# *From Science to Policy – Recreational Water Criteria / Standards: Scientific Bases for Potential Paths Forward*

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CASQA California SWRCB Bacteria Summit
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SOLLER ENVIRONMENTAL
ANALYSIS & INSIGHT FOR DECISION MAKING

# Outline

- Similarities and key differences US EPA 1986 & 2012 water criteria for recreation
- Human impacted waters – important pathogens and features
- Non-human impacted waters – important pathogens and contrast to human impacted waters
- Mixtures of human & non-human contamination
- Findings from CA rec water studies in context of differential risk from human / nonhuman sources
- Take away messages

# 2012 vs 1986 water criteria for recreation

## 2012

**Table 4. Recommended 2012 RWQC.**

| **Criteria Elements** | **Estimated Illness Rate (NGI): 36 per 1,000 primary contact recreators** | | OR | **Estimated Illness Rate (NGI): 32 per 1,000 primary contact recreators** | |
|---|---|---|---|---|---|
| | **Magnitude** | | | **Magnitude** | |
| Indicator | GM (cfu/100 mL)[a] | STV (cfu/100 mL)[a] | | GM (cfu/100 mL)[a] | STV (cfu/100 mL)[a] |
| Enterococci – marine and fresh | 35 | 130 | | 30 | 110 |
| OR | | | | | |
| *E. coli* – fresh | 126 | 410 | | 100 | 320 |
| **Duration and Frequency**: The waterbody GM should not be greater than the selected GM magnitude in any 30-day interval. There should not be greater than a ten percent excursion frequency of the selected STV magnitude in the same 30-day interval. | | | | | |

[a] EPA recommends using EPA Method 1600 (U.S. EPA, 2002a) to measure culturable enterococci, or another equivalent method that measures culturable enterococci and using EPA Method 1603 (U.S. EPA, 2002b) to measure culturable *E. coli*, or any other equivalent method that measures culturable *E. coli*.

## 1986

| | Acceptable Swimming Associated Gastro-enteritis Rate per 1000 swimmers | Steady State Geometric Mean Indicator Density | Designated Beach Area (upper 75% C.L.) Single Sample Max |
|---|---|---|---|
| Freshwater | | | |
| enterococci | 8 | 33 ([1]) | 61 |
| E. coli | 8 | 126 ([2]) | 235 |
| Marine Water | | | |
| enterococci | 19 | 35 ([3]) | 104 |

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# 2012 vs 1986 water criteria for recreation

## Key difference

- 1986 criteria "were selected in order to further carry forward the same level of water quality associated with EPA's previous criteria recommendations to protect the primary contact recreation use"
- 2012 criteria have a much closer linkage to the underpinning level of health protection

  "The mean illness rates associated with the 2012 RWQC water quality recommendations are approximately 32 cases of NGI per 1,000 primary contact recreators for a culturable enterococci GM criterion of 30 cfu per 100 mL and 36 cases of NGI per 1,000 primary contact recreators for a culturable enterococci GM criterion of 35 cfu per 100 mL, in both marine and fresh water"
- The 2012 illness rates were used to estimate equivalent criteria values for culturable *E. coli* and *Enterococcus spp*. via qPCR
- This establishes a risk-based framework for alternative indicators and methods

# Alternative criteria – why and how

**WHY**

- EPA’s epidemiological studies were conducted in recreational waters impacted by treated wastewater
  - Conducted during summer bathing season
  - Account for full range of weather conditions observed
- The fecal indicator bacteria (FIB) / pathogen combination(s) may vary in other sources of contamination and waters impacted by other sources

**HOW**

- States could adopt alternative criteria to reflect local conditions and human exposure patterns
  - Alternative health relationship derived using epidemiology with or without QMRA
  - QMRA results to determine water quality values associated with a specific illness rate
  - Different indicator/method combination
- May be adopted into a state water quality standard provided that they are scientifically defensible, protective of the use, and reviewed and approved by EPA

# Waters impacted by human sources

What pathogens likely cause the majority of illnesses in recreational waters impacted by human sources?

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**Estimating the primary etiologic agents in recreational freshwaters impacted by human sources of faecal contamination☆**

*Jeffrey A. Soller [a,*], Timothy Bartrand [b], Nicholas J. Ashbolt [c], John Ravenscroft [d], Timothy J. Wade [e]*

Contents lists available at ScienceDirect
Water Research
journal homepage: www.elsevier.com/locate/watres
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WATER RESEARCH

Quantification of pathogens and markers of fecal contamination during storm events along popular surfing beaches in San Diego, California

Check for updates

Joshua A. Steele [a,*], A. Denene Blackwood [b], John F. Griffith [a], Rachel T. Noble [b], Kenneth C. Schiff [a]

[a] *Southern California Coastal Water Research Project, 3535 Harbor Blvd. Ste 110, Costa Mesa, CA 92626, USA*
[b] *UNC Institute of Marine Science, 3431 Arendell Street, Morehead City, NC 28557, USA*

# Waters impacted by human sources

**Table 4 – Summary of QMRA results**

| Pathogen | Health-Based Approach | | | POTW Effluent-Based Approach | | |
|---|---|---|---|---|---|---|
| | Illness rate/ 1000 swimmers | Infection Rate/ 1000 swimmers | Estimated mean concentration (organisms/L) | Illness Rate/ 1000 swimmers | Infection Rate/ 1000 swimmers | Estimated mean concentration (organisms/L) |
| All | 30.6 | Unknown | NA | 30.6 | Unknown | NA |
| Rotavirus | 4.8 | 13.6 | 0.7 | 0.3 | 0.7 | 0.04 |
| *Norovirus*[a] | 17.1 | 28.6 | 2.1 | 29.7 | 49.5 | 3.8 |
| Adenovirus | 4.8 | 9.5 | 0.7 | 0.3 | 0.5 | 0.04 |
| *Cryptosporidium* spp. | 0.3 | 0.7 | 0.2 | 0.2 | 0.5 | 0.15 |
| *Giardia lamblia* | 2.2 | 4.9 | 7.6 | 0.01 | 0.03 | 0.05 |
| *Camplyobacter jejuni* | 0.6 | 24.6 | 1.0 | 0.1 | 3.8 | 0.4 |
| *E. coli* O157:H7 | 0.01 | 0.05 | 0.2 | 0.001 | 0.01 | 0.01 |
| *Salmonella enterica* | 0.09 | 0.44 | 122 | 0.0003 | 0.001 | 0.4 |

a Genome copies per liter.

Takeaway: In human impacted waters viruses are likely etiologic agents of concern

# Waters impacted by mixtures of human sources

When recreational waters are impacted by a mixture of human sources, which source is most important?

- Raw sewage
- WWTP effluent

- FIB culture
- FIB qPCR
- Pathogen risk

(FIB = fecal indicator bacteria)

WATER RESEARCH 45 (2011) 2670–2680

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WATER RESEARCH

**Evaluating the importance of faecal sources in human-impacted waters☆**

*Mary E. Schoen*[a,*], *Jeffrey A. Soller*[b], *Nicholas J. Ashbolt*[a]

# Waters impacted by mixtures of human sources

- Hypothetical waterbody had both raw sewage and treated wastewater effluent
- A combination of two different human sources is required to achieve the 35 ENT /100mL and 30/1000 GI illness combination
- The different sources contribute varying levels of impact (culture, qPCR, volume, risk)
- Takeaway: The source contributing the majority of risk in a mixture may be overlooked when only culture based FIB are assessed

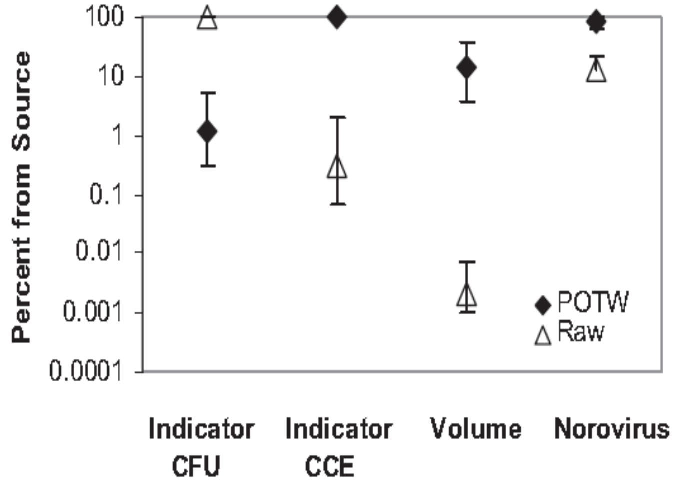


**Fig. 1** – Predicted median source contribution of total indicator density, volume, and pathogen density for a waterbody with a total indicator density of 35 CFU 100 $mL^{-1}$ enterococci and impacted by fresh poorly treated sewage (Raw) and fresh secondary-treated disinfected municipal wastewater (POTW) (Run 1a). The 25th and 75th percentile value predictions are shown as error bars.

# Waters impacted by non-human sources

At a fixed level of fecal indicator bacteria, are the risks in non-human impacted waters the same or different than those in human impacted waters?

## Assessing Pathogen Risk to Swimmers at Non-Sewage Impacted Recreational Beaches

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*Received November 19, 2009. Revised manuscript received February 5, 2010. Accepted February 15, 2010.*

The risk of gastrointestinal illness to swimmers from fresh sewage and non-sewage fecal sources at recreational beaches was predicted using quantitative microbial risk assessment (QMRA). The QMRA estimated the probability of illness for accidental ingestion of recreational water with a specific concentration of fecal indicator bacteria, here the geometric mean enterococci limit of 35 cfu 100 mL$^{-1}$, from either a mixture of sources or an individual source. Using seagulls as an example non-sewage fecal source, the predicted median probability of illness was less than the illness benchmark of 0.01. When the fecal source was changed to poorly treated sewage, a relatively small difference between the median probability of illness and the illness benchmark was predicted. For waters impacted by a mixture of seagull and sewage waste, the dominant source of fecal indicator was not always the predicted dominant source of risk.

relationship between indicator and health outcome at non-POTW impacted beaches has prompted the need to find an alterative way of estimating the conditions under which human health may be impacted (4). Such an alternative approach is implemented here to predict the pathogen risks from non-sewage sources at recreational beaches, using quantitative microbial risk assessment (QMRA) (7−9).

QMRA has been used to predict the public health outcome from exposure to recreational waters in multiple studies (10−16). All but one of these studies focus on waters dominated by human sources; and to our knowledge, only one study focused specifically on the risks from animal sources. Till et al. calculated the probability of illness from bird dominated recreational waters in New Zealand using observed densities of *Campylobacter*. This study, which considered other sources of contamination in addition to avian sources, motivated a revision to New Zealand's water quality guidelines for freshwater recreational areas (13).

The work described here also aims to inform future policy decisions where non-sewage sources dominate the contamination at recreational waters. The primary objective was to predict and prioritize the pathogen risk from non-sewage and sewage sources for a waterbody at the U.S. EPA recommended water quality limit. The second objective was to predict when a non-sewage source of pathogens may dominate the illness risk in a waterbody impacted by a mixture of sources.

### Method

A QMRA approach (7, 8) was constructed to calculate the probability of gastrointestinal (GI) illness for a healthy adult resulting from the accidental ingestion of recreational water impacted by fresh fecal contamination. The probability of GI illness was estimated separately for non-sewage and

WATER RESEARCH 44 (2010) 4674–4691

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IWA WATER RESEARCH

## Estimated human health risks from exposure to recreational waters impacted by human and non-human sources of faecal contamination☆

*Jeffrey A. Soller*[a,*], *Mary E. Schoen*[b], *Timothy Bartrand*[c], *John E. Ravenscroft*[d], *Nicholas J. Ashbolt*[b]

# Waters impacted by human and non-human sources

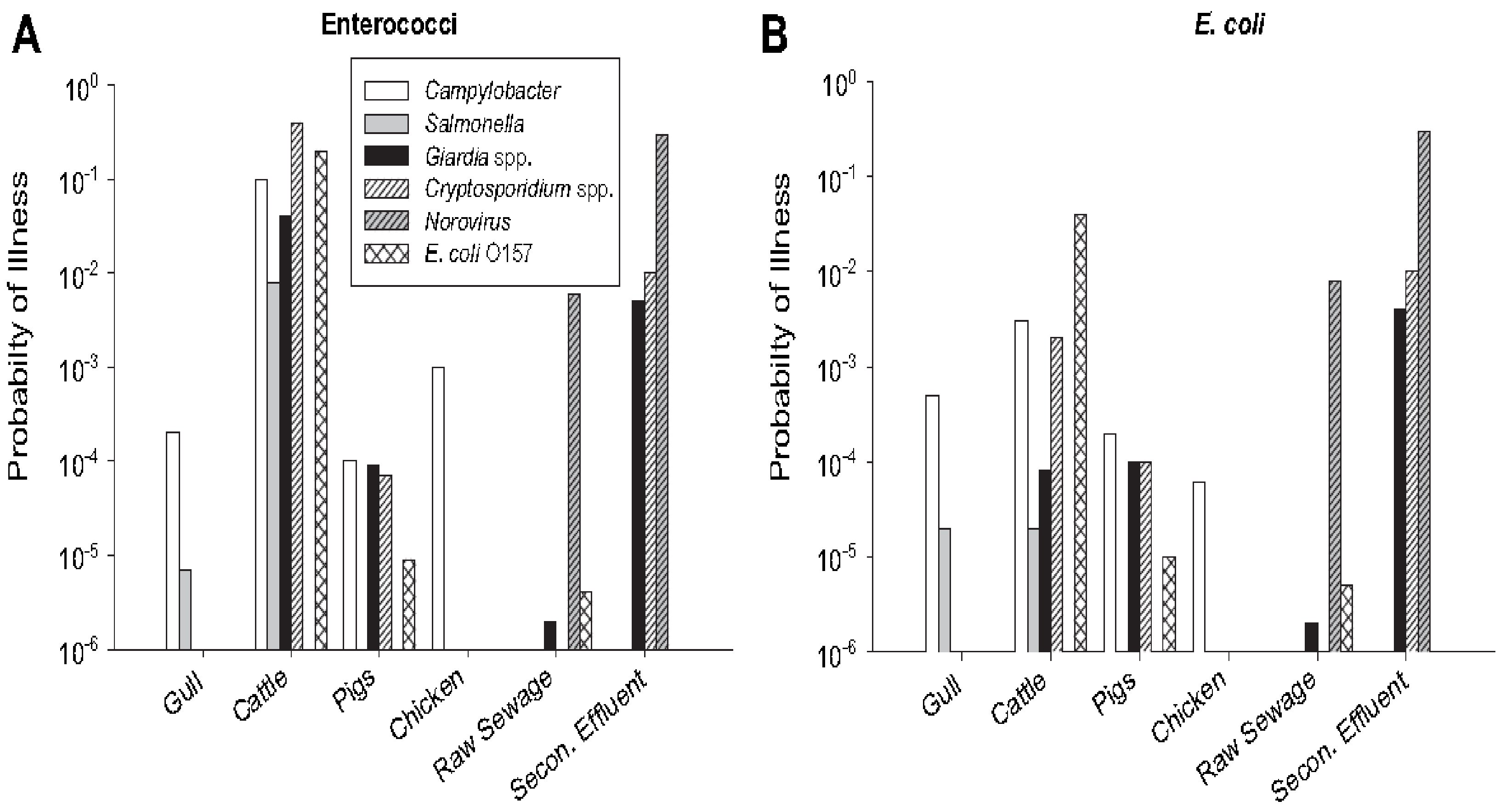


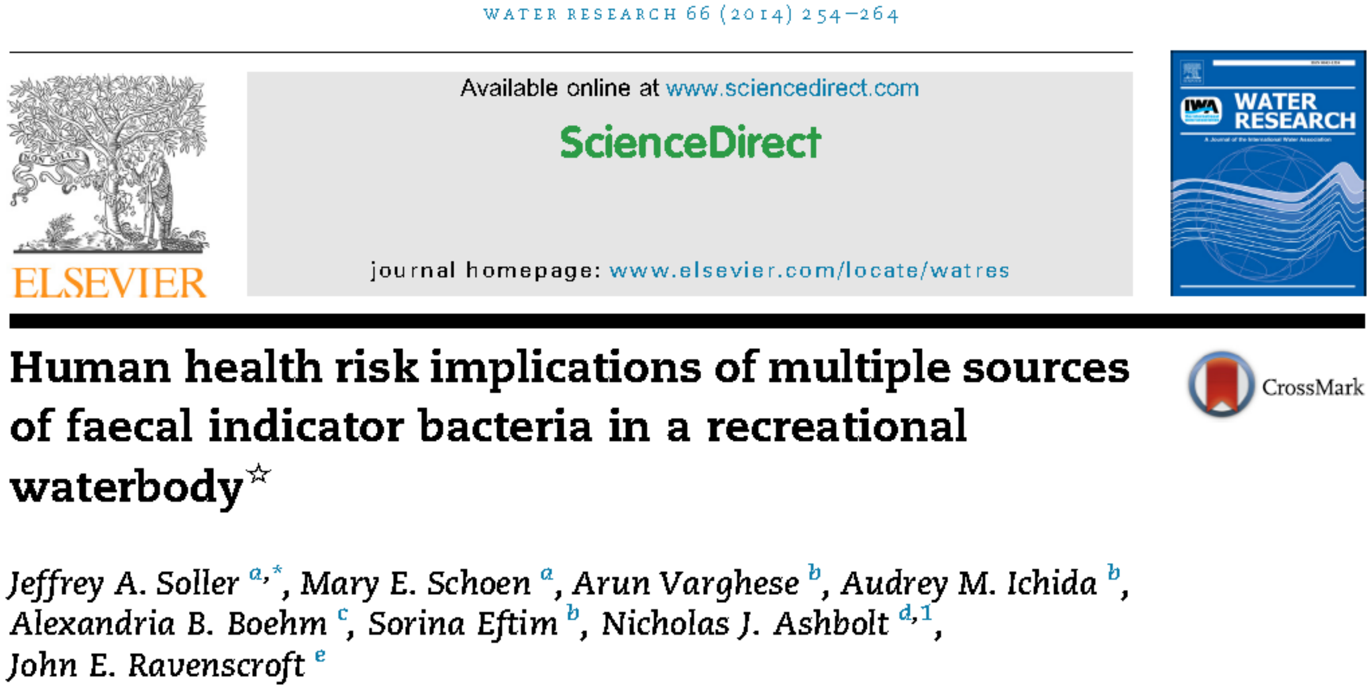

Fig. 2 – Run 1 contribution of each pathogen. Run 1 contribution of each pathogen to the probability of GI illness from ingestion of water containing fresh faecal pollution from animals or sewage at faecal indicator densities of 35 cfu 100 $mL^{-1}$ ENT (2A) and 126 cfu 100 $mL^{-1}$ *E. coli* (2B).

Takeaway: Some non-human sources have lower risks than human sources

# Waters impacted by mixtures of human and non-human sources

What is the risk profile for waters impacted by mixtures of human and non-human sources?

Is it possible to derive FIB values that correspond to a specific risk level for waters impacted by mixtures of human and non-human contamination?


WATER RESEARCH 66 (2014) 254–264

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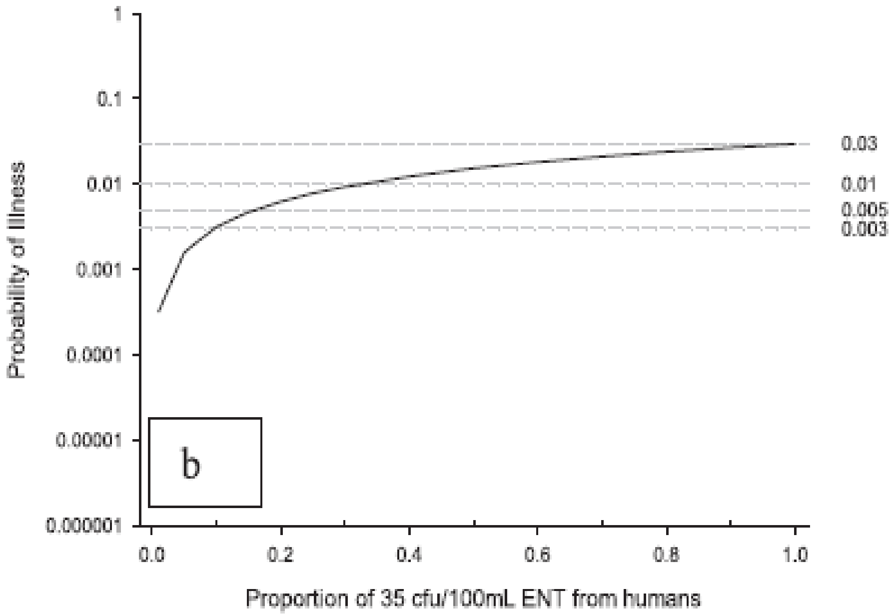
journal homepage: www.elsevier.com/locate/watres

**Human health risk implications of multiple sources of faecal indicator bacteria in a recreational waterbody☆**

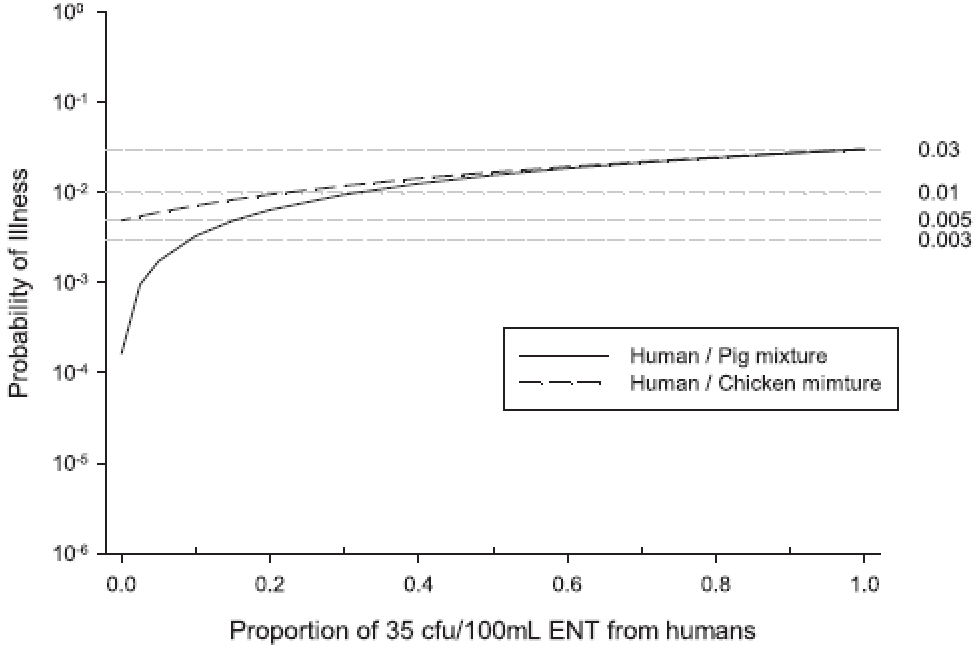
*Jeffrey A. Soller* [a,*], *Mary E. Schoen* [a], *Arun Varghese* [b], *Audrey M. Ichida* [b], *Alexandria B. Boehm* [c], *Sorina Eftim* [b], *Nicholas J. Ashbolt* [d,1], *John E. Ravenscroft* [e]

# Waters impacted by mixtures of human and non-human sources

Human / Non-pathogenic source




Human / animal sources



# Waters impacted by mixtures of human and non-human sources

Enterococci concentrations corresponding to 36/1000 illnesses for various mixed contamination scenarios

**Table 2 – Selected predicted median enterococci densities that correspond to GI illness levels of 0.036 for waters impacted by mixed sources of faecal contamination.**

| Non-human source | Human contribution / Non-human contribution | 0% / 100% | 10% / 90% | 20% / 80% | 30% / 70% | 50% / 50% | 70% / 30% | 100% / 0% |
|---|---|---|---|---|---|---|---|---|
| Pig | | 607 | 278 | 164 | 114 | 70 | 50 | 35 |
| Chicken | | 103 | 95 | 87 | 79 | 62 | 49 | 35 |
| Gull | | 1947 | 339 | 174 | 116 | 70 | 50 | 35 |
| Non-pathogenic source | | – | 350 | 175 | 117 | 70 | 50 | 35 |

Takeaway: In waters with mixed sources, higher levels of Ent can correspond to illness benchmark

# Integrating source specific risk information with results from CA rec water studies - epidemiology

Numerous rec water epi studies conducted in CA

- Avalon, Doheny, Malibu, San Diego, Santa Monica

FIB measured via culture can do a good job in some / many cases

Other indicator / methods can improve health outcome predictions depending on specific conditions at studied location

- F+ coliphage
- Human markers (e.g. HF183)

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WATER RESEARCH

Epidemiologic evaluation of multiple alternate microbial water quality monitoring indicators at three California beaches

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John F. Griffith [a,*], Stephen B. Weisberg [b], Benjamin F. Arnold [c], Yiping Cao [b], Kenneth C. Schiff [b], John M. Colford Jr. [c]

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WATER RESEARCH

**Using rapid indicators for *Enterococcus* to assess the risk of illness after exposure to urban runoff contaminated marine water**

John M. Colford Jr. [a,*], Kenneth C. Schiff [b], John F. Griffith [b], Vince Yau [a,1], Benjamin F. Arnold [a], Catherine C. Wright [a], Joshua S. Gruber [a], Timothy J. Wade [c], Susan Burns [d], Jacqueline Hayes [d], Charles McGee [e], Mark Gold [f], Yiping Cao [b], Rachel T. Noble [g], Richard Haugland [h], Stephen B. Weisberg [b]

# Integrating source specific risk information with results from CA rec water studies – Surfer Health Study (SHS)

SHS - first epi & QMRA study to quantify risks from coastal water exposure after storms

Focus - wet weather stream flows affecting coastal waters

- Human sources of contamination contribute viral and bacterial pathogens to streams during wet weather
- QMRA and epi results closely matched
- Viruses were important predicted cause of GI illness

American Journal of Epidemiology

DOI: 10.1093/aje/kwx019

**Original Contribution**

**Acute Illness Among Surfers After Exposure to Seawater in Dry- and Wet-Weather Conditions**

**Benjamin F. Arnold*, Kenneth C. Schiff, Ayse Ercumen, Jade Benjamin-Chung, Joshua A. Steele, John F. Griffith, Steven J. Steinberg, Paul Smith, Charles D. McGee, Richard Wilson, Chad Nelsen, Stephen B. Weisberg, and John M. Colford, Jr.**

* Correspondence to Dr. Benjamin F. Arnold, Division of Epidemiology, School of Public Health, University of California, Berkeley, 101 Haviland Hall, MC #7358, Berkeley, CA 94720-7358 (e-mail: benarnold@berkeley.edu).

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Water Research

journal homepage: www.elsevier.com/locate/watres

**Incidence of gastrointestinal illness following wet weather recreational exposures: Harmonization of quantitative microbial risk assessment with an epidemiologic investigation of surfers**

Jeffrey A. Soller [a,*], Mary Schoen [a], Joshua A. Steele [b], John F. Griffith [b], Kenneth C. Schiff [b]

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# Pulling it all together

- The 2012 RWQC provides significant opportunities and additional flexibilities to address CA-specific recreational water quality issues
  - Scientifically defensible
  - Protective of the use
- Strong scientific foundation to believe
  - Human enteric viruses are important etiologic agents in human impacted waters
  - Risks associated with some non-human sources is lower than human contamination
  - Nature and magnitude of the source and the source dynamics are critical considerations

# Final thoughts

- Some recreational waters in CA may benefit from consideration of alternative standards or alternative implementation approaches
  - Many coastal CA rec waters are not impacted by treated WWTP effluent
    - different source than EPA epi studies,
    - could have different ratios of fecal indicator bacteria/pathogens
  - Some alternative indicators are more effective at some CA study sites
- Could consider different method(s) and/or different indicator(s)
- Potential to achieve better health protection
- Could allow regulated community ability to focus on effective human health risk reduction rather than solely on fecal indicator bacteria reduction