

Where do we stand on risk assessment of MNPs for early life health?

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Quantifying MNP Risks: From Challenges to Solutions

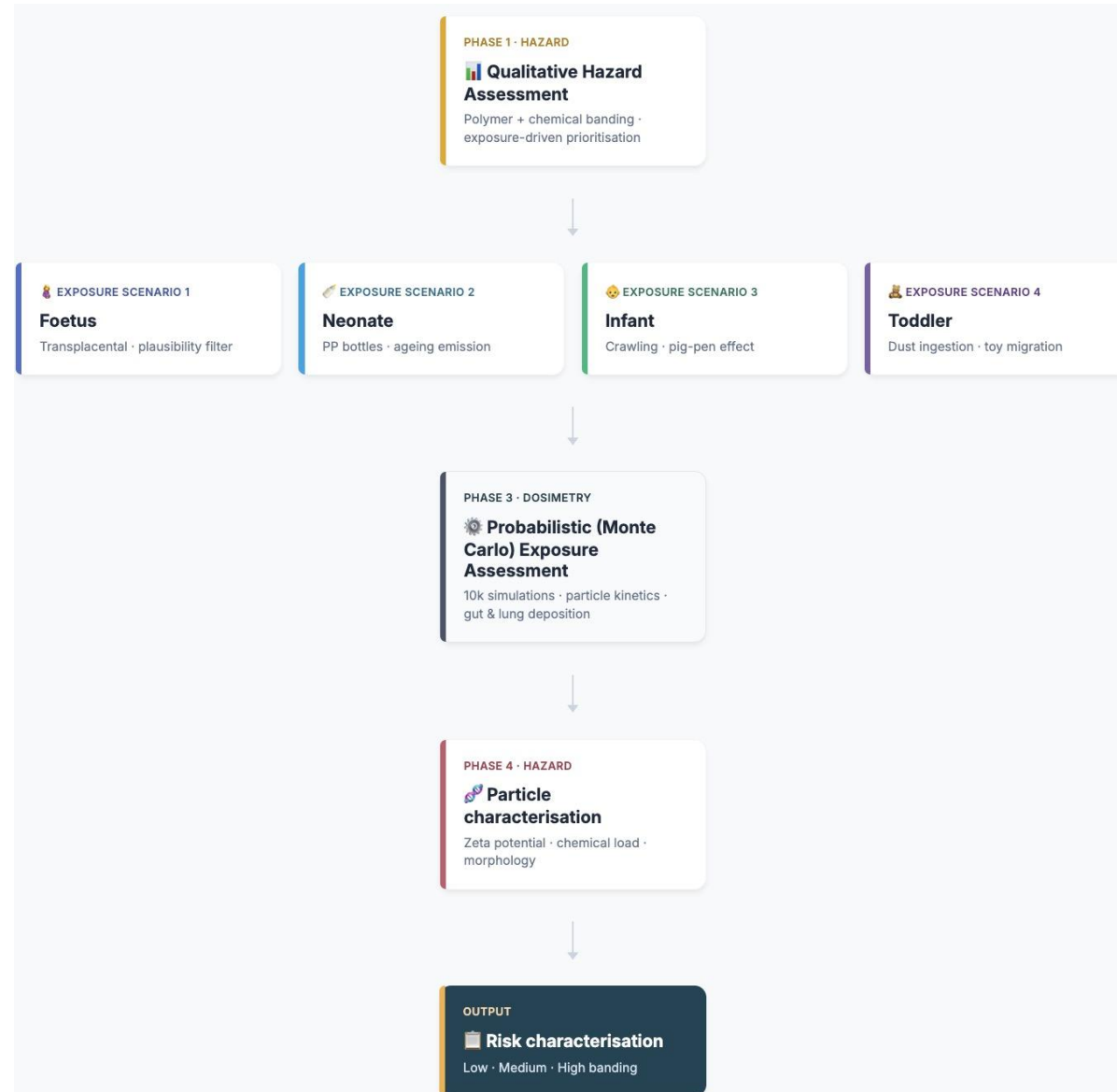
$$Risk \propto Hazard \times Exposure$$

- MNPs present unique risks due to their extreme diversity in **size, shape, and composition**.
- Currently we cannot quantify MNP hazards, but we can make **conservative assumptions** based on polymer composition.
- We can *reasonably* quantify external dose, systemic exposure and internal kinetics by **modelling** based on particle number, size distributions (PSD) and shape.
- **Exposure-led** risk assessment is a pragmatic starting point for vulnerable early-life stages.



The AURORA Risk Assessment Framework

- **Modular & Extensible**, tailored for early life stage risk assessments.
- **Conceptual database** collects standardised particle data.
- **Interactive Exposure Scenarios** available as web-based models.
- All parameters are **empirically anchored**.
- **Phased roadmap** targets current data gaps and critical uncertainties.



Particle / Hazard Characterisation

- Initially we apply a conservative **hazard-banding** approach.

Polymer & Chemical Profile

Source: [Christopher et al. 2024]

Polymer Toxicity

Priority / PRR (Score: 3) ▾

Chemical Vectoring (IAS/NIAS)

Endocrine Disruptors (+4) ▾



Particle / Hazard Characterisation

- Initially we apply a conservative **hazard-banding** approach.
- The **Particle Database** provides a central MNP data repository.

Particle Characterisation Database

Browse individual MNP particle records with physicochemical properties, surface chemistry, lifecycle metadata, and associated chemical loads.

[← Back to Hazard Database](#)

1 Recorded Particles	1 Polymer Types	1 Morphologies	2 Chemical Loads
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Polymer Type: PVC (1.4 g/cm³) Morphology: All morphologies Origin: All origins Search (polymer, notes, ref material): Type to search... [Clear Filters](#)

ID	Polymer	Size (major)	Morphology	Origin	Weathering	Detection	Chem. Loads
4	PVC	80,000 nm	Fragment	Secondary	4/5	μRaman spectroscopy	2

Physicochemical Identity

Polymer Type	PVC
Size (major axis)	80,000 nm
Size (minor axis)	45,000 nm
Morphology	Fragment
Crystallinity	10%
Surface Area	0.6 m ² /g
Refractive Index	1.54

Surface & Interfacial Chemistry

Zeta Potential	-8 mV
Hydrophobicity (Log D)	4.1
Functionalisation	Chalky surface from UV degradation; residual PVC oligomers.
Protein Corona	Yes

Lifecycle & Degradation

Origin	Secondary
Weathering State	4/5
Degradability Notes	PVC is highly persistent; additives may leach under acidic conditions (e.g. stomach).

Utility Metadata

Density	1.4 g/cm ³
Reference Material	—
Detection Method	μRaman spectroscopy
Notes	Weathered PVC construction material



Particle / Hazard Characterisation

- Initially we apply a conservative **hazard-banding** approach.
- The **Particle Database** provides a central MNP data repository.
- Particles can be grouped into reference **Exposure Matrices** (e.g. dusts, water, foodstuffs).
- Facilitates modelling of **cellular interactions, agglomeration, protein corona, and 'Trojan Horse' effects.**



Exposure Matrix Database

Browse reference environmental mixtures (house dust, food, water, etc.) with their particle composition, abundances, size bins, and size distributions.

[← Back to Hazard Database](#)

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Exposure Matrices

12

Composition Entries

6

Size Distributions

Processed seafood

Food Europe (North Atlantic fisheries)

A reference exposure matrix representing MNP contamination in processed fish products. Assumes contamination from packaging (PE films), processing equipment (PET, Nylon fibres), and environmental uptake by fish (PE fragments).

Composition (3 particle types) • 1 size distribution

Polymer	Morphology	Size (nm)	Abundance	Size Bin (nm)	Size Dists.										
PE	Fragment	50,000	50.0%	10,000 – 80,000	<table><thead><tr><th>Type</th><th>Param 1</th><th>Param 2</th><th>Param 3</th><th>Bins</th></tr></thead><tbody><tr><td>Lognormal</td><td>40000</td><td>20000</td><td>—</td><td>100</td></tr></tbody></table>	Type	Param 1	Param 2	Param 3	Bins	Lognormal	40000	20000	—	100
Type	Param 1	Param 2	Param 3	Bins											
Lognormal	40000	20000	—	100											
PET	Fibre	120,000	30.0%	50,000 – 150,000	—										
Nylon-6	Fibre	60,000	20.0%	20,000 – 100,000	—										

Demonstration dataset; actual contamination levels vary widely.

Bottled drinking water (mixed sources)

Water Global

Reference matrix for MNP contamination in commercially available bottled water. Includes particles from bottle shedding (PP, PE), source water contamination, and atmospheric fallout during bottling.

Composition (3 particle types) • 2 size distributions




Polymer	Morphology	Size (nm)	Abundance	Size Bin (nm)	Size Dists.										
PE	Bead	1,500	40.0%	500 – 5,000	<table><thead><tr><th>Type</th><th>Param 1</th><th>Param 2</th><th>Param 3</th><th>Bins</th></tr></thead><tbody><tr><td>Lognormal</td><td>40000</td><td>20000</td><td>—</td><td>100</td></tr></tbody></table>	Type	Param 1	Param 2	Param 3	Bins	Lognormal	40000	20000	—	100
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Early-Life Stage Exposure Scenarios

- 4 proof-of-concept scenarios have been modelled.
- Each model addresses unique exposure pathways per life stage.

Scenario 1: Maternal / Foetal Exposure

Modelled Pathways

-  **Maternal Ingestion:** MNP uptake via food and water sources.
-  **Airway Deposition:** Systemic absorption following inhalation and mucociliary clearance
-  **Placental Translocation:** Direct transfer across the blood-placenta barrier.



Early-Life Stage Exposure Scenarios

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Scenario 2: Neonate (0-6 Months) Exposure

Feeding Risks

- 🗑️ **Bottle Shedding:** MNP release from Polypropylene (PP) feeding bottles.
- 🕒 **Bottle Ageing:** Increased particle release from repeated heating, sterilisation.
- 🛏️ **Crib Environment:** Resting inhalation within immediate sleep micro-areas.



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Scenario 3: Infant (6-12 Months) Exposure

Environmental Interaction

- 👤 **Crawling Activity:** Mechanical resuspension of floor-bound dust.
- 👤 **Hand-to-Mouth:** Oral uptake during exploratory behaviors.
- 🏠 **Dust Concentration:** High exposure density near floor levels.



2






Early-Life Stage Exposure Scenarios

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Scenario 4: Toddler (1-3 Years) Exposure

Dual Pathway Modeling

-  Dual Pathways: Combined modelling of dust ingestion and inhalation.
-  Toy Mouthing: Direct ingestion of MNPs from plastic toys. *Data poor**
-  Chemical Migration: Leaching of additives through saliva contact. **Methodological Placeholder**



How the Models Work

- Inputs are reference matrices and parameter ranges (e.g. breathing rates, water consumption)

Maternal & Foetal Exposure Model

Assess MNP exposure to a developing foetus during pregnancy.

[← Back](#) | [Documentation](#) →

Scientific Modelling Approach

Plausibility Filter (Empirically Anchored) ▼

Step 1 – External Maternal Dose – Particles Entering the Body

$$\text{External} = (\text{C}_{\text{dust}} \times \text{IR}_{\text{breath}} \times \text{Hrs}_{\text{in}}) + (\text{C}_{\text{water}} \times \text{IR}_{\text{water}}) + \text{Diet}$$

Step 2 – Maternal Systemic Dose (sampled across all routes with stochastic f_gut)

$$\text{Systemic}_{\text{maternal}} = \Sigma [\text{Inhalation} \times (\text{Pulm}_{\text{frac}} \times \text{Pulm}_{\text{Trans}} \times 1.2 + \text{MCC}_{\text{frac}} \times \text{f}_{\text{gut}} \times \text{Barrier}) + (\text{Water} + \text{Diet}) \times \text{f}_{\text{gut}} \times \text{Barrier}]$$

Step 3 – Placental Burden Filter (280-day accumulation, reject > limit)

$$\text{Placental}_{\text{burden}} = \Sigma(\text{Systemic} \times \text{f}_{\text{trap}}) \text{ over } 280 \text{ days} \rightarrow \text{Reject if } > \text{placental}_{\text{burden}}_{\text{limit}}$$

Step 4 – Foetal Dose (from surviving scenarios)

$$\text{Foetal} = \text{Systemic}_{\text{surviving}} \times \text{Beta}(1.1, 20)$$

Plausibility Filter (Recommended): Generates a pool of systemic dose scenarios from both ingestion (f_gut, user-defined triangular) and inhalation (pulmonary translocation from kinetic table + MCC → gut with f_gut). Calculates a theoretical placental burden (sum over 280 days with zero clearance), rejects scenarios exceeding a clinical limit (e.g., ~4000 particles/placenta), and calculates foetal dose from surviving scenarios via Beta(1.1, 20) foetal transfer.

1. Exposure Context

Select which reference exposure matrices apply to each exposure route. Each matrix defines the mixture of MNP types (polymer, size, morphology, and fractional abundance) that the model uses to compute composition-weighted dose and hazard scores. Matrices are loaded from the database – change a matrix composition in the database and the next simulation run automatically picks it up.

Inhalation Matrix

Source: [Zhang et al. 2021; Vianello et al. 2019]

Exposure matrix for inhaled dust

European Housedust Referent ▼

Drinking Water Matrix

Source: [Danopoulos et al. 2020]

Exposure matrix for ingested water

Bottled drinking water (mixed s ▼

Water – 4 particle types. Reference matrix

Dietary Matrix

Source: [Cox et al. 2019]

Exposure matrix for ingested food

Seafood - Mixed Sources ▼

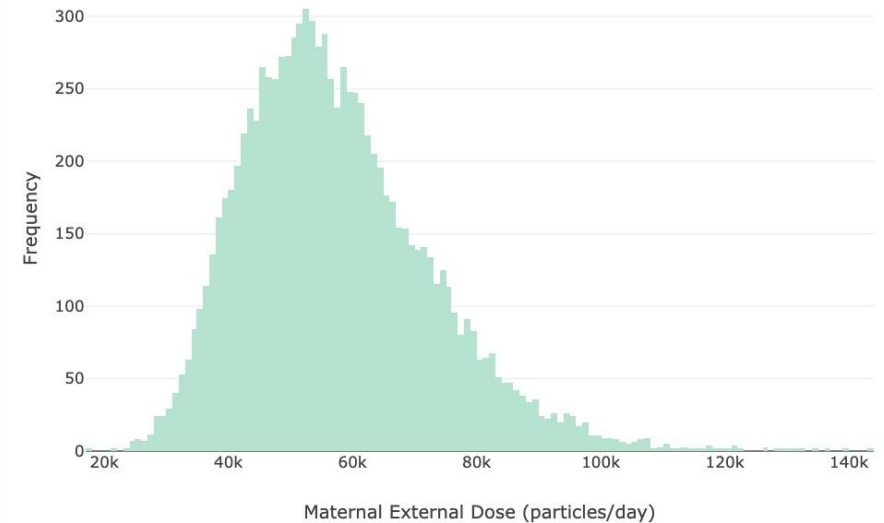
Food – 5 particle types. A reference



How the Models Work

- Inputs are reference matrices and parameter ranges (e.g. breathing rates, water consumption)
- The models simulate 10,000 'days in the life' to calculate **average** and **worst-case exposures**.

Maternal & Foetal Exposure Model Maternal & Foetal Exposure Report



Kinetic Profile

TARGET	P95 (PARTICLES/DAY)	MEAN (PARTICLES/DAY)
■ Foetal	4.73e+1	1.48e+1
■ Maternal Systemic	1.36e+2	9.11e+1
■ Maternal External	8.52e+4	5.75e+4

Kinetic Filter Efficiency (P50): **0.16%** (External → Maternal Systemic)

Placental Transfer Rate (P50): **10.32%** (Systemic → Foetal) Biologically Rejected: **85.8%** of simulated scenarios

Exposure matrix for inhaled dust

European Housedust Referent

Bottled drinking water (mixed s

Water — 4 particle types. Reference matrix

Seafood - Mixed Sources

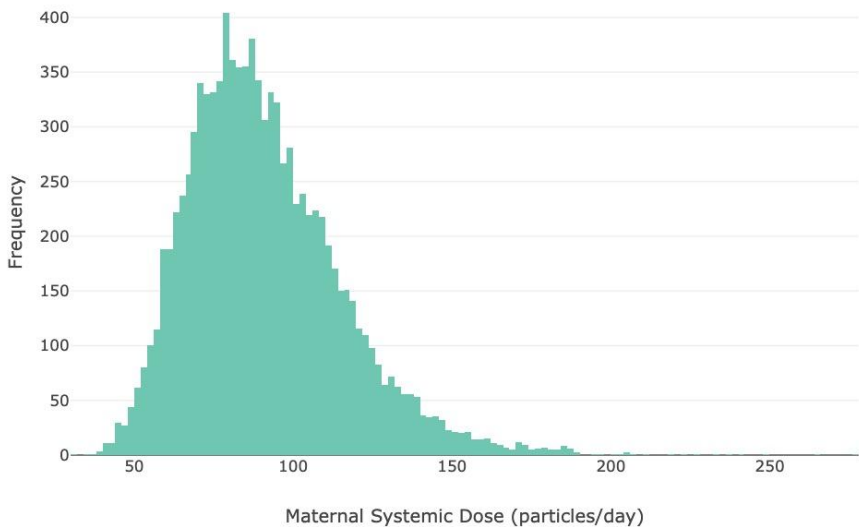
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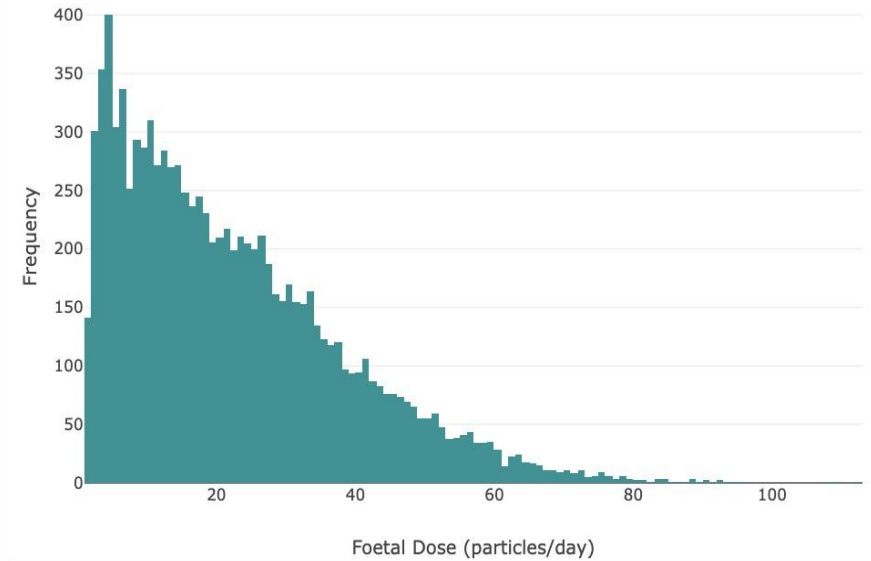
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Maternal & Foetal Exposure Model Maternal & Foetal Exposure Report



Kinetic Profile

TARGET	P95 (PARTICLES/DAY)	MEAN (PARTICLES/DAY)
■ Foetal	5.36e+1	2.23e+1
■ Maternal Systemic	1.37e+2	9.14e+1
■ Maternal External	8.56e+4	5.76e+4

Kinetic Filter Efficiency (P50): **0.16%** (External → Maternal Systemic)

Placental Transfer Rate (P50): **21.57%** (Systemic → Foetal)

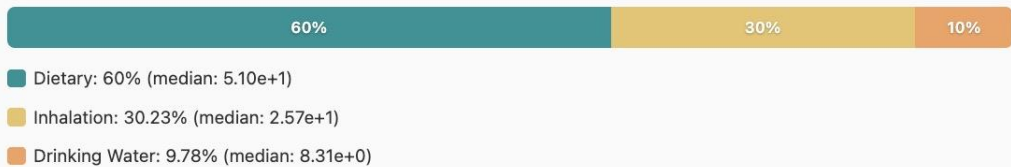


How the Models Work

- Inputs are reference matrices and parameter ranges (e.g. breathing rates, water consumption)
- The models simulate 10,000 'days in the life' to calculate **average** and **worst-case exposures**.
- Particle **size and morphology aware**, allows modelling of deposition & translocation kinetics.

Maternal & Foetal Exposure Model

Pathway Contribution Breakdown



Hazard Score

5 (Tier: Medium)

Polymer Toxicity:	Priority / PRR [x3]
Chemical Vectoring:	Metals/POPs/IAS [+2]
Size Modifier:	(+0)
Morphology Modifier:	(+0)

Total = 3 + 2 + 0 + 0 = 5

Risk Matrix

		Exposure - Final Target		
		Low	Medium	High
Hazard	High	Yellow	Red	Red
	Medium	Green	Yellow	Red
	Low	Green	Green	Yellow

Placental transfer rate (PTR): 22.0% (systemic + foetal)



How the Models Work

- Inputs are reference matrices and parameter ranges (e.g. breathing rates, water consumption)
- The models simulate 10,000 'days in the life' to calculate **average** and **worst-case exposures**.
- Particle **size and morphology aware**, allows modelling of deposition & translocation kinetics.
- Elucidation of **priority exposure pathways** (dust ingestion, feeding bottles).
- Risk (Hazard x Exposure) indicated in a 3x3 **Matrix**.

Maternal & Foetal Exposure Model

Combined Particle Size Distribution (all matrices)



Aggregated across 3 matrix(es) — total fractional abundance: 3.01

[Hide matrix composition details.](#)

Matrix	Particle	Polymer	Size Category	Morphology	Fraction
Inhalation	#2	PET	coarse_micro (120000 nm)	Fibre	10.0%
Inhalation	#5	PP	coarse_micro (75000 nm)	Fibre	6.0%
Inhalation	#1	PE	coarse_micro (50000 nm)	Fragment	4.3%
Inhalation	#6	Nylon-6	coarse_micro (60000 nm)	Fibre	3.3%
Inhalation	#8	PS	fine_micro (5000 nm)	Fragment	2.7%
Inhalation	#4	PVC	coarse_micro (80000 nm)	Fragment	2.3%
Inhalation	#11	PE	fine_nano (50 nm)	Fragment	1.7%
Inhalation	#13	PS	fine_nano (80 nm)	Sphere	1.3%
Inhalation	#15	PS	ultrafine_nano (20 nm)	Sphere	1.0%
Inhalation	#12	PET	submicron (100 nm)	Fibre	0.7%
Inhalation	#14	PP	submicron (150 nm)	Fibre	0.3%
Drinking Water	#7	PE	fine_micro (1500 nm)	Bead	11.7%
Drinking Water	#5	PP	coarse_micro (75000 nm)	Fibre	10.0%
Drinking Water	#3	PS	submicron (200 nm)	Sphere	8.3%
Drinking Water	#11	PE	fine_nano (50 nm)	Fragment	3.3%
Dietary	#1	PE	coarse_micro (50000 nm)	Fragment	15.0%
Dietary	#2	PET	coarse_micro (120000 nm)	Fibre	8.3%
Dietary	#6	Nylon-6	coarse_micro (60000 nm)	Fibre	6.0%
Dietary	#13	PS	fine_nano (80 nm)	Sphere	2.3%
Dietary	#11	PE	fine_nano (50 nm)	Fragment	1.7%

Hazard	High	Yellow	Light Green	Light Red
	Medium	Light Green	Yellow	Light Red
	Low	Light Green	Light Green	Yellow

Fractional transfer rate (FTR): 24.0% (systemic + foetal)



A Scalable Risk Assessment Framework

- Applies exposure models to derive **actionable risk mitigation strategies**.
- Delivers an infrastructure for **standardised MNP datasets**.
- Incentivises **high quality data generation**.
- Enforces scientific **transparency** that **confronts uncertainty**.
- Charts a **roadmap** to fully **quantitative** and **cumulative** risk assessments.
- Offers a clear **strategic direction** for researchers and policy makers.

Thank You...

