



Systems Approach to Environmental AMR Assessment & Management

SAAFE^{CRC}

Solving Antimicrobial Resistance in
Agribusiness, Food & Environments

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Disclosure Statement

Presenter: Nicholas J. Ashbolt / Claire Hayward

Disclosure:

We do not have any relevant financial or non-financial relationships with industry or commerce to disclose

Off-label Drug Use Disclosure:

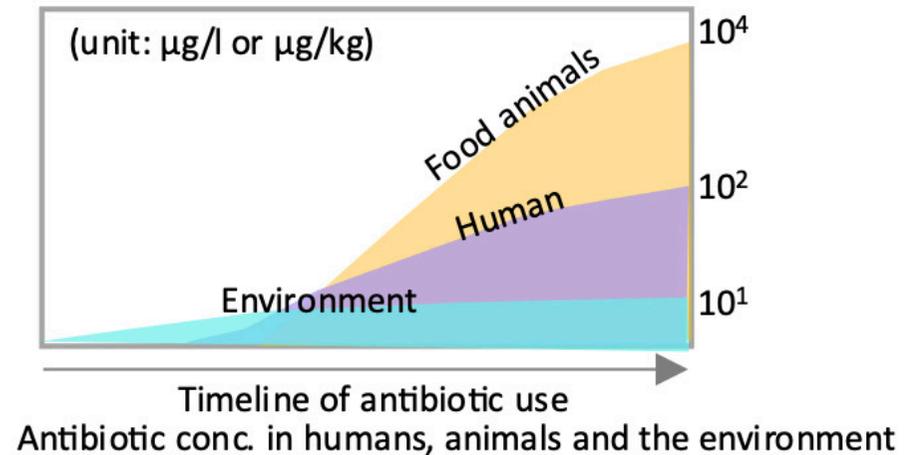
We will not discuss off label or investigational use of drugs



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Determinants of Environmental AMR

- Primary determinants:
 1. Chemical stressors that promote ARG transfer/selection
 2. ARGs and facilitators (mobile genetic elements, MGEs)
 3. Antimicrobial resistant microorganisms (ARMs)
- Beyond direct impacts on health and agriculture, antimicrobial use in production can create environmental AMR hotspots
 - Manure/soils and washdown ponds amplifying ARGs, MGEs and AMR microbial vectors – what we call **Hotspots**



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Project focus: Key Environmental AMR Hotspots & control point targets

- **Hotspots** are environmental zones where AMR spreads and amplifies, threatening drug efficacy.
 - Hospital and municipal effluents
 - Wastewater treatment plants
 - Biosolids and composts
 - Livestock manure & aquaculture
 - Feedstocks, soils & sediments

Project focus areas:

1. Framing the influence diagrams of the systems to be managed,
2. Methods and capacity building, and
3. Research gap filling and oversight knowledge transfer.

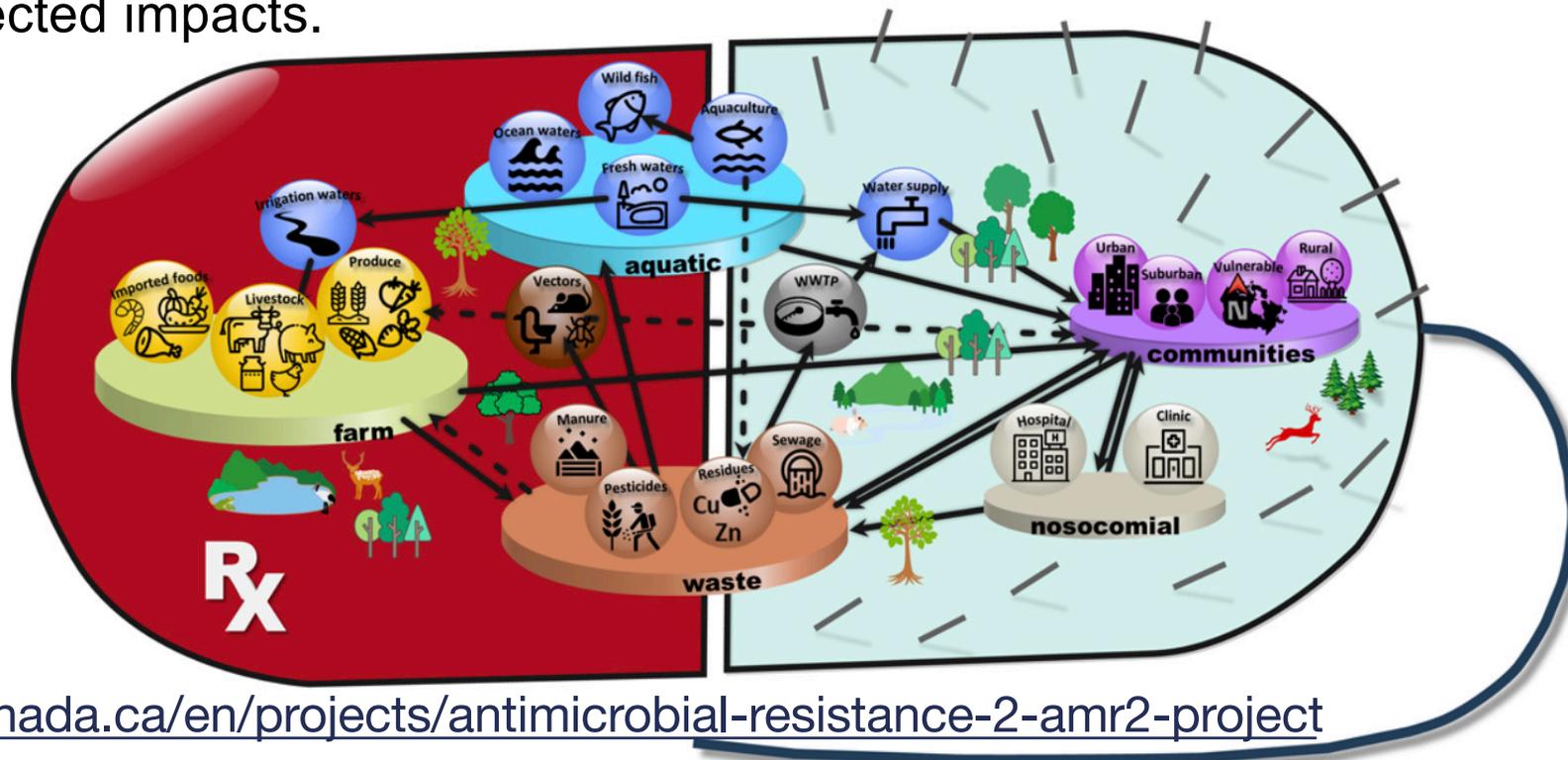


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Need for Systems Approach (to Manage AMR)

5

AMR management needs a systems approach - due to emergence, self-organisation, nonlinearity, and feedback loops, small changes can lead to large, unexpected impacts.



grdi.canada.ca/en/projects/antimicrobial-resistance-2-amr2-project

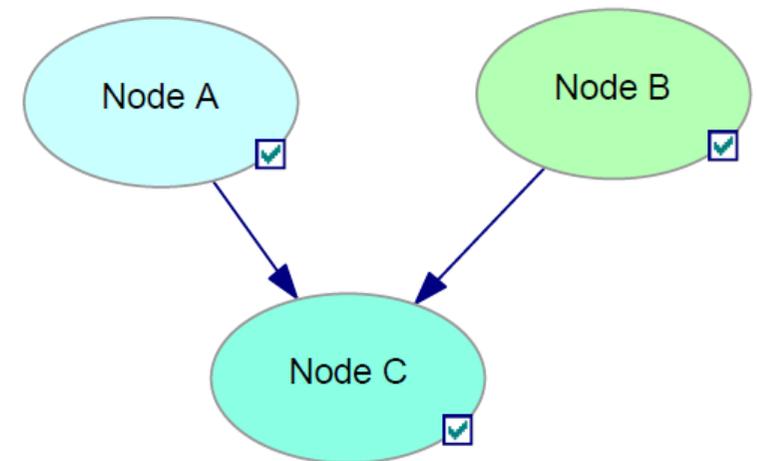


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Bayesian Networks (BNs)

A classic BN structure consists of:

- **Nodes:** Represent variables, which can be continuous, discrete, or categorical.
- **Arcs:** Arrows showing how one variable may influence another (i.e. causal or probabilistic relationships)



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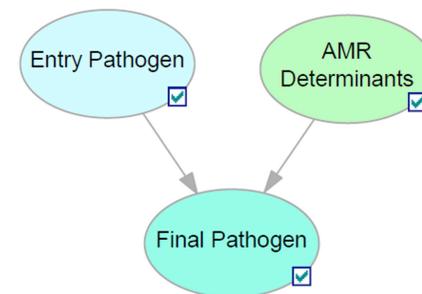
Example: Factors Influencing Environmental AMR associated with Pathogens (Hotspots)⁷

- **Nodes:**

- Entry Pathogens
- AMR Determinants (e.g. resistance genes, mobile genetic elements, chemicals facilitating horizontal gene transfer)
- Final Resistance Profile

- **Arcs illustrate causal links:**

- Entry Pathogen
 - AMR Determinants
- ⇒ Final AMR-Pathogen



For each hotspot

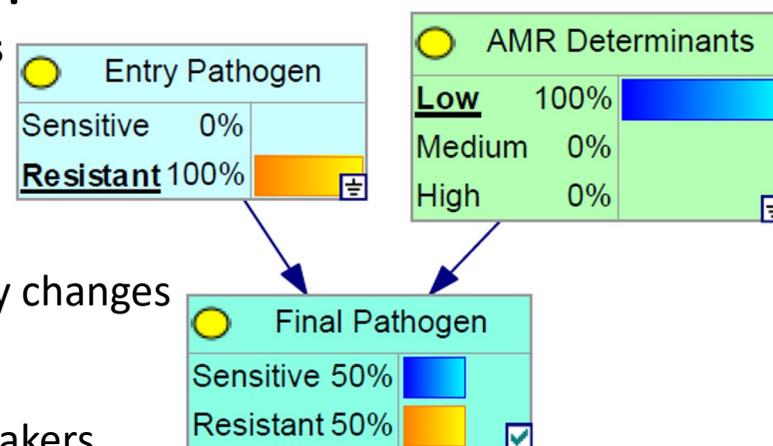


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SAAFE^{CRC} Bayesian Network Approach to Environmental AMR Risk Assessment

- We are developing a **Bayesian Network model** to:
 - Integrate complex AMR exposure pathways to ID **key hotspots**
 - Support **scenario testing and prioritization**
- Model incorporates:
 - Empirical data on **AMR pathogens** in environmental samples
 - **Predictive simulations** of management interventions or policy changes
- Designed as a **decision-support tool** for:
 - Public health, water utilities, agriculture, regulators, and policymakers

Scenario testing

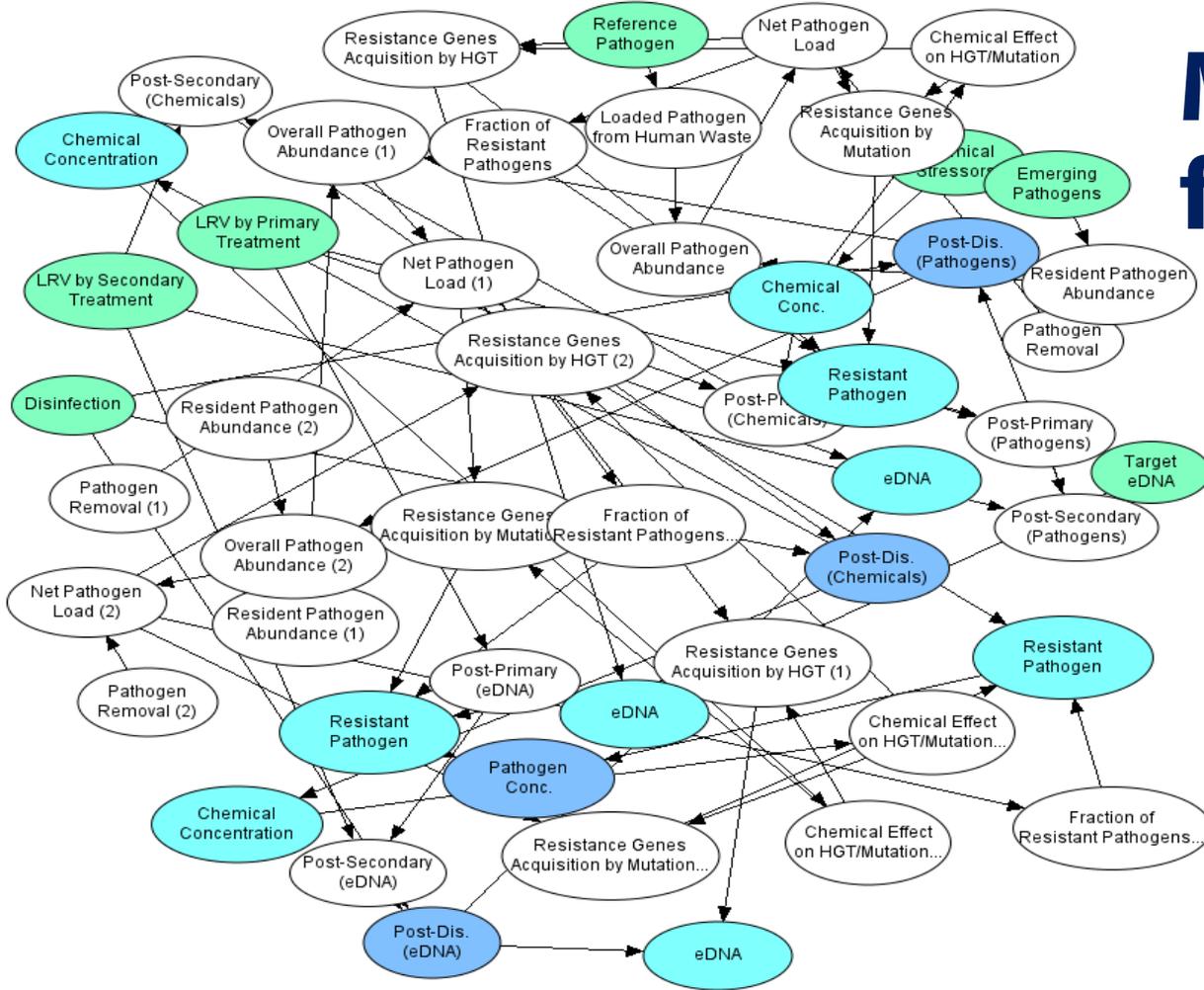


Goal: Enable evidence-based action to reduce environmental AMR risk for South Australian EPA & related industries



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Mapping Complexity for AMR Risks



Environmental AMR Causal-loop Diagram (CLD) from literature & industry engagement



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We Use an Object-Oriented Bayesian Network

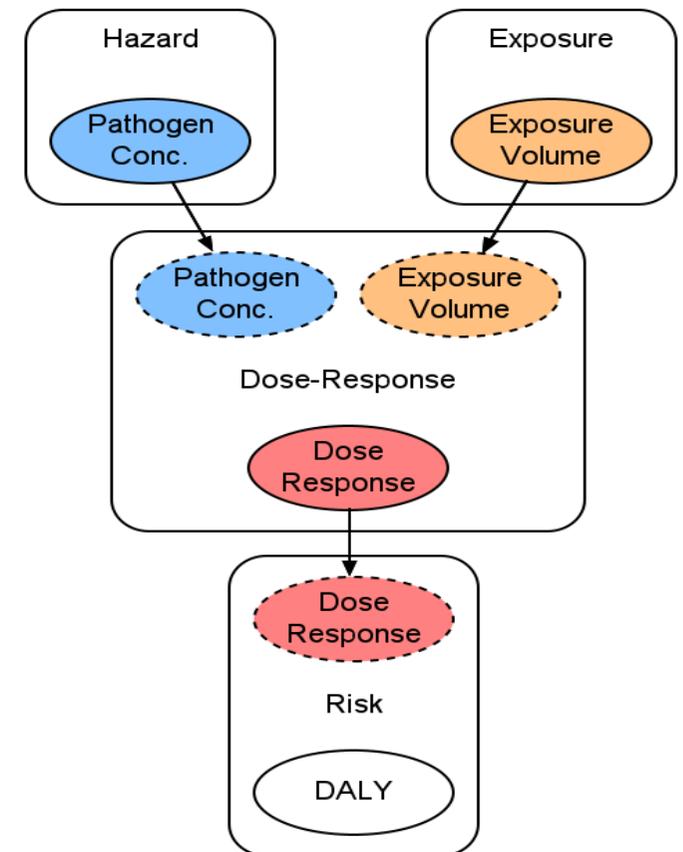
Modular structure

- Sub-models for different risk assessment stages

- Generic, easy to update

Input and output nodes

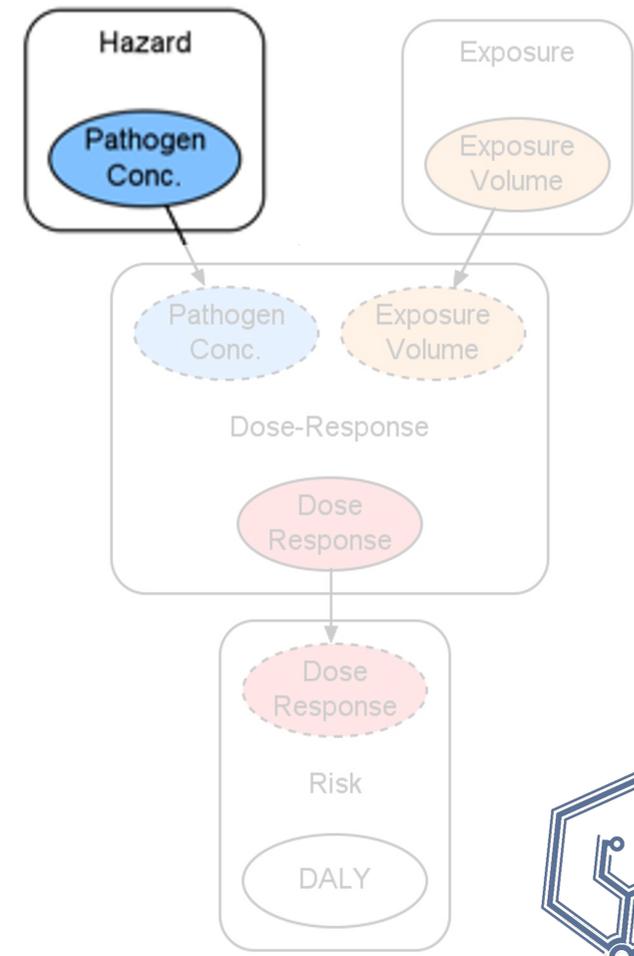
- Inputs feed into sub-models
- Outputs connect models together



Object-Oriented Bayesian Network – Risk Assessment

1. Hazard Characterisation

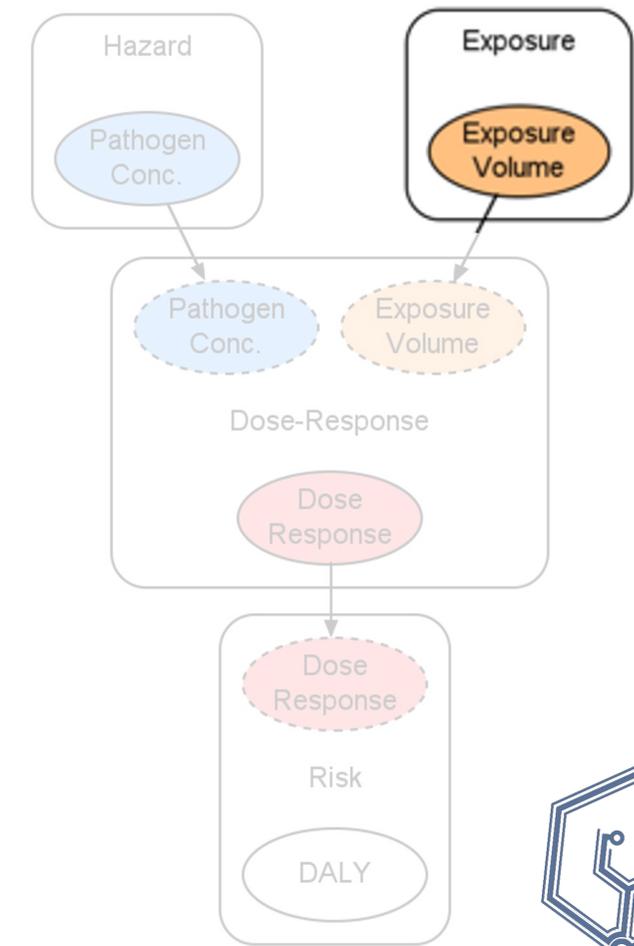
- Concentrations of representative (reference) hazards, risk pathways and hazardous scenarios



Object-Oriented Bayesian Network – Risk Assessment

2. Exposure Assessment

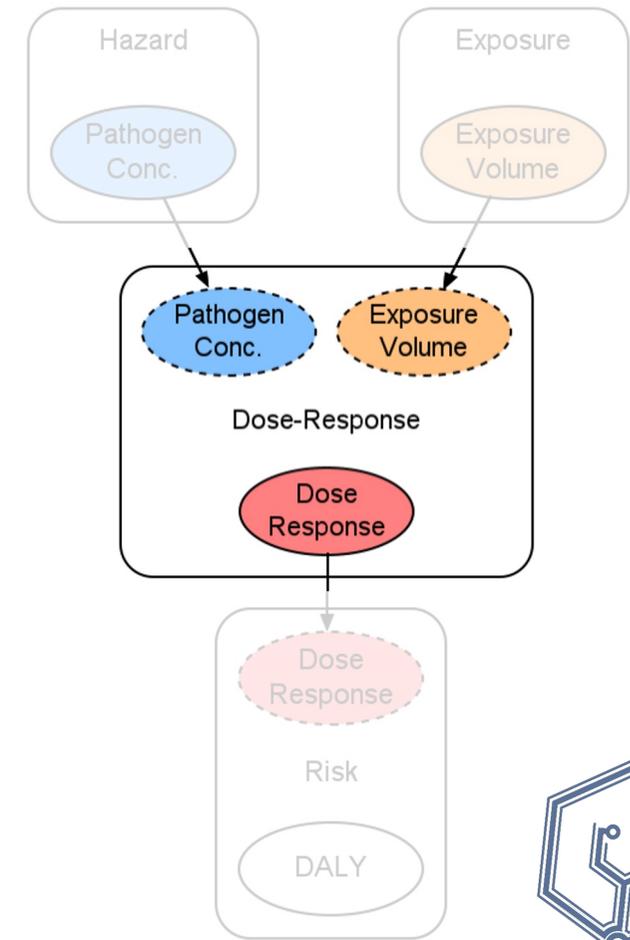
- Describing how and volumes of media humans, animals and crops may encounter with the reference hazards



Object-Oriented Bayesian Network – Risk Assessment

3. Dose-Response

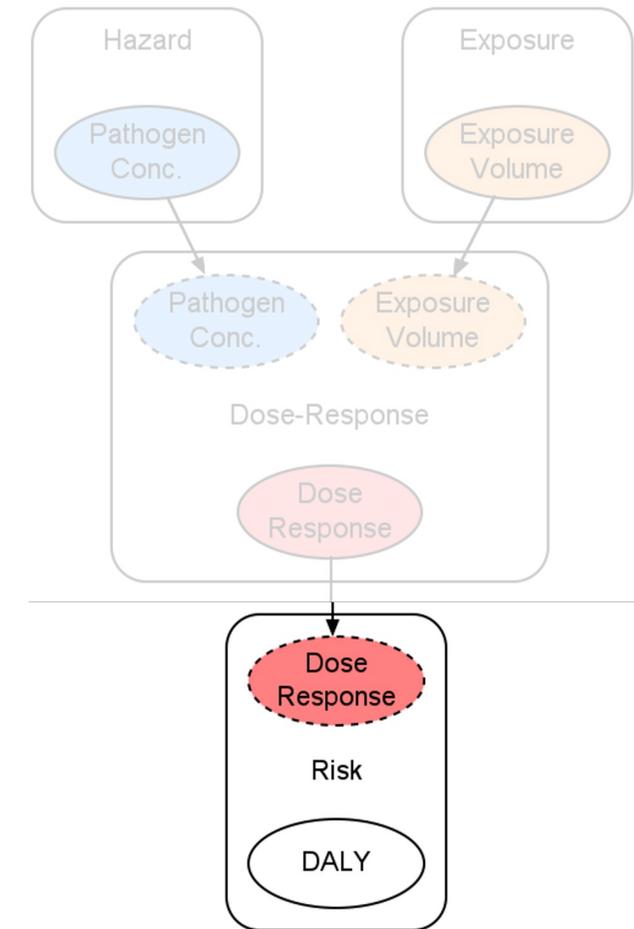
- Quantifies the relationship between hazard dose, ARB infection.



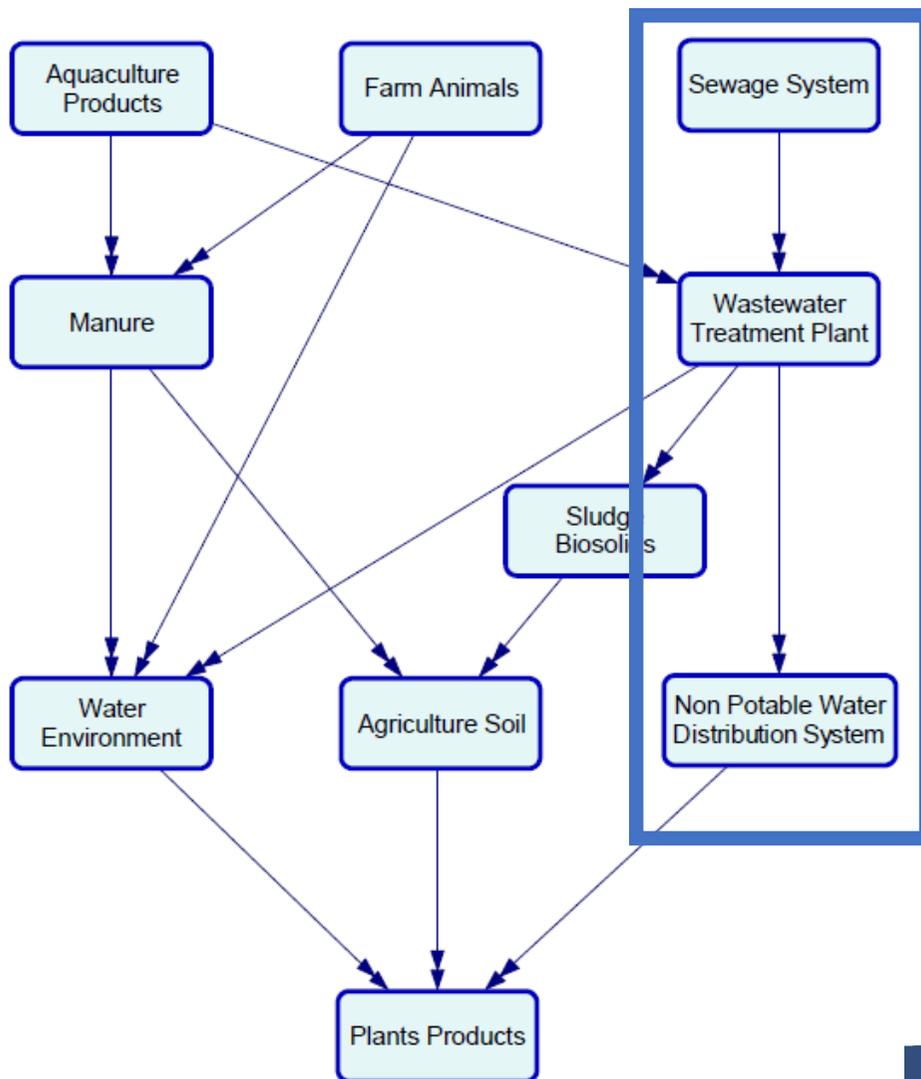
Object-Oriented Bayesian Network – Risk Assessment

4. Risk Characterisation

- Estimates overall health risk & disease burden (Utility, as disability adjusted life years [DALYs])



Our System of Interest



• Agricultural & Water Sectors

- Each blue node represents a potential key hotspot
- Seek to prioritise those of more likely concern and how to mitigate
- Initial focus on municipal wastewater and reuse in agriculture and non-potable household uses



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Key Activities and Progress to date

Systems Analysis of AMR Pathways

1

- Comprehensive mapping of the socio-technical system, spanning:
 - Water, solids, composts
 - Animal excreta and plant production 'products' to select pathogens of interest
- ✓ Summit Workshop held (Sep 2024), Next planned for August 2025: regulator CCPs/targets

Bayesian Network Modelling for Decision Support

2

- Initial GeNIe™ BN model developed
 - Focused on sewage to water reuse and environmental release pathways
 - Targets: ESBL-producing *E. coli*
 - In progress: VRE (*E. faecium*), CRPA (*P. aeruginosa*)

Evidence Generation & Knowledge Dissemination

3

- ✓ Published: Harrison et al. (2024) – Systematic review of AMR in biosolids (Sci Tot Enviro 957: 177455)
- Under Review: Review on free-living protozoa as drivers of AMR in engineered water systems and protection with environmental dispersal (Environ Sci Technol - Water)
- Planning for living labs; e.g. Goulburn Valley Vic – aquaculture, dairy, fruits



Take home messages

- Stewardship alone isn't enough – AMR determinants still enter the environment via therapeutic uses and animal excreta.
- Manure, washdown ponds & water reuse – Key pathways needing better management to reduce environmental AMR.
- Beyond meat & drug efficacy – Helminth treatments may affect soil ecosystems, with unknown AMR impacts.
 - i.e., SAAFE^{CRC} seeking to quantify and cost impacts of concerns beyond meat products to humans and loss of drug efficacy in animal production



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Questions?