Next Generation Risk Assessment for Occupational Chemical Safety – a Real-World Example with Sodium-2-hydroxyethane sulfonate

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Steve Gutsell: Head of Regulatory Science – Chemical Safety

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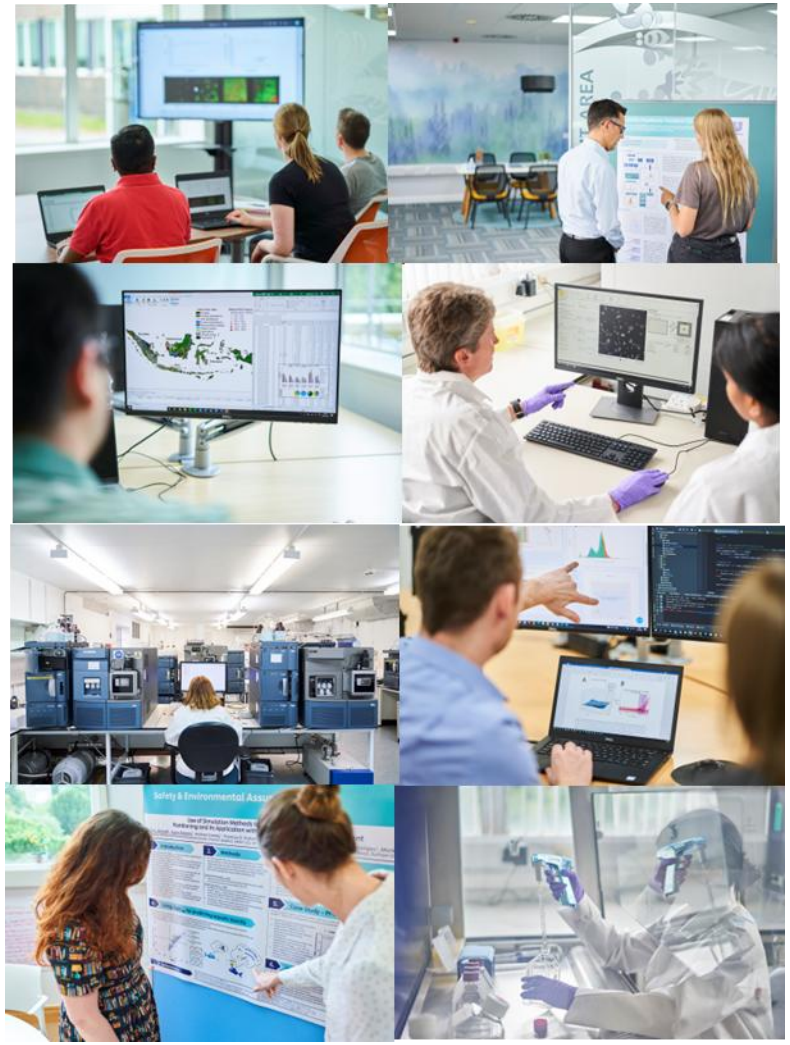
ASCCT-ESTIV 24/07/2025



Please contact adam.wood@unilever.com with any further questions

Overview

1. Current approaches for worker safety assessment.
2. External landscape (NGRA)
3. Overview of Unilever's NGRA journey toolboxes/workflows.
4. Case study chemical: Sodium-2-hydroxyethane sulfonate (SI)

Looking to the future:
- EU roadmap toward phasing out animal testing and REACH revision.

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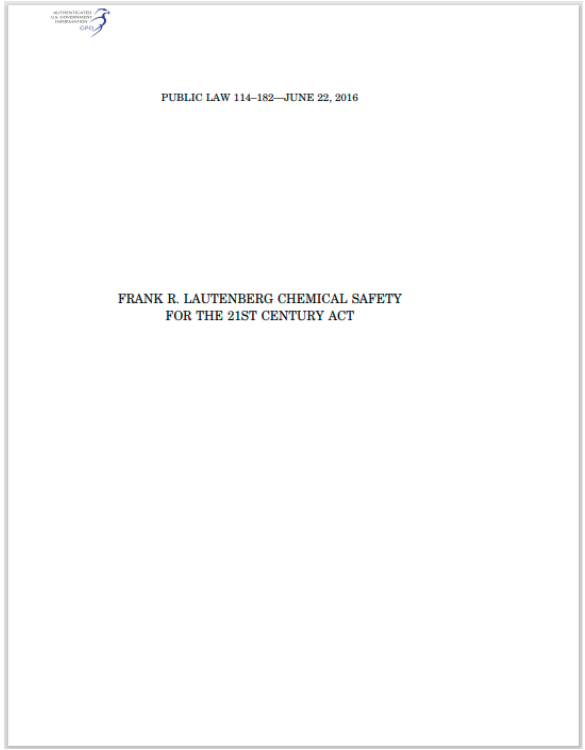
Historical worker safety assessment (systemic toxicity)

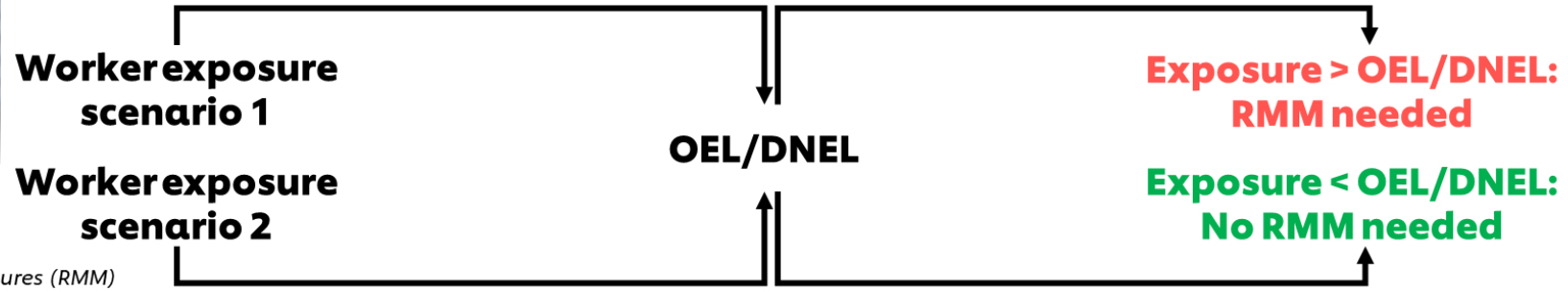
Typically, risks from occupational exposures are determined via comparison with occupational limit values, e.g., occupational exposure limits (OELs) or Derived No-effect levels (DNELs).

Large number of OELs/DNELs based on studies performed using experimental animals.

Paradigm based on animal testing increasingly challenged scientifically and societally.


PUBLIC LAW 114–182—JUNE 22, 2016

FRANK R. LAUTENBERG CHEMICAL SAFETY
FOR THE 21ST CENTURY ACT



Opportunities for improved occupational risk assessments

Reliance on animal testing for worker safety assessment has been reduced, e.g. local toxicity, however, systemic safety assessment remains largely reliant on animal testing.

In addition, several, worker safety, regulatory texts are based on tonnage-driven testing requirements, e.g. EU REACH which has…:

1. Questionable coverage of certain effects at low tonnage bands (e.g. DART)
2. Questionable correlation between tonnage - exposure - risk.

High-throughput (non-animal) methods offer an opportunity for more informative, faster occupational risk assessments

Archives of Toxicology (2023) 97:3075–3083
https://doi.org/10.1007/s00204-023-03601-5

REGULATORY TOXICOLOGY

Check for updates

Analysis of health concerns not addressed by REACH for low tonnage chemicals and opportunities for new approach methodology

Philip Botham[1] · Mark T. D. Cronin[2] · Richard Currie[1] · John Doe[2] · Dorothee Funk-Weyer[3] · Timothy W. Gant[4,5] · Marcel Leist[6] · Sue Marty[7] · Bennard van Ravenzwaay[8] · Carl Westmoreland[9]

Received: 20 July 2023 / Accepted: 30 August 2023 / Published online: 27 September 2023
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Botham et al., Archives of Toxicology (2023), 97: 30753082

Claessens *et al. Journal of Occupational Medicine and Toxicology* (2025) 20:10
https://doi.org/10.1186/s12995-025-00456-7

Journal of Occupational Medicine and Toxicology

REVIEW Open Access

Check for updates

Risk assessment and management of chemical hazards for pregnant workers: a qualitative review of guidance from EU member states

Thomas Claessens[1*], Karin Sørig Hougaard[2,3] and Steven Ronsmans[1]

Claessens et al., Journal of Occupational Medicine and Toxicology (2025), 20:10

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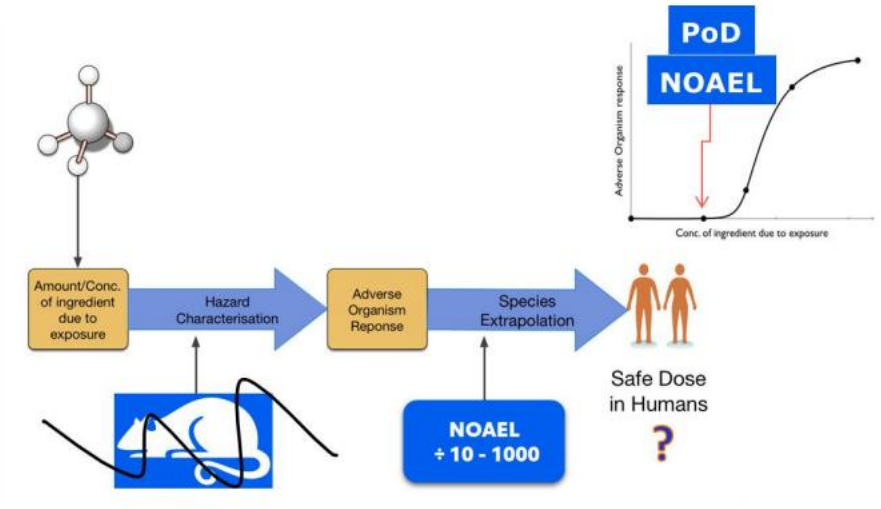
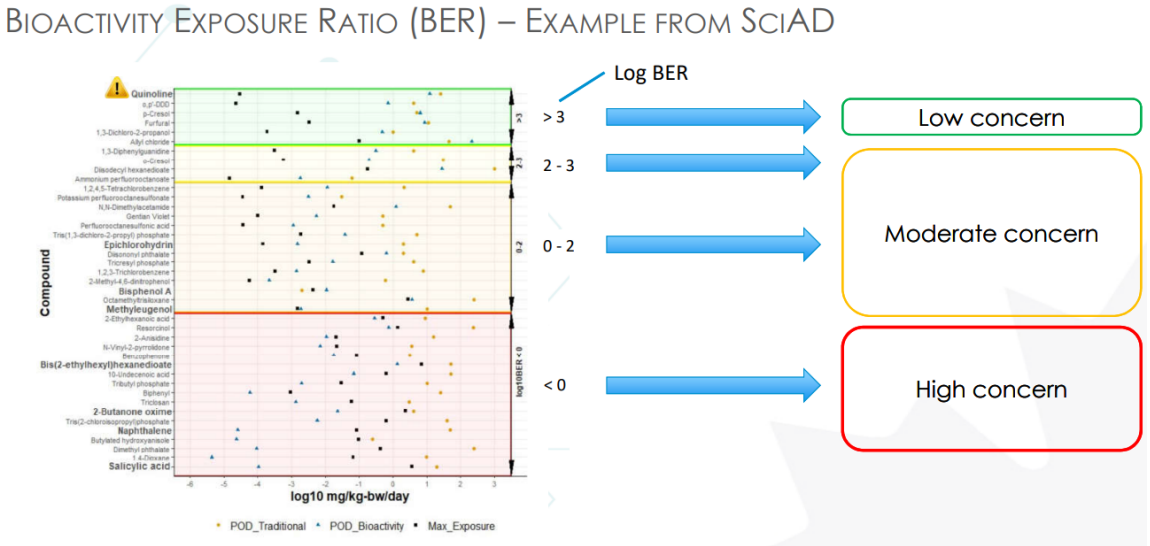
Next Generation Risk Assessment (NGRA)

- Same underlying paradigm for risk assessment (hazard ID, characterisation, exposure estimation and risk characterisation).
- Hazard ID/characterisation instead based on integrating non-animal methods (NAMs), e.g. *in silico, in vitro, in chemico*.
- Risks characterised in same manner, i.e. comparison of NAM PoDs with exposure estimate – the 'bioactivity exposure ratio (BER)'
- Likely to be used in a tiered manner, where depending on risk characterisation output, increasing attention may be paid to mechanistic interpretation.



Historical (animal-based) risk assessment paradigm



Use of the BER approach for prioritisation by Health Canada

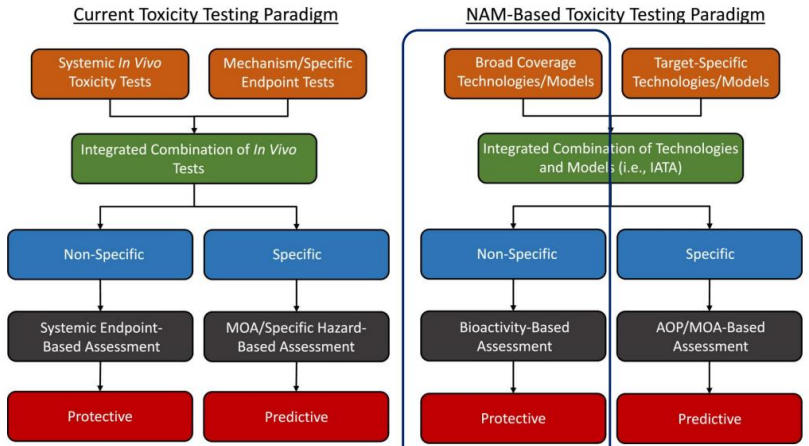
NAM development – protection vs prediction

Rapid development of NAMs for use in risk assessment. Two alternate philosophies:

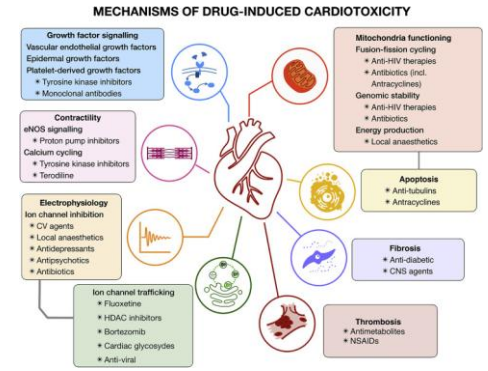
1.) NAMs that measure early biological changes (irrespective of toxicological significance) which are used in a way that ensures estimated exposures fall below such changes (protection).

2. NAMs developed to predict (possibly quantitatively) adverse effects

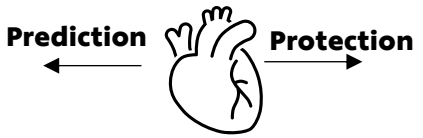
Both have a place in future risk assessment ar both likely to be used in a tiered manner



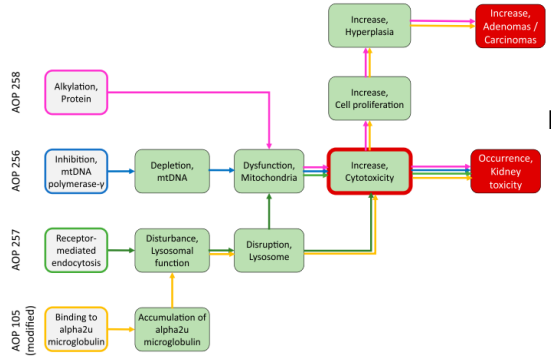
Browne *et al.*, (2024) https://doi.org/10.1016/j.yrtph.2024.105579



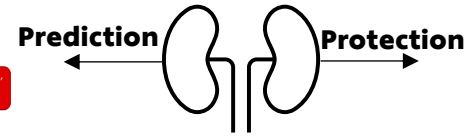
Manoshina et al., (2021). Cell Reports Medicine. 2:3 100216

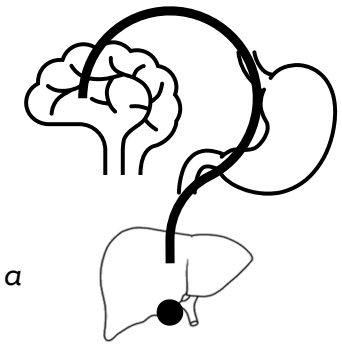


NAMs capturing early biological changes protective of apical effects



Mally and Jarzina (2022). Frontiers in Toxicology





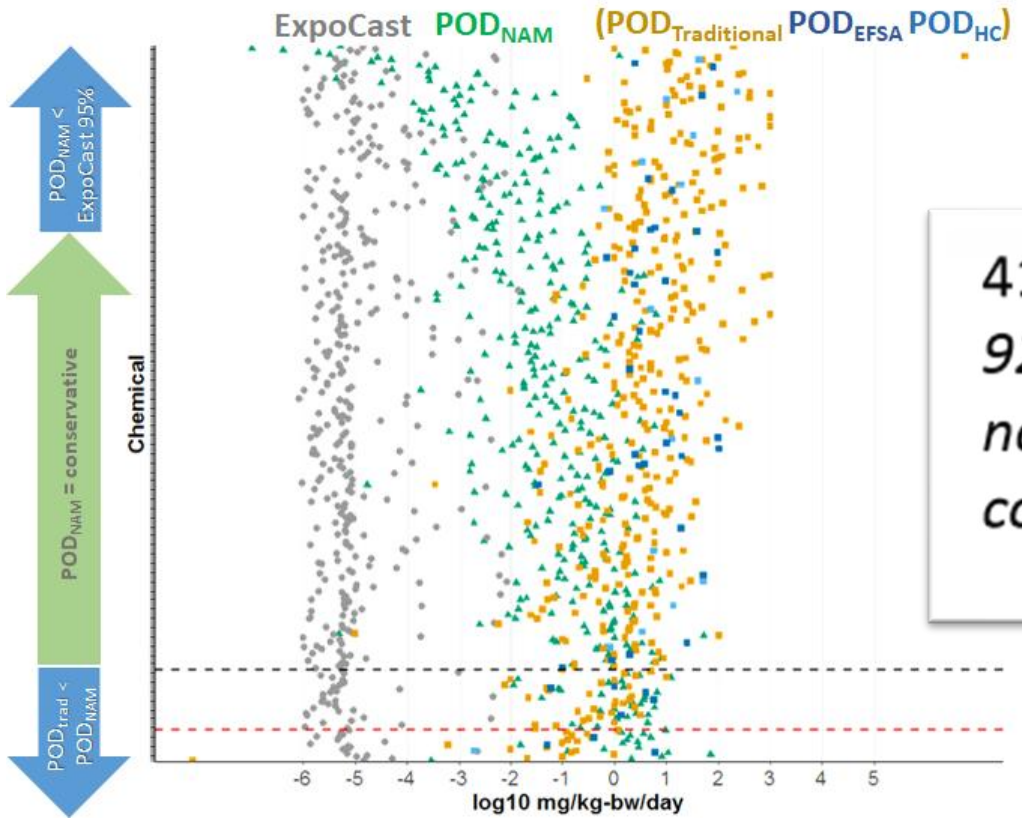
"There are 78 major human organs; let's say there are five different ways in which chemicals could be toxic to each one (an underestimate); and let's say we need five key events (including a molecular initiating event) measured across each IATA with new in vitro tests. That's around 2000 assays conducted at just one dose and at one time point for complete human AOP-driven biological coverage." Carmichael et al., (2022). Altex, 39:3

- Limited coverage approaches
- Cell based/reporter assays
- Data rich approaches
- Transcriptomics
- Cell painting

State of the art (>20-years)

Value of approach for large subset of chemicals

Human Exposure PODs NAMs Animal




OXFORD SOT Society of Toxicology academic.oup.com/toxsci Tox Spotlight article

TOXICOLOGICAL SCIENCES, 173(1), 2020, 202–225
doi: 10.1093/toxsci/kfz201
Advance Access Publication Date: September 18, 2019
Research Article

Utility of *In Vitro* Bioactivity as a Lower Bound Estimate of *In Vivo* Adverse Effect Levels and in Risk-Based Prioritization

Katie Paul Friedman,*,1 Matthew Gagne,† Lit-Hsin Loo,‡ Panagiotis Karamertzanis,§ Tatiana Netzeva,§ Tomasz Sobanski,§ Jill A. Franzosa,¶ Ann M. Richard,* Ryan R. Lougee,*,|| Andrea Gissi,§ Jia-Ying Joey Lee,‡ Michelle Angrish,|| Jean Lou Dorne,|| Stiven Foster,# Kathleen Raffaele,# Tina Bahadori,# Maureen R. Gwinn,* Jason Lambert,* Maurice Whelan,** Mike Rasenberg,§ Tara Barton-Maclaren,† and Russell S. Thomas*

More recent activities – different tools, similar findings – NAM PoDs generally more sensitive than traditional PoDSs


OXFORD SOT Society of Toxicology academic.oup.com/toxsci Tox Spotlight article

Toxicological Sciences, 2025, **205(1)**, 74–105
https://doi.org/10.1093/toxsci/kfaf019
Advance Access Publication Date: February 19, 2025
Research article

Integration of new approach methods for the assessment of data-poor chemicals

Katie Paul Friedman[1,*], Russell S. Thomas[1], John F. Wambaugh[1], Joshua A. Harrill[1], Richard S. Judson[1], Timothy J. Shafer[1], Antony J. Williams[1], Jia-Ying Joey Lee[2], Lit-Hsin Loo[2], Matthew Gagne[2], Alexandra S. Long[3], Tara S. Barton-Maclaren[3], Maurice Whelan[4], Mounir Bouhifd[3], Mike Rasenberg[6], Ulla Simanainen[3], Tomasz Sobanski[5]

414/448 chemicals = *92% of the time this naïve approach appears conservative*

Case Studies Demonstrating Application of Bioactivity as a Protective POD

'… understanding how construction of NAM-based POD estimates may offer equivalent levels of public health protection as the PODs produced by animal methods …' Paul Friedman *et al*, 2023, Computational Toxicology, 28, 10028

BER = bioactivity exposure ratio (ratio of PoD NAM/exposure) ~ margin of safety/exposure

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APCRA ACCELERATING THE PACE OF CHEMICAL RISK ASSESSMENT

Paul Friedman et al., 2020. Toxicol. Sci **173**, 202-225

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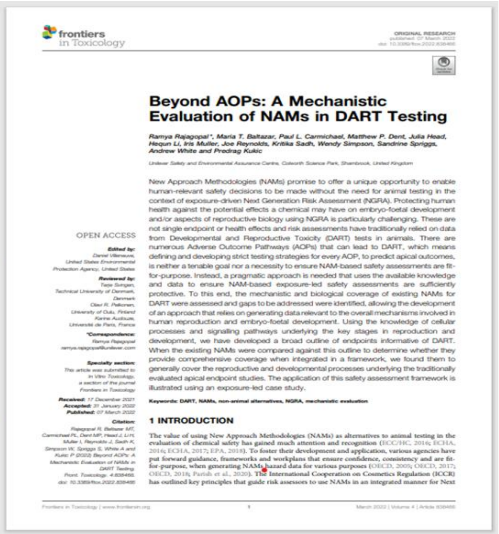
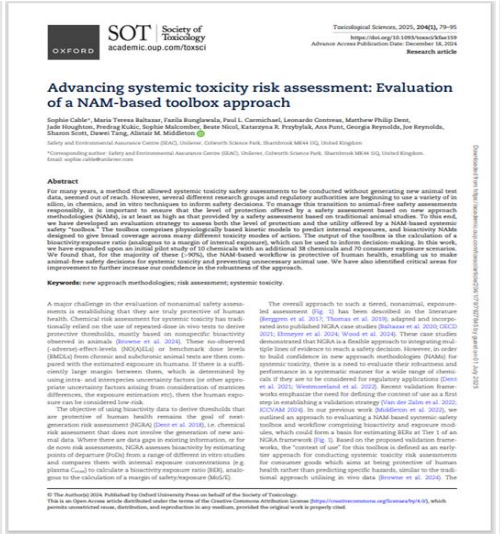
Unilever's NGRA journey: Case studies > toolbox evaluations > real-world use


A Next-Generation Risk Assessment Case Study for Coumarin in Cosmetic Products


Are Non-animal Systemic Safety Assessments Protective? A Toolbox and Workflow


Beyond AOPs: A Mechanistic Evaluation of NAMs in DART Testing


Advancing systemic toxicity risk assessment: Evaluation of a NAM-based toolbox approach


An advancement in developmental and reproductive toxicity (DART) risk assessment: evaluation of a bioactivity and exposure-based NAM toolbox

2020

First NGRA case study on Coumarin

2022

Toolbox and workflow for conducting NGRA established with threshold BER for decision making

2024

Conceptual DART toolbox and workflow established

Evaluation of toolbox, workflow and BER threshold. Encouraging results (>95% protectiveness)

2025

Toolbox and workflow for DART established (Muller et al., (accepted)

Confidence with models, best practice and ability to apply to different sectors (from consumer>worker)

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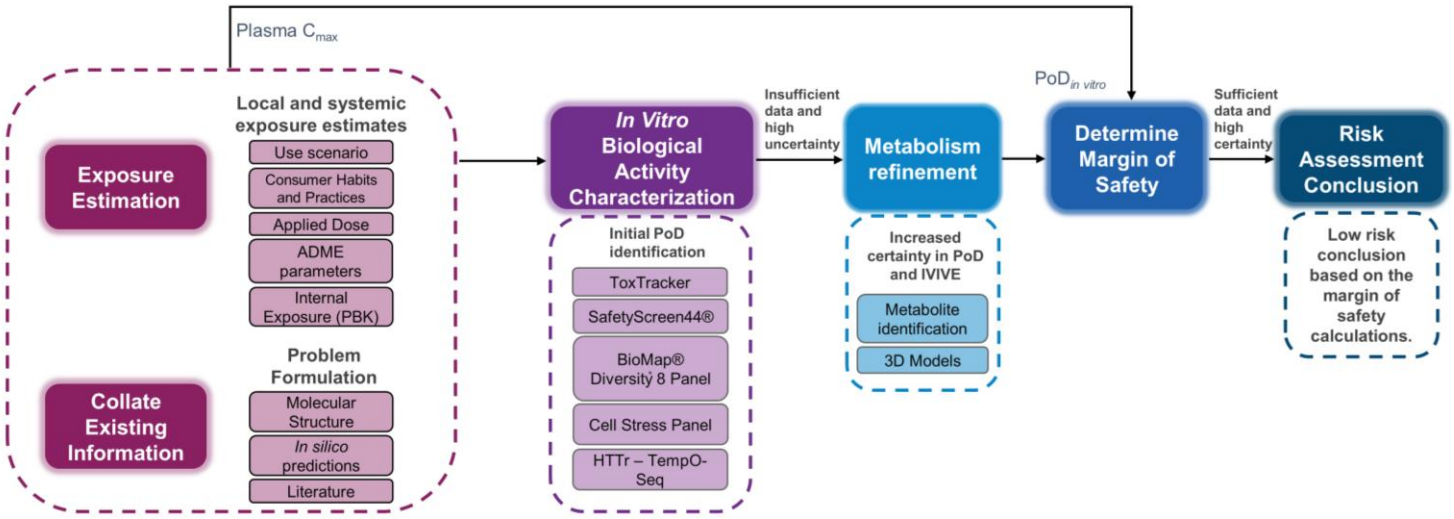
Translating principles to practice with case studies




OXFORD SOT Society of Toxicology
academic.oup.com/toxsci
TOXICOLOGICAL SCIENCES, 176(1), 2020, 236–252
doi: 10.1093/toxsci/kfaa048
Advance Access Publication Date: April 10, 2020
Research article

A Next-Generation Risk Assessment Case Study for Coumarin in Cosmetic Products

Maria T. Baltazar,[1] Sophie Cable, Paul L. Carmichael, Richard Cubberley, Tom Cull, Mona Delagrange, Matthew P. Dent, Sarah Hatherell, Jade Houghton, Predrag Kukic, Hequn Li, Mi-Young Lee, Sophie Malcomber, Alistair M. Middleton, Thomas E. Moxon, Alexis V. Nathanail, Beate Nicol, Ruth Pendlington, Georgia Reynolds, Joe Reynolds, Andrew White, and Carl Westmoreland

Unilever Safety and Environmental Assurance Centre, Colworth Science Park, Sharnbrook, Bedfordshire MK44 1LQ, UK


frontiers | Frontiers in Pharmacology
OPEN ACCESS

Next generation risk assessment: an *ab initio* case study to assess the systemic safety of the cosmetic ingredient, benzyl salicylate, after dermal exposure

Johanna Ebmeyer[1*†], Abdulkarim Najjar[1*†], Daniela Lange[1*†], Mareike Boettcher[1], Silja Voß[1], Katrin Brandmair[1], Jaqueline Meinhardt[1], Jochen Kuehnl[1], Nicola J. Hewitt[2], Christopher-Tilman Krueger[1] and Andreas Schepky[1]

- Principles around using high-throughput test batteries translated to case study in 2020.
- Demonstrated feasibility of approach based on realistic test battery.
- In recent years, further case studies have been published following similar principles.
- **Shift has been needed from case-studies to larger evaluations with larger numbers of chemicals.**

Other NGRAs are available!

Unilever's NGRA journey: Case studies > toolbox evaluations > real-world use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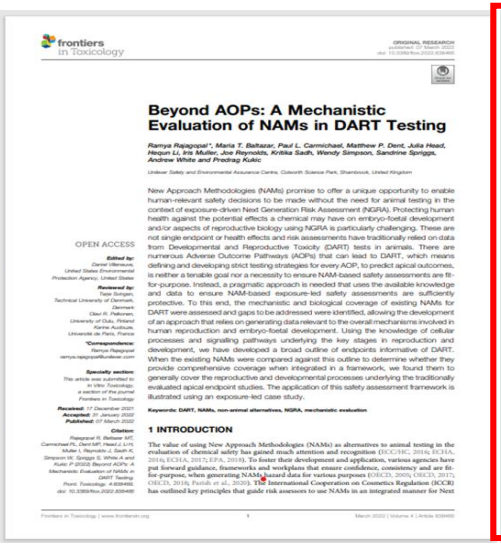
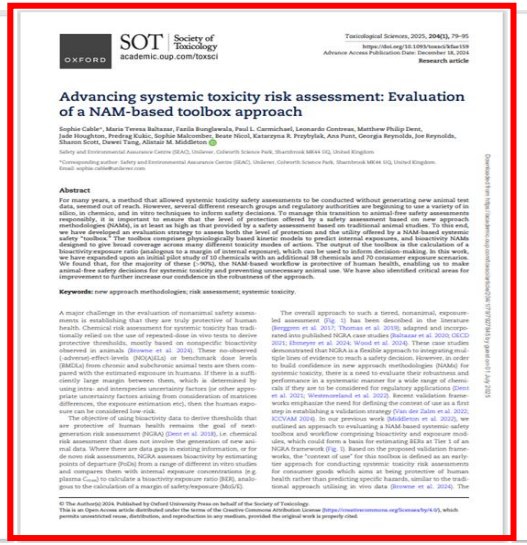

Beyond AOPs: A Mechanistic Evaluation of NAMs in DART Testing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Unilever systemic toolbox evaluations

To evaluate the value of a pragmatic suite of NAMs for making protective safety decisions, a **'toolbox'** and **'workflow'** has been **established** and **evaluated**, entailing:

OXFORD SOT Society of Toxicology academic.oup.com/toxsci Tox Spotlight article

TOXICOLOGICAL SCIENCES, 189(1), 2022, 124–147
https://doi.org/10.1093/toxsci/kfac068
Dryad Digital Repository DOI: https://doi.10.5061/dryad.fbg79cnx1
Advance Access Publication Date: 13 July 2022
Research article

Are Non-animal Systemic Safety Assessments Protective? A Toolbox and Workflow

Alistair M. Middleton,*,1 Joe Reynolds,* Sophie Cable,* Maria Teresa Baltazar,* Hequn Li,* Samantha Bevan,† Paul L. Carmichael,* Matthew Philip Dent,* Sarah Hatherell,* Jade Houghton,* Predrag Kukic,* Mark Liddell,* Sophie Malcomber,* Beate Nicol,* Benjamin Park,† Hiral Patel,‡ Sharon Scott,* Chris Sparham,* Paul Walker,† and Andrew White*

*Unilever Safety and Environmental Assurance Centre, Bedfordshire MK44 1LQ, UK; †Cyprotex Discovery Ltd, Cheshire SK10 4TG, UK and ‡Charles River Laboratories, Cambridgeshire, CB10 1XL, UK

1To whom correspondence should be addressed at Unilever Safety and Environmental Assurance Centre, Colworth Science Park, Sharnbrook, Bedfordshire MK44 1LQ, UK. E-mail: alistair.middleton@unilever.com.

- ✓ Toolbox of NAMs established
- ✓ Exposure (24) and risk classifications for 10 chemicals
- ✓ BERs calculated for all chemicals/exposures
- ✓ Threshold BER proposed

PBK parameterization level	BER threshold
L1 (in silico parameters)	110
L2 (at least 1 in vitro parameter)	11
L3 (model calibrated to human clinical data)	2.5

2022

2024

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Toxicological Sciences, 2025, 1–17
https://doi.org/10.1093/toxsci/kfae159
Advance Access Publication Date: December 18, 2024
Research article

Advancing systemic toxicity risk assessment: Evaluation of a NAM-based toolbox approach

Sophie Cable*, Maria Teresa Baltazar, Fazila Bunglawala, Paul L. Carmichael, Leonardo Contreas, Matthew Philip Dent, Jade Houghton, Predrag Kukic, Sophie Malcomber, Beate Nicol, Katarzyna R. Przybylak, Ans Punt, Georgia Reynolds, Joe Reynolds, Sharon Scott, Dawei Tang, Alistair M. Middleton

Safety and Environmental Assurance Centre (SEAC), Unilever, Colworth Science Park, Sharnbrook MK44 1LQ, United Kingdom

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- ✓ BERs calculated for 38 chemicals (70 exposure scenarios)
- ✓ Protectiveness (>90%) and utility (~<30%) determined
- ✓ Comparisons with animal PoDs for same substances

PBK level	Protectiveness	Utility
L1	93% (43 out of 46)	8% (2 out of 24)
L2	93% (43 out of 46)	27% (6 out of 22)
L3	98% (40 out of 41)	0% (0 out of 3)
Highest	96% (44 out of 46)	29% (7 out of 24)

* Protectiveness = correct identification of a high-risk exposure scenario as high risk. Utility = identified as an uncertain risk – **further work needed!**

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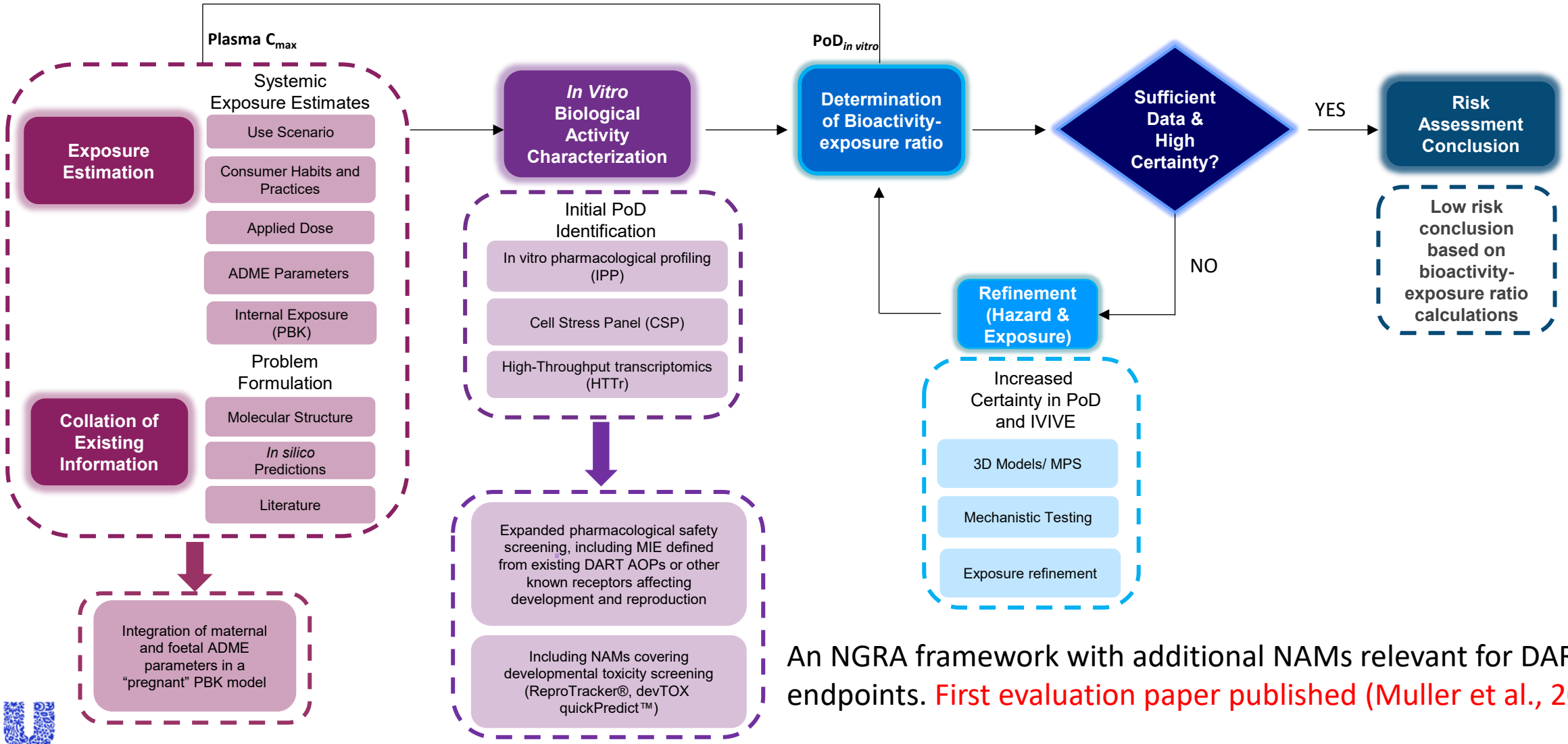
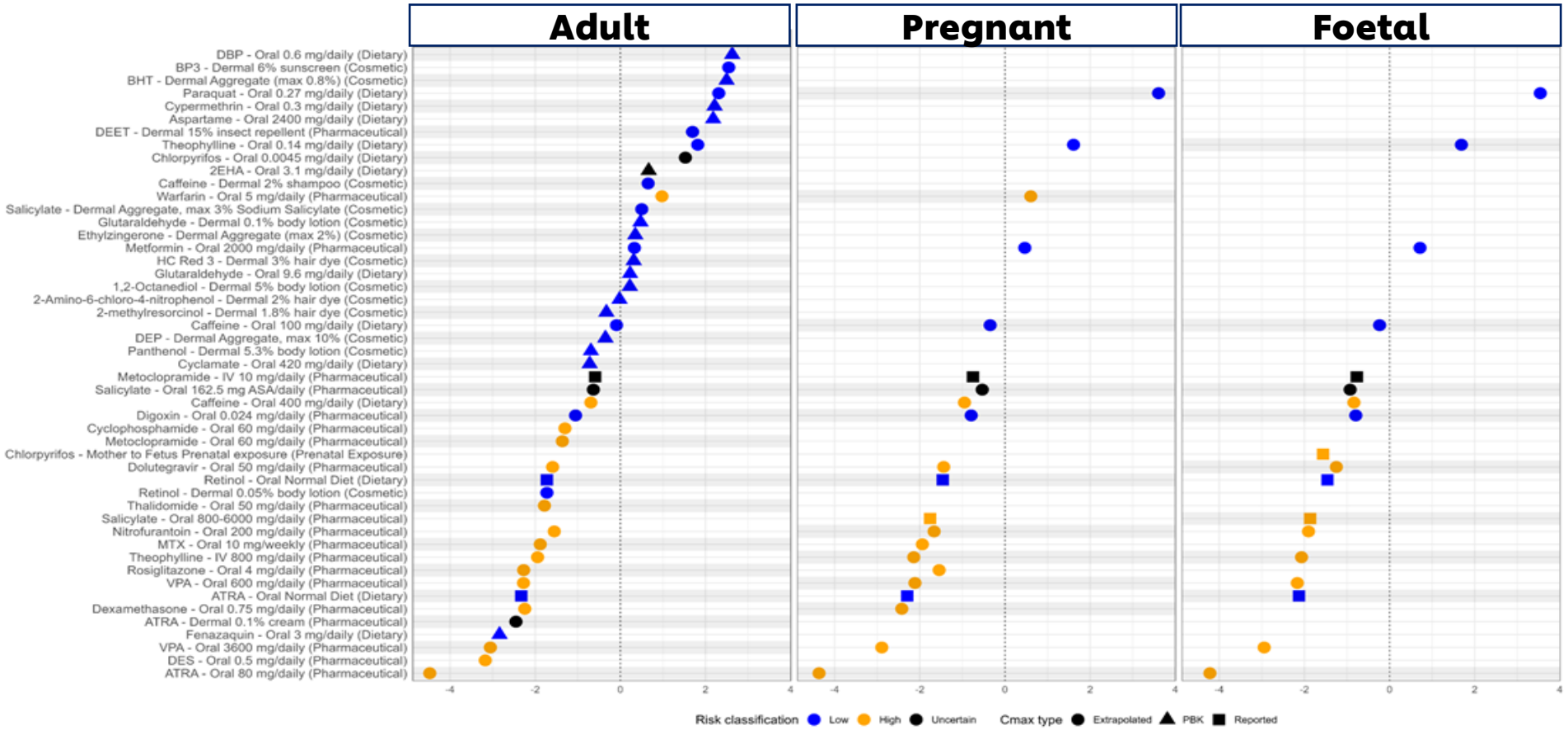
Integrating DART Safety Assessment into Existing NGRA Framework:



An NGRA framework with additional NAMs relevant for DART endpoints. First evaluation paper published (Muller et al., 2025)

Rajagopal et al. Frontiers in Toxicology, Volume 4, March 2022,

The DART framework is protective for most high-risk scenarios when using a BER threshold of 1



- 16 of the 17 high risk exposure scenarios, as determined by traditional risk assessment methods, are identified as uncertain risk in our NGRA approach (yellow, BER<1)
- 17 of the 27 low risk exposure scenarios are identified as well in the NGRA framework as low risk using our framework (blue, BER >1).

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Unilever

Application of NGRA to occupational safety assessment – challenges…

- Simultaneous exposure over multiple routes (dermal and inhalation) and limited biomonitoring data to calibrate PBK models.
- Different exposure estimation models.
- Large number of scenarios to consider (factory, professional, cleaning etc).
- Complex supply chains and ways of working under worker safety regulations (lead registrant/confidential information).

Perceived industry challenges for uptake of occupational NGRA

↑ Complexity ↑ Resource

↑ Uncertainty ↓ Confidence

↓ Regulatory acceptance

↑ Conservatism

Case studies needed to improve confidence of chemical sector with NGRA and to address worker safety specific challenges that make its uptake more challenging from a (non) technical perspective.


Regulatory Toxicology and Pharmacology 147 (2024) 105557

Contents lists available at ScienceDirect

Regulatory Toxicology and Pharmacology

journal homepage: www.elsevier.com/locate/yrtph

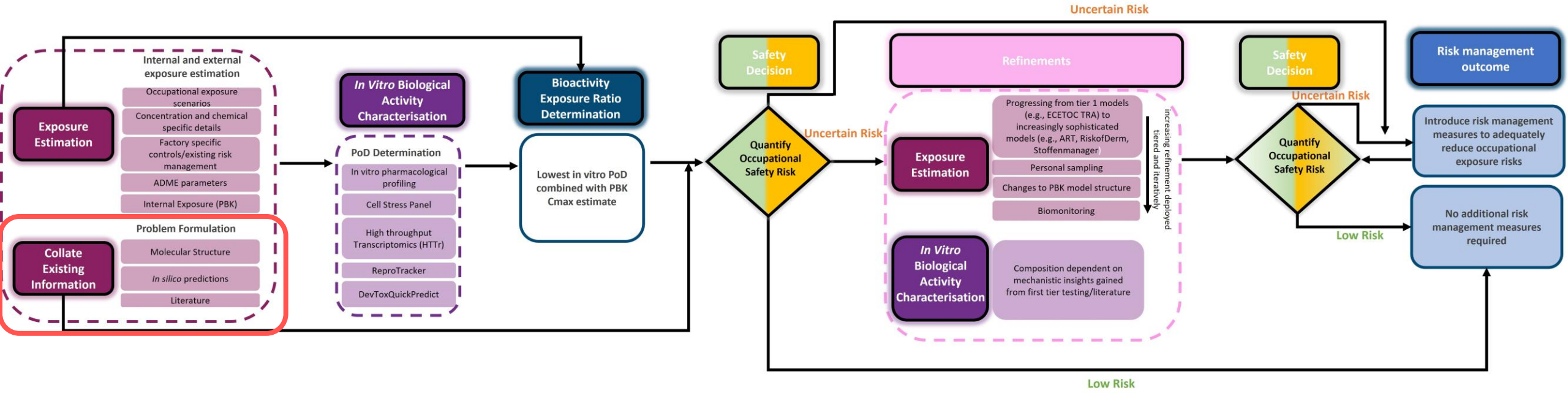
ELSEVIER

The last resort requirement under REACH: From principle to practice

Donna S. Macmillan [a,*], Anders Bergqvist [b], Eleanor Burgess-Allen [c], Ian Callan [d], James Dawick [d], Benjamin Carrick [e], Graham Ellis [f], Roberto Ferro [g], Katy Goyak [h], Chantal Smulders [i], Ricky A. Stackhouse [j], Espe Troyano [k], Carl Westmoreland [l], Blanca Serrano Ramón [m], Vanessa Rocha [n], Xiaoling Zhang [k]

"there is a fear, or assumption, that non-animal methods will be rejected by regulators, borne out of experience that they must provide information directly equivalent to that of animal tests."

Problem formulation

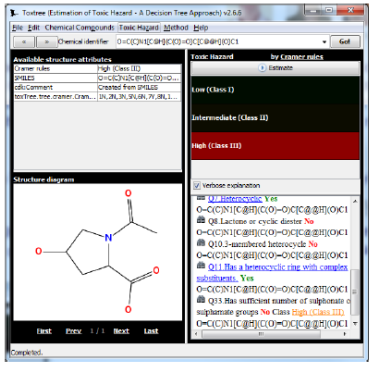


Wood *et al.*, (2024)

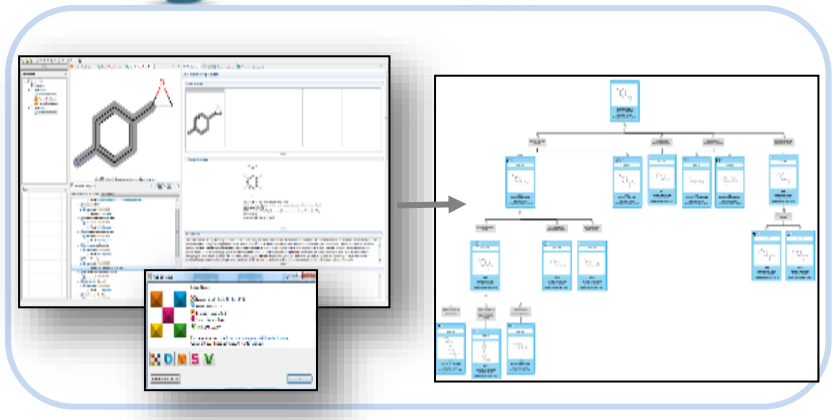
Problem formulation, *in silico* predictions and literature data

- Sodium-2-hydroxyethane sulfonate (SI) is widely used in the manufacture of alkyl isethionate surfactants.
- Historical toxicology studies: 90-day oral (NOAEL: 200 mg/kg bw/day) and developmental toxicity (rats) (NOAEL: >1000 mg/kg bw/day).
  - Comprehensive *in silico* profiling performed - Lack of any concerns.

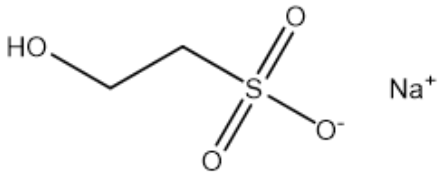
ToxTree



Derek nexus Meteor nexus

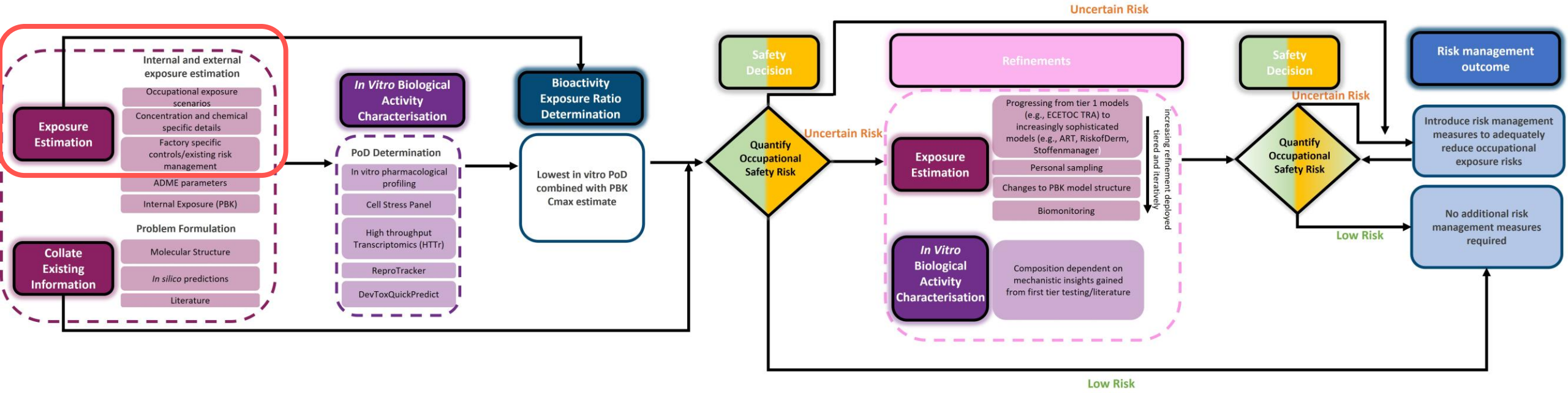


OECD QSAR TOOLBOX



SMILES	Biotransformation Name	Phase	General	ED		DART			Carcinogenicity		Genotoxicity				Irritation	Protein Binding	Chromosome Damage	DNA Binding
			Derek Nexus	*OPERA*	*VEGA*	*Derek Nexus*	*VEGA*	*OECD QSAR Toolbox*	*Derek Nexus*	*OECD QSAR Toolbx*	*Derek Nexus*	OECD QSAR Toolbox	VEGA	TIMES	*Derek Nexus*	*OECD QSAR Toolbox*	*VEGA*	*OECD QSAR Toolbox*
OCCS(O)(=O)=O	SI parent	N/A	N	N	N	N	N	N	N	N	N	N	N*	N	N	N	N	N
OC(CS(O)(=O)=O)=O	Oxidation of Primary Alcohols	Phase I	N			N			N		N			N	N			
OC1C(OCCS(O)(=O)=O)OC(C(O)C1O)C(O)=O	Glucuronidation of Primary and Secondary Aliphatic and Benzylic Alcohols	Phase II	N			N			N		N			N	N			
OS(OCCS(O)(=O)=O)(=O)=O	O-Sulphonation of Aliphatic Alcohols	Phase II	N			N			N		N			N	N			

Exposure assessment – external:



External exposure assessment:

- Life cycle assessment performed to identify relevant scenarios of use (process categories/PROCs).

- From these PROCs, exposures are typically estimated using variety of modelling software packages (e.g., ECETOC TRA, ART etc).

- Although worker exposure to SI occurs from a limited number of scenarios, approach can still be followed for more complex supply chains.

- External exposure estimates serve as inputs to SI specific PBK model.

PROC number:	Description:
PROC 1	Chemical production or refinery in closed process without likelihood of exposure or processes with equivalent containment conditions.
PROC 2	Chemical production or refinery in closed continuous process with occasional controlled exposure or processes with equivalent containment conditions
PROC 3	Manufacture or formulation in the chemical industry in closed batch processes with occasional controlled exposure or processes with equivalent containment condition
PROC 4	Chemical production where opportunity for exposure arises
PROC 5	Mixing or blending in batch processes
PROC 7	Industrial spraying
PROC 8a	Transfer of substance or mixture (charging and discharging) at non-dedicated facilities
PROC 8b	Transfer of substance or mixture (charging and discharging) at dedicated facilities
PROC 9	Transfer of substance or mixture into small containers (dedicated filling line, including weighing)
PROC 13	Treatment of articles by dipping and pouring
PROC 14	Tabletting, compression, extrusion, pelletisation, granulation
PROC 15	Use as laboratory reagent
PROC 21	Low energy manipulation and handling of substances bound in/on materials or articles
PROC 28	Manual maintenance (cleaning and repair) of machinery

Exposure Scenario	PROC 1	PROC 2	PROC 3	PROC 4	PROC 5	PROC 7	PROC 8a	PROC 8b	PROC 9	PROC 13	PROC 14	PROC 15	PROC 21	PROC 28
Manufacture of substance	☑	☑	☑					☑				☑		☑
Use as Intermediate	☑	☑	☑					☑	☑			☑		☑
Formulation	☑	☑	☑	☑	☑	☑	☑	☑	☑		☑	☑		
Repacking		☑						☑						
Use in Printing inks							☑			☑			☑	
Use as processing aid	☑	☑	☑	☑			☑	☑						
Service Life of fabrics													☑	

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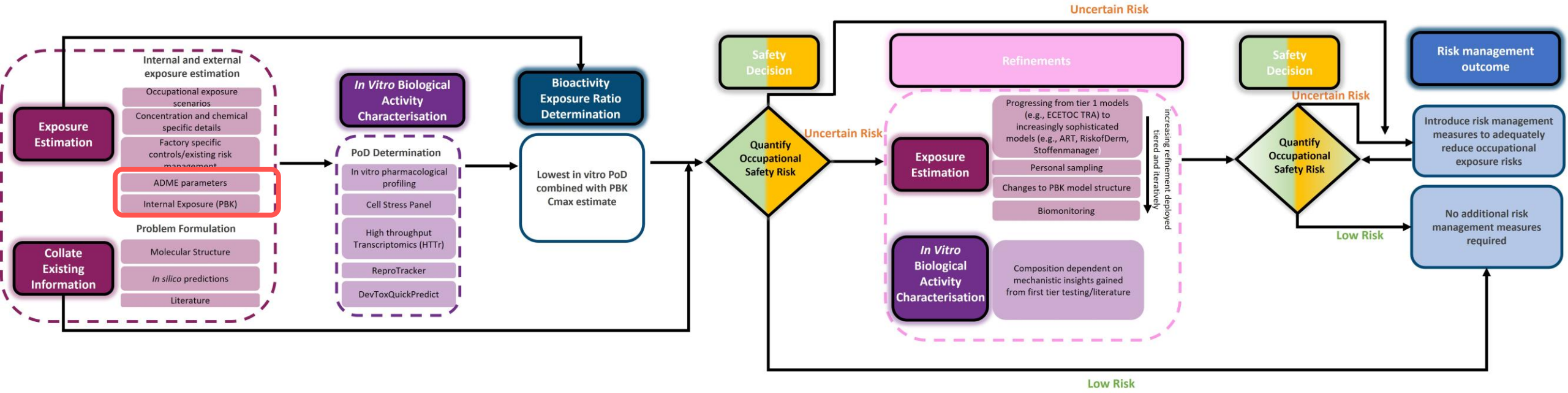
Exposure assessment – internal:



Internal exposure assessment - PBK

- Worst-case exposures were selected by consultant using simple procedure.
- Procedure converts inhalation and dermal exposures into an intravenous infusion.

Worker contributing scenario	Dermal exposure estimate	Inhalation exposure estimate	Max total time per day (TT)	Duration per occasion	Frequency	Exposure rate dermal	Exposure rate inhalation	Rate of systemic exposure from dermal	Rate of systemic exposure from inhalation	Total systemic exposure rate	Total dose/day	GastroPlus infusion dose/occasion
PROC 8b 'Transfer into drums – indoor'	mg/kg bw/day	mg/m^3	h	h	per day	mg/h	mg/h	mg/h	mg/h	mg/h	mg	mg
	0.034	0.38	8	8	1	0.26	0.47	0.00043	0.47	0.47	3.75	3.75

Step 1: Conversion of dermal exposure estimate to dermal exposure rate

Inputs: Duration of exposure and bodyweight

Output: mg/h

Step 2: Conversion of inhalation exposure estimate to inhalation exposure rate

Inputs: Duration of exposure and volume of air intake/worker

Output: mg/h

Step 3: Accounting for dermal bioavailability for dermal exposure:

Input: dermal exposure rate * dermal bioavailability

Output: mg/h

Step 4: Accounting for inhalation bioavailability** for inhalation exposures:

Input: Inhalation exposure rate * inhalation bioavailability

Output: mg/h

Step 5: Total aggregate exposure (inhalation + dermal)

Input: Altered inhalation exposure rate + altered dermal exposure rate

Output: mg/h

Step 6: Total dose/day

Input: Aggregate exposure rate multiplied by duration of exposure

Output: mg/day

Uncertainty table – inhalation bioavailability in tier 1 NGRA

Exposure assessment input	Tier 1 strategy	Impact on risk assessment	Capability need
Inhalation bioavailability	**Treated as 100%**	**↓↓ Real value likely to be much lower**	**Inhalation bioavailability models (factory relevant)**

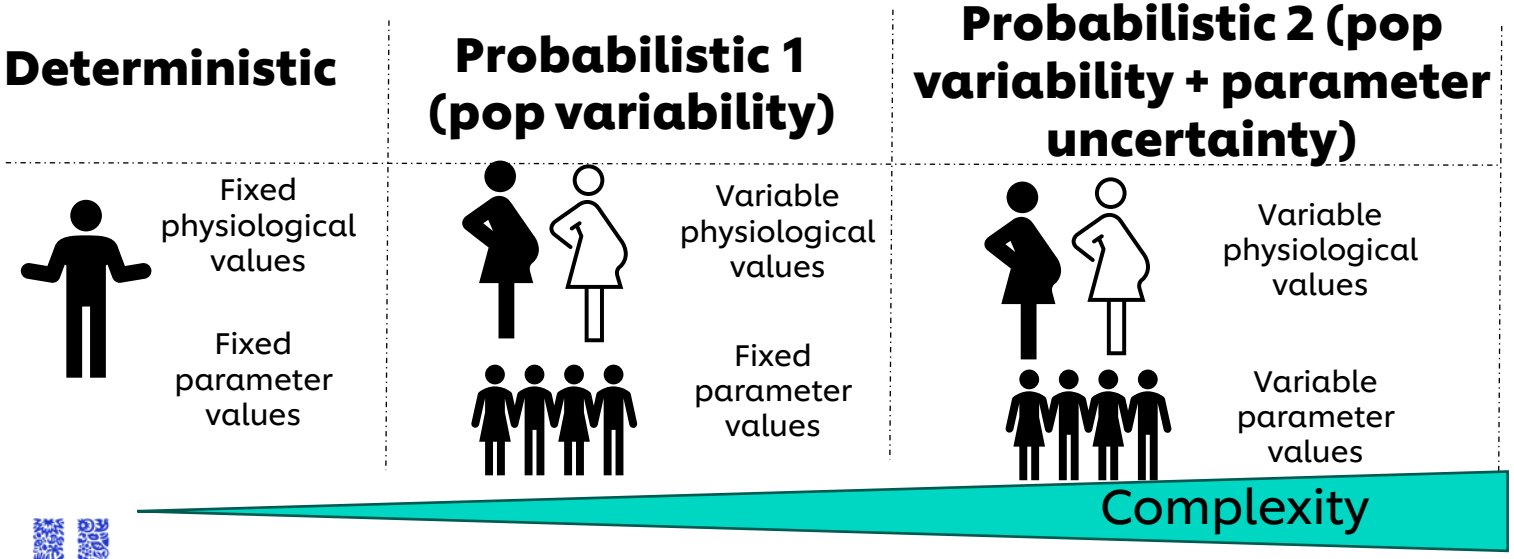
Procedure is described in detail in Wood et al (2024)

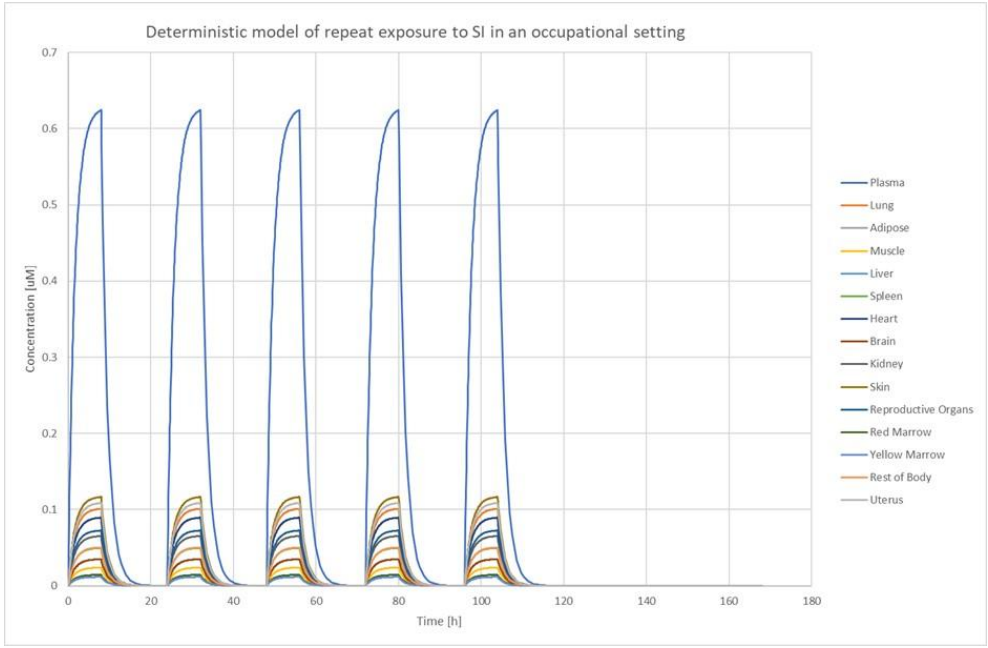
Internal exposure assessment - PBK

- 3 PBK simulation types – pregnant individual, worker and pregnant population.
- Models built using SI specific ADME data, e.g., hepatic metabolism using standard protocols.
- Probabilistic models - ranges for uncertain parameters (e.g., fraction unbound)/variable population parameters (e.g., blood flows).

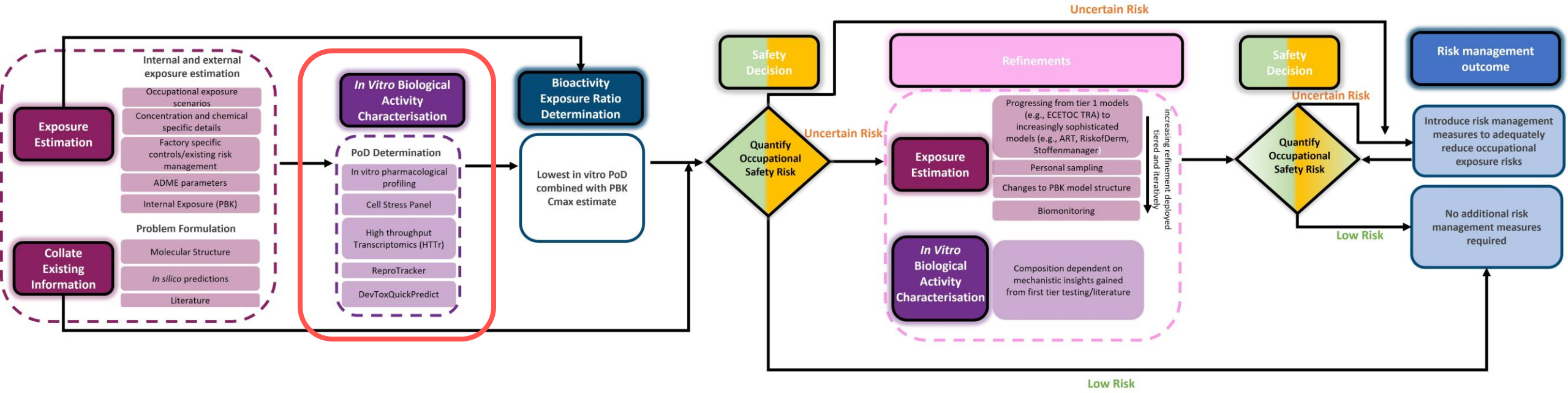
PBK simulation	C_{max} (µM)	Mean C_{max} (µM)	95th percentile C_{max} (µM)
Single person, deterministic	0.62	-	-
General workforce, probabilistic	-	0.61	0.74
Pregnant population, probabilistic	-	0.58	0.80

PBK types



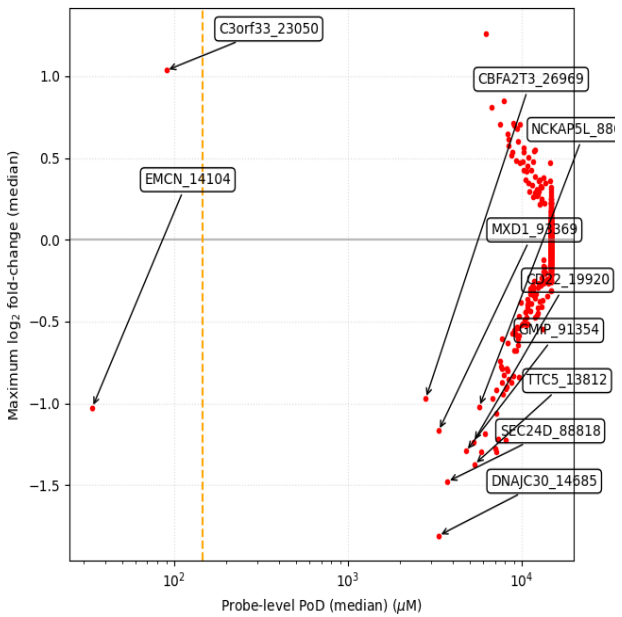


In Vitro Biological Activity Characterisation

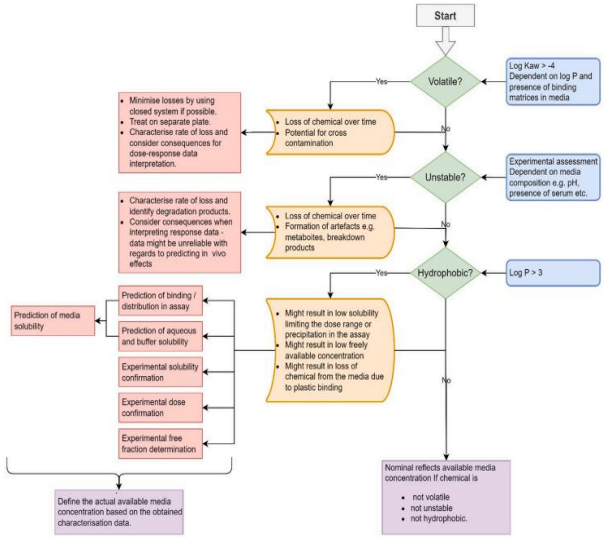


Limited bioactivity across 5 NAM assays:

- SI showed limited bioactivity across all assays.
- Lowest PoD - transcriptomics (MCF-7 cell line), based on a single probe significantly more sensitive than others.
- Some deviation from nominal concentration was observed in dose-confirmation assays due to a dosing error. PoD adjusted based on achieved concentrations to increase confidence in QIVIVE.
- **Final PoD taken forward = 104 µM**.



Workflow for in vitro disposition data needs



Nicol et al (2024).

Platform	CSP (Global PoD)	*IPP*	HTTr (MCF-7) (BIFROST)	HTTr (HepG2) (BIFROST)	HTTr (HepaRG) (BIFROST)	HTTr (MCF-7) (BMDExpress)	HTTr (HepG2) (BMDExpress)	HTTr (HepaRG) (BMDExpress)	Stemina/ devTOX quickPredict	Reprotracker
PoD (µM) (Nominal)	7300	>100	150	2500	1200	2860	4210	1040	>1000	>1000
Correction factor based on dose-confirmation study (%)	69.1%	Not determined	69.1%	69.1%	69.1%	69.1%	69.1%	69.1%	None necessary	Not determined
Corrected PoD (µM)	5044	>100	104	1728	829	1976	2909	719	>1000	>1000

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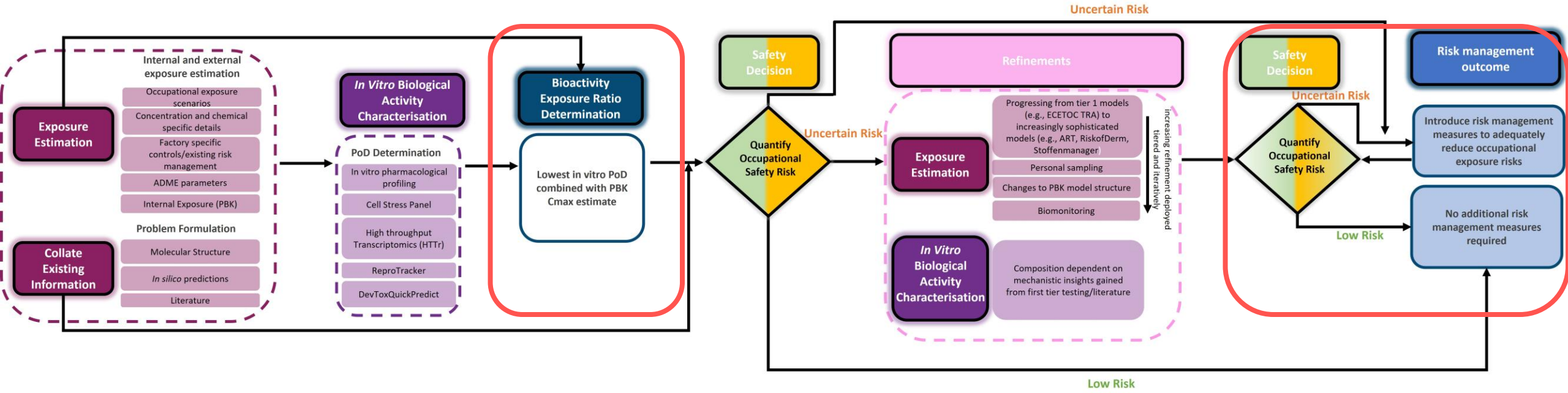
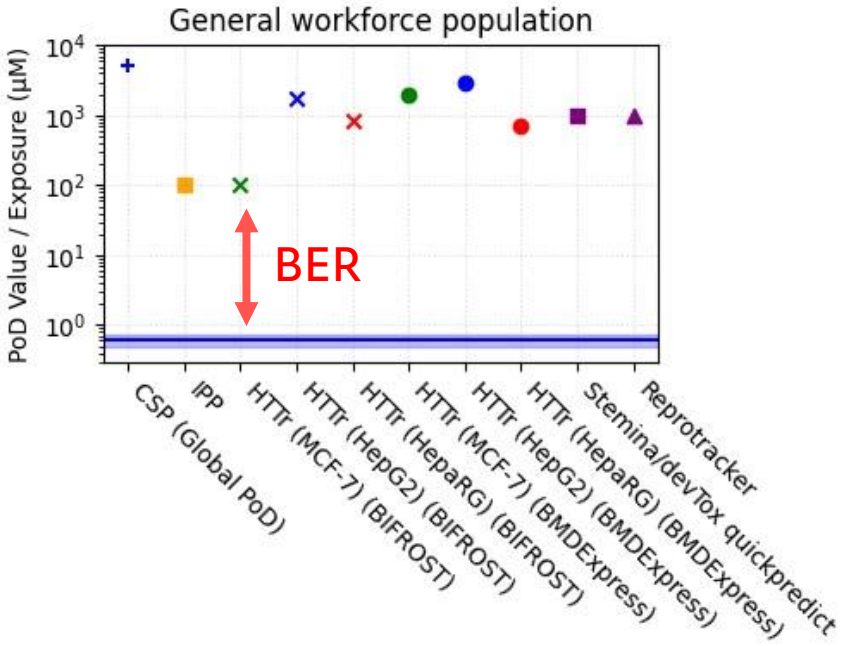
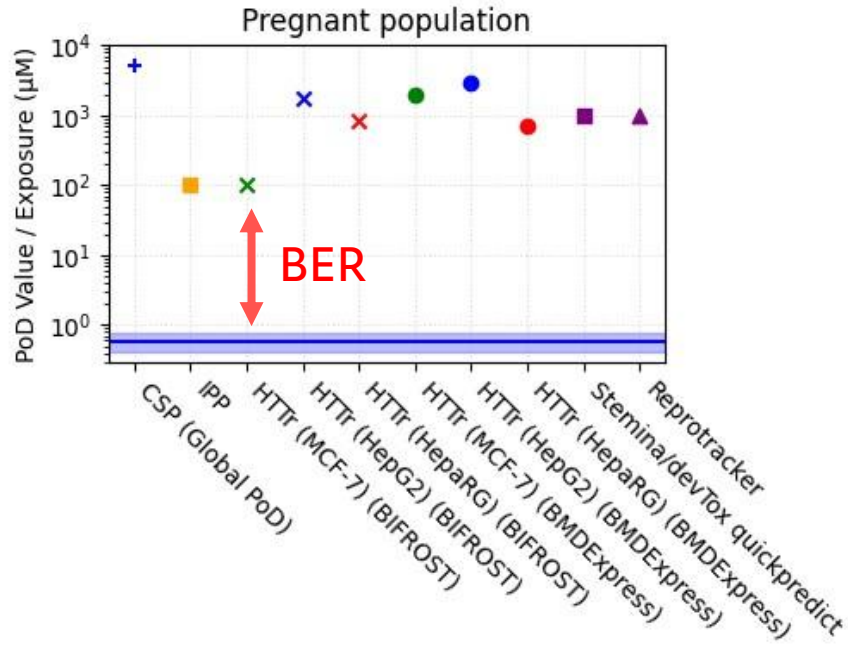
Bioactivity Exposure Ratio Determination and Safety Decision



Bioactivity Exposure Ratio Determination and Safety Decision

- Lowest PoD compared with exposure estimates.
- Most conservative BER (calculated from lowest PoD and 95th percentile pregnant population Cmax) was 130.
- In combination with existing data and lack of *in silico* alerts, current occupational exposures to SI are a low risk.
- Decision consistent with one that could be made using historical animal data (RCRs <1).





Route	Type of effect	Risk characterisation type	DNEL	PROC 8B Exposure estimate (ECETOC TRA)	RCR (ECETOC TRA)	Worst-case BER (ECETOC TRA)
Inhalation	Systemic effects - long term	Quantitative	4.9 mg/m3	0.38 mg/m3	0.078	130
Dermal	Systemic effects - long term	Quantitative	294 mg/kg bw/day	0.034 mg/kg bw/day	<0.001	
Combined routes, systemic long term					0.078	

Wrap up

For SI:

- Limited bioactivity across a broad range of bioactivity assays. Consistent with in silico profiling results and existing knowledge on the substance.
- Current occupational exposures (and any RMM already in place) is sufficient for protection of workers.
- Performance of additional animal testing would not provide any human health benefit.

General:

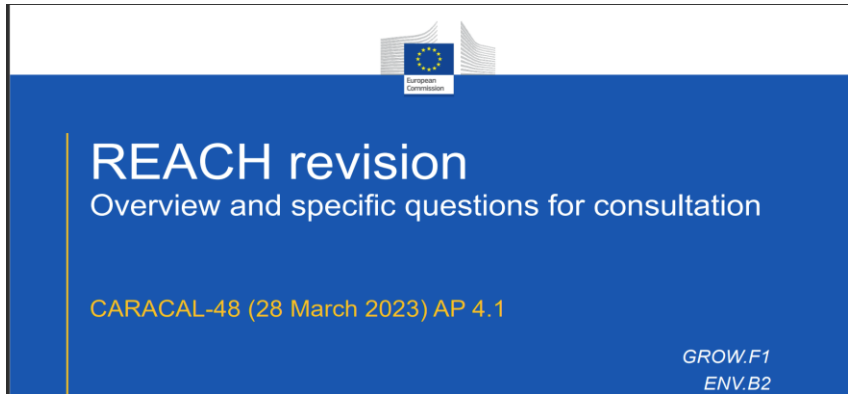
- Current lack of published examples of application of NGRA to worker safety. Framework developed here includes multiple options for refinement and is applicable to large subset of substances to which worker exposure occurs.
- Simple procedure to convert external inhalation/dermal exposures to infusion dose can be used by consultants to manage feasibility of PBK modelling and NGRA under REACH WoW.
- NGRA frameworks such as this can be implemented to address shortcomings of tonnage driven testing requirements.

Looking to the future…

- EU roadmap towards phasing out animal testing is targeting all relevant pieces of legislation, including worker safety.
- Greater emphasis of non-animal methods (in guidance and legislation) expected as a result of roadmap actions and from REACH revision.

Important points:

- Lifecycle management improvements are needed by the chemical industry.
- Exposure estimation module builds layer on layer of conservatism (external > internal) - **Tiering!**



Acknowledgements:

NGRA (especially this one) is a multidisciplinary exercise requiring the involvement of a multitude of individuals across a broad range of expertise areas.

- Unilever safety scientists: Richard Cubberley, Matt Dent, Jade Houghton, Predrag Kukic, Sophie Malcomber, Sue Martin, Beate Nicol, Joe Reynolds, Gordon Riley, Sharon Scott, Carl Westmoreland, Mesha Williams, Kathryn Wolton
- Clariant: Catherine Breffa, Joachim Eichhorn, Fabian Grimm, MoungSook Lee
- Leuna Vantage: Caroline Chaine, Tristan Zellman,
- ERM: Willemien Wieland, Colin Smith
- Bibra: Chris Waine, Dan Threlfall
- Vitis regulatory: Peter Sladen, Mike Crookes
- The numerous CROs where data is generated (Charles River, Toxys, Cyprotex, Bioclavis, Stemina, Eurofins, Pharmacelsus).

Contents of talk today form the basis of a paper titled "Next Generation Risk Assessment for Occupational Chemical Safety – a Real World Example with Sodium-2-hydroxyethane sulfonate" Published in Toxicology (August 2024) (https://doi.org/10.1016/j.tox.2024.153835)