# Microbial Risk Assessment: Pathogen Infectivity

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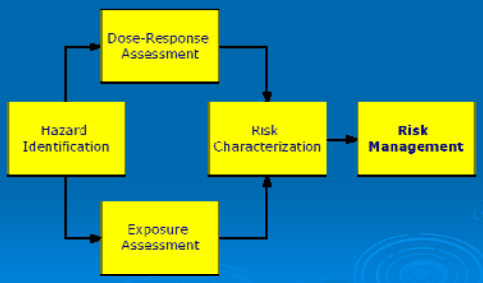
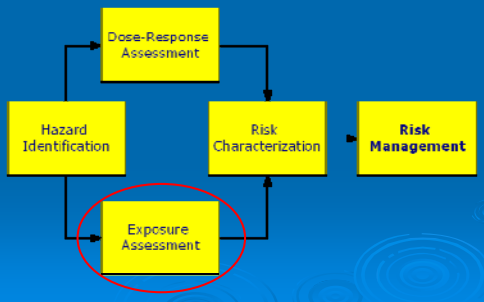
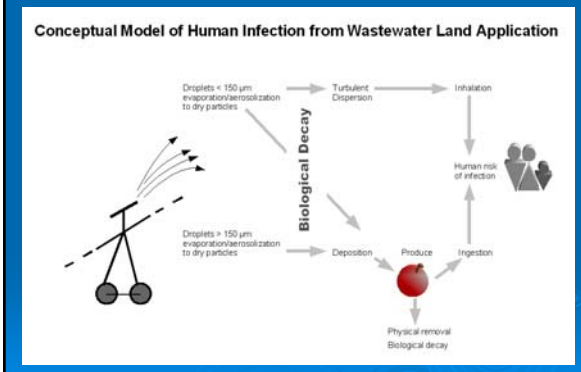
## Quantitative Microbial Risk Assessment




## Quantitative Microbial Risk Assessment



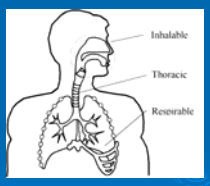




## Risk from Airborne Microbes

- Some pathogens cause gastrointestinal infection while others may cause respiratory infection.
- Our initial focus has been on enteric pathogens such as *E. coli* O157:H7.
- How to address the potential for gastrointestinal illness following aerosol inhalation?

## Deposition in Respiratory Tract by Particle Size

- Nasopharyngeal region
  - Deposition of particles from 10 to 30 µm.
  - Particles may be swallowed.
- Trachea, Bronchi, Bronchioles
  - deposition of particles from 2.5 to 10 µm.
  - Particles may be swallowed.
- Alveoli
  - deposition of smallest particles (2.5 µm and smaller).



## Determining Dose from Airborne Microbes

For enteric pathogens, daily dose is a function of:

- Concentration of microbe colony-forming units in air.
- Receptor inhalation rate.
- Fraction of inhaled aerosol that is potentially ingested.
- Duration of exposure.

## Pathogen Concentration on Homegrown Produce

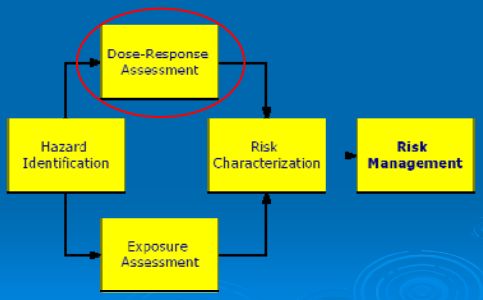
Concentration is a function of:

- Rate of deposition on plant surfaces.
- Portion of deposition intercepted by edible parts of plants.
- Factors that may decrease microbe concentrations on plant surfaces.
- How many land application events occur prior to harvest.

Once the concentration on produce has been estimated, the following are needed to estimate a daily dose:

- How much produce is consumed by receptors.
- How much of that is homegrown.
- How produce is prepared.
  - Effect of washing on microbial concentration.
  - Effect of cooking on microbial survival.

## Quantitative Microbial Risk Assessment




## Dose-Response Assessment

The goal is to obtain a mathematical relationship between the number of microbial pathogens to which a receptor is exposed (dose) and the risk of an adverse outcome (response) from that dose.

## Pathogen Dose-Response

Dose-response infection models are based on best fit to experimental data. For some pathogens, an **exponential** model best describes the probability of infection in humans:

$$P_i = 1-\exp(-rN)$$

In which *N* is the number of organisms ingested and *r* is the fraction of organisms surviving host-microorganism interaction to initiate infection.

## Pathogen Dose-Response

For other pathogens, a modified exponential model called **beta-Poisson** better represents infection probability:

$$P_i = 1-(1+N/\beta)^{-\alpha}$$

Where $\alpha$ and $\beta$ are parameters characterizing the host-microorganism interaction. The values are determined from human studies.

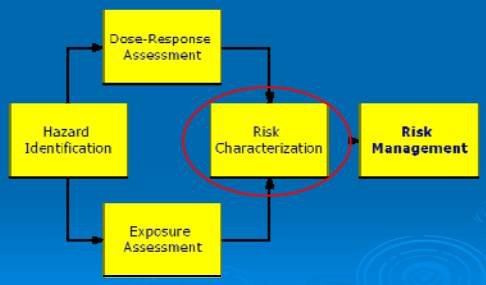
## Pathogen Dose-Response Models

***Table 1. Best-fit dose-response parameters from enteric pathogen ingestion studies.***

| Microorganism | Best model | *Model parameters* |
|---|---|---|
| Echovirus 12 | Beta-Poisson | $\alpha = 0.374$; $\beta = 186.69$ |
| Rotavirus | Beta-Poisson | $\alpha = 0.26$; $\beta = 0.42$ |
| Poliovirus I | Exponential | $r = 0.009102$ |
| Poliovirus I | Beta-Poisson | $\alpha = 0.1097$; $\beta = 1524$ |
| Poliovirus III | Beta-Poisson | $\alpha = 0.409$; $\beta = 0.788$ |
| *Cryptosporidium* | Exponential | $r = 0.004191$ |
| *Giardia lamblia* | Exponential | $r = 0.02$ |
| *Salmonella* | Exponential | $r = 0.00752$ |
| *Escherichia coli* | Beta-Poisson | $\alpha = 0.1705$; $\beta = 1.61 \times 10^6$ |

Adopted from Gerba (2000), as modified from Regli et al. (1991).

## Quantitative Microbial Risk Assessment




## Annual Risk from Ingested Microbial Pathogens

Once the risk of infection from ingested airborne pathogens is determined based on a single application event, annual risk is given by:

$$P_{Aa} = 1 - (1 - P_i)^n$$

where n = number of events/year; and annual risk of infection from pathogens on produce is given by:

$$P_{Ap} = 1 - (1 - P_i)^q$$

Where q = days of produce consumption/year

## Uncertainties

- Microbial die-off may be over- or underestimated.
- Infectivity of bacteria present may be better described by a different model, or the same model with different parameters.
- Exposure to fomites not addressed.
- Secondary transmission not addressed.
- Risk from all potential pathogens is not addressed.

## What Level of Risk is "Acceptable"?

CERCLA acceptable cancer risk range:

1in one million ($1x10^{-6}$) to 1 in ten thousand ($1x10^{-4}$) Incremental Excess Lifetime Cancer RISK (IELCR)

## Acceptable Risk

- Risk associated with exposure to a chemical carcinogen is expressed as incremental excess lifetime cancer risk (over background risk).
- Should infection risks from exposure to microbial pathogens be expressed in terms of:
  - Risk/event (or risk/day)?
  - Annual risk?
  - Lifetime risk?
  - Risk in excess of that from "background" exposure to microbial pathogens?

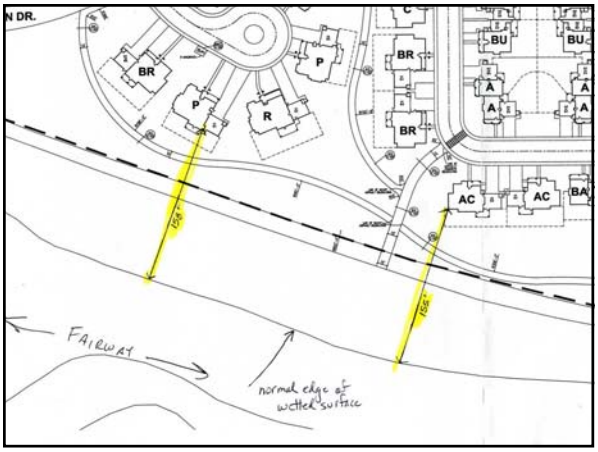
## Use of MIRA in U.S. Drinking Water Standards

- In the Surface Water Treatment Rule (1989), EPA required a risk of less than one *Giardia* infection per 10,000 people per year ($1x10^{-4}$).
  - Assumption: *Giardia* is more resistant to disinfection than most other microbial pathogens.
- Risk of illness:
  - Assumption: 50% frequency of clinical illness following *Giardia* infection, so the estimated annual risk of illness is 1 in 20,000.

Source: C. Gerba et al., as cited by P. Hunter and L. Fewtrell in Water Quality: Guidelines, Standards, and Health, World Health Organization, 2001.

## Golf Course Site

- 23 CFU/100ml Total Coliform
- New housing development leaves only 150 foot buffer zone
- Night time irrigation (mostly stable conditions)
- 50 GPM applied upwind from any receptor



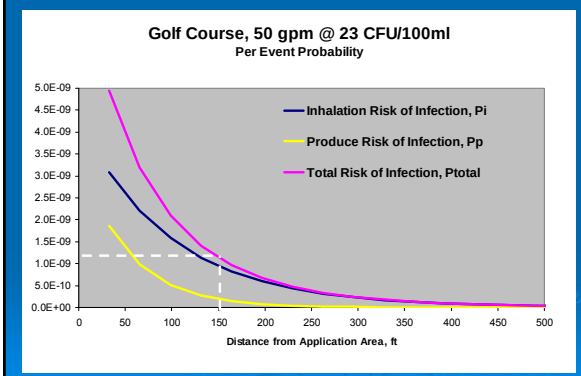

## Golf Course System Parameters

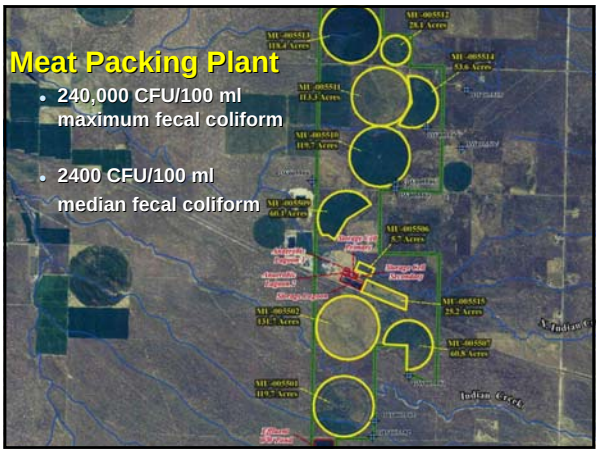
**DISPERSION AND DEPOSITION CALCULATIONS** Based on EPA, 1982

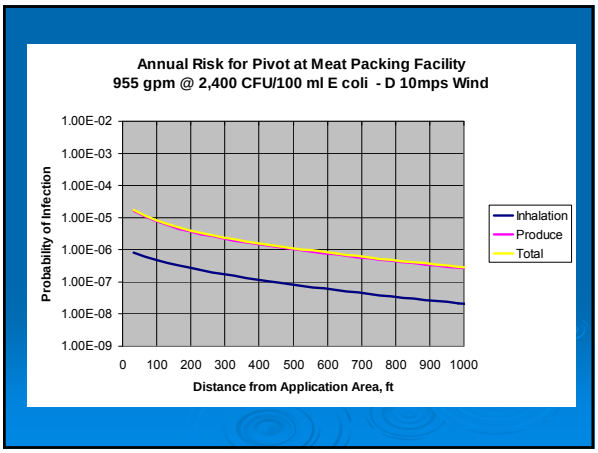
Source Term, Concentration and Deposition Page (viability, risk and pathogen-specific parameters are addressed on Microbe worksheets)

| Input Parameters | | | Intermediate Calculations | |
|---|---|---|---|---|
| Microorganism Loading in Wastewater | 2.30E+01 | CFU/100ml | Microorganism Loading in Wastewater | 2.30E+02 CFU/liter |
| Wastewater Total Solids Content | 1000 | mg/l | Microorganism Emission Rate | 7.27E+02 CFU/s |
| Total Wastewater Flow Rate | 50 | gal/min | Total Wastewater Flow Rate | 3.16 liter/sec |
| Wastewater Solids Density | 1 | gm/cm3 | | |
| **Aerosolization Efficiency (Default is Kincaid 2002)** | | | | |
| Sprinkler Type/Orifice | RB30-sb 5/32 | | | |
| Kincaid Droplet Distribution Test No. | 58 | | **Final Aerosolized (desiccated) Droplet Diameter** | |
| Aerosolization Efficiency(Fraction < 100um) | 0.0030 | (E) | Aerosolized Droplet Original Diameter | 0.1 mm |
| Fraction Droplets 100 um to 200um | 0.0090 | | Volume of 0.1mm droplet | 4.189E-06 cm3 |
| | | | Solids Mass in Droplet | 4.189E-09 gm |
| | | | Volume of Dried Solids | 4.189E-09 cm3 |
| | | | Physical Diameter of Aerosol | 0.00100 cm |
| | | | Physical Diameter of Aerosol | 10.0 um |

Green indicates input values entered by the user






## Meat Packing Plant Case Study

### Conclusion:

QMIRA was used to allow a variance from the standard 50 foot buffer zone for public access based on limited exposure time for persons walking/stopping along the highway.