Health, environmental, and life cycle impact assessment

Impact Pathways

Anna Lia S. Tromer Dragsdahl
PhD in Absolute Sustainability Assessment of Novel Entities

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Learning Objectives

At the end of this teaching session, you will be able to:

xplain why it is necessary to do impact modelling

utline the concept of impact pathways using mples for chemicals in consumer products

valuate chemical alternatives with regards to de-offs in life cycle impacts.

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What we want

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What we don't want

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Recent News

Deadly floods, storms and heatwaves: Europe suffered the 'serious impacts' of climate change in 2024

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Alarm bells ring over dead zones in Danish waters

Excessive nitrogen from farming is causing Denmark's oceans to lose important marine animal and plant life. Researchers and organizations are calling for swift political action.

MIE OLSEN / October 12, 2023

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Toxic 'forever' chemicals found in excessive levels in global groundwater, study says

By Sandee LaMotte, CNN

6 minute read · Published 11:00 AM EDT, Mon April 8, 2024

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Deadly and growing impact of air pollution laid bare in new UNICEF-backed report

© UNICEF/Ali Junaid | In Karachi, Pakistan, a woman burns trash to cook food causing air pollution.

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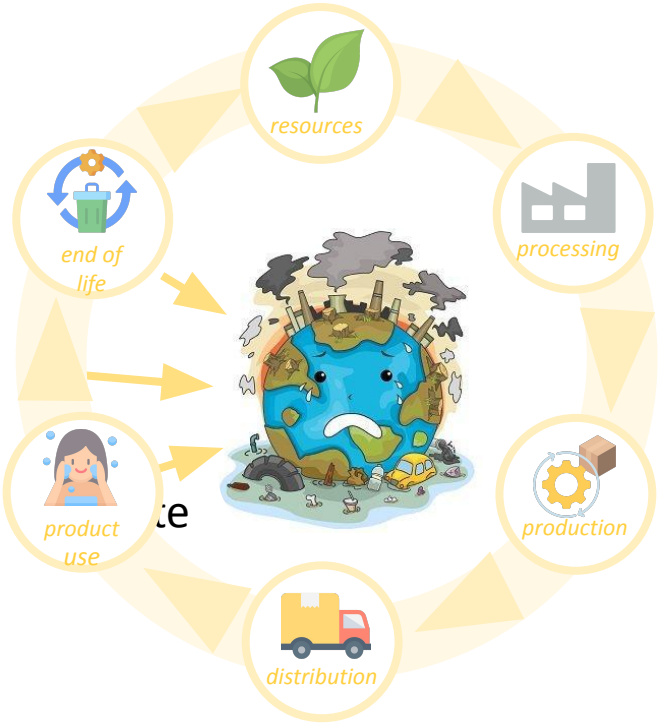
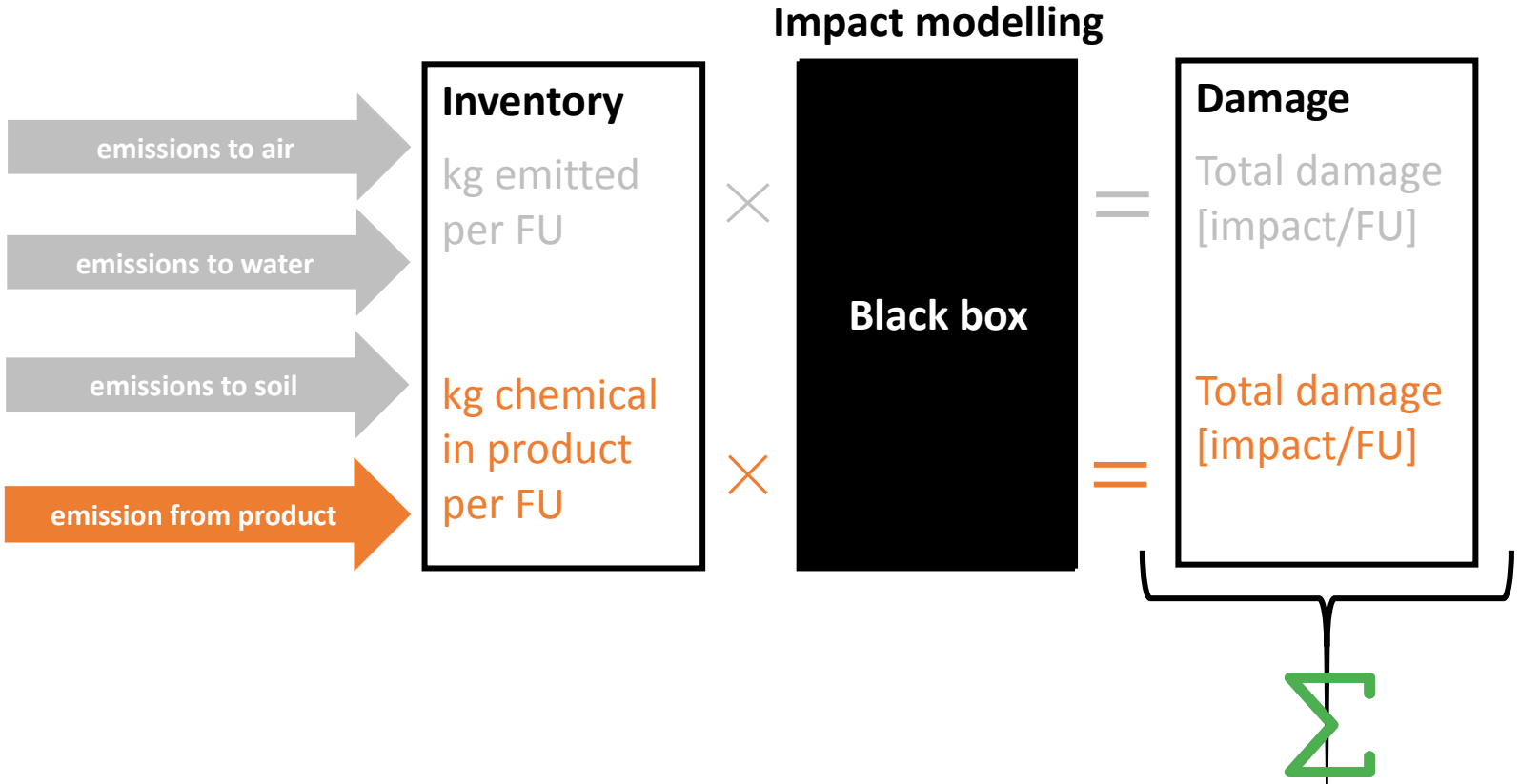
Assessing Life Cycle Impacts





FU = Functional unit

Use of 0.79 g deodorant per day applied on the skin of an adult user

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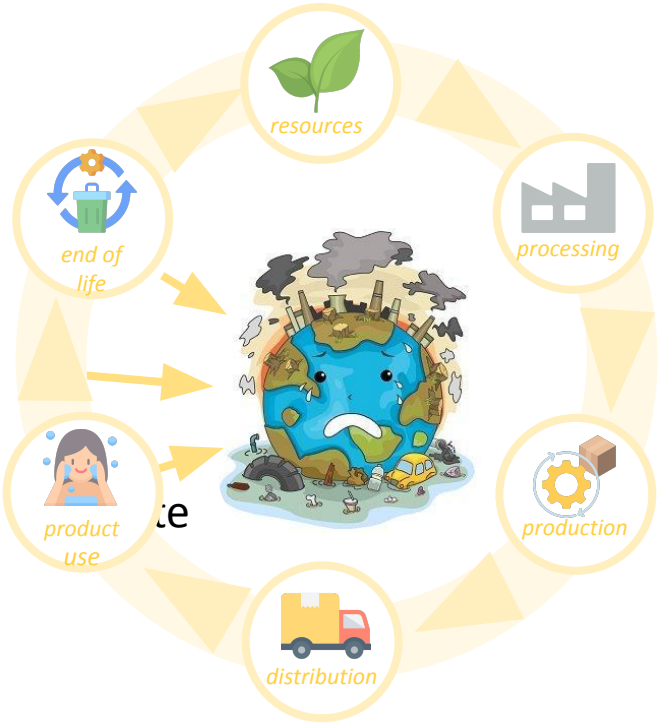
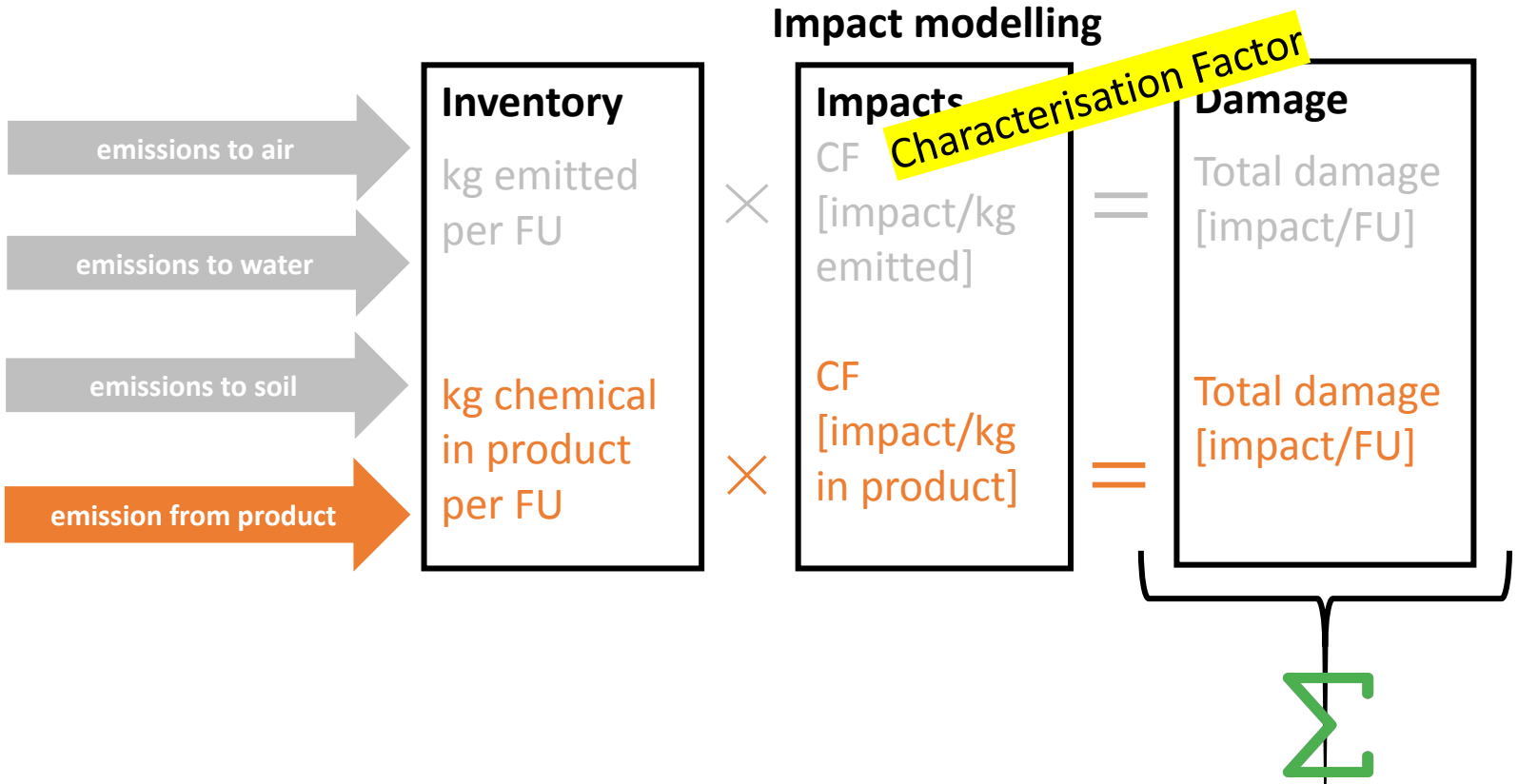
Assessing Life Cycle Impacts





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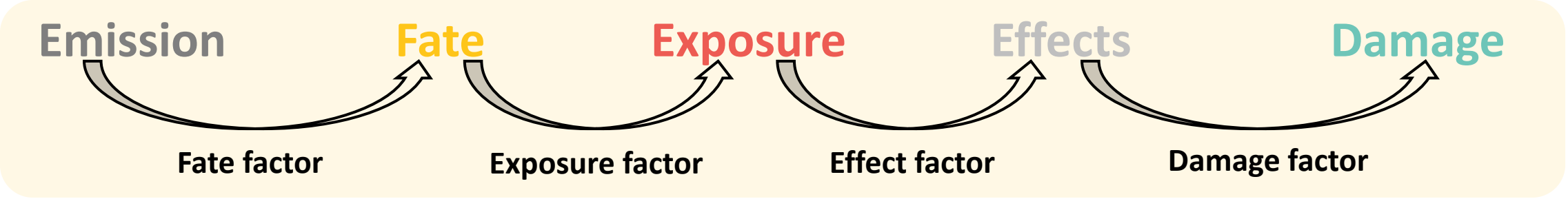
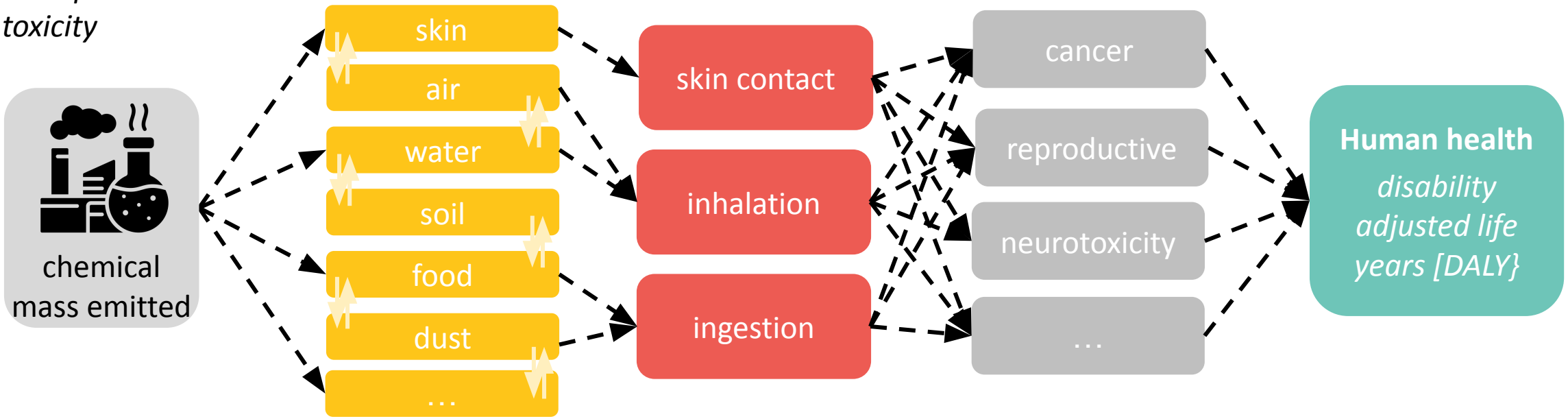


Example: Human toxicity



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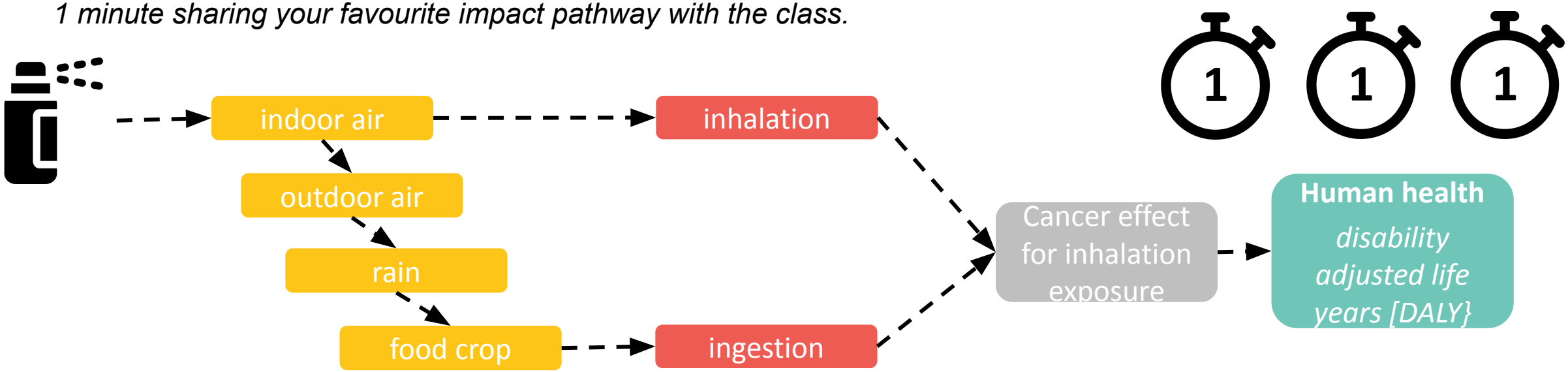
Impact pathways for chemicals in consumer products

Brainstorm potential direct and indirect impact pathways how a chemical in a cosmetic product can harm humans and ecosystems

Think Pair Share. *Spend 1 minute thinking individually, 1 minute discussing ideas with a partner, and 1 minute sharing your favourite impact pathway with the class.*



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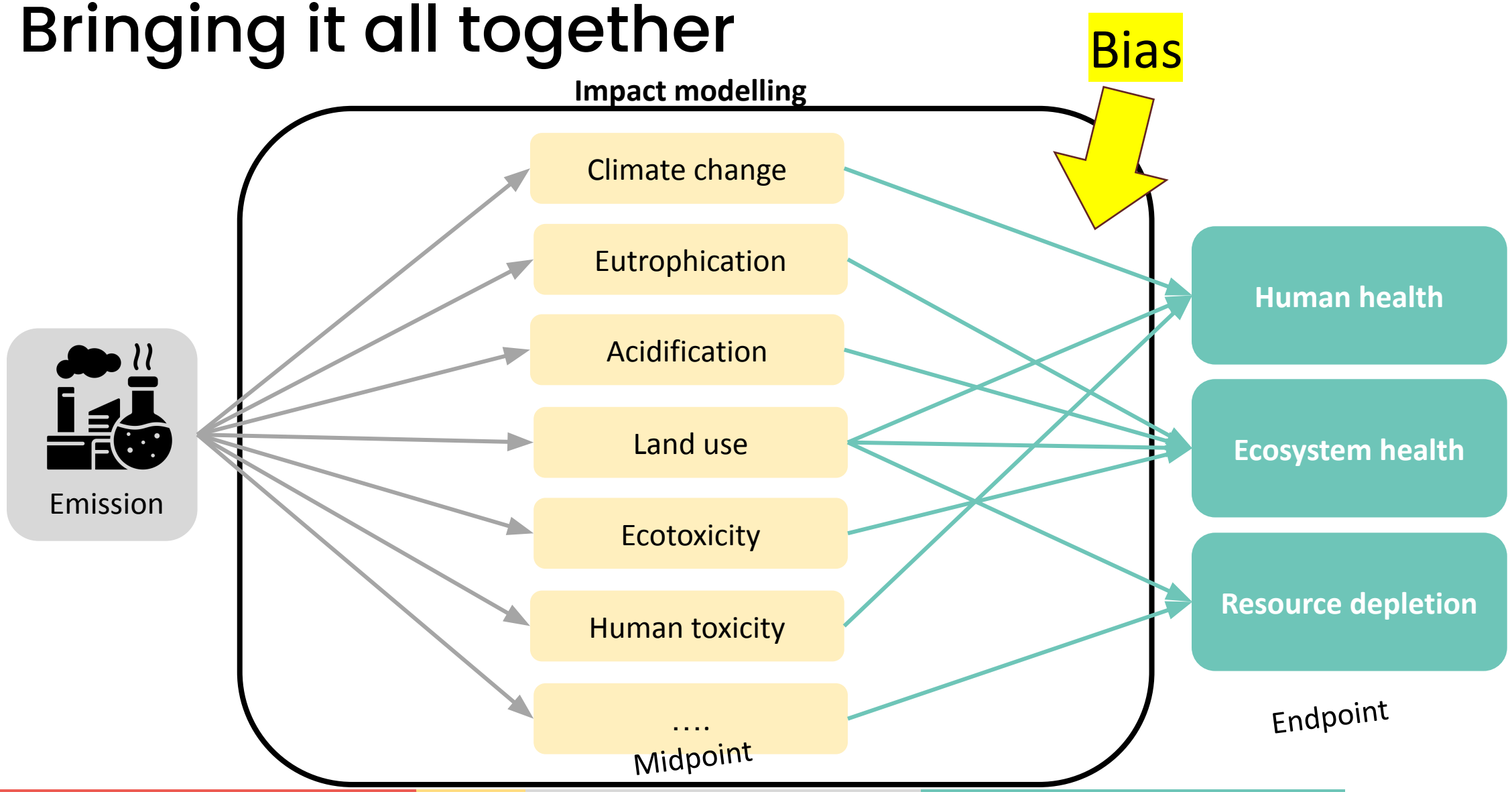
Bringing it all together



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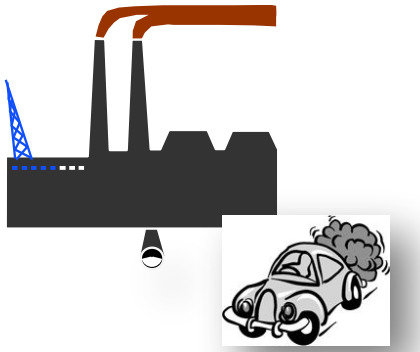
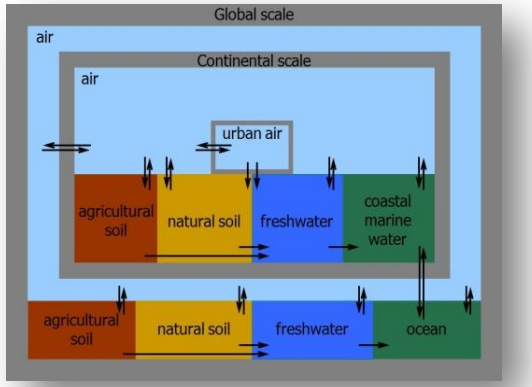
Impact Pathway: Human toxicity impacts





Emission

Emission flow
[$kg_{emitted}$/d]

Fate

Mass in environment
[$kg_{in\ compartment}$]

Fate factor, FF

[$kg_{in\ compartment}$ per $kg_{emitted}$/d]

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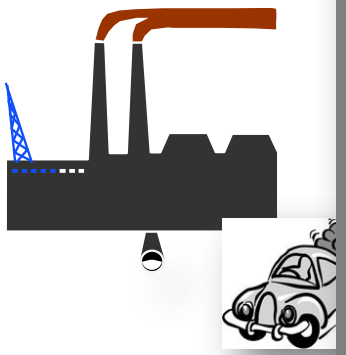
Impact Pathway: Human toxicity impacts

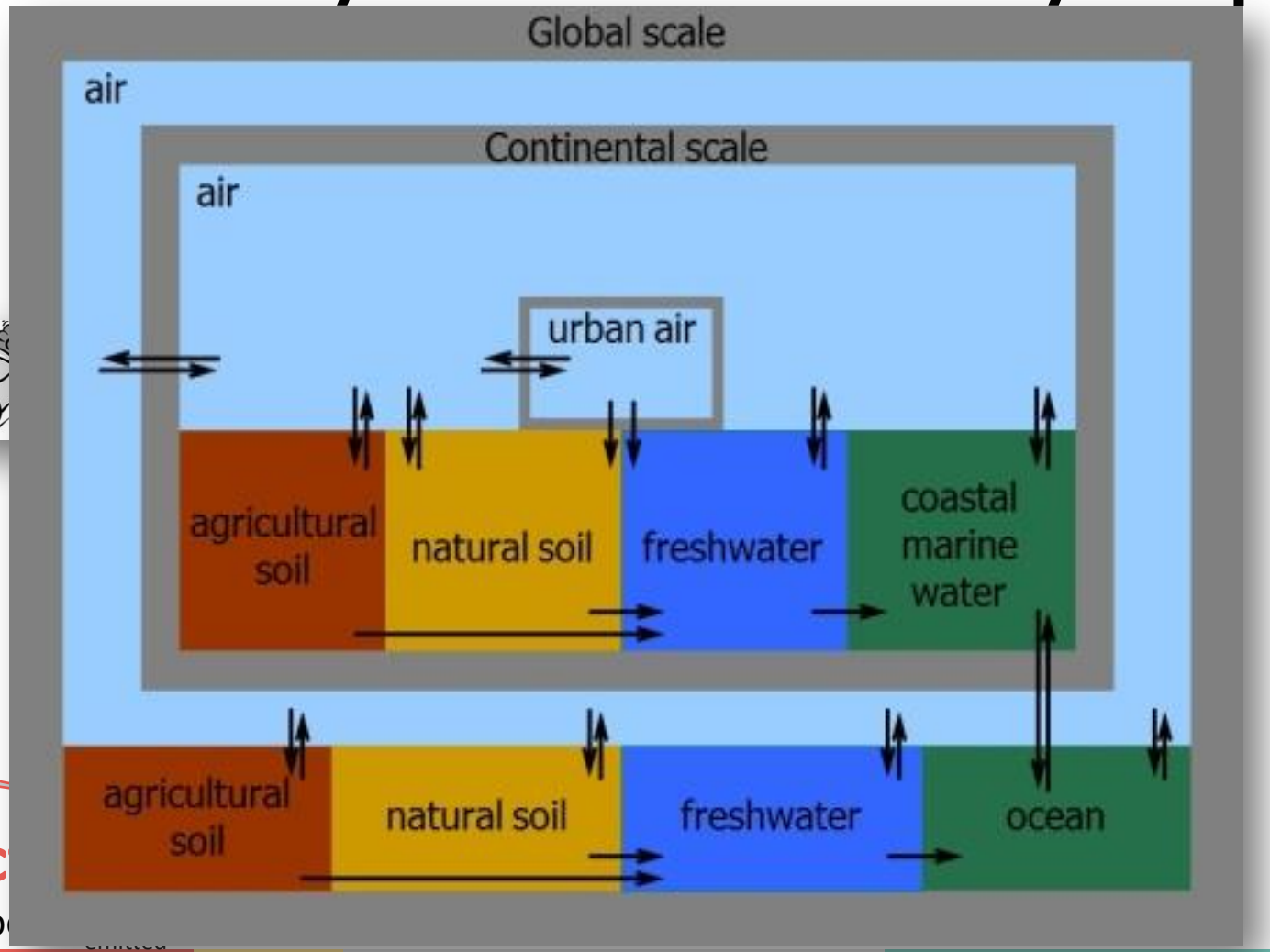


Emission

Emission flow
[$kg_{emitted}$/d]

Fate fac

[$kg_{in\ compartment}$ p



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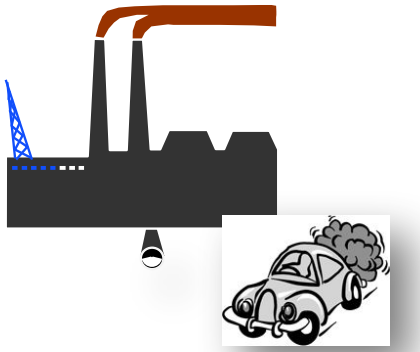
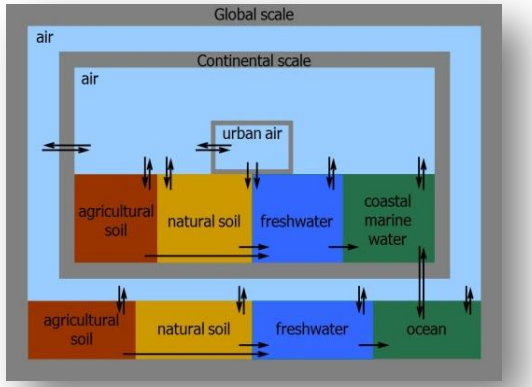
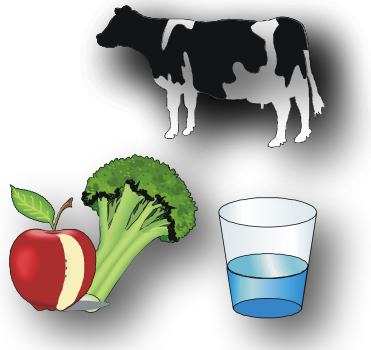
Impact Pathway: Human toxicity impacts







Emission

Emission flow
[$kg_{emitted}$/d]

Fate

Mass in environment
[$kg_{in\ compartment}$]

Exposure

Human intake
[kg_{intake}/d]

Effects

Potential effects
[disease cases/d]

Fate factor, FF

[$kg_{in\ compartment}$ per $kg_{emitted}$/d]

Exposure factor, XF

[kg_{intake}/d per $kg_{in\ compartment}$]

Effect factor, EF

[disease cases/d per kg_{intake}/d]

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A safer and more sustainable alternative

	Formaldehyde	Phenoxyethanol
Consumer risk		
Cancer risk [-]	4.44E-04	0.00E+00
Non-cancer hazard quotient (HQ) [-]	0.132	0.053
Life cycle impacts [DALY/d]		
Global warming	2.91E-6	7.80E-6
Stratospheric ozone depletion	2.27E-10	1.10E-9
Water consumption	3.86E-8	2.29E-7
Particulate matter formation	2.11E-6	7.43E-6
Ionizing radiation	7.17E-10	4.16E-9

acceptable risks

cancer risk < $1e^{-6}$

non-cancer HQ < 1

Select the safer and more sustainable chemical if possible.

Answer the poll on vevox.app

144-897-253

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Can you select a safer and more sustainable option between the two alternatives?

Yes, formaldehyde has lower risks and lower life cycle impact

?%

No, but phenoxyethanol has lower risks, which is commonly weighed higher than life cycle impacts

?%

No, they have the same risks and life cycle impact

?%

No, they cannot be compared because they perform differently across impact categories

?%

Answer options

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RESULTS SLIDE

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We have a winner!

	Formaldehyde	Phenoxyethanol
Consumer risk		
Cancer risk [-]	4.44E-04	0.00E+00
Non-cancer hazard quotient (HQ) [-]	0.132	0.053
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Questions?

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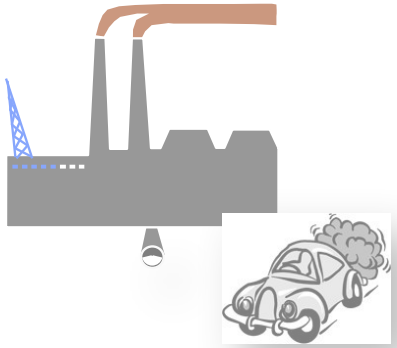
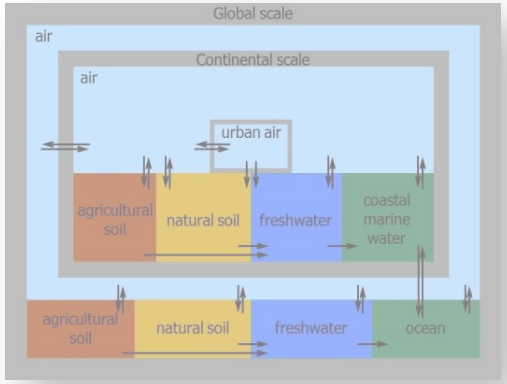
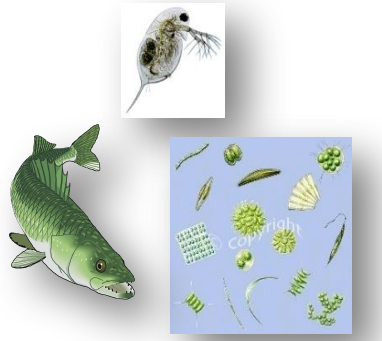
Back-up: Impact pathway: Ecotoxicity impacts







Emission

Emission flow [$kg_{emitted}$/d]

Fate

Mass in environment [$kg_{in\ compartment}$]

Exposure

Dissolved mass fraction [$kg_{bioavailable}$]

Effects

Potential effects [PAF x m^3]

PAF = potentially affected fraction

Fate factor, FF

[$kg_{in\ compartment}$ per $kg_{emitted}$/d]

Exposure factor, XF

[$kg_{bioavailable}$ per $kg_{in\ compartment}$]

Effect factor, EF

[PAF x m^3 per $kg_{bioavailable}$]

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Back-up: From affected species to biodiversity loss

- Area of Protection relevant for ecotoxicity: Ecosystem Quality
- typically expressed as a loss of biodiversity, represented by change in species richness of the ecosystem
- translation of the Potentially Affected fraction of species (PAF) into the potentially disappeared fraction of species (PDF) by a factor of 0.5 as an assumption that half of the affected species dies:

$$\mathbf{SF_{eco} = 0.5\ PDF/PAF}$$

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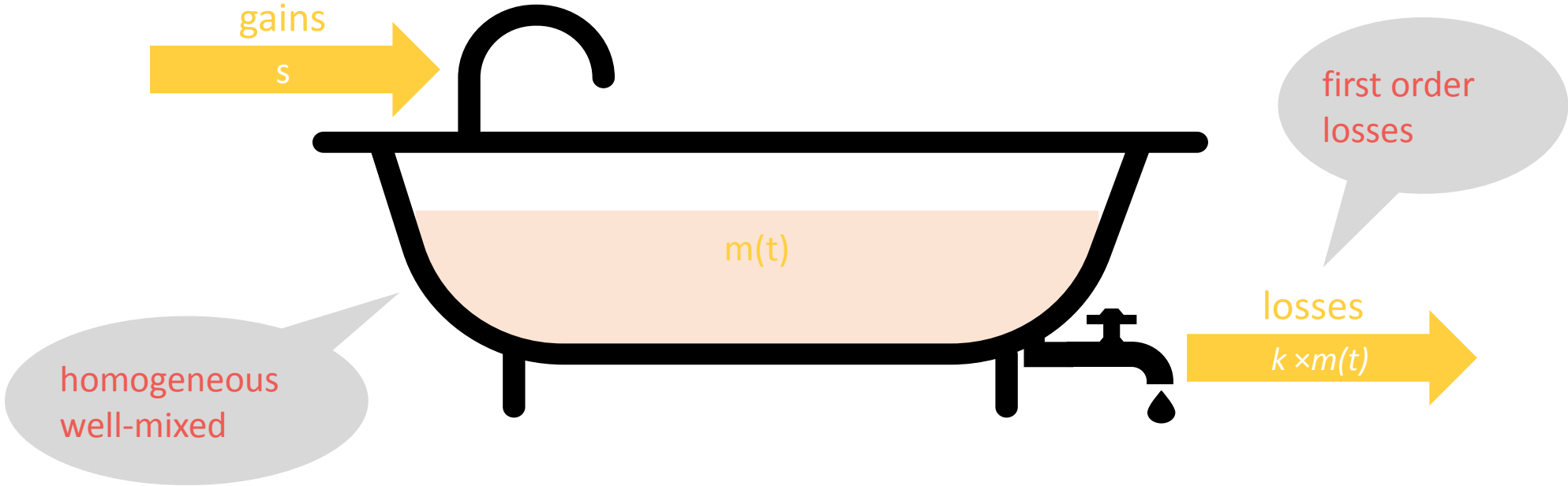
Back-up: FATE factor: How much goes where? Let's mass balance!

Mass Balance for a single compartment



$$\frac{dm(t)}{dt} = \sum mass\ flows = s - k \cdot m(t)$$

Emission source rate: s [kg/d]

Mass in compartment: m [kg]

Removal rate coefficient: k [1/d]
= mass eliminated per day

Rate constant: $k_{tot} = k_1 + k_2 + k_3 + \ldots$

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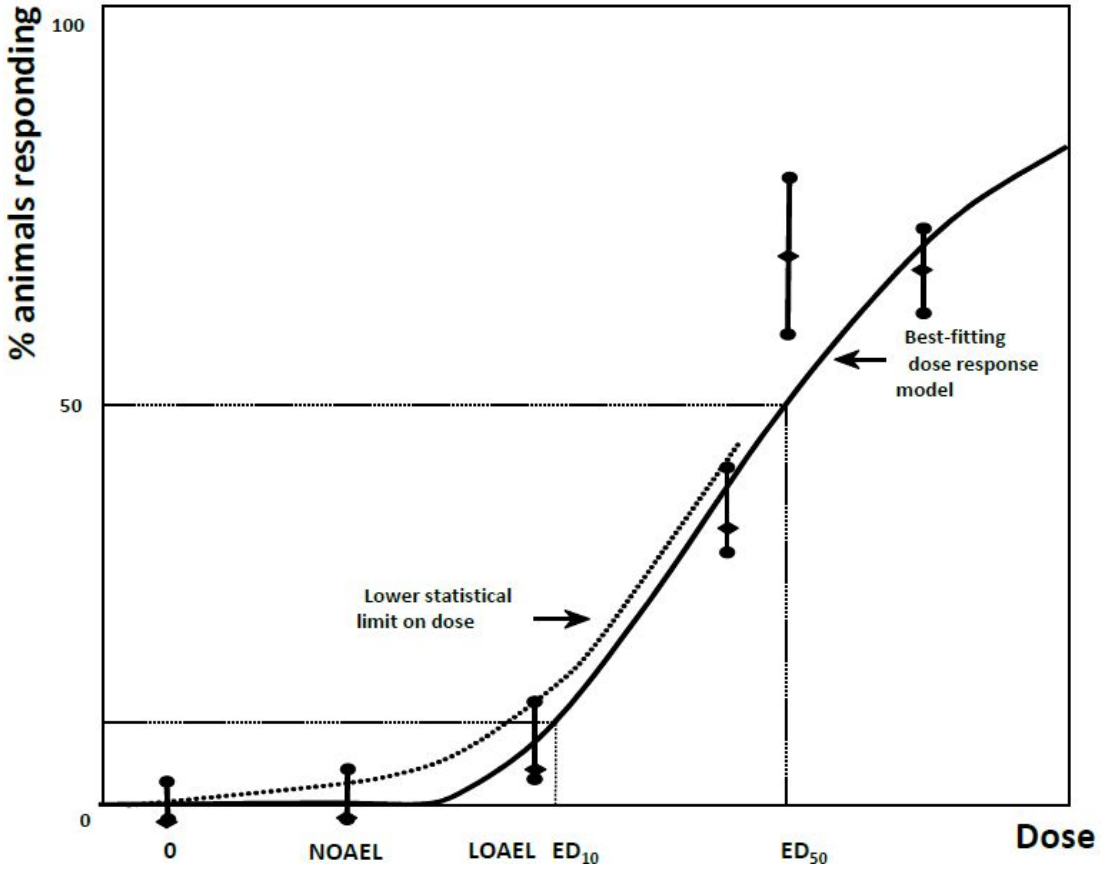
Back-up: EFFECT: Dose response models & metrics



Background | NOAEL | ED_{10} 10% over background | ED_{50} or TD_{50} 50% over background

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What is “exposure” ?

Defining Exposure:

«Contact between stressors and receptors, and the associated sources, pathways and processes.» (Fantke et al. 2020)

- Contact with air, water, soil, food, or consumer products containing potentially harmful substances
- Contact takes place at an exposure surface (mouth, skin, eyes) over an exposure period.

Exposure Assessment

The process of estimating or measuring the magnitude, frequency and duration of exposure to an agent, along with the number and characteristics of the population exposed. Ideally, it describes the sources, pathways, routes, and the uncertainties in the assessment.

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Human Exposure Factors (XF) – *direct exposure*

Direct exposure: $\boldsymbol{XF_{k,i}^{direct}}$ [kg_{intake}/d per $kg_{in\ compartment}$]

The exposure factor for direct exposure is the rate coefficient for transfer of contaminants in compartment *k*, to humans through drinking water or breathing air. Thus, it is equivalent to the rate of consumption of the medium by humans:

$$XF_{\text{air,inhalation}}^{\text{direct}} = \frac{IR_{\text{inhalation}}\ [\text{m}^3/\text{d}] \times n_{\text{persons}}}{V_{\text{air}}\ [\text{m}^3]}$$

$$XF_{\text{water,ingestion}}^{\text{direct}} = \frac{IR_{\text{water ingestion}}\ [\text{m}^3/\text{d}] \times n_{\text{persons}}}{V_{\text{water}}\ [\text{m}^3]}$$

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