Impact category: Climate Change

TECHNISCHE UNIVERSITÄT DARMSTADT

Term	Example
Impact category	Climate Change
LCI results	Amount of a greenhouse gas per functional unit
Characterization model	Baseline model of 100 years of the Intergovernmental Panel on Climate Change
Category indicator	Infrared radiative forcing (W/m2)
Characterization factor	Global warming potential (GWP100) for each greenhouse gas (kg CO_2-equivalents/kg gas)
Category indicator result	Kilograms of CO_2-equivalents per functional unit
Category endpoints	Coral reefs, forests, crops
Environmental relevance	Infrared radiative forcing is a proxy for potential effects on the climate, depending on the integrated atmospheric heat adsorption caused by emissions and the distribution over time of the heat absorption.

Impact category: acidification

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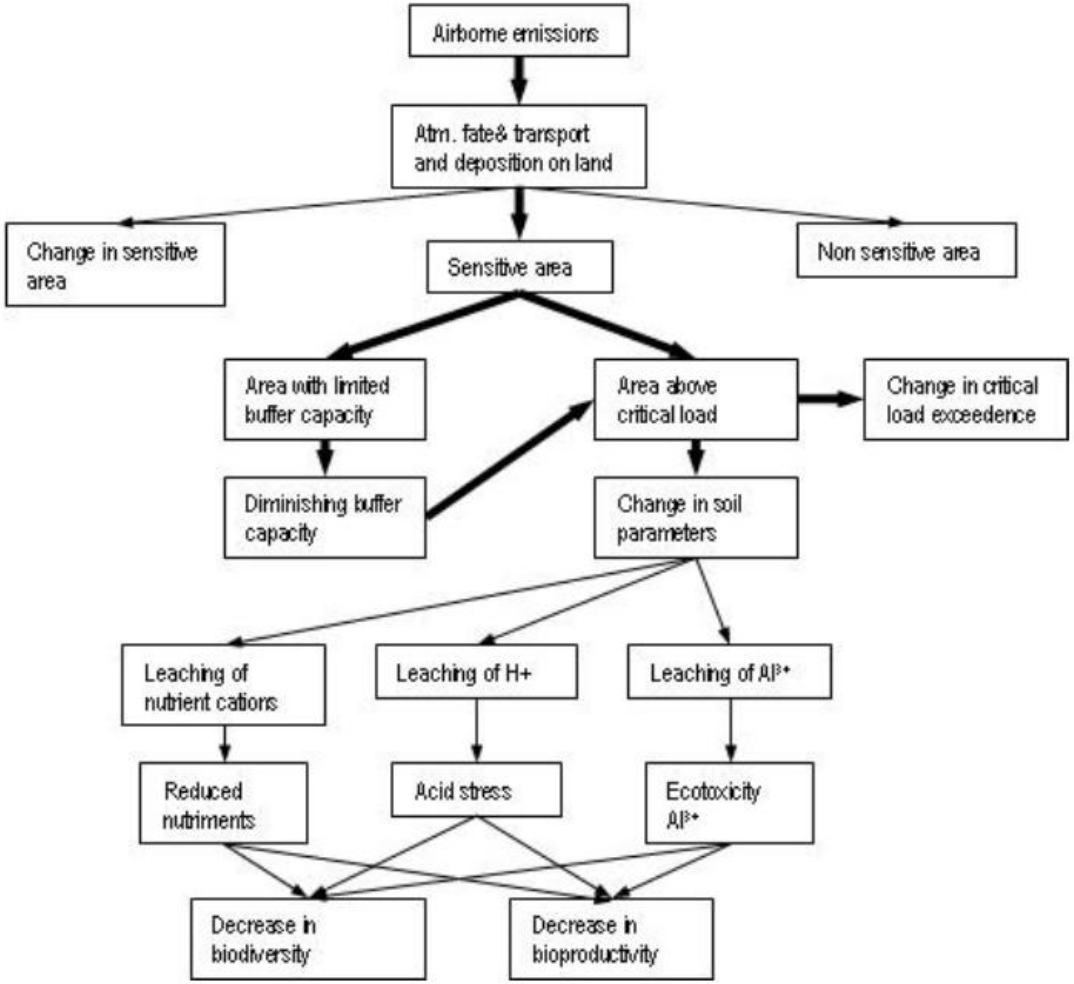
Definition	
Impact indicator	
Characterization model	
Characterization factor	
Unit	
Categories of damage (Endpoint)	

Impact category: acidification

TECHNISCHE UNIVERSITÄT DARMSTADT

Definition	Assessment of the acidifying effects of anthropogenic emissions (NOx, SO2, NH3)
Impact indicator	Increasing acidity in water and soil systems through the hydrogen ion concentration
Characterization model	■ Consideration of the aeolian transport of substances, the transfer to the recipient (Environment), emitted mole of H + ions per kg of pollutants deposited and the change of the ecosystem at varying cation capacity ■ Models: IMPACT 2002+, CML 2001, ReCiPe 2008
Characterization factor	■ Acidification Potential ■ kg SO2-equivalent / kg emissions
Unit	kg SO2-equivalent
Categories of damage (Endpoint)	Damage to the ecosystem quality →decrease in biodiversity

Impact category: acidification



Quelle: European Commission, 2010

Impact categorie: Ozone depletion

TECHNISCHE UNIVERSITÄT DARMSTADT

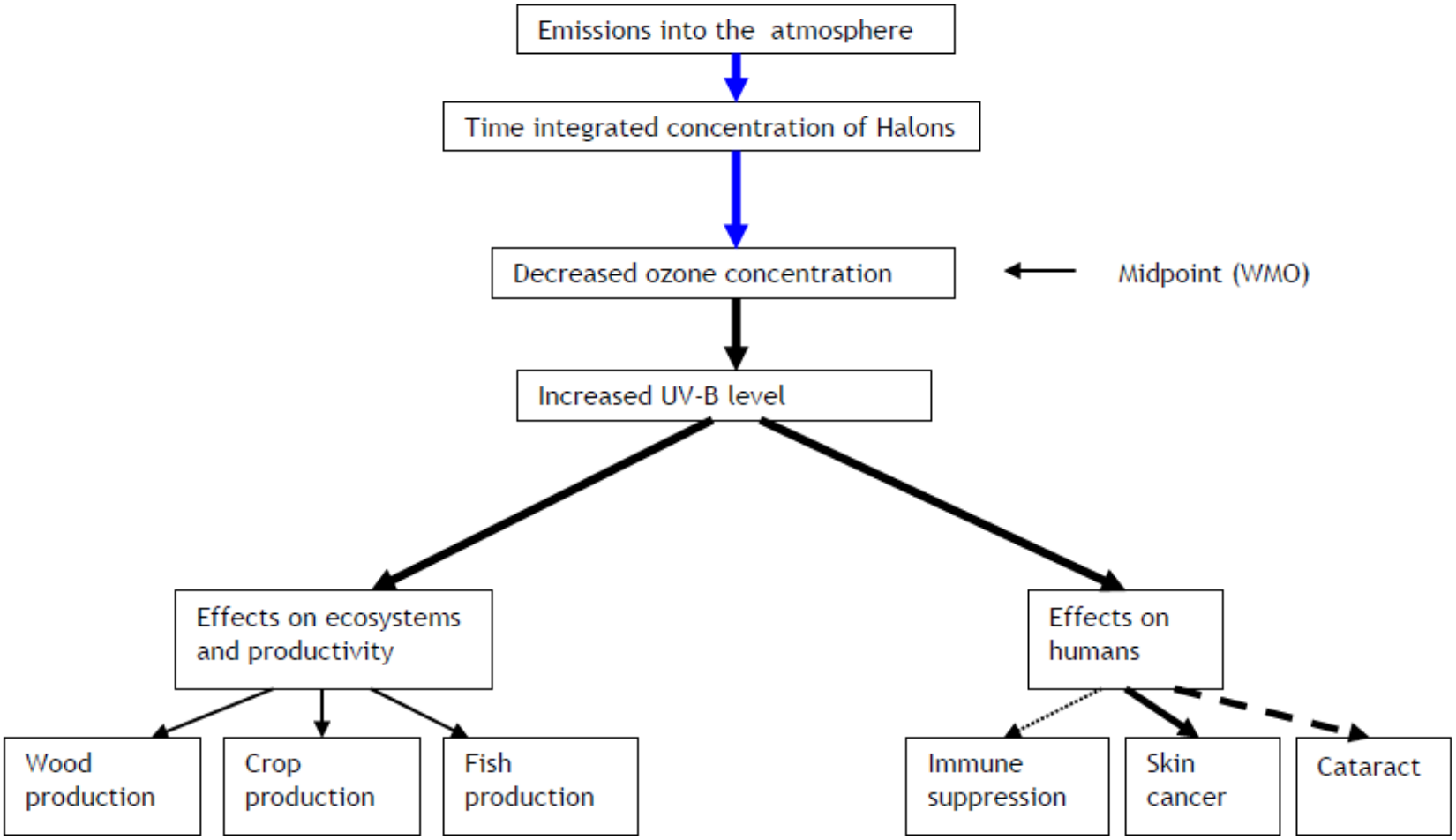
Definition	
Impact indicator	
characterization model	
characterization factor	
Unit	
Categories of damage (Endpoint)	

Impact categorie: Ozone depletion

TECHNISCHE UNIVERSITÄT DARMSTADT

Definition	Assessment of the depletion of the stratospheric ozone layer due to anthropogenic emissions of ozone depleting substances (CFCs in particular)
Impact indicator	Decreasing stratospheric ozone concentration: prevents ultraviolet UV-B radiation from entering the atmosphere
characterization model	■ Consideration of the atmospheric residence time of ozone depleting substances, the formation of EESC (= Equivalent Effective Stratospheric Chlorine) and the resulting stratospheric ozone depletion ■ Models: CML 2001, ReCiPe 2008
characterization factor	■ ODP = ozone depletion potential, relative measure to build a EESC ■ kg CFC-11-equivalent/kg emissions
Unit	kg CFC-11-equivalent
Categories of damage (Endpoint)	Human health, ecosystem quality

Impact categorie: Ozone depletion



Quelle: European Commission, 2010

Impact category: eutrophication

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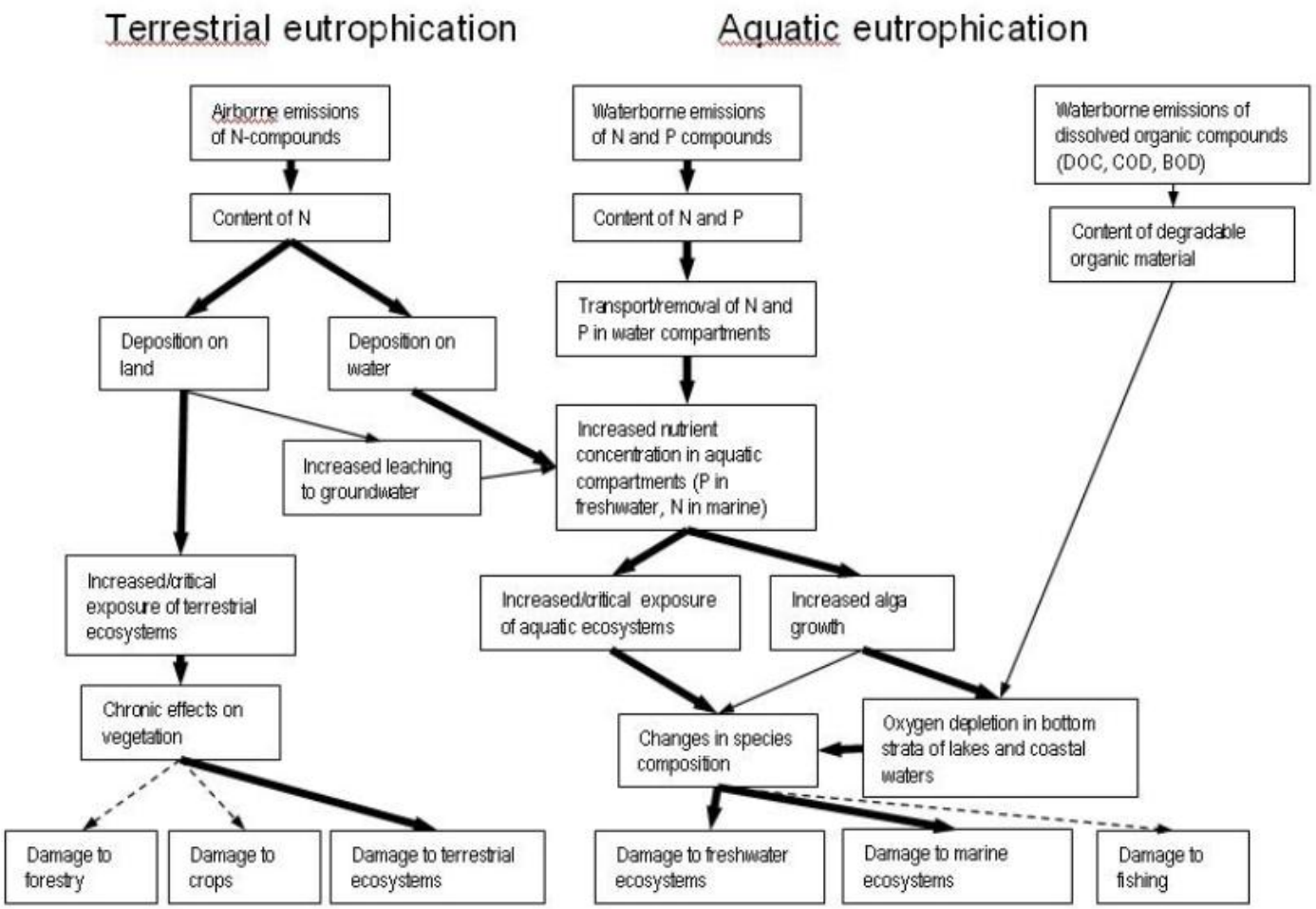
Definition	= nitrification, nutrient accumulation ■ Assessment of the effects caused by nutrient accumulation ■ Distinction in terrestrial and aquatic (freshwater and marine) eutrophication
Impact indicator	■ Increase in the nitrogen respectively phosphorus concentration and the undesirable associated formation of biomass ■ Terrestrial and marine: N-concentration ■ Freshwater: P-concentration
Characterization model	■ Consideration of the transport of substances into the air or water, the transfer to the recipient (environment) and the change of the ecosystem at changing nutrient availability ■ Models: IMPACT 2002+, CML 2001, ReCiPe 2008
Characterization factor	■ eutrophication potential ■ kg PO4-equivalent/ kg emissions or kg NO3-equivalent/kg emissions
Unit	kg PO4-equvalent or kg NO3-equivalent
Damage categories (Endpoint)	Damage to the ecosystem quality

Impact category: eutrophication



Quelle: European Commission, 2010

Impact category : particulate matter/ respiratory inorganics

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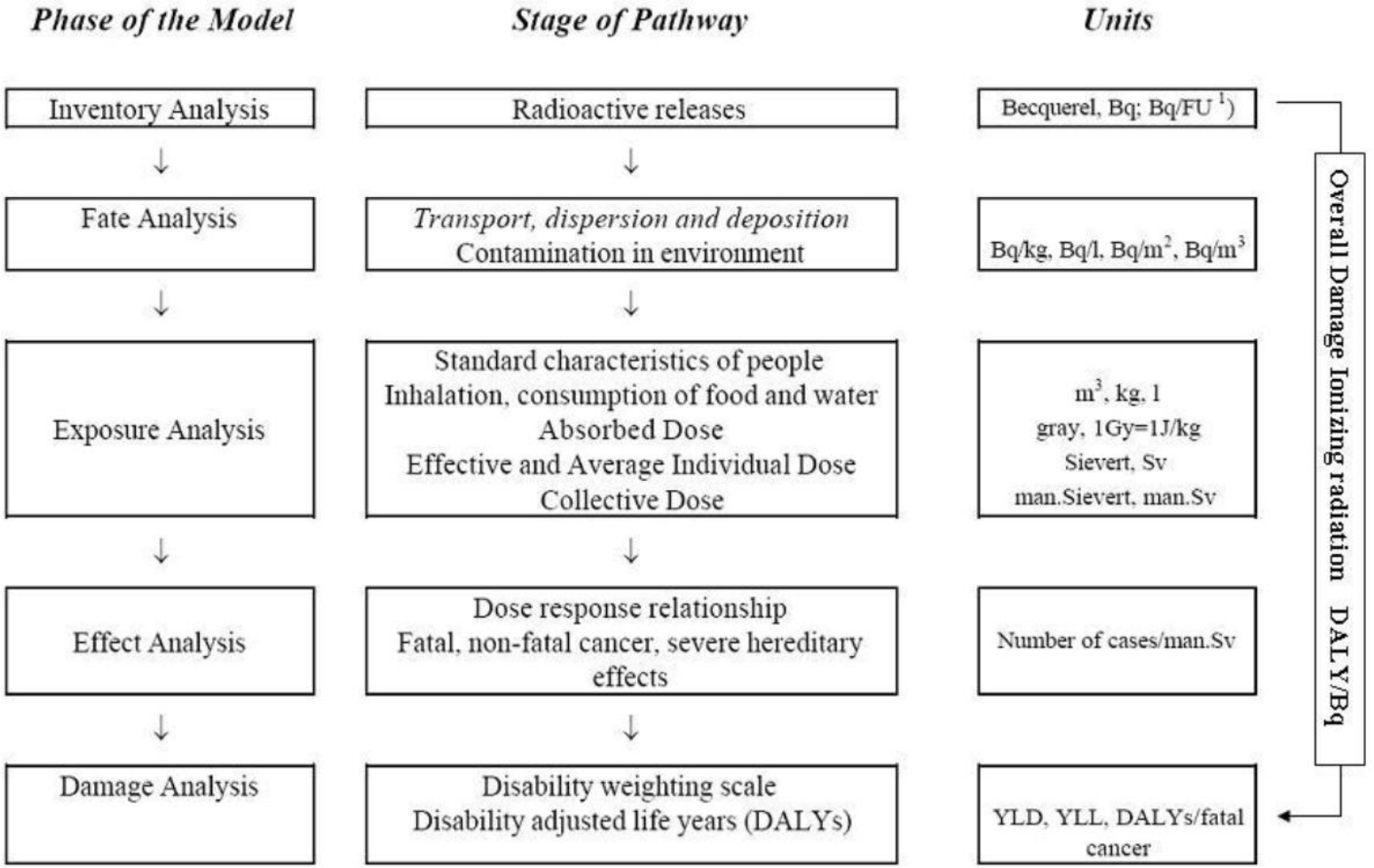
Definition	Assessment of the increase in particulate matter (PM) due to emission of primary and secondary particles
Impact indicator	Increase in: ■ TSP (total suspended particulates) ■ PM10 (<10 µm) ■ PM2.5 (<2.5 µm) ■ PM0.1 (<0.1 µm)
Characterization model	■ Consideration of the environmental behavior, the burden and the dose response of a pollutant for Midpoint and the severity for Endpoint ■ Models: IMPACT 2002+, ReCiPe 2008
Characterization factor	Particulate matter potential
Unit	kg particulate matter
Damage categories (Endpoint)	Human Health (Calculation of Years of Life Lost (YLL), Years of Life Disabled (YLD), and DALYs)

Impact category: ionising radiation

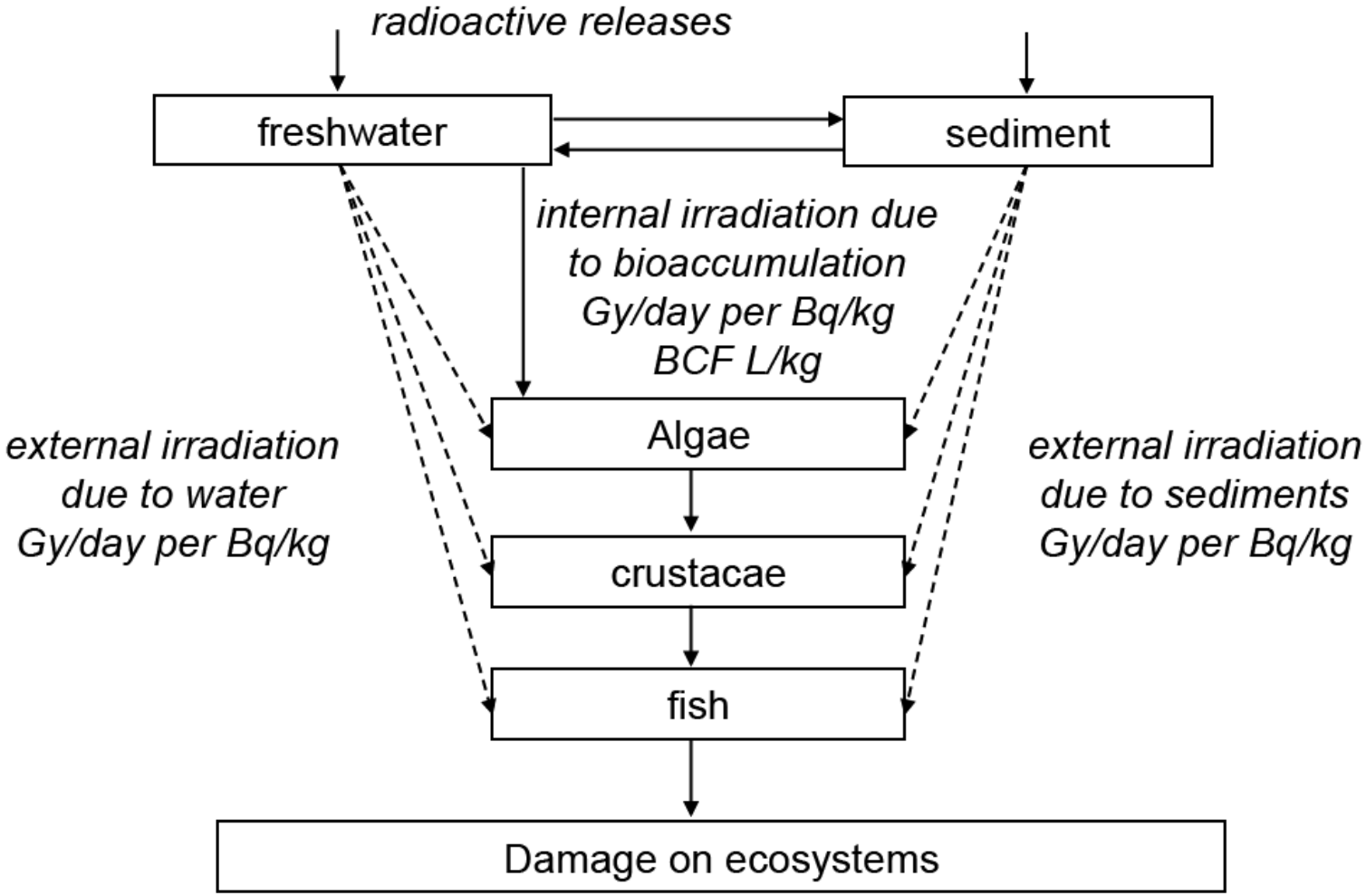
Definition	■ Assessment of the effects of ionizing radiation on humans and the environment ■ Ionizing radiation types: α-, β-, γ-rays and neutrons
Impact indicator	Effects by the absorbed dose
Characterization model	■ Taken into account the emissions emitted and calculation of their radiation behavior and burden, based on detailed nuclear-physical knowledge ■ based on the same framework conditions as human toxicity and ecotoxicity ■ Models: IMPACT 2002+, ReCiPe 2008
Characterization factor	ionising radiation potential
Unit	kg U^{235}
Damage categories (Endpoint)	Human health, ecosystem quality

Impact category: ionising radiation



Quelle: European Commission, 2010

Impact category: ionising radiation



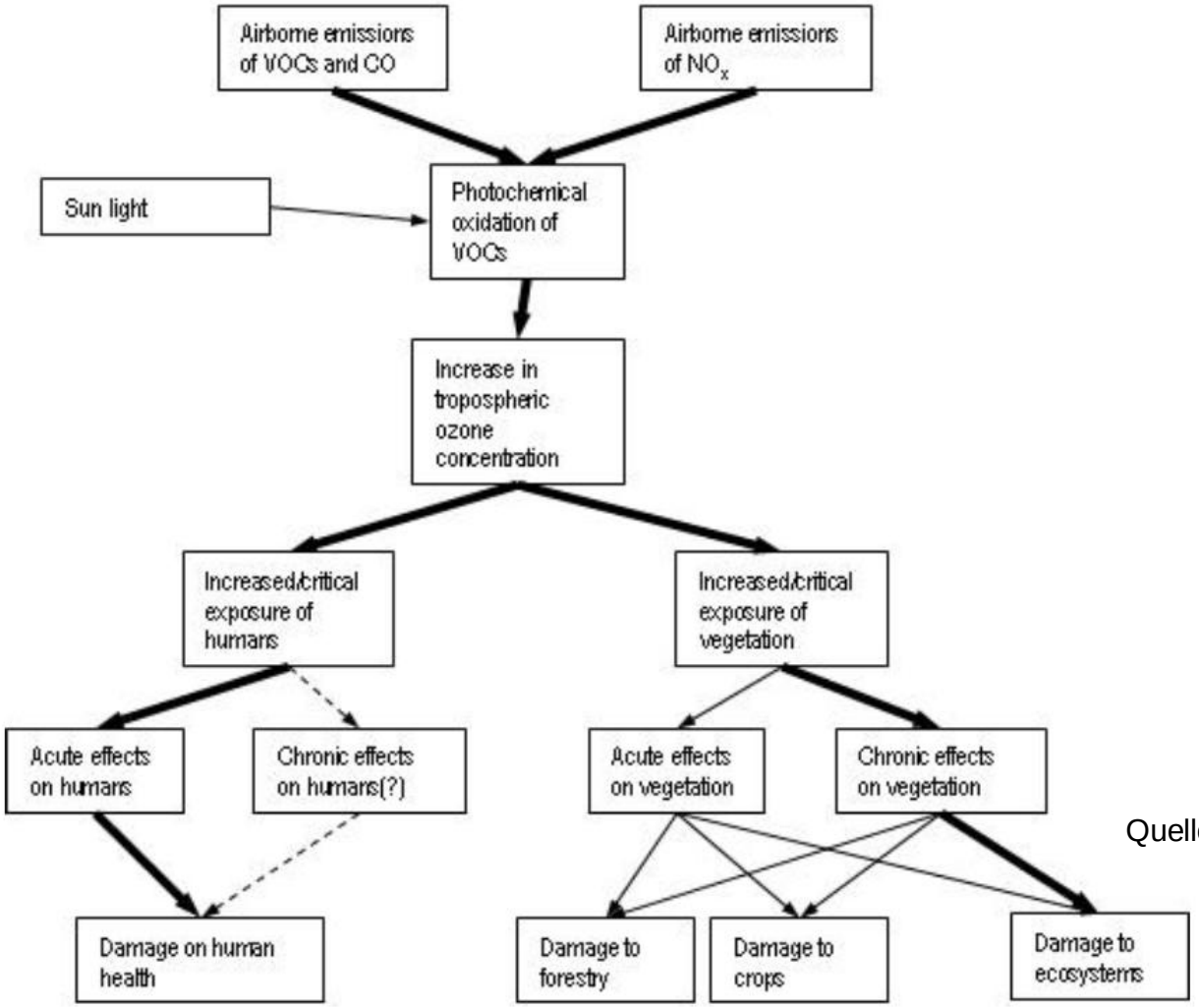
Quelle: European Commission, 2010

Impact category: photochemical ozone formation

TECHNISCHE UNIVERSITÄT DARMSTADT

Definition	Assessment of the effects of smog on humans and the environment caused by VOCs, CO and NOx
Impact indicator	Increase in the photochemical formed ozone (smog)
Characterization model	Two different types of models: ■ nonlinear/dynamic: Consideration of the Meteorology, the chemical composition of the atmosphere and associated emissions of other air pollutants ■ Simplified: individual VOCs are neglected and only a few characteristic factors are calculated
Characterization factor	Photochemical ozone creation potential (POCP) or Maximum Incremental Reactivity (MIR)
Unit	kg NMVOC (=non methane volatile organic carbon compound)
Damage categories (Endpoint)	Human health, ecosystem quality

Impact category: photochemical ozone formation



Quelle: European Commission, 2010

Selection of impact categories

TECHNISCHE UNIVERSITÄT DARMSTADT

Often used impact categories:

- climate change
- stratospheric ozone depletion
- acidification
- eutrophication
- particulate matter
- ionizing radiation
- photochemical ozone formation
- resource depletion
- loss of soil / soil degradation
- toxicity

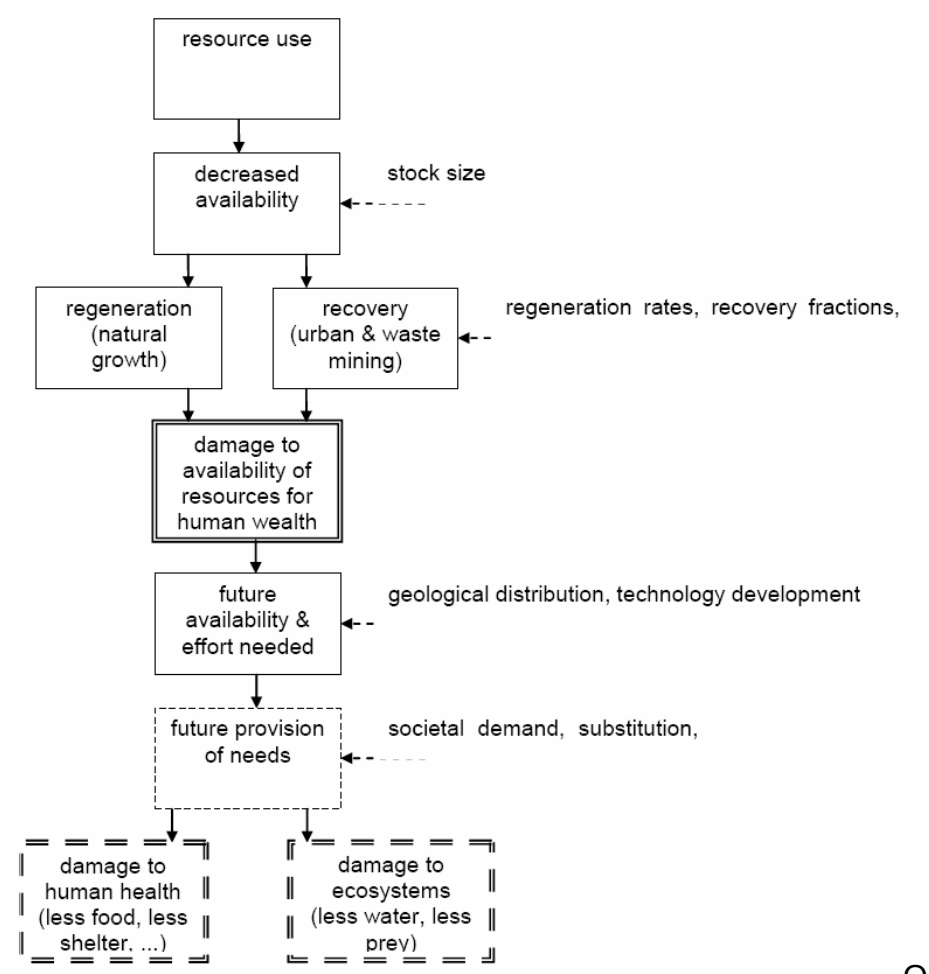
} **Type of intervention:** material usage

Impact category: resource depletion

TECHNISCHE UNIVERSITÄT DARMSTADT

Definition	Decreasing availability of resources as a result of their use outside of the rate of renewal / replacement
Impact indicator	Decrease in non-renewable (minerals and fossil fuels) and renewable (hydro, wind, and wood) resources
Characterization model	Distinction in: ■ renewable: model includes weight, volume, and exergy ■ nonrenewable: model includes either energy or mass, exergy or entropy, effects and the use of the storages (e.g. minerals to ground fuels with energy) ■ Models: IMPACT 2002+, ReCiPe 2008
Characterization factor	Resource depletion potential
Unit	■ Water consumption: m^3 ■ Mineral resource depletion: kg ■ Fossil fuel depletion: MJ
Damage categories (Endpoint)	Damage to natural resources

Impact category: resource depletion



Quelle: European Commission, 2010

Selection of Impact catgories

TECHNISCHE UNIVERSITÄT DARMSTADT

Often used impact categories:

- climate change
- stratospheric ozone depletion
- acidification
- eutrophication
- particulate matter
- ionizing radiation
- photochemical ozone formation
- resource depletion
- loss of soil / soil degradation
- toxicity

} **Type of intervention:**

Land use

Impact category: land use

TECHNISCHE UNIVERSITÄT DARMSTADT

Definition	Assessment of the impact of land use due to agriculture, anthropogenic settlement and extraction of minerals / resources
Impact indicator	Species loss, change in primary production, amount of organic dry matter content, soil loss
Characterization model	■ Observation of a particular area in a certain time, taking into account a quality indicator of a reference situation ■ Models: IMPACT 2002+, ReCiPe 2008
Characterization factor	land occupation/ transformation potential
Unit	m^2/a
Damage categories (Endpoint)	Natural resource depletion

Land use (I)

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- Used area size (Fi) per functional unit (FU)

$$\text{Total impact effect} = \sum_i F_i \left[\frac{m^2}{FE}\right]$$

- Additional involvement of the usage type by usage categories

Case 1

usage types
forest
agriculture
recuperation
traffic
water
industry
buildings

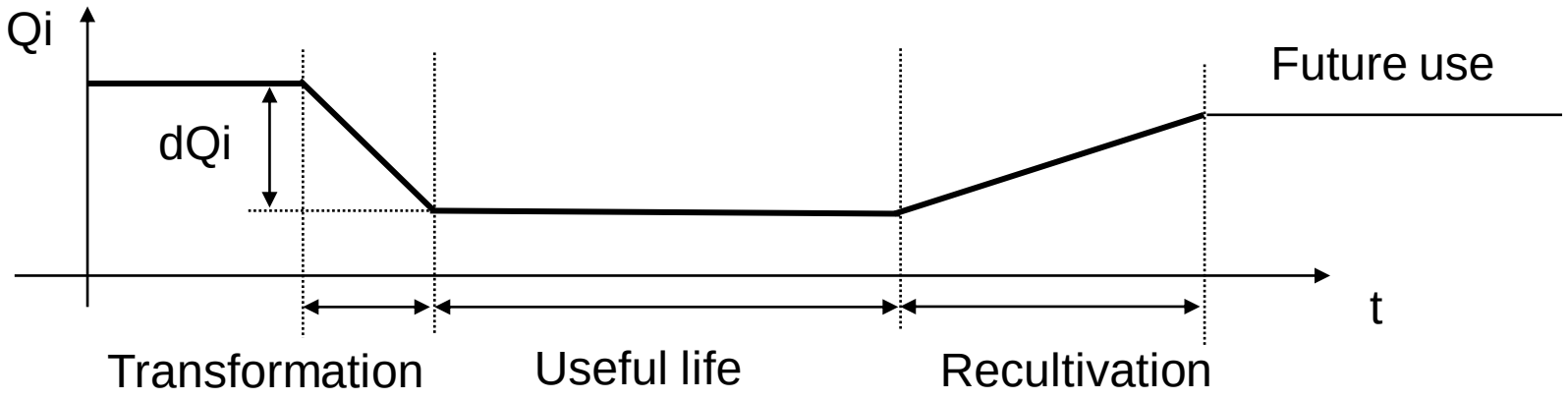
Case 2

usage type	hemeroby	degree of naturalne
ecosystem unaffected	Ahemerobic	natural
no / occasional use	oligohemerobic	close to natural
Forestry, pastures, meadows	mesohemerobic	semi-natural
forest monocultures	Beta euhemerobic	conditionally-far from
Arable land, garden land, viticultur	Alpha euhemerobi	far from nature
Sports, mining areas, disposal sit	polyhemerobic	foreign to nature
sealing	Metahemerobic	artificially

Land use (II)

- Description of the physical change (dQI) of Surface properties (i) over the useful life

  -Flora and fauna
  -Species (animals)
  -Soil functions (water and nutrient cycle)
  -design form



Selection of Impact categories

TECHNISCHE UNIVERSITÄT DARMSTADT

Often used impact categories:

- climate change
- stratospheric ozone depletion
- acidification
- eutrophication
- particulate matter
- ionizing radiation
- photochemical ozone formation
- resource depletion
- loss of soil / soil degradation
- toxicity

Type of intervention: Substance emission
Indikator: Midpoint- and/or Endpoint-Indicator

Impact category: toxicity

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Toxicity can be divided into:

- Human toxicity
- Ecotoxicity

=> Different effect endpoints!

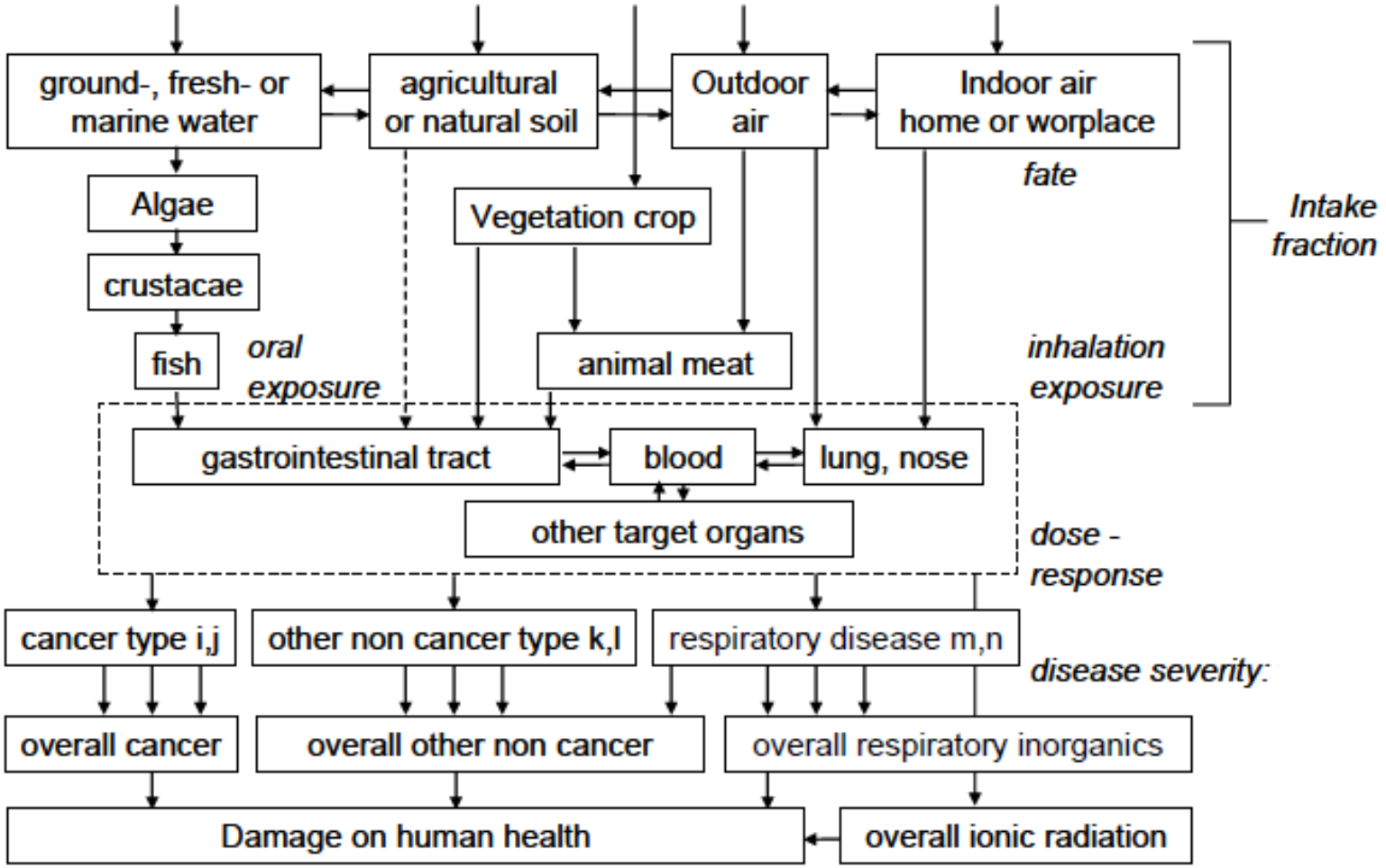
=> Characterization models derived from the risk assessment of chemical substances

Impact category: human toxicity

TECHNISCHE UNIVERSITÄT DARMSTADT

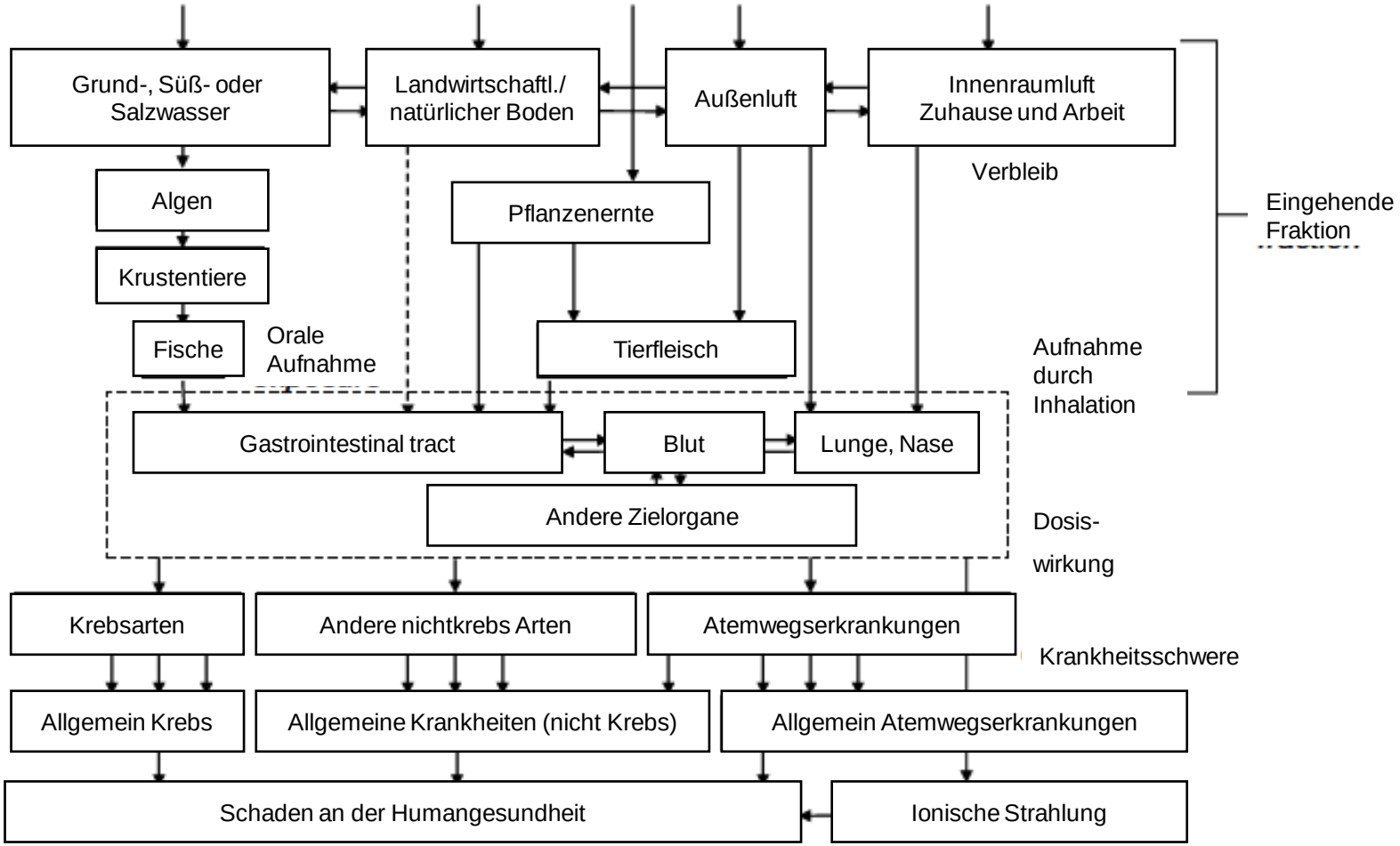
Definition	Assessment of toxic effects of substances on humans
Impact indicator	■ Problem: no common characteristics of chemicals known → no common indicator ■ Four subcategories: cancer, respiratory diseases, other non carcinogenic effects, effects to ionizing radiation
Characterization model	■ Consideration of the fate of chemicals in the environment, human intake and various toxicological responses (effects and severity) ■ Models: IMPACT 2002, IMPACT 2002+, CML 2001, ReCiPe 2008
Characterization factor	human toxicity potential (HTP)
Unit	■ YLL (= Years of Life Lost) ■ YLD (=Years of Life Disabled)
Damage categories (Endpoint)	Human health

Impact category: human toxicity



Quelle: European Commission, 2010

Impact category: human toxicity



Quelle: European Commission, 2010

Human toxicity (I)

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Simple weighting by boundary or guide values

from the Health and Safety:

- In Germany often maximum allowable concentration are used (MAC) as quasi-midpoint indicators.
- Result: "Human toxicity potential" (HTP), describes a "critical volume human toxicity", i.e. the volume of air that is charged up to the MAC value.
- The HTP can be normalized to a reference substance, eg 1.4 dichlorobenzene

Criticism: MAK values include an certain latitude of judgement, i.e. they are "political" values

Acutely highly toxic substances may be overrated, since they are usually only emitted in accidents at high doses in the environment and therefore play for the exposure to the environmental media a minor role

Human toxicity (II)

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Characterization with additional estimation of exposure

- Based on the, in the toxicology usual, analysis of uptake routes and includes the necessary chemicals in the exposure assessment analysis.
- In principle, the same approach for human- and ecotoxicity, based on the risk assessment of chemicals

Problem: Many toxicity endpoints

Impact category: ecotoxicity

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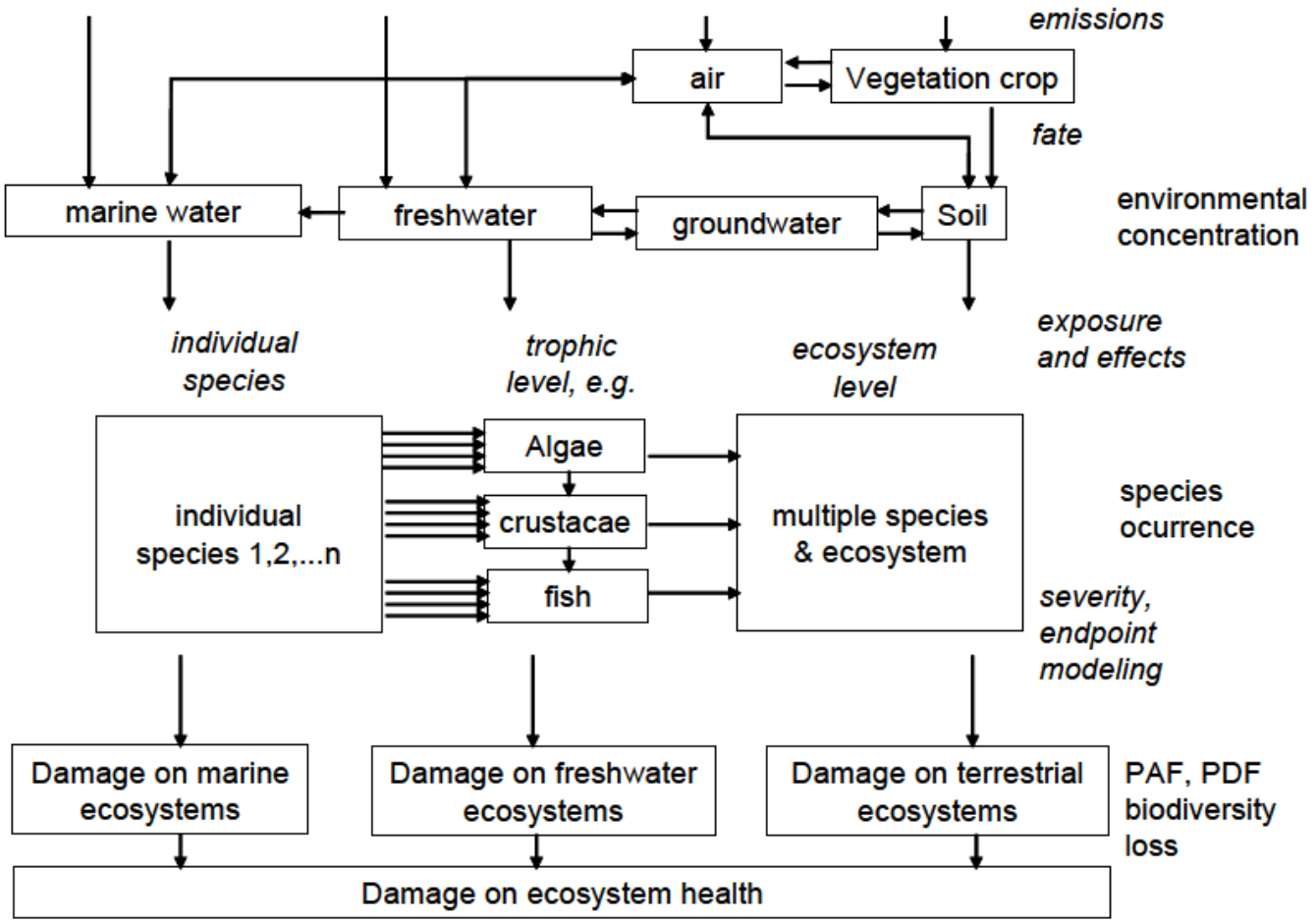
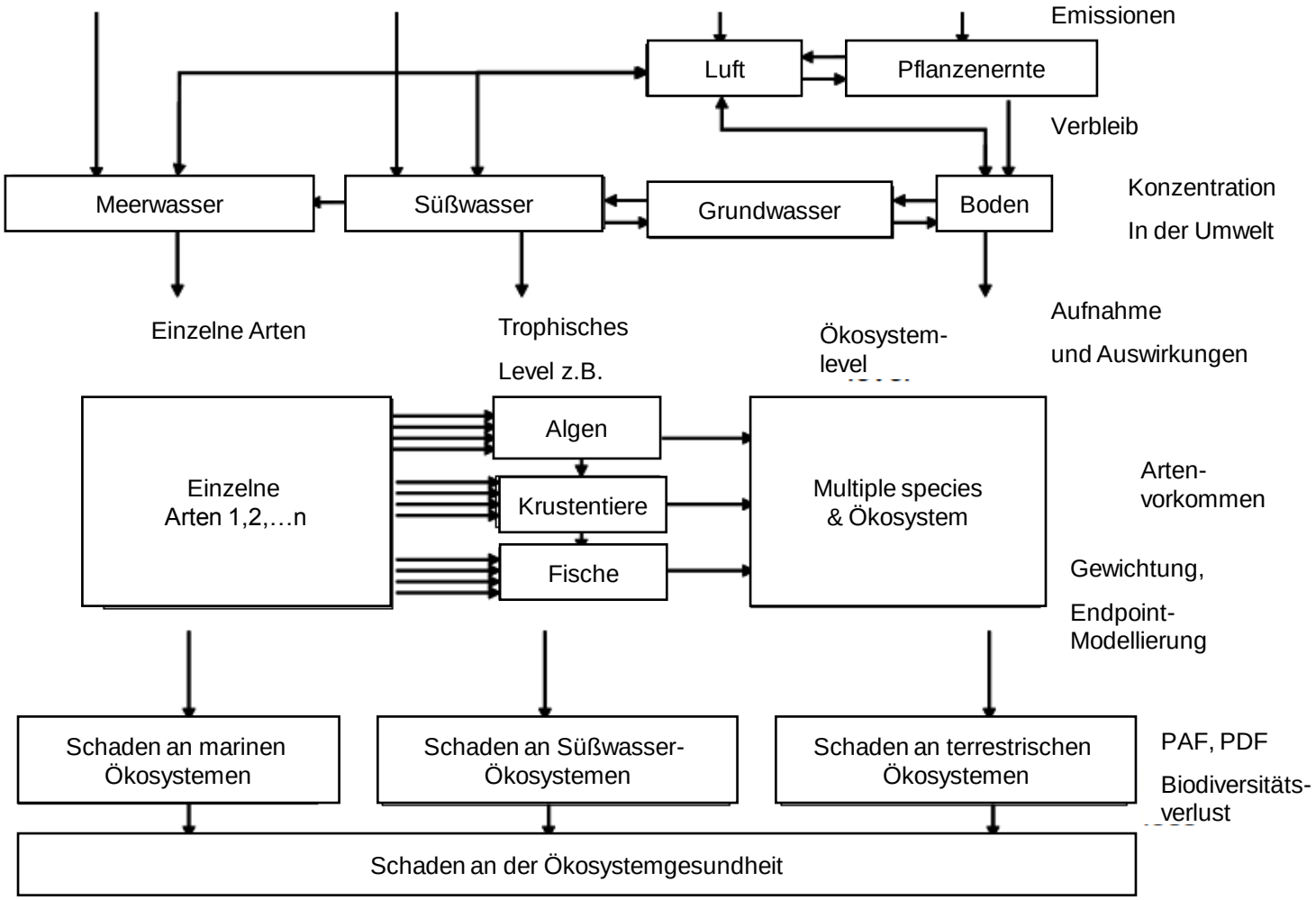
Definition	Assessment of the toxic effects of chemicals on an ecosystem
Impact indicator	Biodiversity loss / extinction of particular species
Characterization model	■ Consideration of the fate of chemicals in the environment, the inclusion of individual species and different toxicological responses (effects and severity) ■ Models: IMPACT 2002, IMPACT 2002+, CML 2001, ReCiPe 2008
Characterization factor	ecotoxicity potential
Unit	■ PDF (= Potentially Disappeared Fraction of species) ■ PAF (= Potentially Affected Fraction of species)
Damage categories (Endpoint)	Damage to the ecosystem quality (species extinction)

Impact category: ecotoxicity



Quelle: European Commission, 2010

Impact category: ecotoxicity

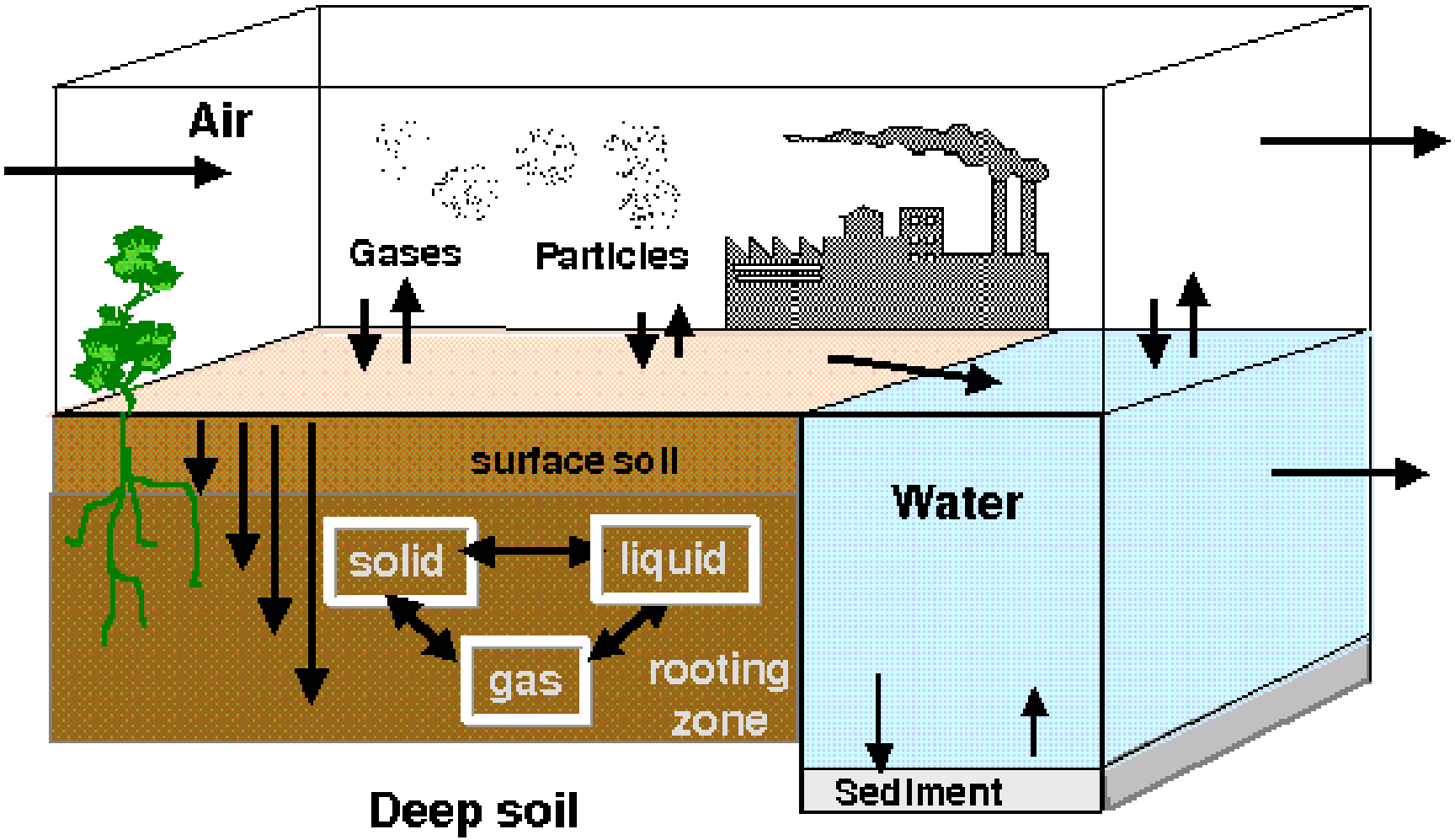


Quelle: European Commission, 2010

Risk assessment of chemical substances

What quantities of a substance are emitted?	*Inventory Analysis*
How disperses the material in the environment?	Spreading, (distribution, accumulation, decomposition)
What quantities of a substance assimilate the organisms?	Exposure
What consequences does the inclusion of a substance have through an organism?	Toxicity

spreading model CalTox



Overview Impact categories

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Wirkungskategorie	*Wirkungsindikator*	*Charakterisierungsfaktor*	*Einheit*	*Schadenskategorie*
Klimawandel	Infrarot-Strahlungsantrieb	Treibhauseffekt (GWP)	kg CO2-Äquivalente	Humangesundheit Ökosystemqualität
Ozonabbau	Stratosphärische Ozonkonzentration	Ozonabbaupotential	kg CFC-11-Äquivalente	Humangesundheit Ökosystemqualität
Versauerung	Säuregehalt durch H^+-Ionen	Versauerungspotential	kg SO2-Äquivalente	Ökosystemqualität
Eutrophierung	Phosphor-/Stickstoffkonzentration	Eutrophierungspotential	kg PO4-Äquivalente	Ökosystemqualität
Ökotoxizität	Artensterben	Ökotoxizitätspotential	PDF/ PAF	Ökosystemqualität
Humantoxizität	Kein gemeinsamer Indikator	Humantoxizitätspotential	YLL & YLD	Humangesundheit
Feinstaub	TSP/ PM10/ PM2.5/ PM0.1	Feinstaubpotential	kg Feinstaub	Humangesundheit
Ionisierende Strahlung	Absorbierte Dosis	Ionisierendes Strahlungspotential	kg U^{235}	Humangesundheit Ökosystemqualität
Photochemische Ozonbildung	Photochemische gebildetes Ozon	POCP oder MIR	kg NMVOC	Humangesundheit Ökosystemqualität
Landnutzung	Artenverlust	Landnutzungspotential	m^2/a	Natürliche Ressourcen
Ressourcen-verbrauch	(nicht-) erneuerbare Ressourcen	Ressourcenverbrauchs-potential	m^3 oder kg oder MJ	Natürliche Ressourcen

http://www.tu-chemnitz.de/mb/InstBF/ufa/ufainha.htm