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THE PUBLIC HEALTH SIGNIFICANCE OF BACTERIAL INDICATORS IN DRINKING WATER

Martin J. Allen, Ph.D.

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Indicator Concept

- Impossible to monitor for all pathogens
- Indicator organisms signal recent fecal contamination
- Indicator organisms always present in fecal material
- Indicator organisms persistence similar to pathogens
- Detection methods relatively simple

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Technical Issues Related to Pathogen Detection

- Low numbers of pathogens
- Human or non-human strains
- Pathogens difficult to detect
- Cannot determine viability
- Need large sample volumes
- Few water labs equipped or staffed
- Days to weeks for results

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Common Indicators for Source Water and Drinking Water

- Total Coliforms
- Fecal Coliforms
- *Escherichia coli*

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Functional Definition of the Coliform Group

- Metabolize lactose to produce acid and gas
- Possesses the enzyme β-glucuronidase (only *E. coli)*

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COLIFORM GENERA

- ***Escherichia* - human and animal feces**
- ***Enterobacter* - environment, feces**
- ***Klebsiella* - *environment, feces***
- ***Citrobacter* - environment**
- ***Serratia* - environment**

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Relative Number of Fecal and Nonfecal Types of Coliform Bacteria in Various Substances

(Source: Iowa State College Engineering Experiment Station Bulletin, 62(1921), p. 79.)

Sources	Number of Strains Observed	Percentage of Strains of *Aerobacter aerogenes* type	Percentage of Strains of *E. coli* type
Human Feces	2534	5.9	94.1
Animal Feces	1832	7.4	92.6
Water	2137	35.2	64.8
Milk	1382	43.1	56.9
Grain	288	81.7	18.3
Soil	853	88.1	11.9

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Percentage of Genera of Coliforms in Human and Animal Feces

(*Source:* Escherichia coli: The Fecal Coliform. *A.P. Dufour. Special Technical Pub. 65, ASTM, pp. 48–58, 1977.*)

Animal (Number examined)	*E. coli*	*Klebsiella spp.*	*Enterobacter/ Citrobacter*
Chicken (11)	90	1	9
Cow (15)	99.9	—	0.1
Sheep (10)	97	—	3
Goat (8)	92	8	—
Pig (15)	83.5	6.8	9.7
Dog (7)	91	—	—
Cat (7)	100	—	—
Horse (3)	100	—	—
Human (26)	96.8	1.5	1.7
Average %	94.5		

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Evolution of Indicators

- 1890s - *Bacillus (Escherichia) coli proposed but no specific test available*
- *1904 - "Fecal coliform test" -thermo-tolerant E. coli (44.5C)*
- *1914 - Total coliform proposed by U.S. Treasury Department (35C)*

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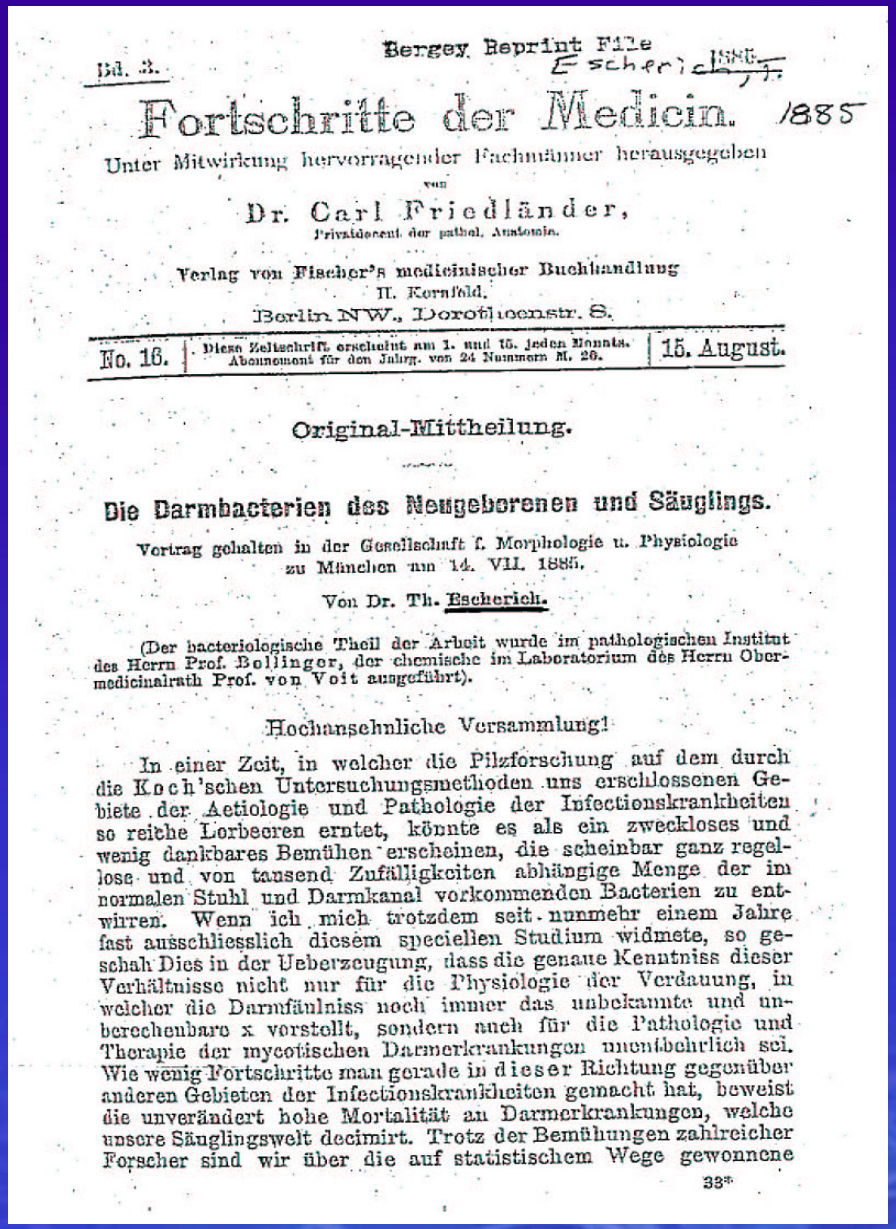

Bergey Reprint File
Escherich 1885

Bd. 3.

Fortschritte der Medicin. 1885

Unter Mitwirkung hervorragender Fachmänner herausgegeben

von

Dr. Carl Friedländer,

Privatdocent der pathol. Anatomie.

Verlag von Fischer's medicinischer Buchhandlung
H. Kornfeld.
Berlin NW., Dorotheenstr. 8.

No. 16. | Diese Zeitschrift erscheint am 1. und 15. jeden Monats. Abonnement für den Jahrg. von 24 Nummern M. 26. | 15. August.

Original-Mittheilung.

Die Darmbacterien des Neugeborenen und Säuglings.

Vortrag gehalten in der Gesellschaft f. Morphologie u. Physiologie zu München am 14. VII. 1885.

Von Dr. Th. Escherich.

(Der bacteriologische Theil der Arbeit wurde im pathologischen Institut des Herrn Prof. Bollinger, der chemische im Laboratorium des Herrn Obermedicinalrath Prof. von Voit ausgeführt).

Hochansehnliche Versammlung!

In einer Zeit, in welcher die Pilzforschung auf dem durch die Koch'schen Untersuchungsmethoden uns erschlossenen Gebiete der Aetiologie und Pathologie der Infectionskrankheiten so reiche Lorbeeren erntet, könnte es als ein zweckloses und wenig dankbares Bemühen erscheinen, die scheinbar ganz regellose und von tausend Zufälligkeiten abhängige Menge der im normalen Stuhl und Darmkanal vorkommenden Bacterien zu entwirren. Wenn ich mich trotzdem seit nunmehr einem Jahre fast ausschliesslich diesem speciellen Studium widmete, so geschah Dies in der Ueberzeugung, dass die genaue Kenntniss dieser Verhältnisse nicht nur für die Physiologie der Verdauung, in welcher die Darmfäulniss noch immer das unbekannte und unberechenbare x vorstellt, sondern auch für die Pathologie und Therapie der mycotischen Darmerkrankungen unentbehrlich sei. Wie wenig Fortschritte man gerade in dieser Richtung gegenüber anderen Gebieten der Infectionskrankheiten gemacht hat, beweist die unverändert hohe Mortalität an Darmerkrankungen, welche unsere Säuglingswelt decimirt. Trotz der Bemühungen zahlreicher Forscher sind wir über die auf statistischem Wege gewonnene

Copy of original 1885 manuscript by Th. Escherich on *Bacillus coli as best indicator of pathogens.*

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Bacterial Regrowth in Distribution Systems

- Common phenomenon
- Attachment and colonization
- *Enterobacter* and *Klebsiella - coliforms*
- Promoted by nutrients, warmer temperatures, low flow (time), low disinfection residuals

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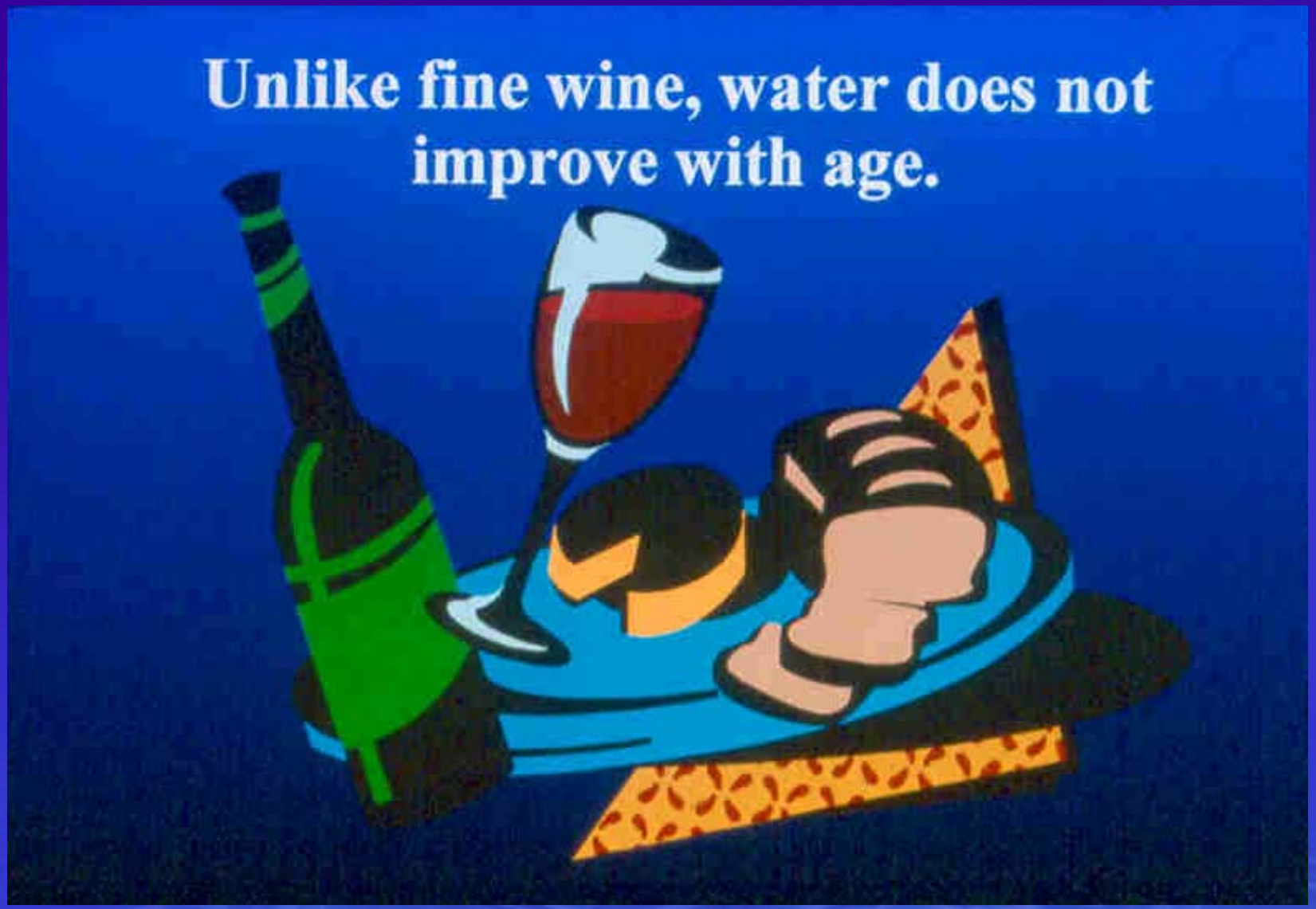

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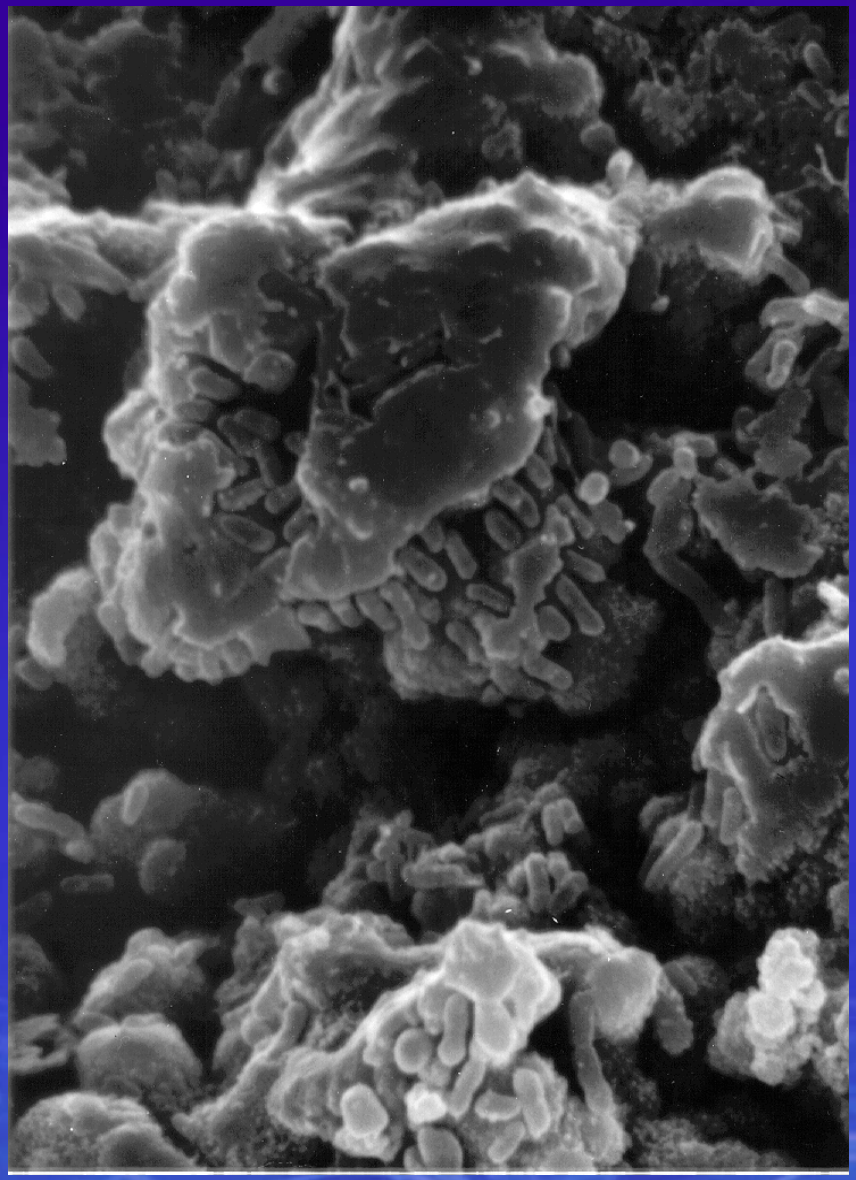

Bacteria in water main tubercles-New Haven, CT; M.Allen,1977

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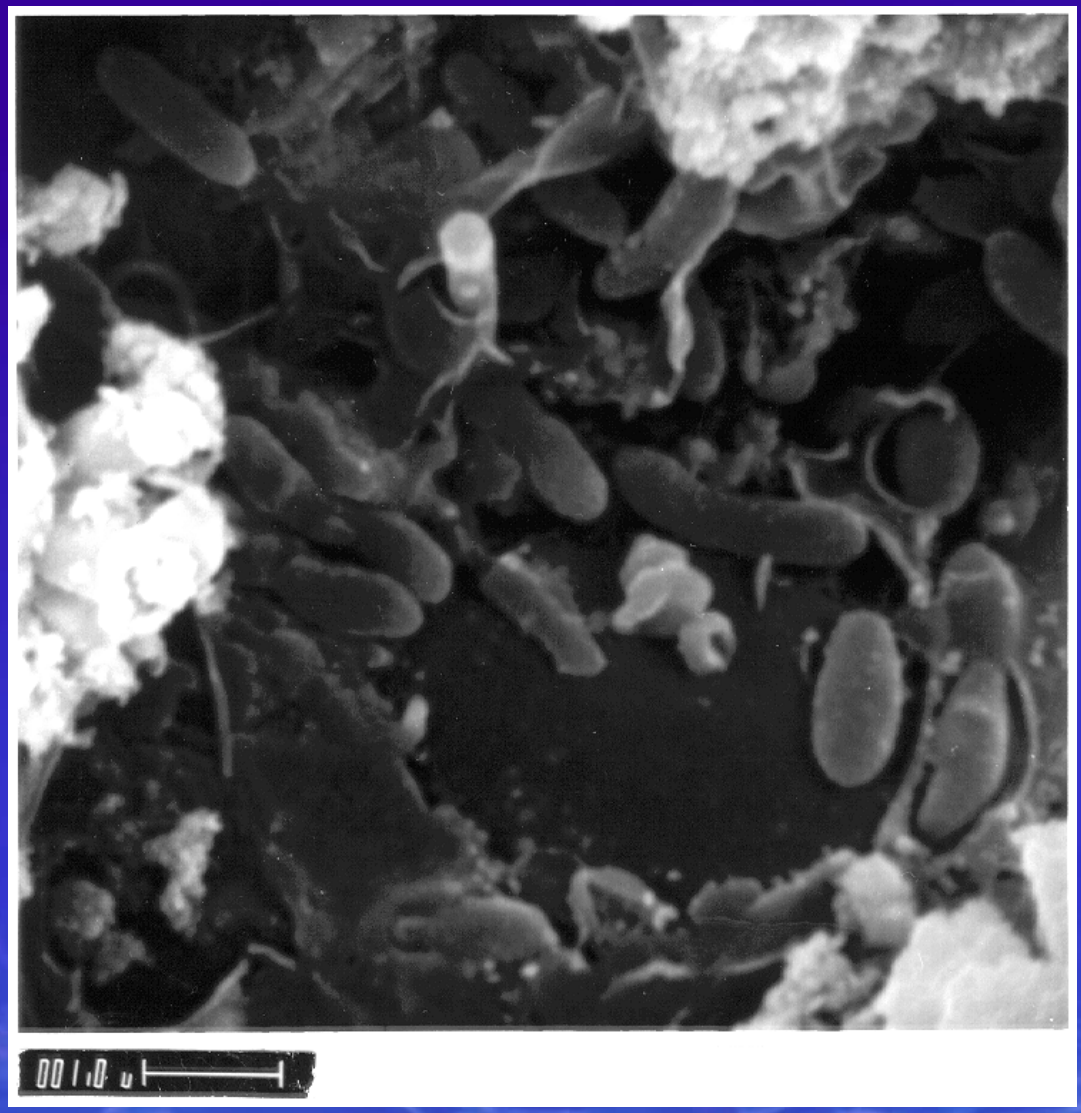

Bacteria in water main tubercles-New Haven, CT; M. Allen, 1977

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Ramifications of Regrowth

- Accelerated corrosion
- Loss of disinfectant residual
- Increased turbidity
- Taste and odor complaints
- Increased frequency of coliform-positive sample
- Unwarranted boil advisories

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Fecal Coliform Method

- Enumerates “thermotolerant” coliforms, **NOT** necessarily coliforms of fecal origin
- Enumerates *Klebsiella* which is **NOT** of fecal origin
- 15 percent of *Klebsiella* ***ARE*** thermotolerant
- 10 -15 percent of *E. coli* **NOT** thermotolerant

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Klebsiella and Human Disease

- No waterborne disease ever associated with *Klebsiella* in drinking water - all hospital-acquired (nosocomial infections)
- Review article by I.B.R. Duncan, University of Toronto
- *Toxicity Assessment: An International Journal, Vol. 3,581-598; 1988.*
- *…Klebsiella* in water supplies should therefore not be considered a hazard to human health.

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Why Enumeration Methods are Flawed

- Microorganisms not uniformly distributed
- Membrane filtration method underestimates numbers (>60% defective by USEPA)
- HPC interferences (>500cfu/ml)
- Wide variability in microbial data

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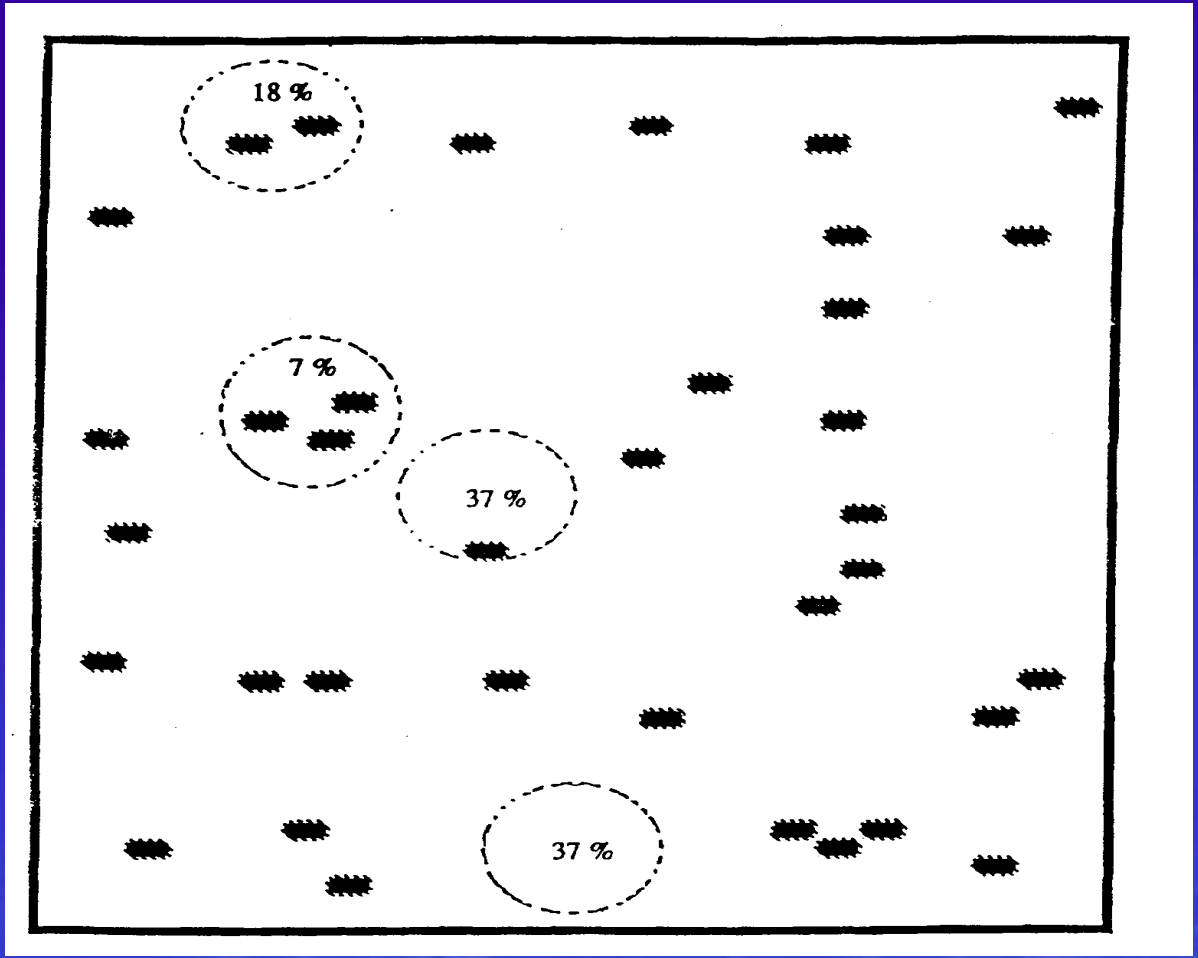
VARIABILITY OF AN INDIVIDUAL, WELL-MIXED SAMPLE



Random dispersion - 36 volumes of bacteria

- **37 % - one bacterium**
- **37 % - no bacteria**
- **18 % - two bacteria**
- **7 % - >two bacteria**

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Source: W. Pipes *et al*; Applied Environmental Microbiology 45(2):603-609, 1983

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Bacterial Numbers Have No Public Health Significance in Drinking Water

RECOMMENDATIONS

- Use coliform group to monitor treatment efficiencies/water quality in distribution systems
- Discontinue use of fecal coliforms to quantify fecal loading in source waters
- Discontinue use of fecal coliforms for drinking water

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RECOMMENDATIONS (continued)

- Use E.coli methods that don't require confirmation steps (days to complete)

- Use simple methods that provide credible data to make correct public health decisions is the shortest possible time (utilities should be able to monitor for *E. coli*)

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RAMIFICATIONS OF PUBLIC ADVISORIES

- Inundate 911 emergency switchboards
- Economic hardships to entire community (schools, hospitals, dental offices, restaurants, tourist, hotels, etc.)
- Need definitive end-point when to end advisory
- “Crying Wolf Syndrome”

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World Health Organization
Sustainable Development and
Healthy Environments

WHO/SDE/WSH/02.10
English only

Heterotrophic Plate Count Measurement in Drinking Water Safety Management

Geneva 24-25 April 2002

Protection of the Human Environment
Water, Sanitation and Health
Geneva, 2002

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WHO Recommendations

- **Expert panel on HPC Bacteria**
- **April 25-26, 2002 in Geneva**
- ***Pseudonomas aeruginosa, Klebsiella pneumonia, Aeromonas* spp, and *Actinetobacter* spp - no clinical evidence they cause gastrointestional infections from drinking water.**

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Walkerton Inquiry

- Chapter 5:Drinking Water Standards-Recommendation 27
- "The Advisory Council of Standards should consider whether to replace the total coliform test with an *E. coli* test."
- Total coliform test is not efficient

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THAT'S ALL FOLKS!

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