Exposure Assessment

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Quantitative Microbial Risk Assessment

Identify pathogen of concern

Dose-response data from humans

Model infection probability

Clinical data to estimate probability of disease and mortality

Predict probability of disease from exposure

Validate model from outbreak data

Four Step Risk Assessment

- Hazard Identification: To describe acute and chronic human health effects; sensitive populations, immunology need to be understood.
- Dose-Response: To characterize the relationship between various doses administered and subsequent health effects; have human data sets but lacking appropriate animal models to increase assessment.
- Exposure Assessment: To determine the size and nature of the population exposed and the route, amount, and duration of exposure. Temporal and spatial exposure with changes in microbial populations a concern.
- Risk Characterization: To integrate the information from exposure, dose response, and health steps to estimate magnitude of health risks. Monte Carlo analysis to give distribution of risks and population/community models needed.

Exposure Assessment

- Evaluation of pathways that allow microorganisms to be transported from the source to the point of contact with human beings and
- Estimation of the amount of exposure that is possible to take place between humans and contaminants.
- Temporal and spatial exposure with changes in microbial populations a concern.

Exposure Assessment and Risk Characterization

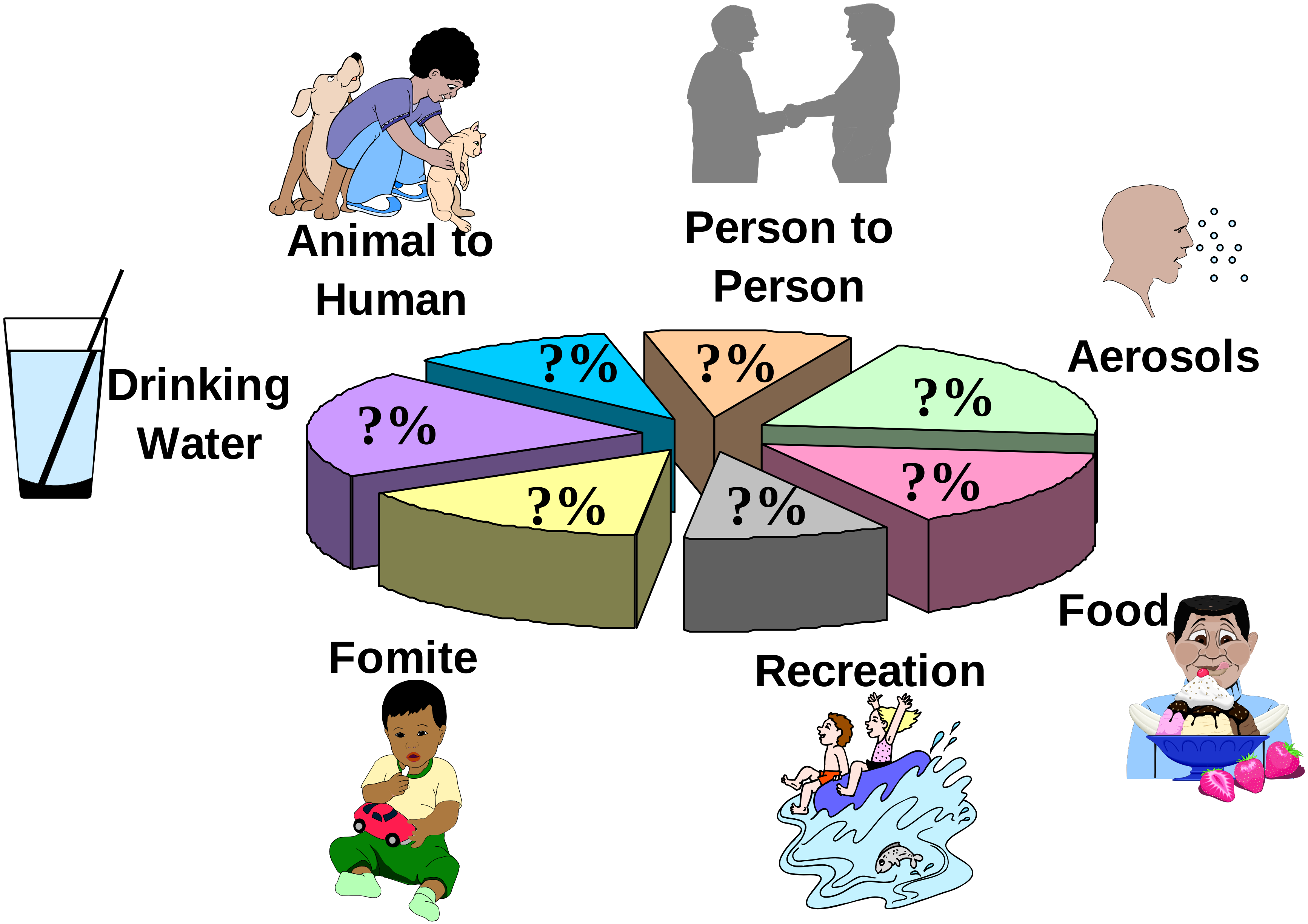
- Exposure and levels of contamination are the most important aspect for providing input to risk characterization.
- Need better monitoring data, better transport models.
- Will need new methods, QPCR, for better assessment of non-cultivatible viruses, parasites and bacteria.
- Monitor water, air, sewage, fomites, etc.
- Essential for Good Risk Management Decisions

Routes of Exposure

- Ingestion
  - Water
  - Food
  - Hand to mouth (fomites)
- Inhalation (aerosols)
- Dermal

Need to define the pathways for quantifying the exposure. This is done through measurements and modeling transport and survival.

Possible Disease Transmission Routes



Factors Important in Assessing Exposure

- Route of Exposures
- Duration of exposures
  - Seconds, minutes, hours,
- Number of exposures
  - How many times in a day, month, year
- Degree of exposures
  - Liters of water ingested
  - Liters of air inhaled
  - Grams of food ingested

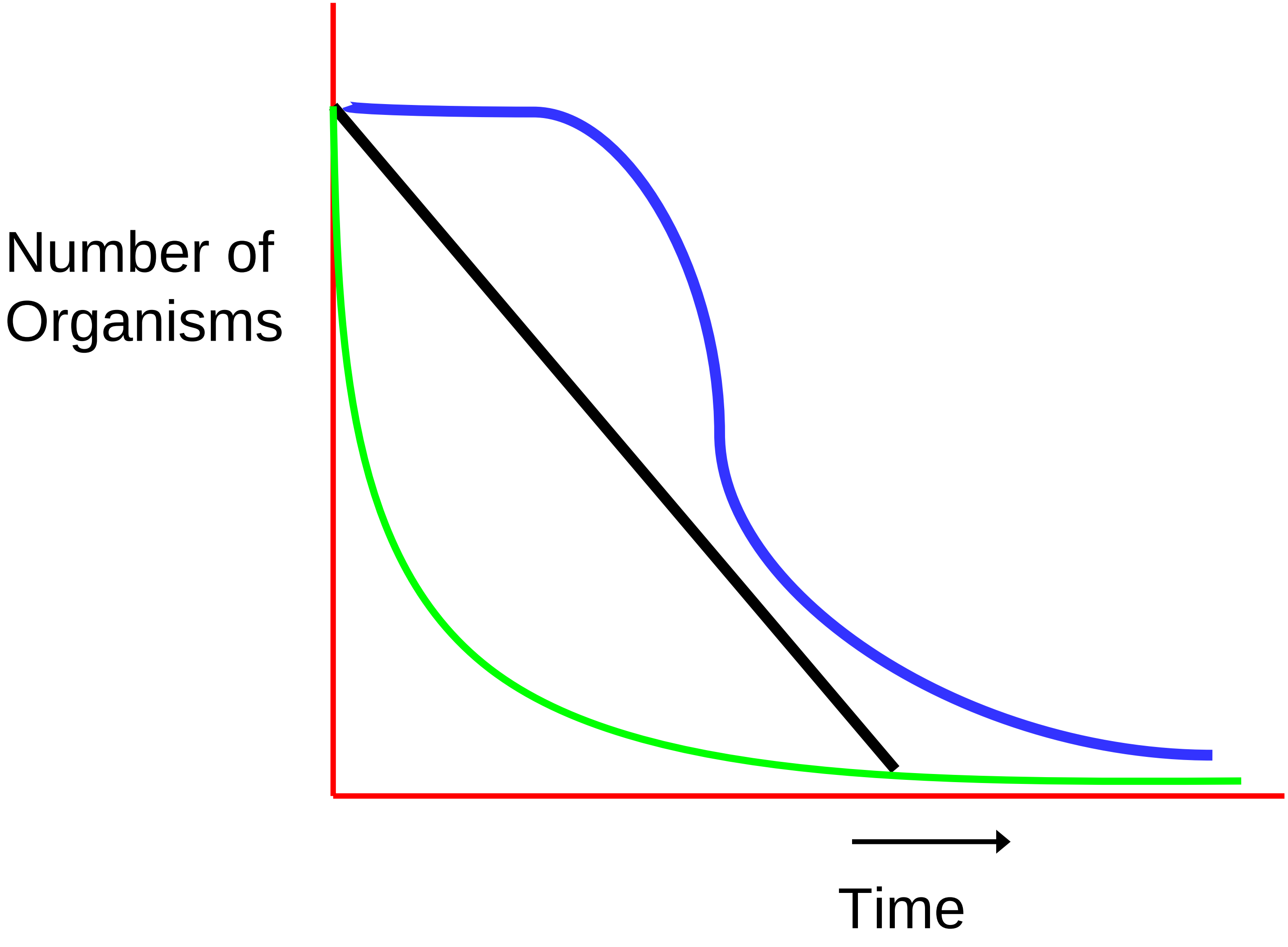
Occurrence Analysis for the Exposure Process

- Concentrations
- Frequency
- Spatial and Temporal Variations
- Regrowth and Die-off
- Transport

Important Things to Remember about Microbial Transport & Fate

- Microbes are colloids – not solutes
  - Log-normal or Poisson distributions
- Microbial transport is influenced by electrostatic and hydrophobic interactions
- Microbes are individuals
  - Not all individuals behave the same
- Concentrations of microbes change with time via die-off and re-growth SURVIVAL ESTIMATES EXTREMELY IMPORTANT

Microbial Die-off generally defined as a rate



Microbial Inactivation (die-off) Reduction versus time

$$\mathbf{LOG_{10}(N_t/N_o) = -k_d t}$$

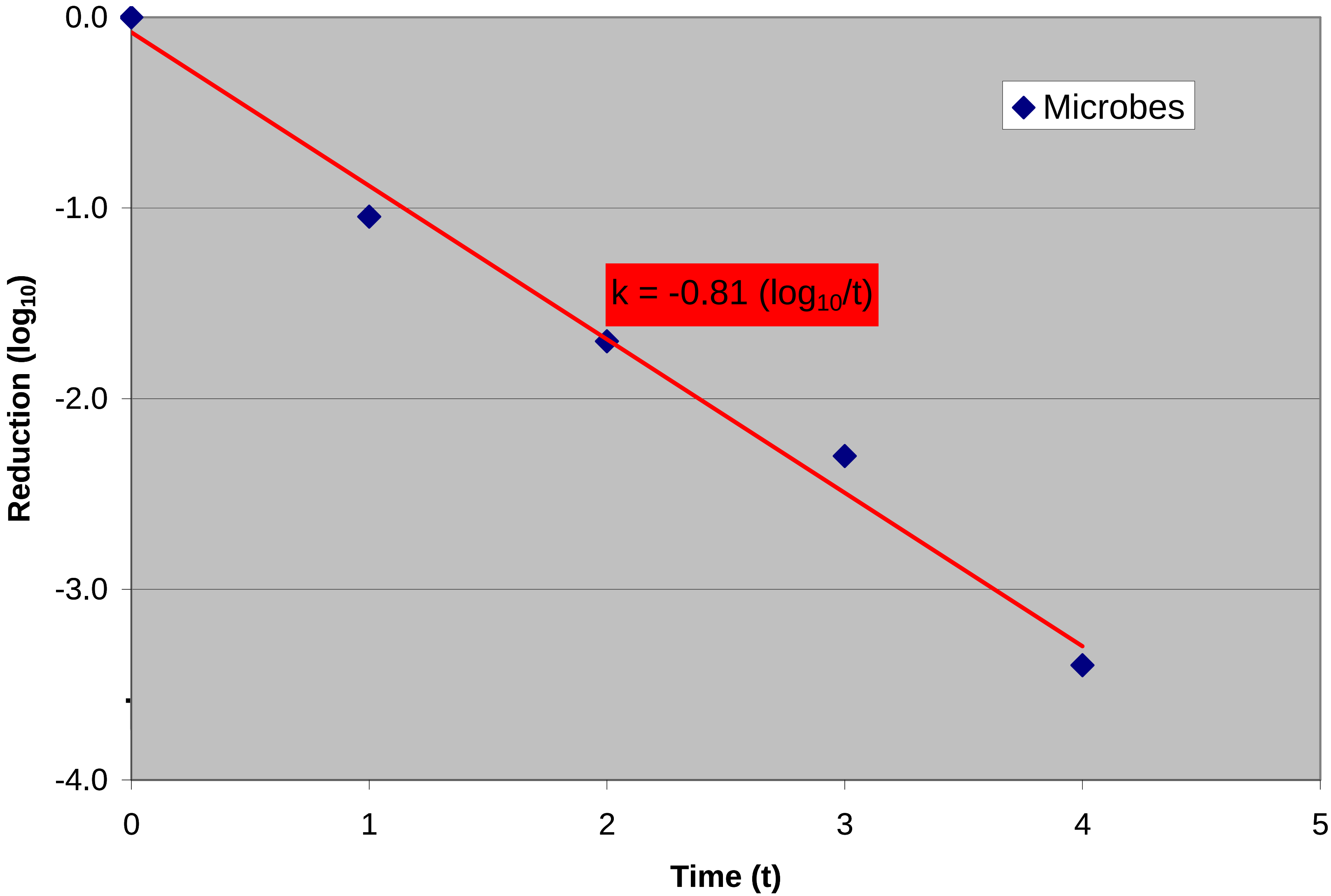
N_t = microbial number at time t

N_o = initial microbial number

K_d = inactivation rate as a function of a parameter

t = time

Microbial Inactivation (die-off)



Factors that influence Microbe Survival

- Type of Microbe
- Temperature
- Light (UV portion)
- Matrix (water, air, soil, fomites etc)

Relative humidity

Moisture content

Organic material, pH, inorganic salts

Presence of and adsorption to solids

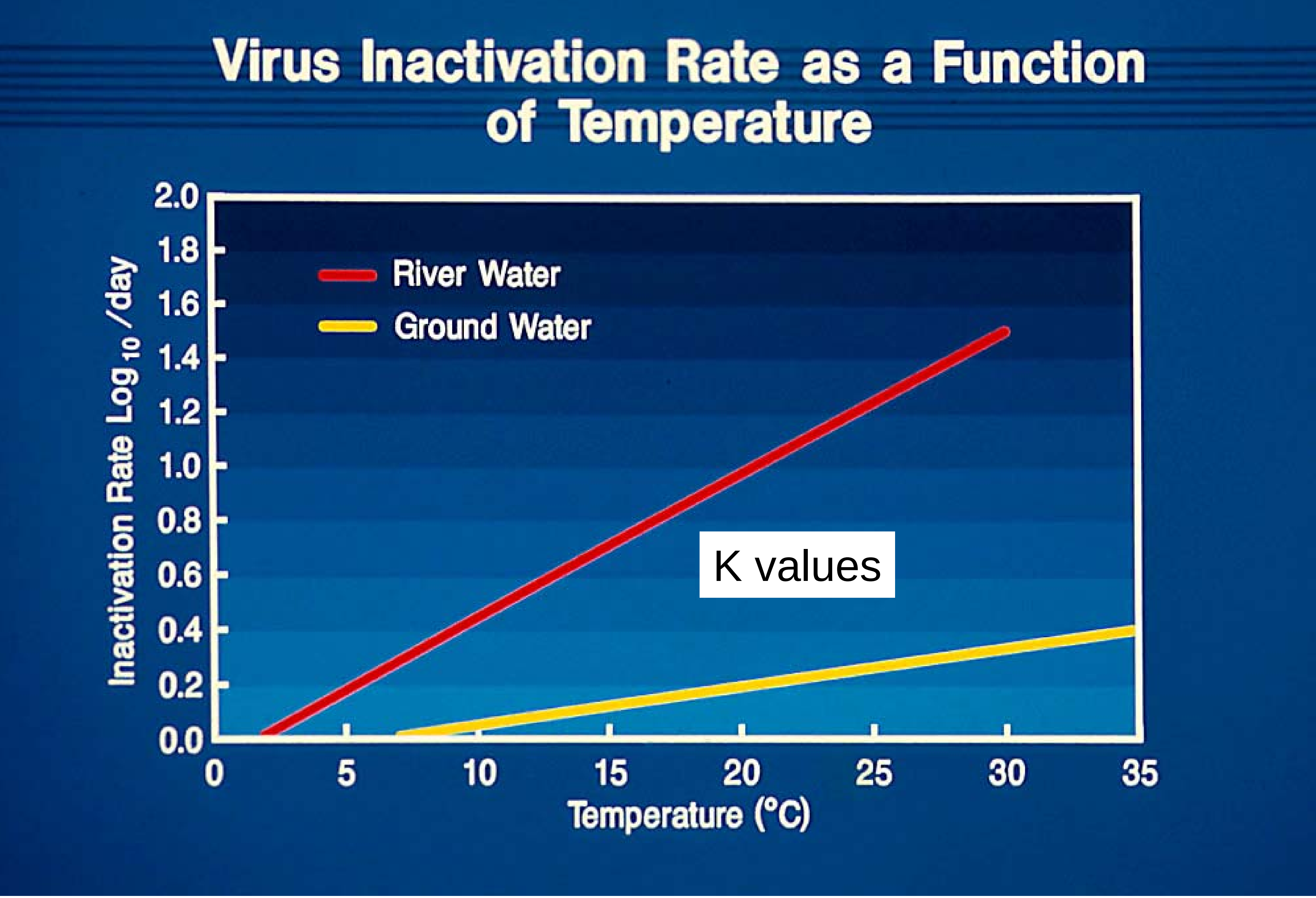
- Antagonistic Microflora
- Time

Factors that influence Enteric Virus and Bacteria Survival in Surface Waters

• Temperature	• Longer survival at lower temperatures
• UV Light	• Related to amount of sunshine
• Organic Matter	• Longer survival in presence of organic matter
• Seawater vs. Freshwater	• Shorter survival in seawater
• Sediments	• Prolonged survival in sediments; regrowth of enteric bacteria possible in sediments
• Antagonistic Microflora	• Certain marine microbes prey on bacteria or are antagonistic to virus survival; survival is reduced in the presence of non-enteric microorganisms

Factors that influence Enteric Virus and Bacteria Survival at/near Soil Surface

Temperature	Longer survival at lower temperatures
Soil Moisture	Related to amount of sunshine
Organic Matter	Longer survival in presence of organic matter
Rate of Moisture Loss	The greater the evaporation rate the more rapid the rate of inactivation
Antagonistic Microflora	Certain microbes prey on bacteria or are antagonistic to survival; survival is reduced in the presence of non-enteric microorganisms


Virus Inactivation Rate as a Function of Temperature
River Water
Ground Water
K values
Inactivation Rate Log10 /day
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
25
30
35
Temperature (°C)

MS-2 Coliphage Decay in Groundwater

$$\text{Decay Rate } (\log_{10}/\text{day}) = -0.181 + 0.0214 \text{ (temperature } ^\circ\text{C)}$$

Bio aerosols

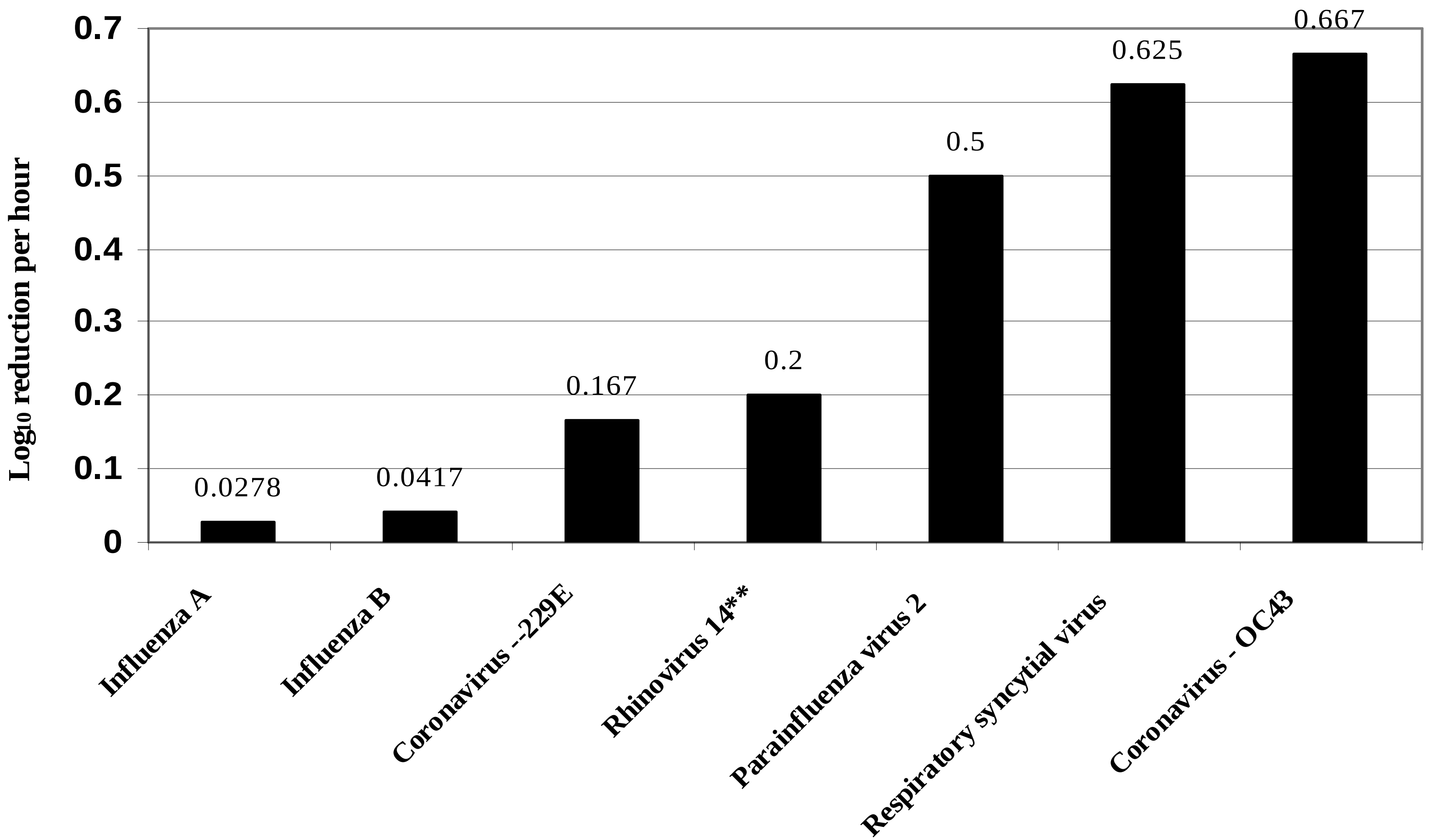
Types of Bioaerosols

- Sneezing
- Showers
- Cooling towers
- Waste handling
  - Sewage treatment
  - Land application of biosolids and sewage
  - Compost facilities

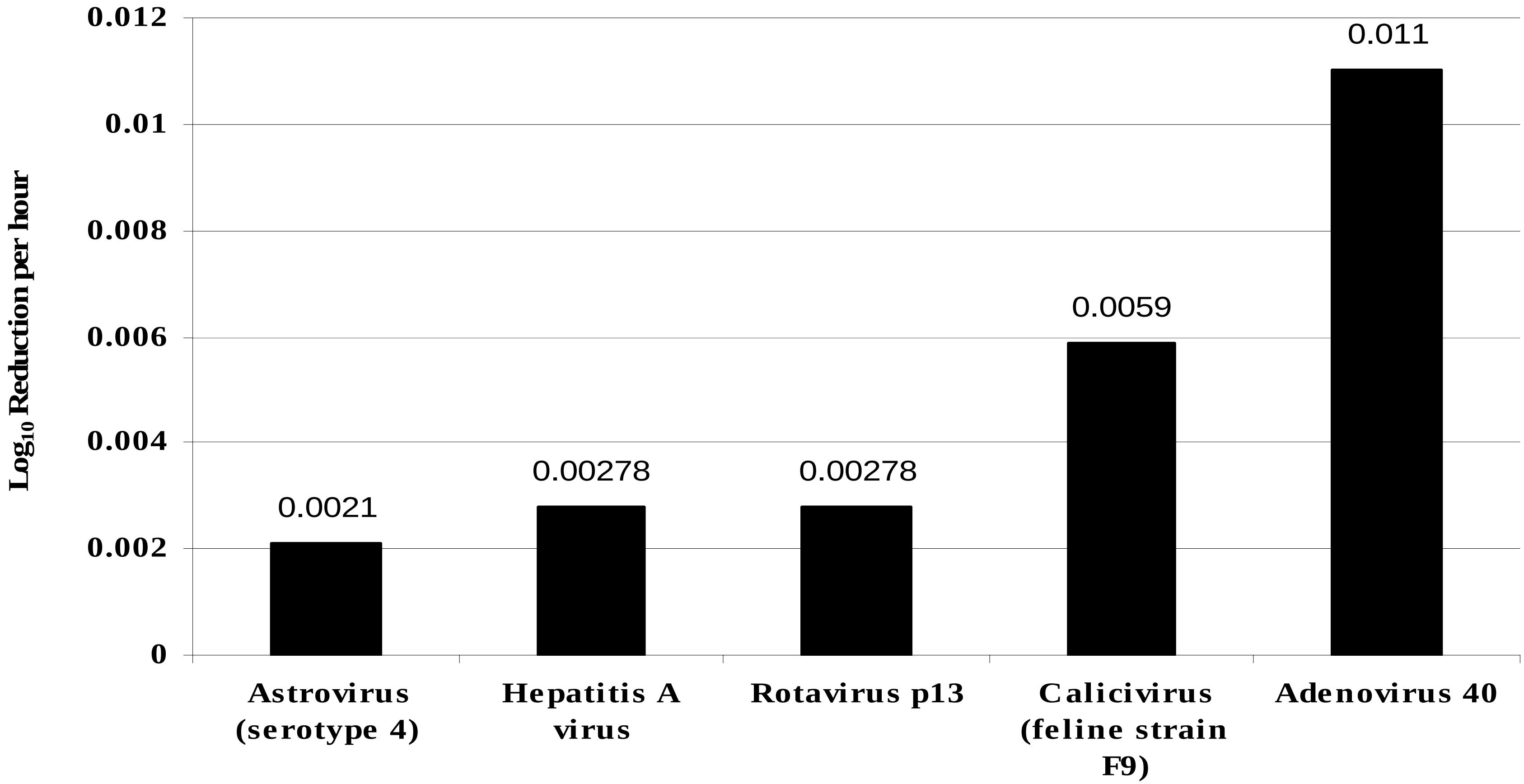
Factors Affecting the Survival of Microorganisms in Aerosols

- Relative humidity
  - Depends upon the microorganism – optimal may be at either high, low, or medium relative humidity
- Sunlight (UV light)
  - Longer survival at night
- Suspending media
  - Lower survival in the presence of organic matter
- Temperature
  - Greater survival at lower temperatures

Inactivation of Respiratory Viruses on Fomites



Inactivation of Enteric Viruses on Fomites



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MINIREVIEWS

Persistence of Category A Select Agents in the Environment[∇]

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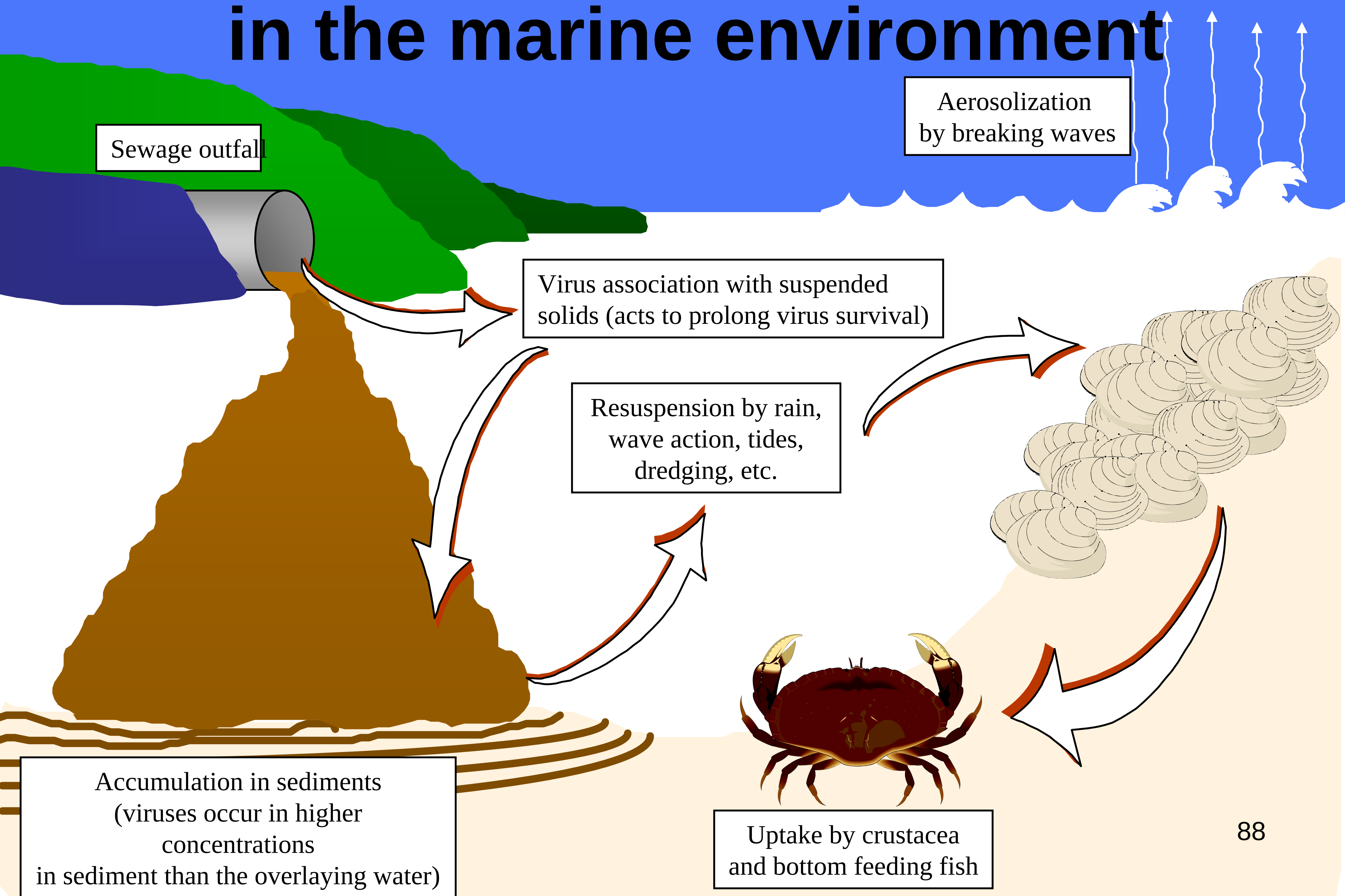
TABLE 4. Survival of category A biological agents as aerosols

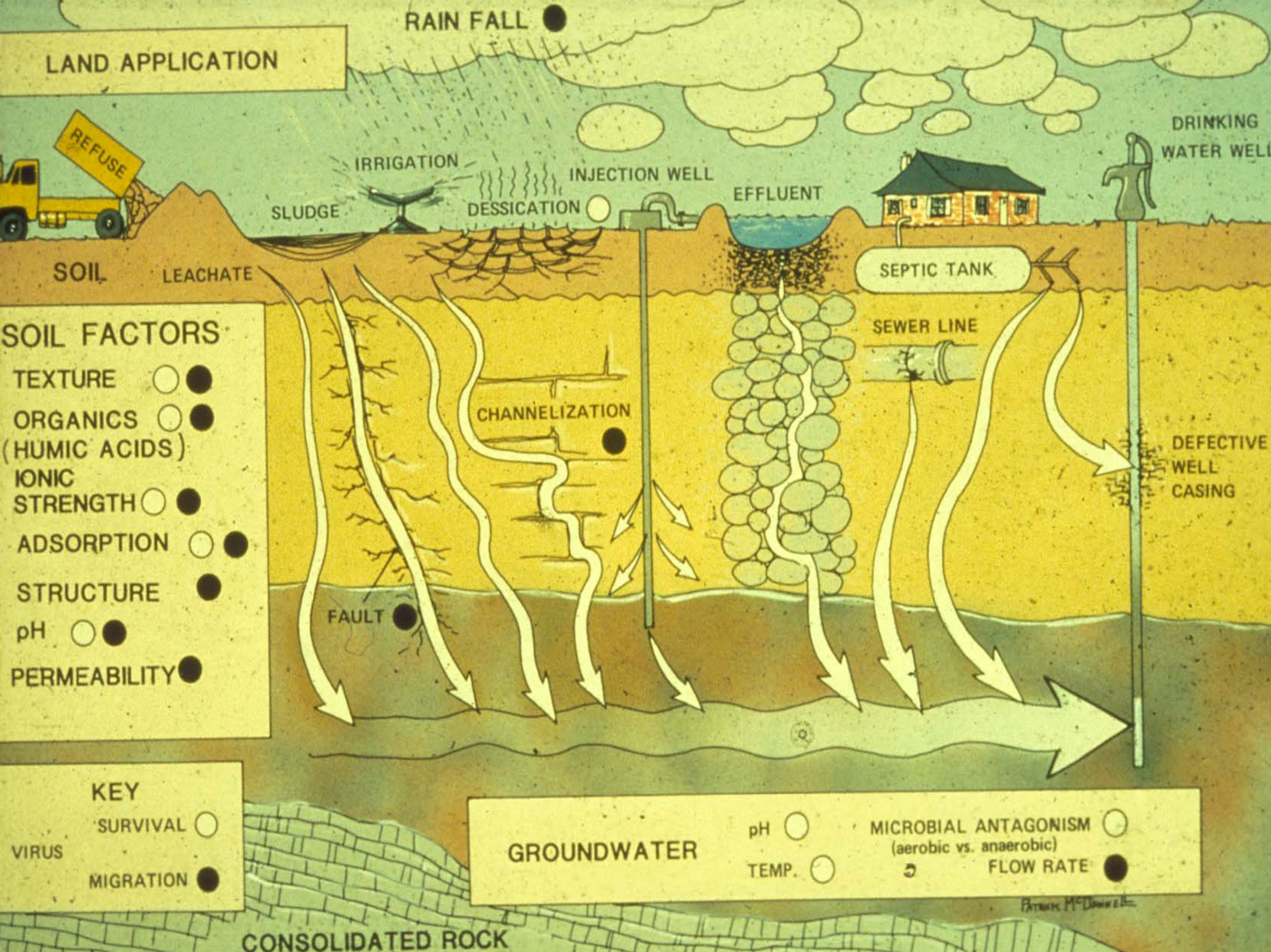
Disease and agent (exptl conditions, suspending medium)	Initial titer	Temp (°C)	rH (%)	T_{90} (h)	T_{99} (h)	K_i	Reference
Anthrax							
Bacillus anthracis (multiple hours in night air)						Complete recovery	62
Bacillus anthracis						4.64×10^{-7} HPAC[c]	82
Tularemia							
Francisella tularensis SCHU S5 (PBS[b])	1.5×10^{11} CFU/ml	−40	Ambient	1.02	2.05	0.97	27
		−29	Ambient	3.97	7.93	0.25	
		−7	Ambient	2.68	5.35	0.37	
		24	85	1.80	3.60	0.55	
		29	85	1.10	2.21	0.90	
		35	85	0.48	0.96	2.08	
Francisella tularensis LVS (culture medium with a wet dissemination)	3.0×10^{10} CFU/ml	90		65.6[a]	131[a]	0.03	20, 21
		80		1.91[a]	3.82[a]	1.20	
		70		1.10[a]	2.20[a]	2.09	
		60		0.28[a]	0.57[a]	8.00	
		50		0.24	0.48[a]	9.59	
		40		0.24	0.49[a]	9.39	
		30		0.25	0.50[a]	9.20	
		20		0.58[a]	1.16[a]	3.97	

Transport Pathways

- Sources
- Types of microbes
- Concentrations
- Exposure sites
- Movement from source to exposure
- Factors influencing transport & survival

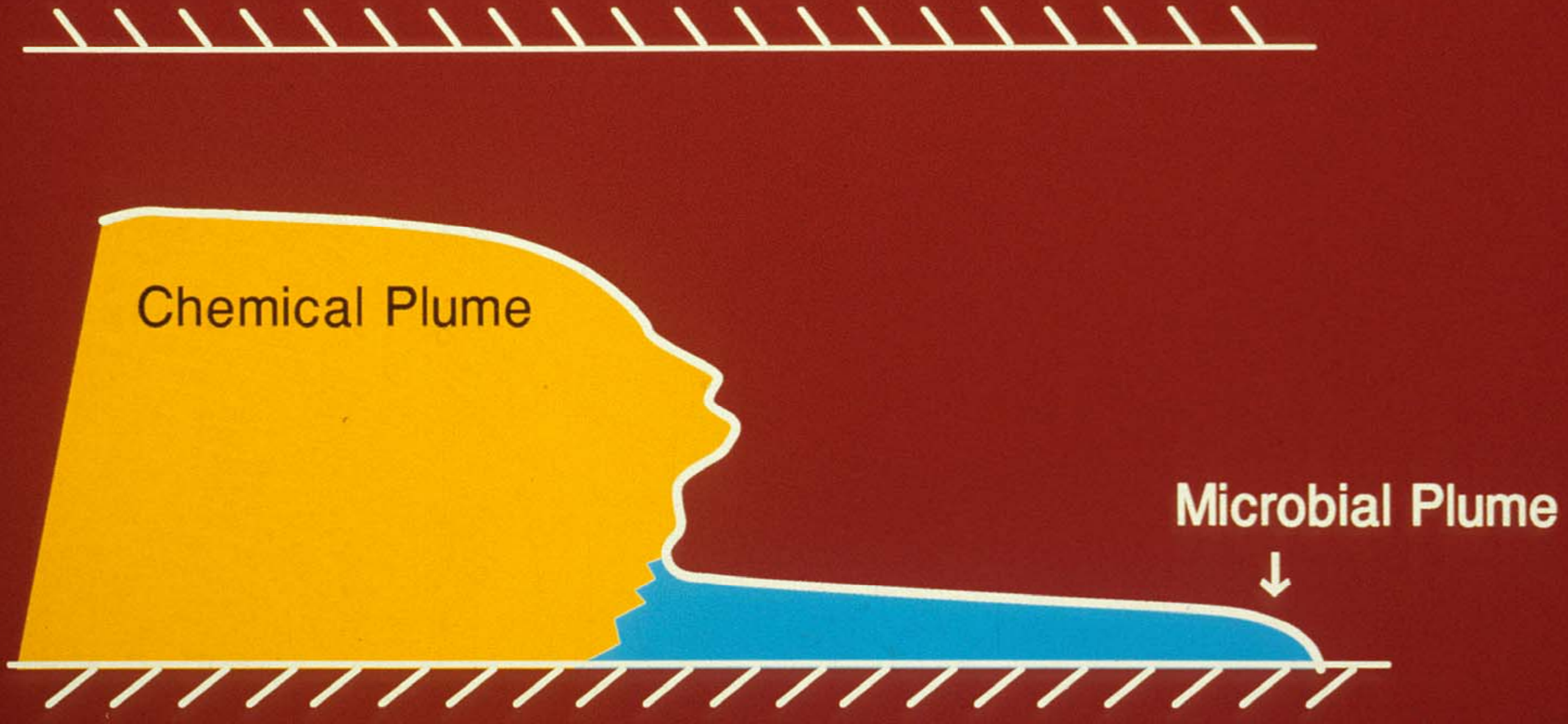
Transport and fate of enteric viruses in the marine environment

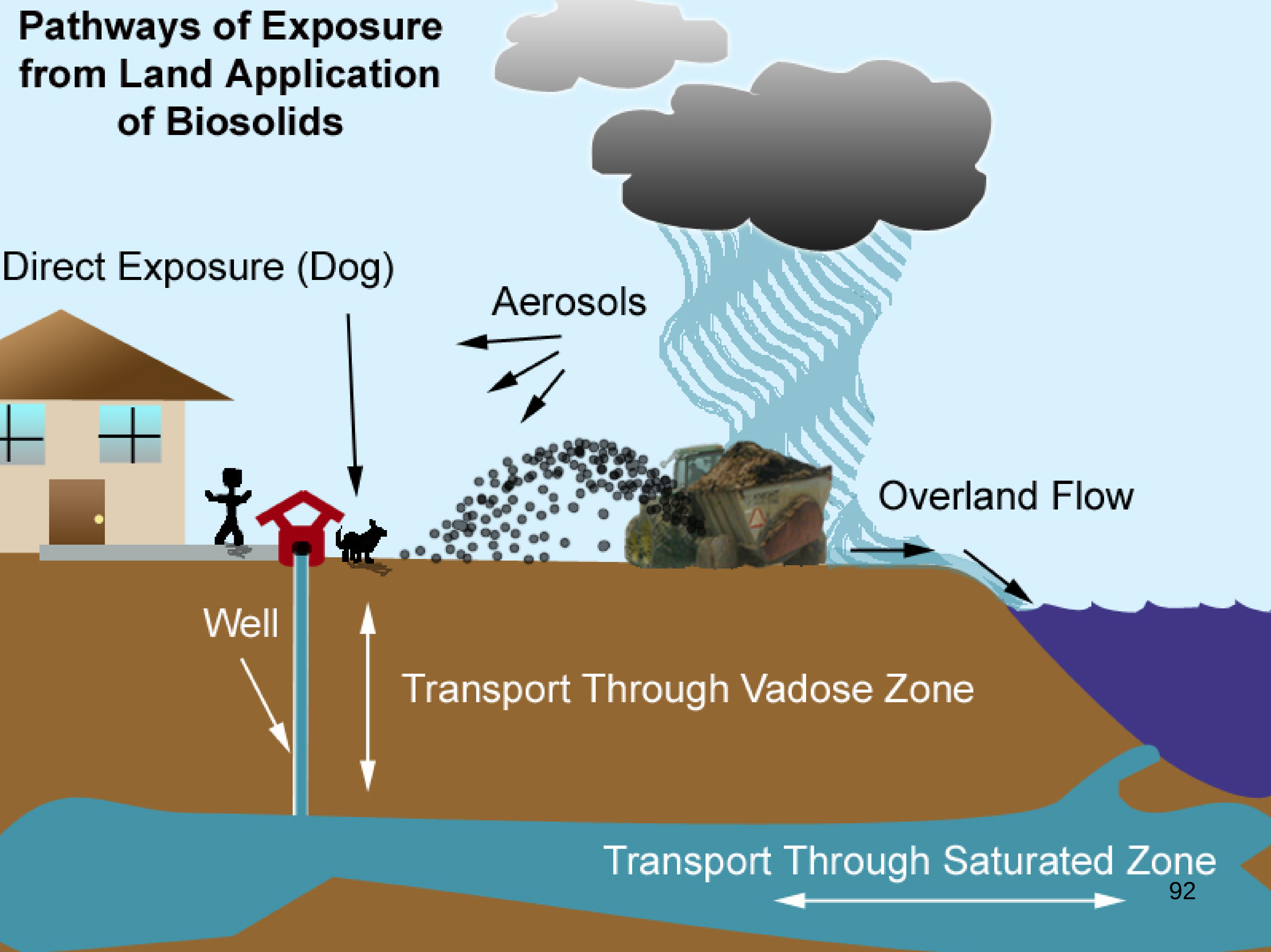


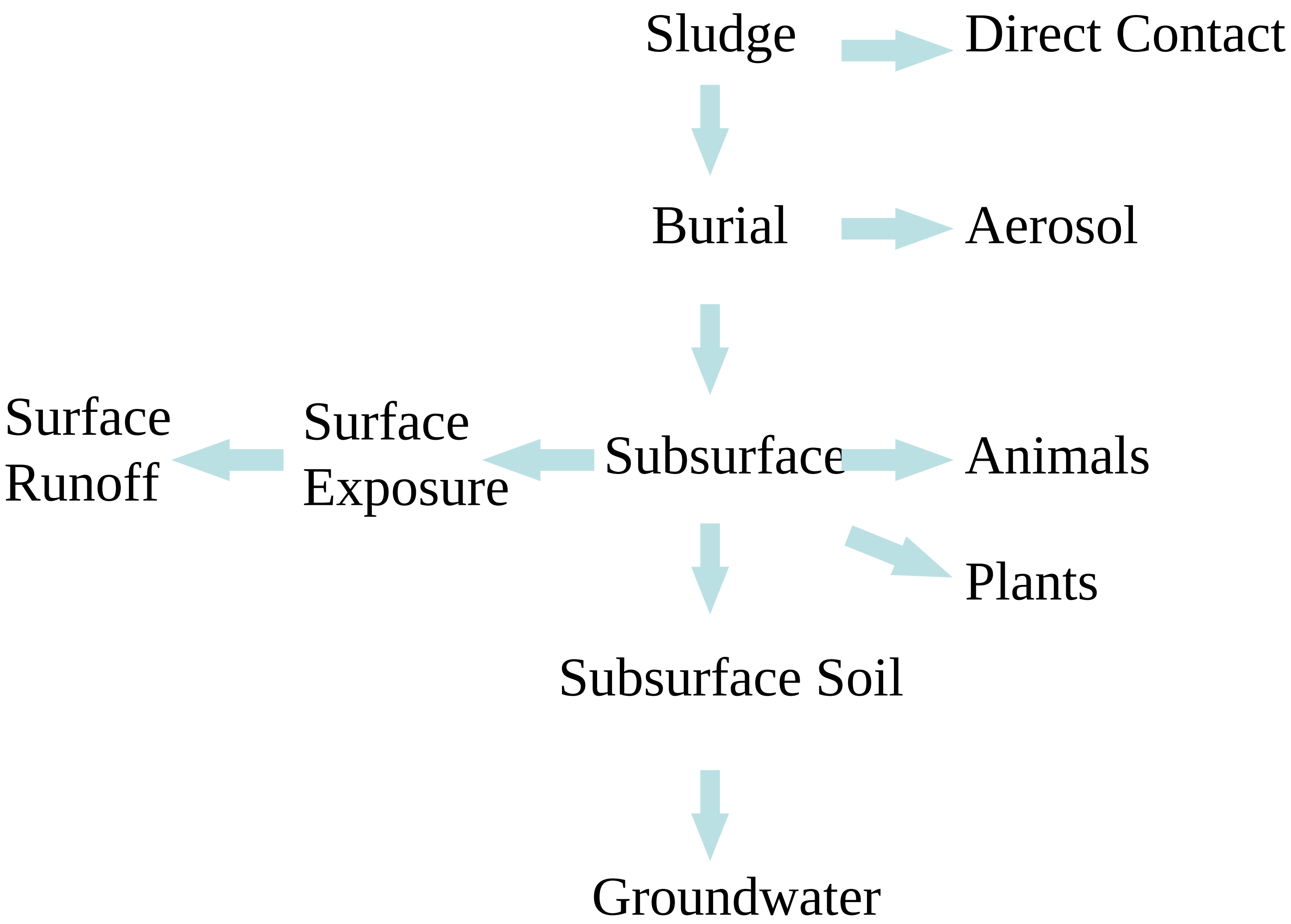


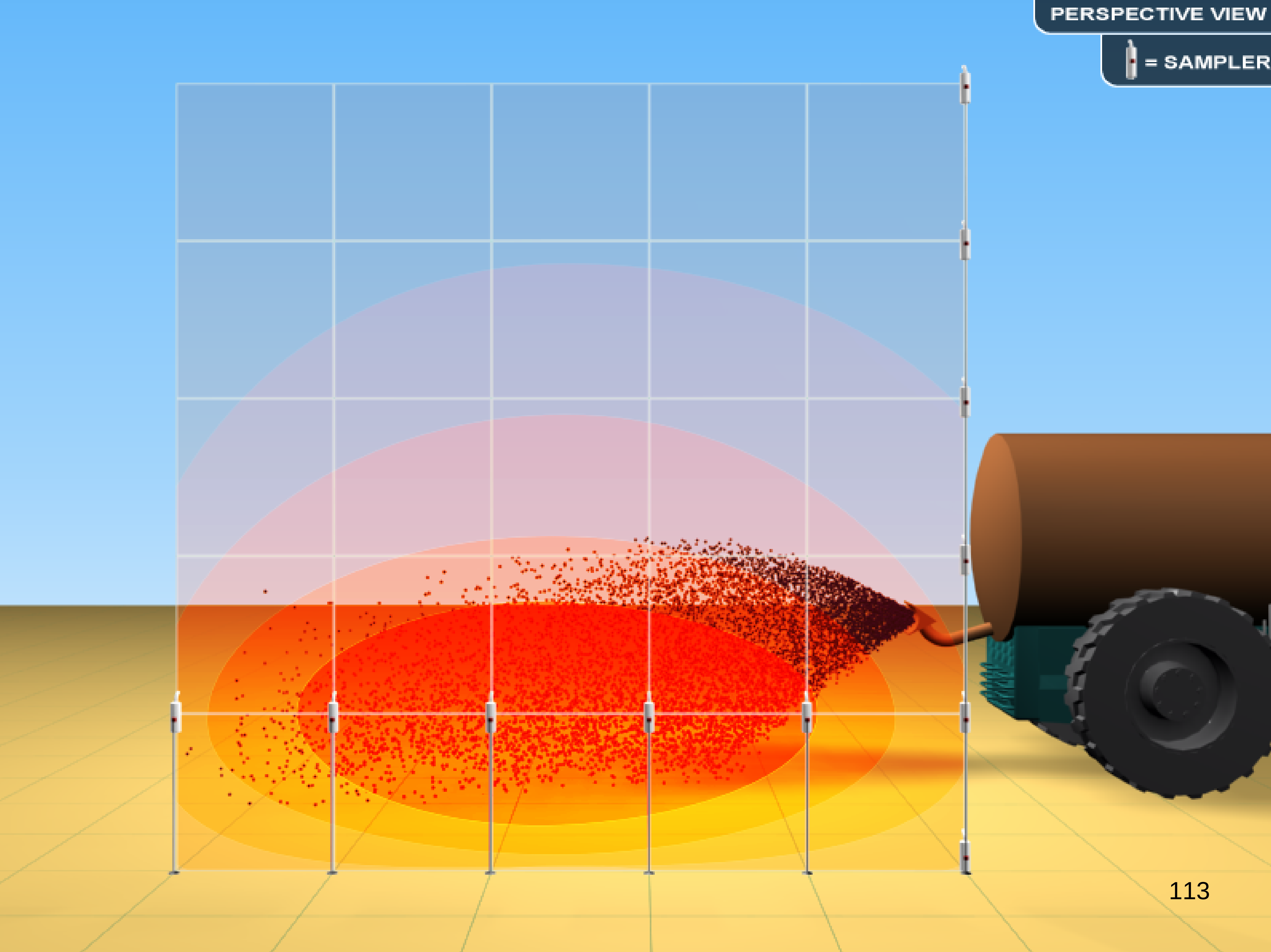
RAIN FALL
LAND APPLICATION
REFUSE
IRRIGATION
SLUDGE
DESSICATION
INJECTION WELL
EFFLUENT
DRINKING WATER WELL
SOIL
LEACHATE
SEPTIC TANK
SOIL FACTORS
TEXTURE
ORGANICS (HUMIC ACIDS)
IONIC STRENGTH
ADSORPTION
STRUCTURE
pH
PERMEABILITY
SEWER LINE
CHANNELIZATION
DEFECTIVE WELL CASING
FAULT
KEY
VIRUS
SURVIVAL
MIGRATION
GROUNDWATER
pH
TEMP.
MICROBIAL ANTAGONISM
(aerobic vs. anaerobic)
FLOW RATE
CONSOLIDATED ROCK

Cross-Sectional View of Contaminant Spreading




Pathways of Exposure from Land Application of Biosolids
Direct Exposure (Dog)
Aerosols
Overland Flow
Well
Transport Through Vadose Zone
Transport Through Saturated Zone


Sludge
Direct Contact
Burial
Aerosol
Surface Runoff
Surface Exposure
Subsurface
Animals
Plants
Subsurface Soil
Groundwater


PERSPECTIVE VIEW
= SAMPLER

Steps in Estimating Exposure from Pathogens in Biosolids

Pathogen concentration in biosolids

Number of Pathogens after treatment

Concentration after land application

A person comes into contact with the biosolids

Duration of exposure
One day

Amount of hand contact

Amount swallowed
50-480 mg

Exposure in the Indoor Environment Life in the 21st Century

- Most of our time is spend indoors
- More people work in offices than ever before
- We travel more than ever before
- We spend less time cleaning than the last generation (but with modern appliances)
- We spend more time in public places
- We are more mobile and have more electronic equipment (e.g. cell phones)

Disease Spread by Fomites

- Route of exposure
  - Children under 12 months bring hands to their face 60 times per hour
  - Cross contamination of foods
- Which fomites are important
  - How often does hand contact occur on which fomites?
- Frequency of pathogens on fomites in a given environment
- Concentration of pathogen on a fomite

Transmission by Fomites

- Hard surfaces
  - Phones, tap handles, desk tops, door knobs, cutting boards, table tops
- Cleaning clothes
  - Sponges, dish clothes
- Clothing
  - Laundry, towels, bed sheets

Transmission by Fomites

- Bathroom (Bano)
  - Sinks, taps, bottom of the toilet seat
  - Norovirus, *Graidia*, *Cryptosporidium*, Shigella
- Kitchen
  - Sponge, sink, cutting board
  - *Salmonella, Campylobacter*
- Schools
  - Norovirus, rhinovirus, *Salmonella*

% Time Coliform **Bacteria Detected (public restrooms)**

• Top of the toilet seat	20
• Flush handle	6
• Wall behind toilet	9
• Floor in front of toilet	64
• Sink	61
• Tap	15
• Urinal – inside	30
• Urinal flush handle	0
• Sanitary napkin disposal –outside	57
• Door knob	4

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Occurrence of bacteria and biochemical markers on public surfaces

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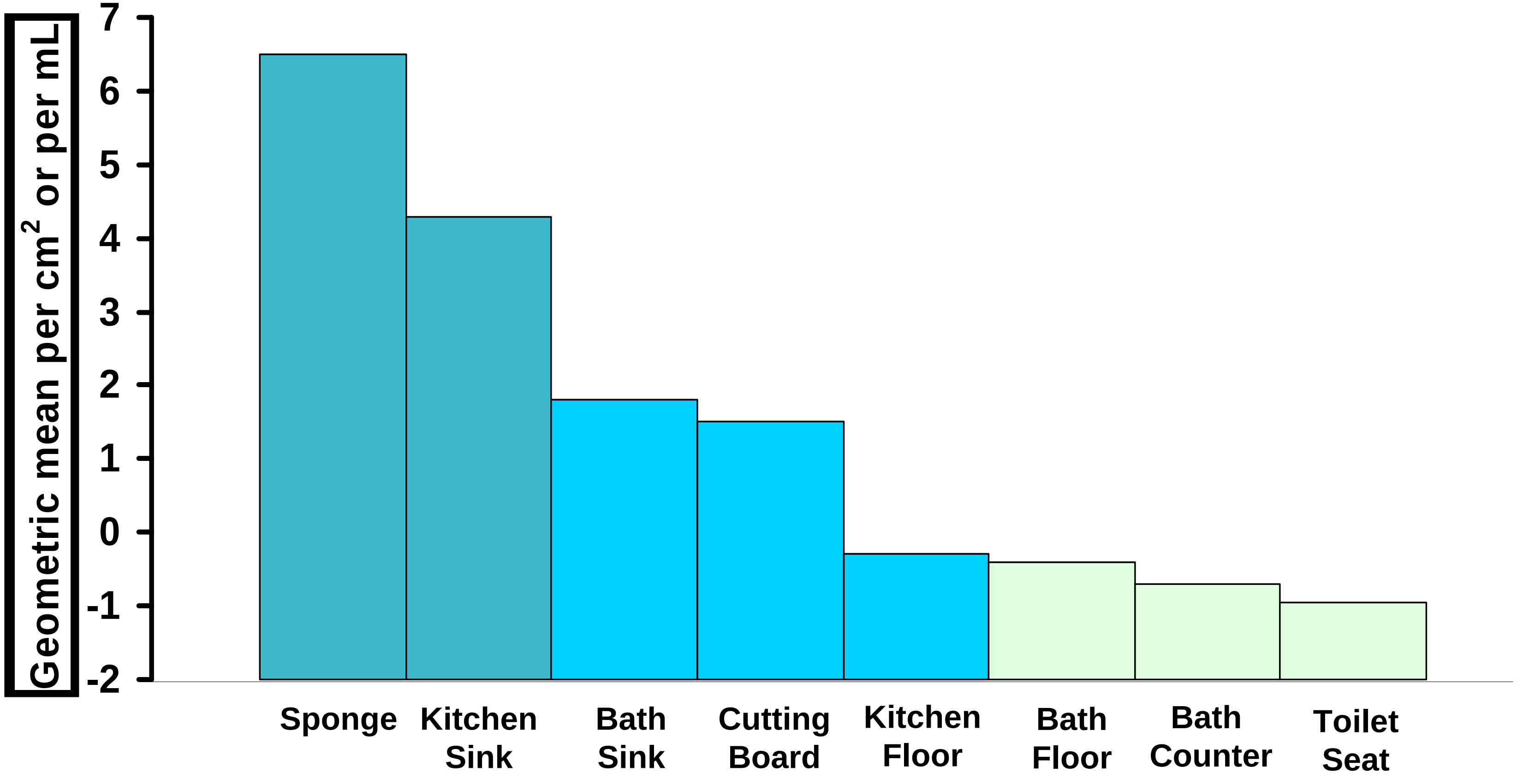
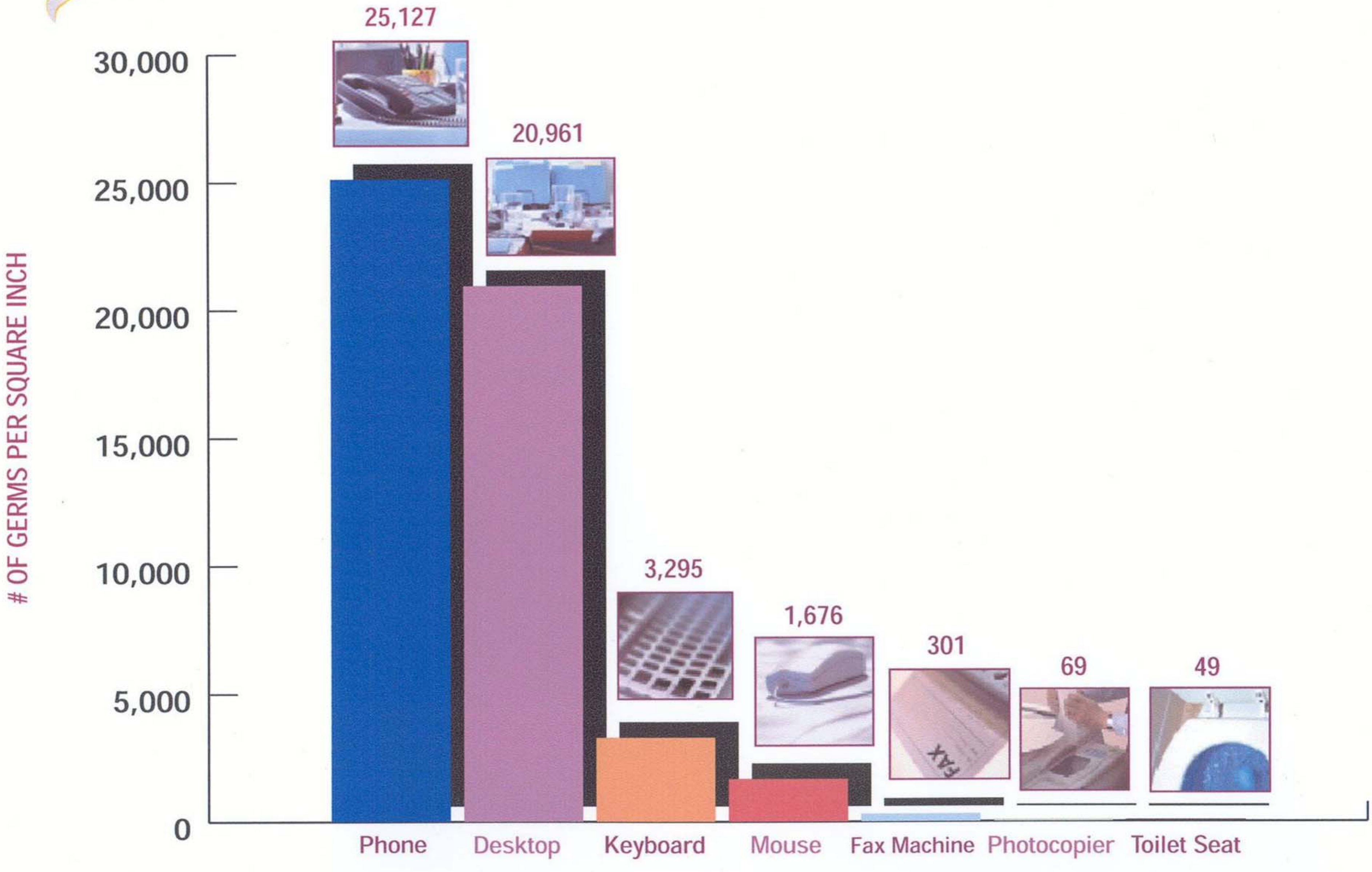
Table II. Percentage of specific surfaces positive for protein and biochemical markers.

Surface (n)		% > 200 μg/10 cm^2 Protein Test (n)*	% Positive for Biochemical Markers (n)†
Playground equipment	(42)	74 (31)	36 (15)
Bus rails/armrests	(31)	61 (19)	35 (11)
Shopping cart handles	(24)	54 (13)	21 (5)
Chair/seat armrests	(68)	51 (35)	21 (14)
Vending machine buttons	(43)	47 (20)	14 (6)
Escalator handrails	(37)	46 (17)	19 (7)
Public bathroom surfaces	(165)	46 (76)	25 (41)
Customer-shared pens	(19)	42 (8)	16 (3)
Public telephones	(47)	34 (16)	13 (6)
Elevator buttons	(21)	29 (6)	10 (2)

*Positive protein results reading of $\geqslant 3$ (> 200 μg/ml) with the visual assure kit. †Positive for at least one of the following: amylase, urea, or hemoglobin.

Sites by Coliform Densities





OF GERMS PER SQUARE INCH
30,000
25,000
20,000
15,000
10,000
5,000
0
25,127
20,961
3,295
1,676
301
69
49
FAX
Phone
Desktop
Keyboard
Mouse
Fax Machine
Photocopier
Toilet Seat

The Forgotten Fomites Critical Control Points for cleaning and management

- Phone (cell phone)
- TV remote
- Computer keyboard
- Computer mouse
- Sink taps/handles
- Sponges/cleaning clothes
- Laundry

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Enteric Virus Survival during Household Laundering and Impact of Disinfection with Sodium Hypochlorite∇

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This study was conducted to determine whether enteric viruses (adenovirus, rotavirus, and hepatitis A virus) added to cotton cloth swatches survive the wash cycle, the rinse cycle, and a 28-min permanent press drying cycle as commonly practiced in households in the United States. Detergent with and without bleach (sodium hypochlorite) was added to washing machines containing sterile and virus-inoculated 58-cm^2 swatches, 3.2 kg of cotton T-shirts and underwear, and a soiled pillowcase designed to simulate the conditions (pH, organic load, etc.) encountered in soiled laundry. The most important factors for the reduction of virus in laundry were passage through the drying cycle and the addition of sodium hypochlorite. Washing with detergent alone was not found to be effective for the removal or inactivation of enteric viruses, as significant concentrations of virus were found on the swatches (reductions of 92 to 99%). It was also demonstrated that viruses are readily transferred from contaminated cloths to uncontaminated clothes. The use of sodium hypochlorite reduced the number of infectious viruses on the swatches after washing and drying by at least 99.99%. Laundering practices in common use in the United States do not eliminate enteric and respiratory viruses from clothes. The use of bleach can further reduce the numbers of enteric viruses in laundry.

DRYING CYCLE (HEAT) and BLEACH

Risk of Rotavirus Infection from Laundering

Concentration of Virus	Assumption
2×10^7	The amount in 0.001 gr of feces
2×10^5	After washing 99% reduction cm^2 clothing
2×10^4	After 28 min. drying
200	1% transferred to hands
2	1% transferred to mouth

→ Risk of infection ~ 1:10

Exposure Summary

- Large numbers of pathogens can be excreted into the environment.
- There are many examples of pathways of exposure.
- Hands play a prominent role in the indoor environment.
- Water plays a prominent role in the outdoor environment.
- Prevalence, concentrations and transport from the source to the exposure site needs to be accounted for in calculating the transmission/exposure.
- Survival is very important factor, which depends on environmental factors and the type of microbe and may be from hours to months.
- Quantitative assessment of inactivation rates and transport are important in modeling exposures.