Wastewater Bio-aerosol Fate and Transport Modeling for Microbial Risk Assessment

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What is Bio-aerosol?



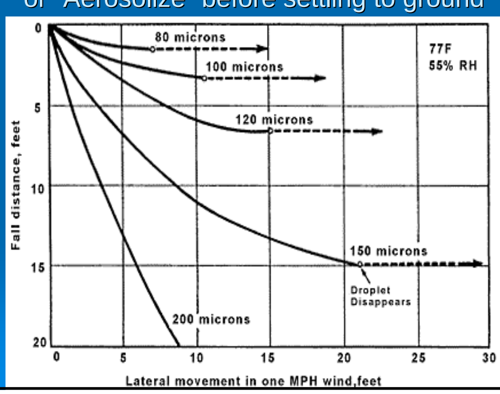

MIRA Rationale and Goals

- Achieve a better understanding of the potential health risk associated with exposure to microbial pathogens during spray irrigation.
- Develop a methodology for assessing buffer zones based on appropriate science.
- Develop a flexible risk management process incorporating a variety of choices in spray irrigation procedures and equipment.

Microbial Risk from Spray Droplet Bio-aerosols

- What is the science?

Fine Droplets < 150 μm rapidly Evaporate or "Aerosolize" before settling to ground



- What do we know?
  - Bio-aerosol has been documented to travel great distances.

Foot and Mouth Disease transmission from Brittany to Jersey Island Isle of Wight across the English Channel, 1981

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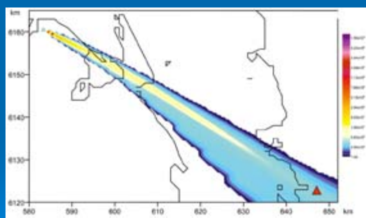
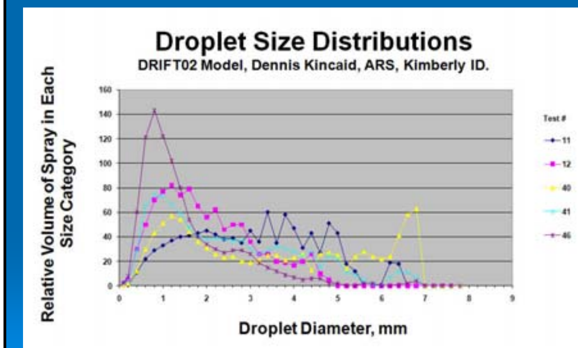


Foot and Mouth Disease transmission in 1982 from Funen to Skelskor Denmark 70 km across the Great Belt Strait.



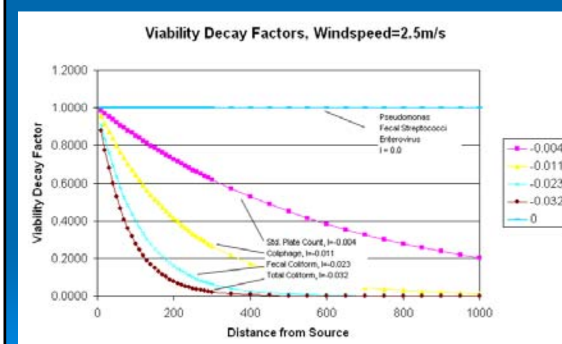
Aerosolized pathogen concentrations decrease with distance due to dispersion and die-off.

Table 2. Microorganism Densities in Air at Several Wastewater Treatment Facilities

Microorganism	Distance Downwind	Geometric Mean Microorganisms/Cubic Meter[a]: Spray Irrigation: Pleasanton	Spray Irrigation: Fort Huachuca	Spray Irrigation: Deer Creek Lake	Aeration Basin: Egan Plant	Aeration Basin: Durham Plant
"Standard Plate Count"						
	Upwind	970	41	89	4400	ND[b]
	10-30 m	5400	800	500	29000	ND
	31-80 m	1390	570	440	9000	ND
	81-200 m	880	130	140	7100	ND
Total Coliform						
	Upwind	0.2	1.3	0.7	1.3	<0.02[c]
	10-30 m	11.5	6.1	2.2	12.4	14.1
	31-80 m	5.0	0.7	4.8	6.9	8.2
	81-200 m	1.5	0.4	ND	3.2	1.9
Fecal Coliform						
	Upwind	0.04	ND	ND	0.2	ND
	10-30 m	2.1	ND	ND	0.7	ND
	31-80 m	1.0	ND	ND	0.5	ND
	81-200 m	0.5	ND	ND	0.3	ND
Coliphage[d]						
	Upwind	0.02	ND	ND	0.02	<0.04
	10-30 m	0.7	ND	ND	0.08	2.3
	31-80 m	0.8	ND	ND	0.04	1.1
	81-200 m	0.4	ND	ND	<0.04	0.6

From: *Estimating Microorganism Densities in Aerosols from Spray Irrigation of Wastewater*, May 1992 (EPA-600/9-82-003)

Experimental field observations of die-off rates



EPA 1982 Viability/Decay Factors

Aerosolized pathogens are viable downwind. Lower concentrations with daytime application due to greater dispersion and die-off.

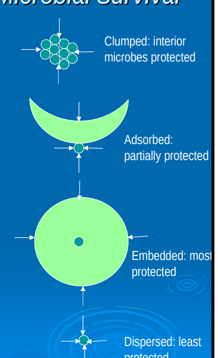
E. coli **marker species downwind from sewage spray irrigation (Israel)**

Expt no.	Wind velocity (m/s)	Solar irradiation (gram calories/cm²)	Relative humidity (%)	Temperature (°C)	*E. coli* concn: Effluent (bacteria per ml × 10^5)	*E. coli* concn: Air (bacteria per m³)
Day						
1	2.9	58.0	60.0	22.7	4.9	70
2	2.8	65.0	56.0	23.4	4.0	94
3	3.2	76.0	53.0	24.7	3.5	91
4	3.4	70.0	50.0	25.5	4.8	21
5	3.6	65.0	47.0	26.0	4.0	44
6	3.9	56.0	48.0	25.0	5.0	40
Mean	3.3	65.0	52.0	24.6	4.3	60
Night						
1	1.5		85.0	21.3	2.1	370
2	0.8		86.0	21.1	1.9	1,130
3	0.8		75.0	21.2	1.9	1,040
4	0.6		63.0	21.0	1.3	700
5	0.6		61.0	20.9	1.3	590
6	0.9		59.0	20.8	1.5	420
Mean	0.9		71.5	21.0	1.6	710

Teltsch and Katzenelson (1979)

Role of Solids-Association in Microbial Survival

- Microbes can be on or in other, usually larger particles or they can be aggregated (clumped together)
- Association of microbes with solids or particles and microbial aggregation is generally protective
- Microbes are shielded from environmental agents by association with solids



From "Microbial Survival in the Environment", Mark D. Sobsey

Microbial Risk from Spray Droplet Bio-aerosols

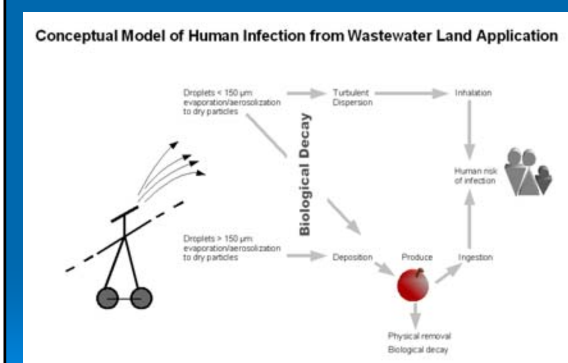
- What do we know? - Summary
  - Very fine droplets (<150 um) evaporate very fast in dry air leaving very small bio-aerosol which may travel a greater distance.
  - Bio-aerosol has been documented to travel great distances.
  - Dispersion and Die-off greatly reduce the concentrations of microbes as bio-aerosol travels downwind.

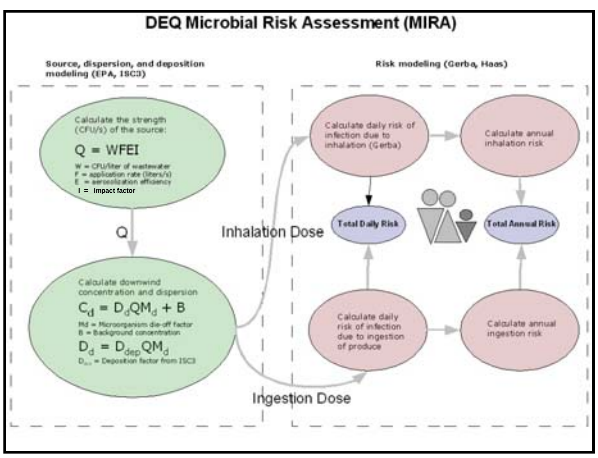
Microbial Risk from Spray Droplet-derived Bio-aerosols

- What is not well understood?
  - Waste characterization is limited
  - Data on viability is limited
  - Immune system response to infection variable and uncertain.
  - Epidemiological evidence of health effects appears to be very limited.
- Thus, there is considerable uncertainty in predicting absolute risk of disease.

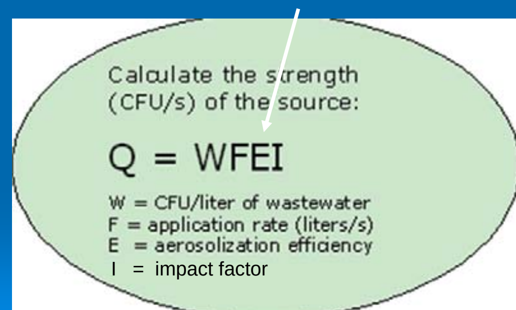
Nevertheless, we believe that simulation of microbial fate, transport and risk due to atmospheric release of bio-aerosols:

- is appropriate,
- accounts for key factors in fate, transport and exposure
- has a basis in proven chemical risk assessment methodologies, and
- provides a useful tool for managing relative risk.



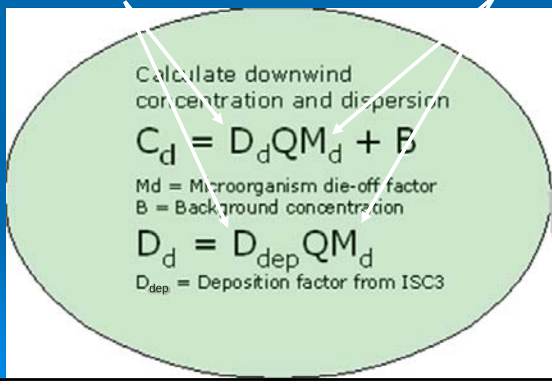


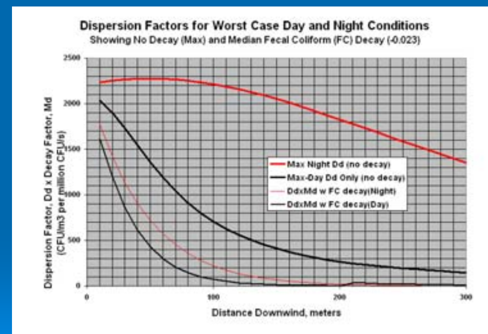
Aerosolization Efficiency From Dr. Dennis Kincaid's Drift Model

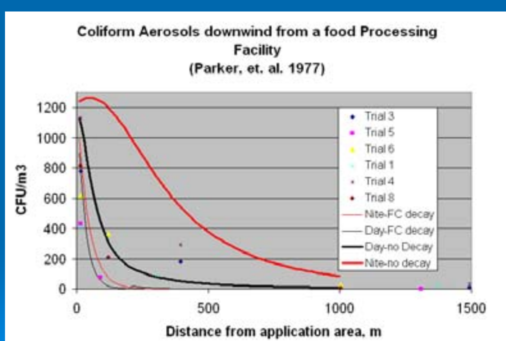


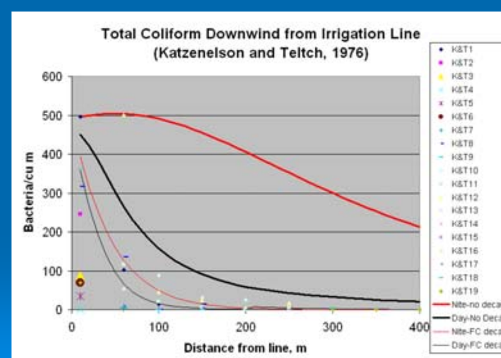
ISC3 Dispersion Model

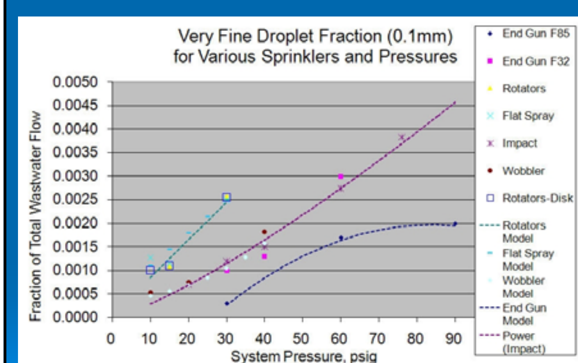
EPA, 1982











Tier I Screening Tool

- Generalized worst-case dispersion
- Very Conservative
- If risk is acceptable, no need for more refined analysis.

Key Points

- QMIRA analysis based on:
  - 1982 EPA methodology
  - Kincaid droplet distribution data
  - Refined dispersion modeling
  - Published dose-response models
- Provides a rational basis for evaluating alternative system designs.
- Methodology seems consistent with established buffer zone guidance.
- Gives DEQ an additional tool for evaluating unusual (high or low risk) scenarios.