wikipedia.org/wiki/National_Institute_for_Health_and_Care_Excellence

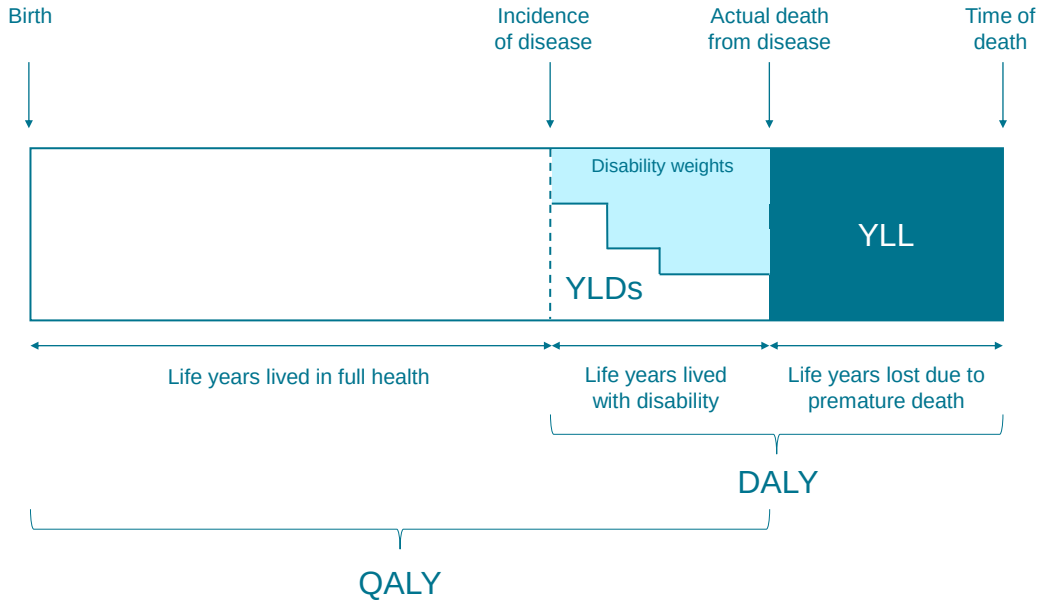
Pietro & Sacristan (2003). doi.org/10.1186/1477-7525-1-80

Disability Adjusted Life Years (DALY)



One DALY = one lost year of healthy life

Disability Adjusted Life Years (DALY)



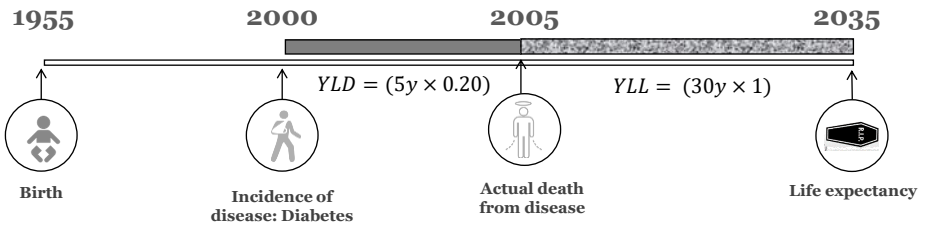
Disability Adjusted Life Years (DALY): a simplified example

Onset Diabetes:

with out any

treatment

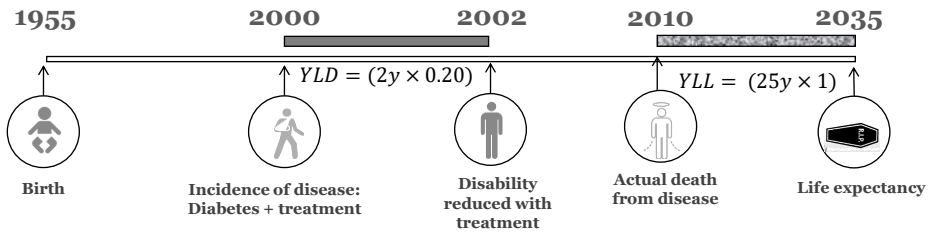
$DALY = 31\ years$



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.

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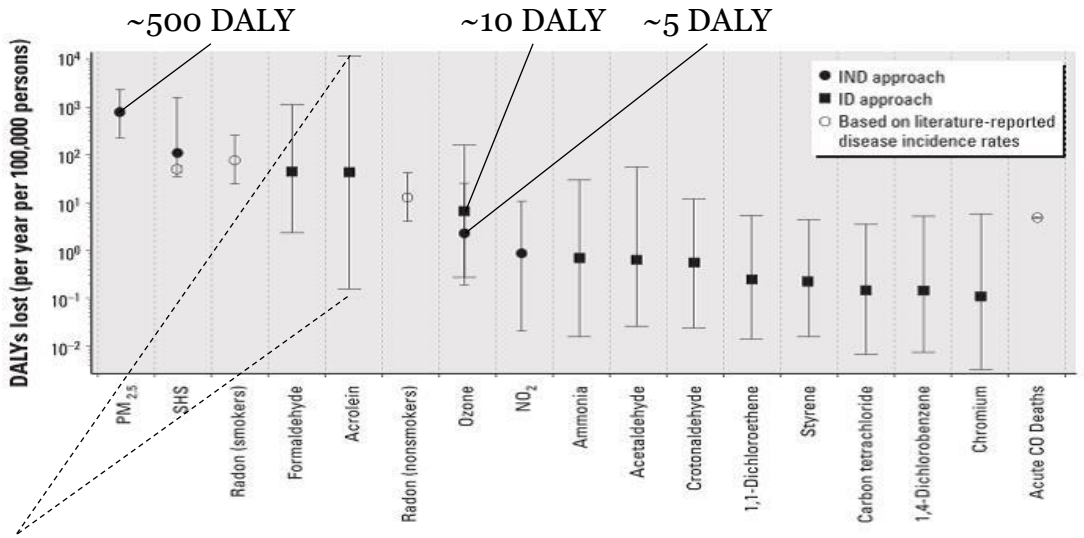
Disability Adjusted Life Years (DALY): An impact assessment approach for indoor air quality



Note the magnitude of confidence intervals

Commonly found indoor air pollutants.

Logue et al. (2012). doi.org/10.1289/ehp.1104035

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Summary

Section 4

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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

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Thought experiment

In a household.
Perfectly mixed pollutant: $PM_{2.5}$.
1 year of exposure.

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

$DALY_{PM_{2.5}} = (1 \times 0.2) + (80 - 9)$

$DALY_{PM_{2.5}} = 71.2\ years$

$DALY_{PM_{2.5}} = (1 \times 0.2) + (82.5 - 81)$

$DALY_{PM_{2.5}} = 4.4\ years$

8 years old (male)

80 years old (female)

Friday, April 9, 2021

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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