Probabilistic Risk Assessment Model to Study Risk of *E. coli* O157:H7 Contamination in Hard Cheeses

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E. coli O157:H7 Overview

- Serious cause of foodborne illness
  - Annually 62,400 cases, 52 deaths
- Properties of *E. coli* O157:H7
  - Produces Verocytotoxin (VTEC)
  - Survival and growth factors
  - Symptoms of illness
- Vehicles of transmission
  - Survival in dairy products
  - *E. coli* O157:H7 outbreaks linked to cheese

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Model Objectives

- Adapt probabilistic model-based tools and techniques developed in engineering disciplines to food safety applications
- Apply adapted PRA techniques to cheese making process in order to determine:
  - Risk significant activities/events
  - Control strategies
  - Societal impacts due to hazard exposure
  - Areas for additional data collection/analysis
- Develop software platform to support PRA model

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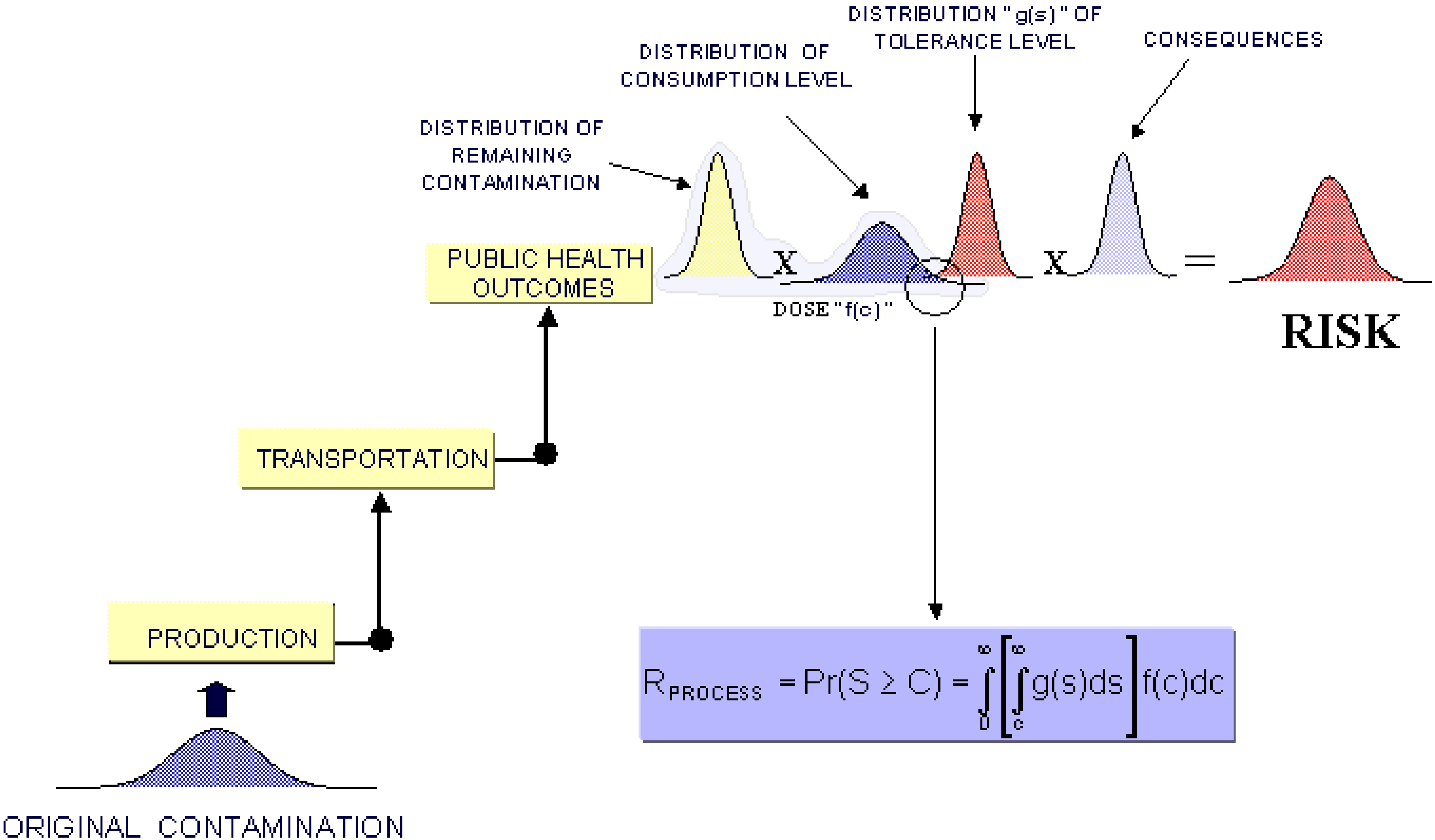
PRA Model Overview



$$R_{PROCESS} = \Pr(S \geq C) = \int_0^{\infty} \left[\int_c^{\infty} g(s)ds \right] f(c)dc$$

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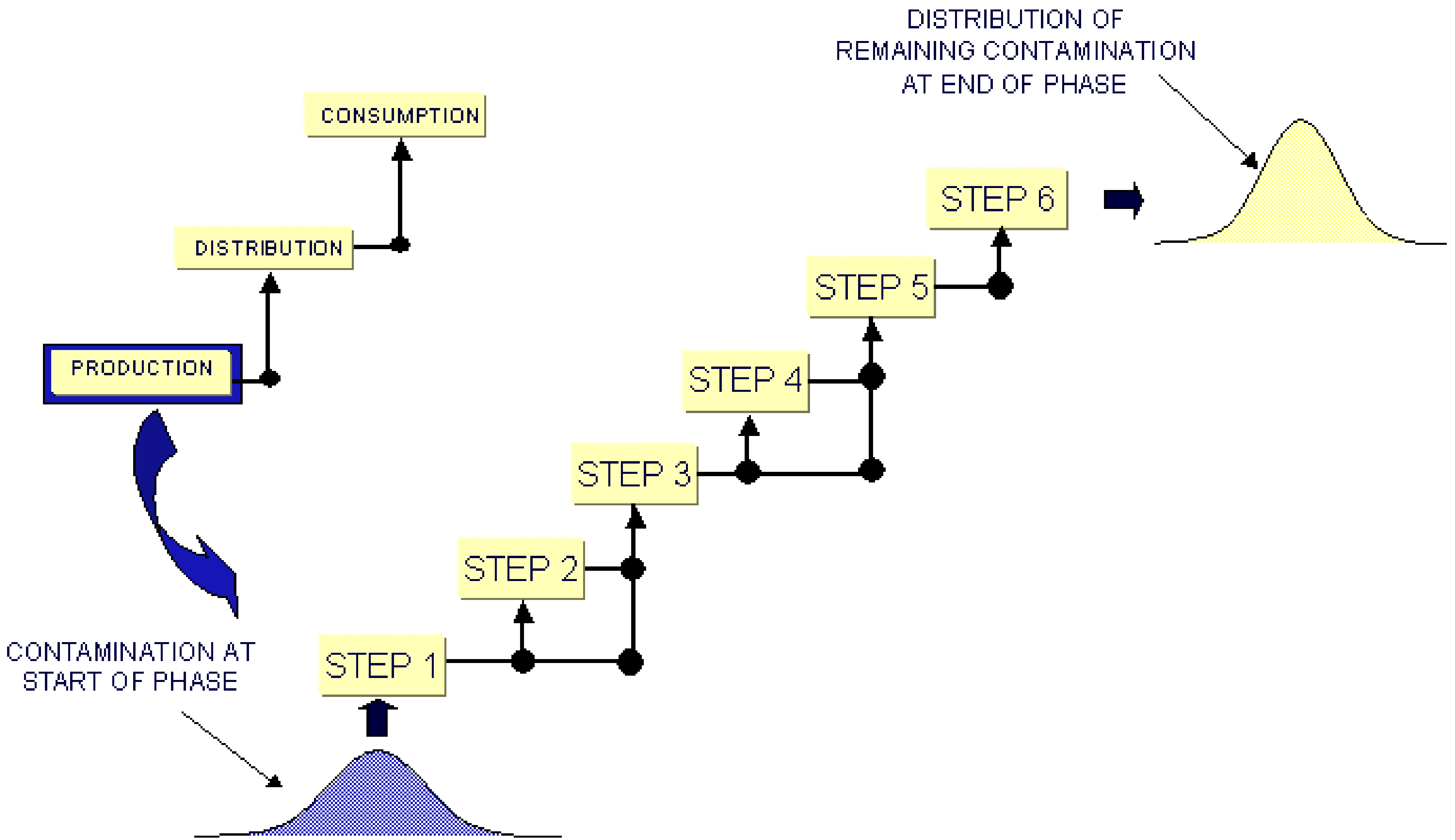
Expanded PRA Model



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Production Phase

- Identifies steps in cheese making process
  - Various options for each step
  - Scenario built based on user selections
- Contamination propagated through phase using Multiplicative Factors method
  - Mathematical predictive model
  - Developed by obtaining contamination level at input and output of step

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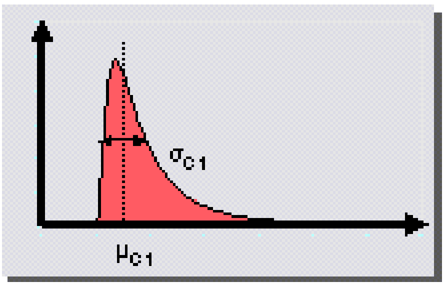
Multiplicative Factors Approach

CONTAMINATION LEVEL
BEFORE STEP "n"

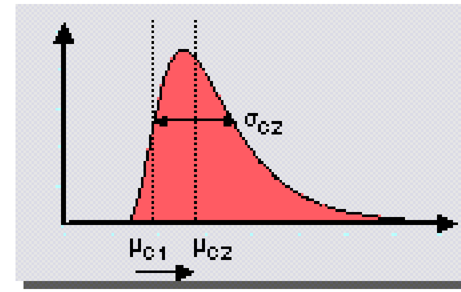


STEP "n"

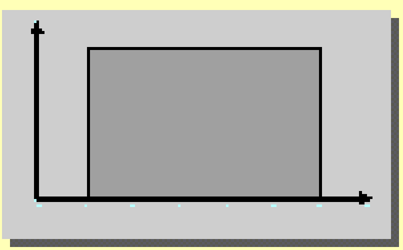
MONTECARLO SIMULATION

C2 = A x C1

CONTAMINATION LEVEL
AFTER STEP "n"



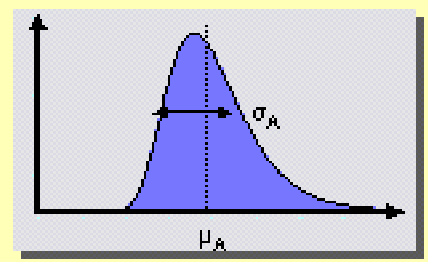
BAYESIAN APPROACH



PRIOR DISTRIBUTION OF
MULTIPLICATIVE FACTOR (A)

DATA
4.5
3.2
5.0
3.5
...
...
...

LIKELIHOOD OF
OBSERVED DATA



POSTERIOR DISTRIBUTION OF
MULTIPLICATIVE FACTOR (A)

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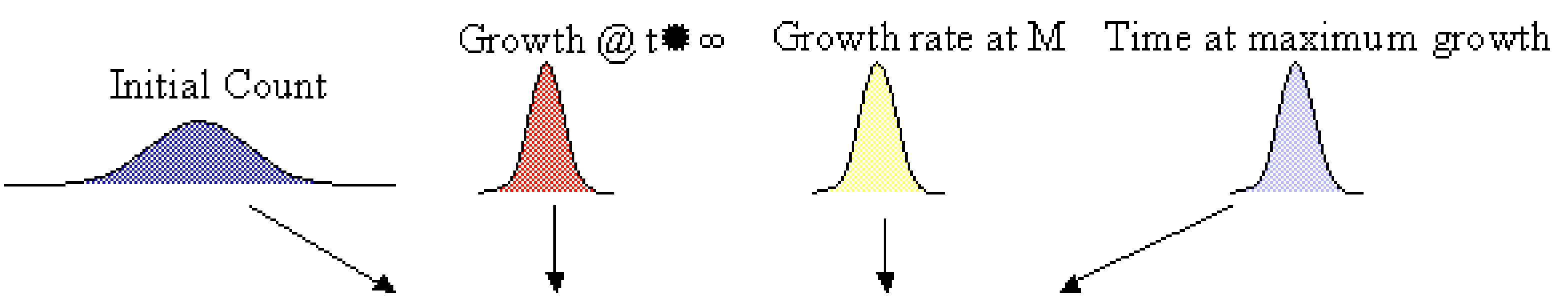
Transportation Phase

- Identifies steps in transportation and distribution of cheese
- Determine conditions affecting growth of *E. coli* O157:H7 during transportation phase
- Gompertz model best represents *E. coli* O157:H7 growth behavior in cheese



$$L(t) = A + C * \exp[-\exp(-B\,(t - M))]$$

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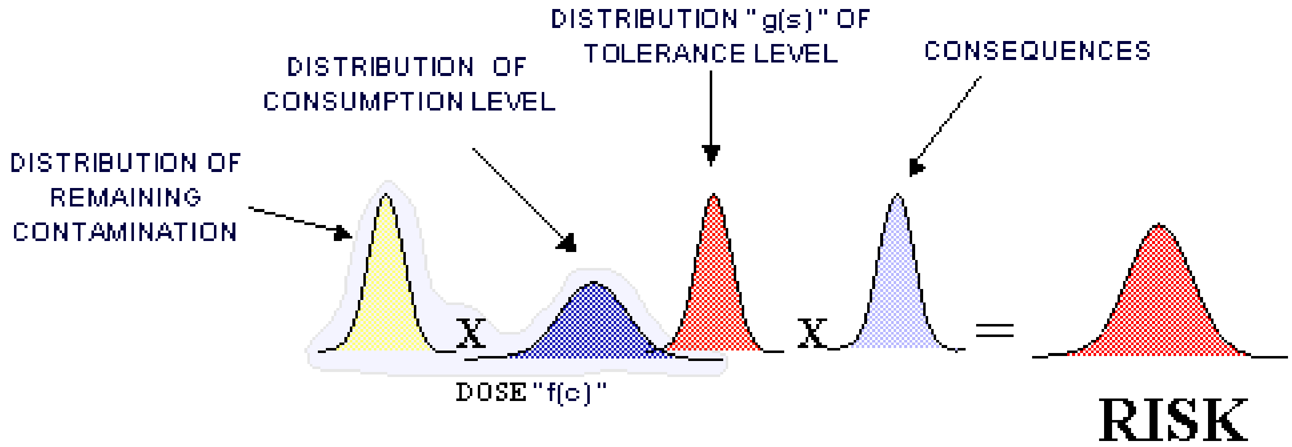
Public Health Outcomes Phase



- Links *E. coli* O157:H7 exposure with adverse health outcomes
- Individual outcome and consequences based on health status and number of bacteria consumed

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Dose-Response Approach

- Models: Exponential, Beta-Poisson, and Weibull-Gamma
- Dose-response parameters estimated for various data sets
- Uncertainty about which data set provides best estimation of dose-response
  - Analytical Hierarchy Process (AHP) Method
    - Weights alternatives based on criteria resulting in weighted-average parameters

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Consequence Analysis

- Types of consequences
- *E. coli* O157:H7 food outbreak data collected from annual CDC Report and additional reported cases
  - Number illnesses, Hospitalizations, HUS/TTP, and Mortality
- Consequence distributions based on previous *E. coli* O157:H7 risk assessments

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Case Study

- **Modeled cheddar cheese production**
  - Initial Contamination: 10 ± 5 CFU/ml raw milk
  - Best-case transportation times & temperatures
  - 1500 people exposed, Beta-Poisson (AHP)
- **Risk assessment tool**
  - Final Contamination, Number Ill, Population Sensitivity
- **Risk management tool**
  - Ripening Time, Milk Storage, Milk Treatment

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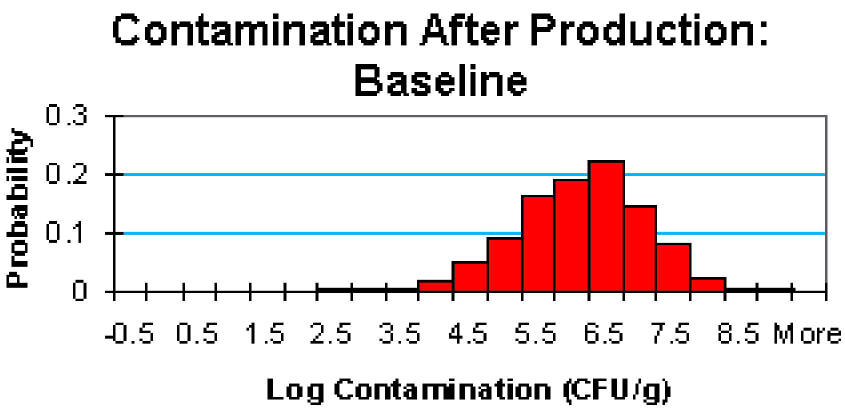
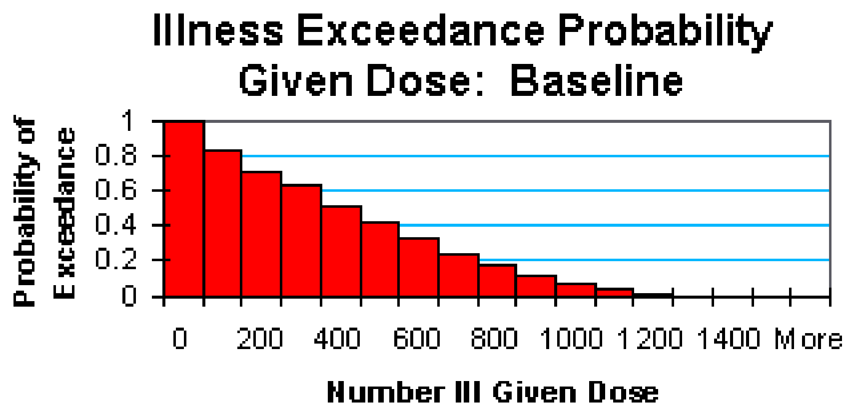
Risk Assessment: Dose & Number Ill





- Baseline average contamination: 6.8 CFU/g
- Baseline average number of people becoming ill given contamination level: 455

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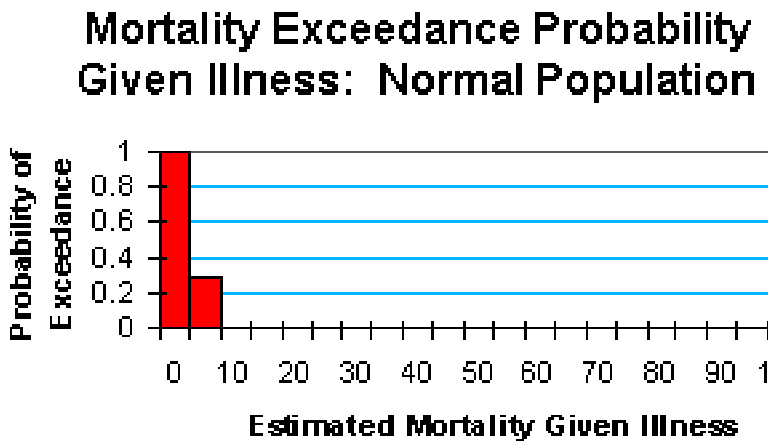
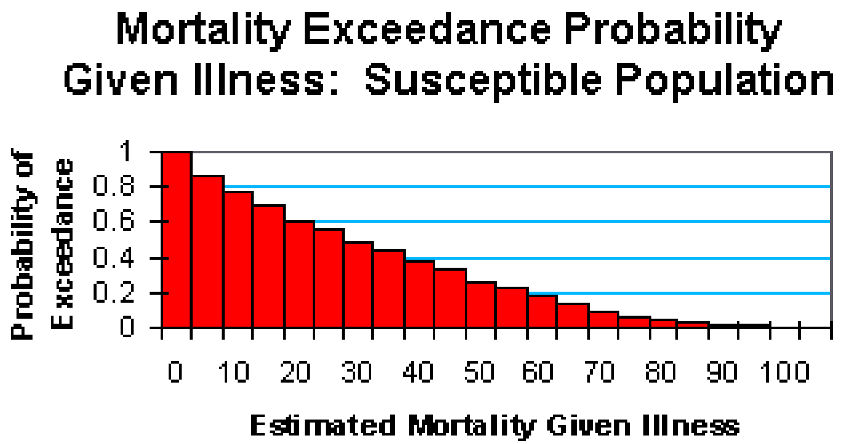
Risk Assessment: Pop. Sensitivity





- Number of deaths given contamination level calculated based on population type
  - Average number deaths for normal population: 3.4
  - Average number deaths for susceptible population: 33.6
- Risk assessment tool calculates various other consequences

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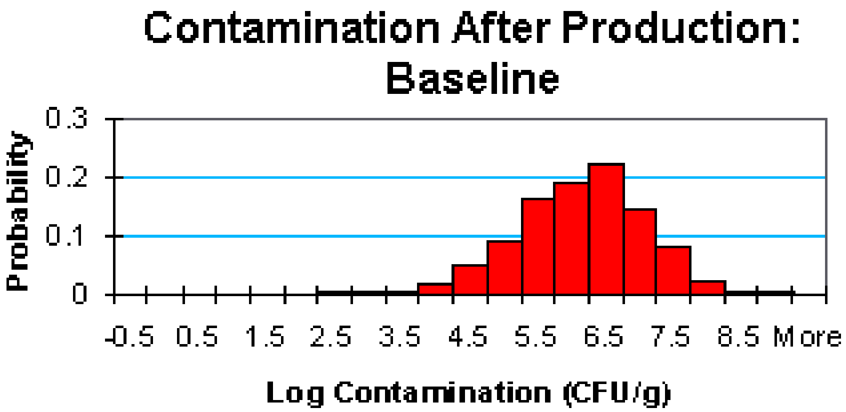
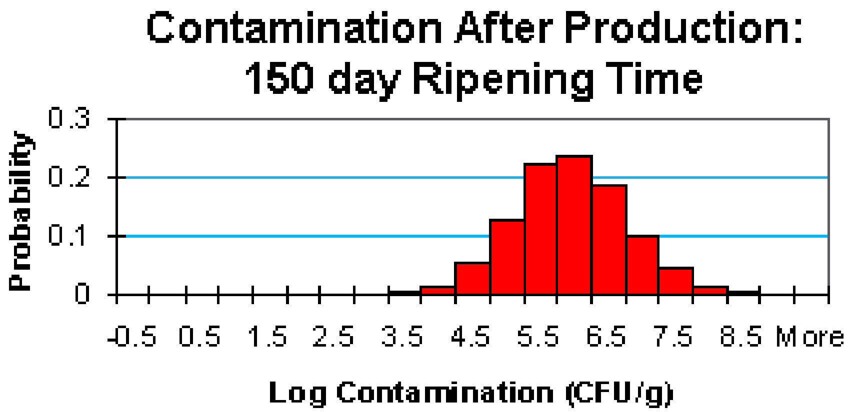
Risk Management: Ripening Time





- Reduce contamination by lengthening ripening time
  - 75 day (baseline) vs. 150 day
  - 6.8 CFU/g (baseline) vs. 6.5 CFU/g

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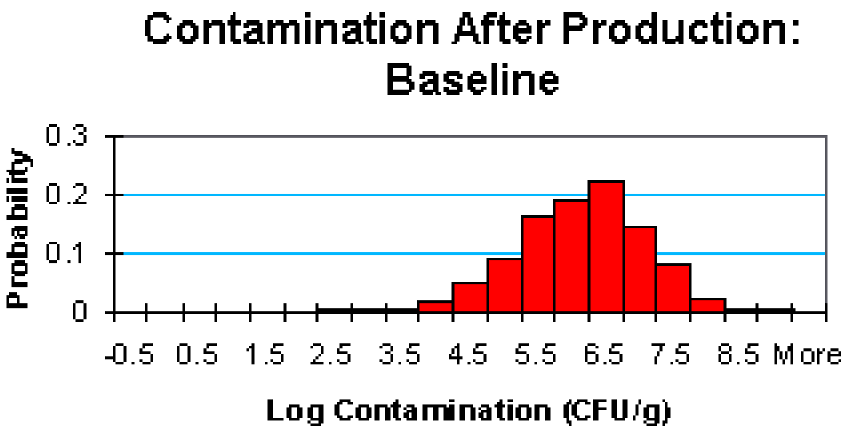
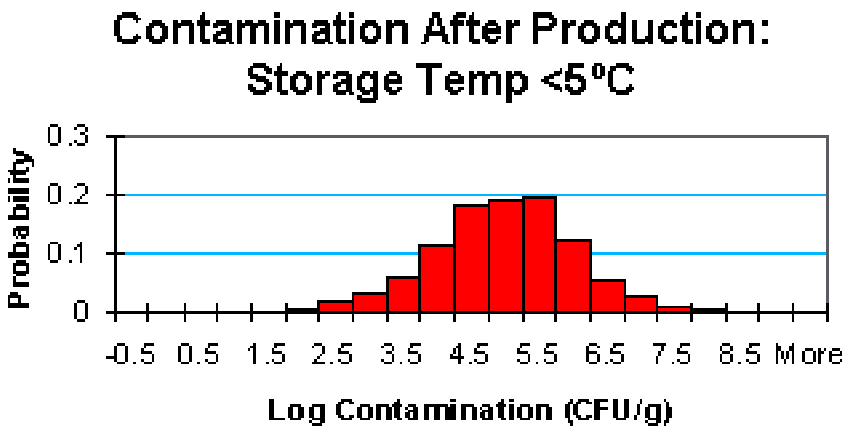
Risk Management: Milk Storage





- Reduce contamination by lowering milk storage temperature
  - 5ºC<t<8ºC (baseline) vs. t<5ºC
  - 6.8 CFU/g (baseline) vs. 5.7 CFU/g

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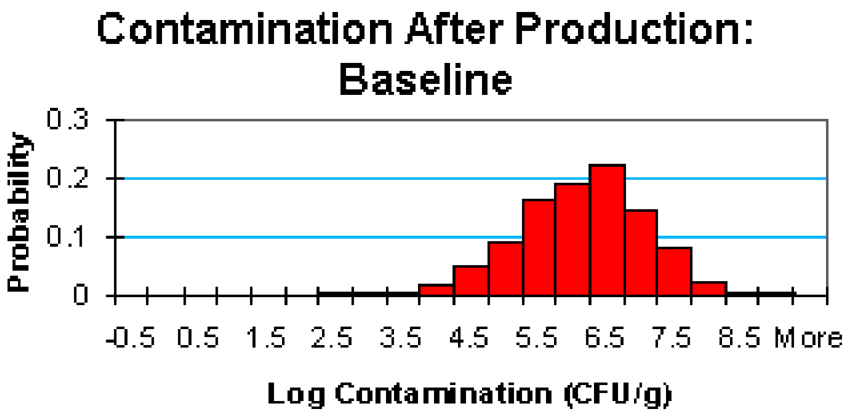
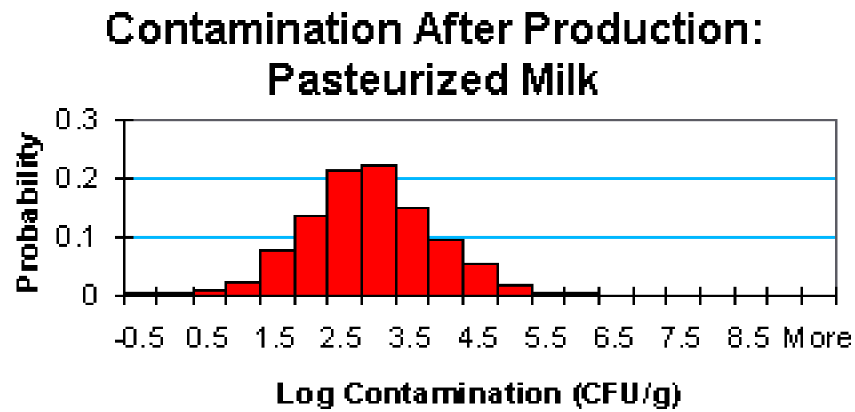
Risk Management: Milk Treatment





- Reduce contamination by pasteurization of raw milk
  - Raw Milk (baseline) vs. Pasteurized Milk
  - 6.8 CFU/g (baseline) vs. 3.6 CFU/g

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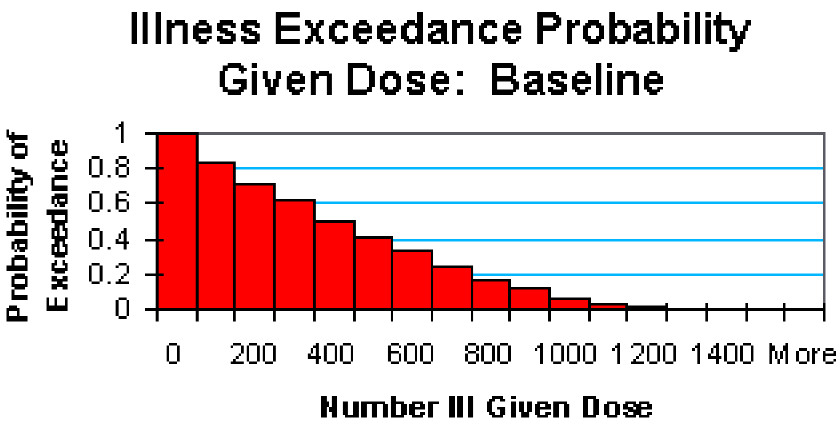
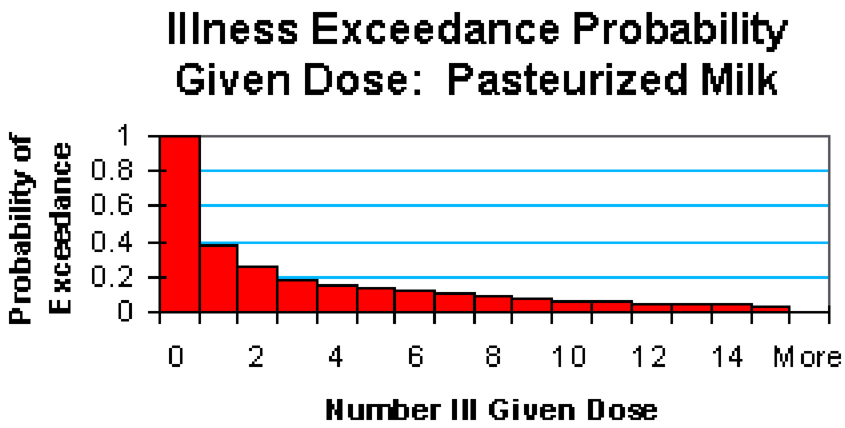
Risk Management: Milk Treatment





- Pasteurization leads to significant reduction in number of people becoming ill
  - 3 CFU/g decrease in contamination
  - Reduces illness by factor of 100

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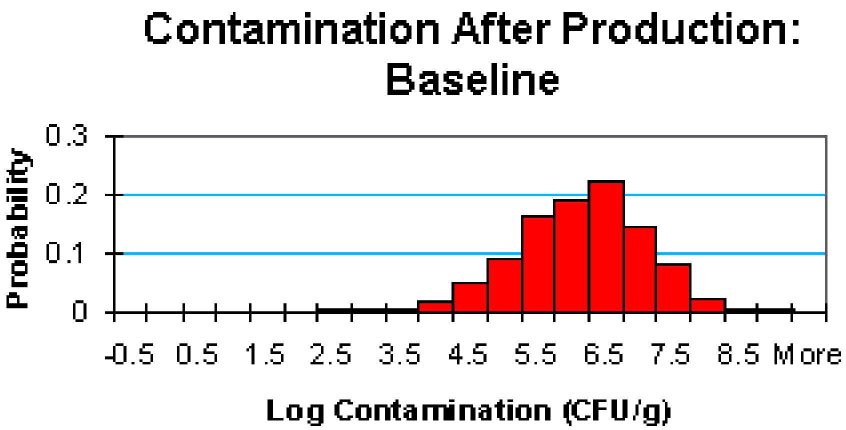
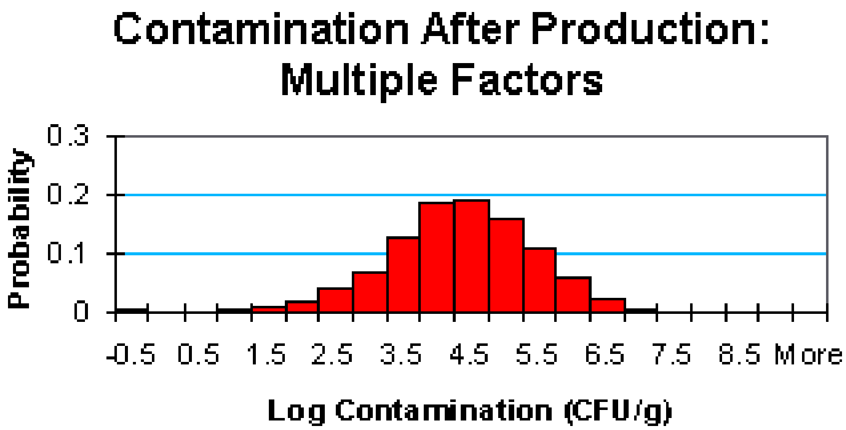
Risk Management: Multiple Factors





- Reduce contamination by several small changes
  - 75 day (baseline) vs. 150 day
  - 5ºC<t<8ºC (baseline) vs. t<5ºC
  - Raw Milk (baseline) vs. Sub-Pasteurization
  - 6.8 CFU/g (baseline) vs. 5.1 CFU/g

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Conclusions

- Other case studies
- PRA model describes *E. coli* O157:H7 behavior from production, transportation, and consumption to predict risk of human exposure
  - Data Uncertainty
  - Model to Model Variability
- Allows risk managers to estimate risk, assess societal impacts, and identify control strategies

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