Statistical Methods to Identify Low-level Bias in Radioanalytical Data

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Historical

- Unexpected “false” positive results associated with analysis of environmental media
  - Groundwater, Soil, Concrete
  - Analyses performed to environmental limits (Low MDCs, DCGLs)
- HTD’s
  - LSC (Fe-55, Ni-63, Tc-99, Pu-241)
  - GPC (Sr-90)
  - Alpha spectroscopy (Am-241)

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Impact/Needs

- Impact
  - Results not representative of aquifer or sampled media
  - Required additional resources

- Analytical Needs
  - Method to distinguish false positives from real detects
  - Method to identify and quantify analytical bias at low levels (near MDC)

Definitions

- Bias
  - Limiting mean different from the true value
  - Consistent error of same size and magnitude

- Low-level Bias Assessment
  - Limiting mean different from expected zero analyte concentration
  - Limiting mean concentration or bias near MDC

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Bias Assessment Methods

- Parametric Statistics
  - Outlier detection
  - Z-score testing
  - Normality testing
  - Student t-testing

General Assumptions

- Data comprised of 2-distributions
  - Underlying background/baseline
    - Attributed to instrument noise
    - Normally distributed around limiting mean
  - Plant related nuclides with unknown spatial distribution (non normal)

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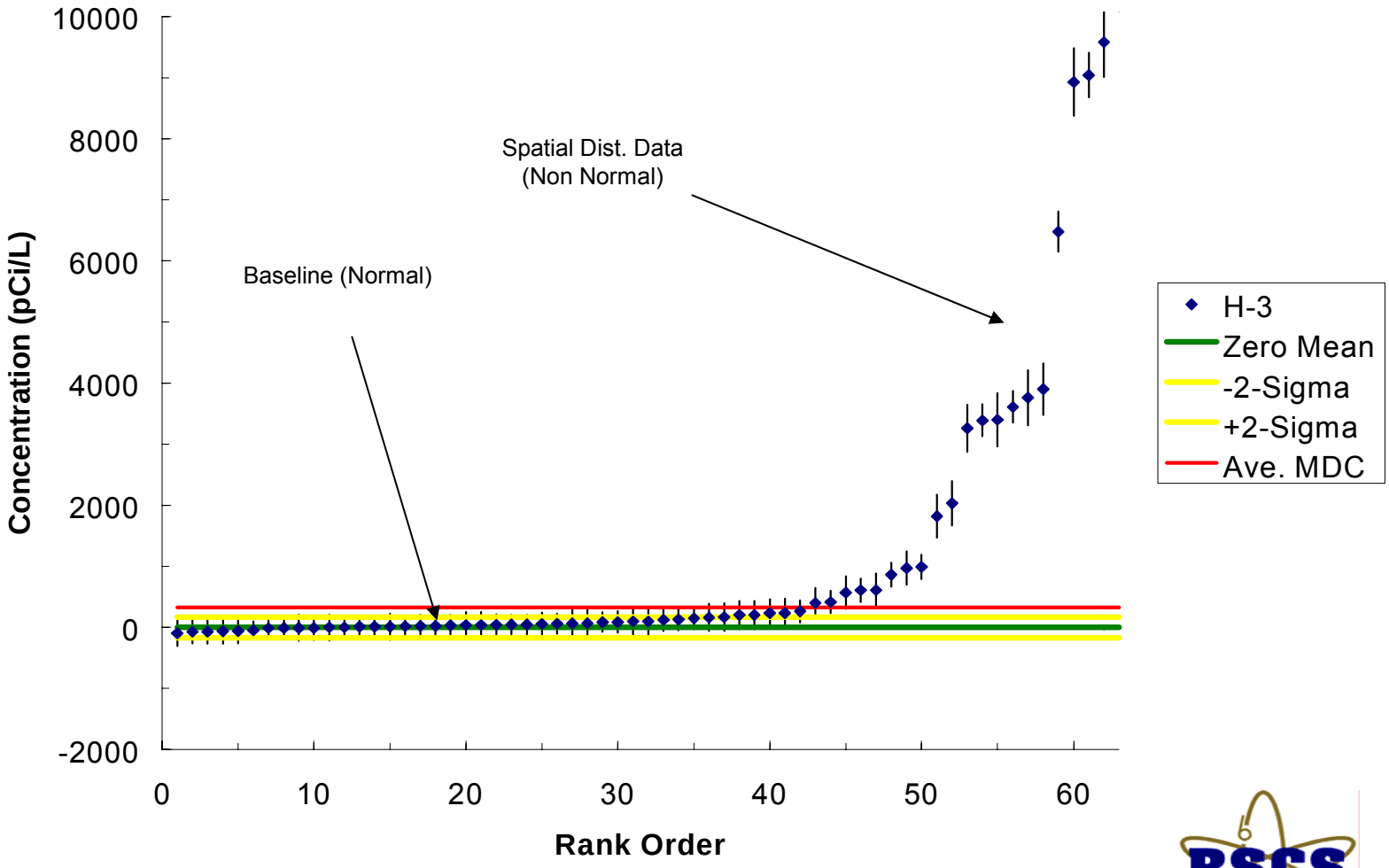
H-3 Rank Order for Dec-2004



Bias Assessment Methods

- Segregate data into logical sub-sets
  - Discrete sample events
  - Lab processing batch
- Sort by Rank Order
- Perform Outlier Testing
- Evaluate limiting mean distribution for normality
- Test if limiting mean different from 0
- Limiting mean sign indicates positive, negative bias

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Outlier Testing

- Arrange data by rank (ascending) order
- Compute running mean by rank order
- Compute robust sigma statistic (σ_o)
  - Based on background signal only!
  - Derived from sample MDCs ($MDC=2*k*\sigma_o$)
- Compute modified Z-score $(x_i-X)/\sigma_o$
- Z-score > critical-T are outliers and not part of underlying background distribution

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Normal Distribution Test

- Arrange data by rank order
- Compute mean and std. dev. statistics
- Compute Filliben r-statistic (normal probability plot correlation)
  - Compute sample order median statistics
  - Compute theoretical order median statistics for normal distribution
- Computed r-value near unity is normal

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Limiting Mean t-Test

- Compute limiting mean, std. dev. statistics
- Compute t-test statistic where $\mu_o=0$

$$t = \left| \frac{\left(\overline{X} - \mu_o\right)}{s/\sqrt{n}} \right|$$

- t-Test statistics > critical t-value statistically different from $\mu_o=0$ assumption
- Sign of limiting mean indicates positive or negative bias

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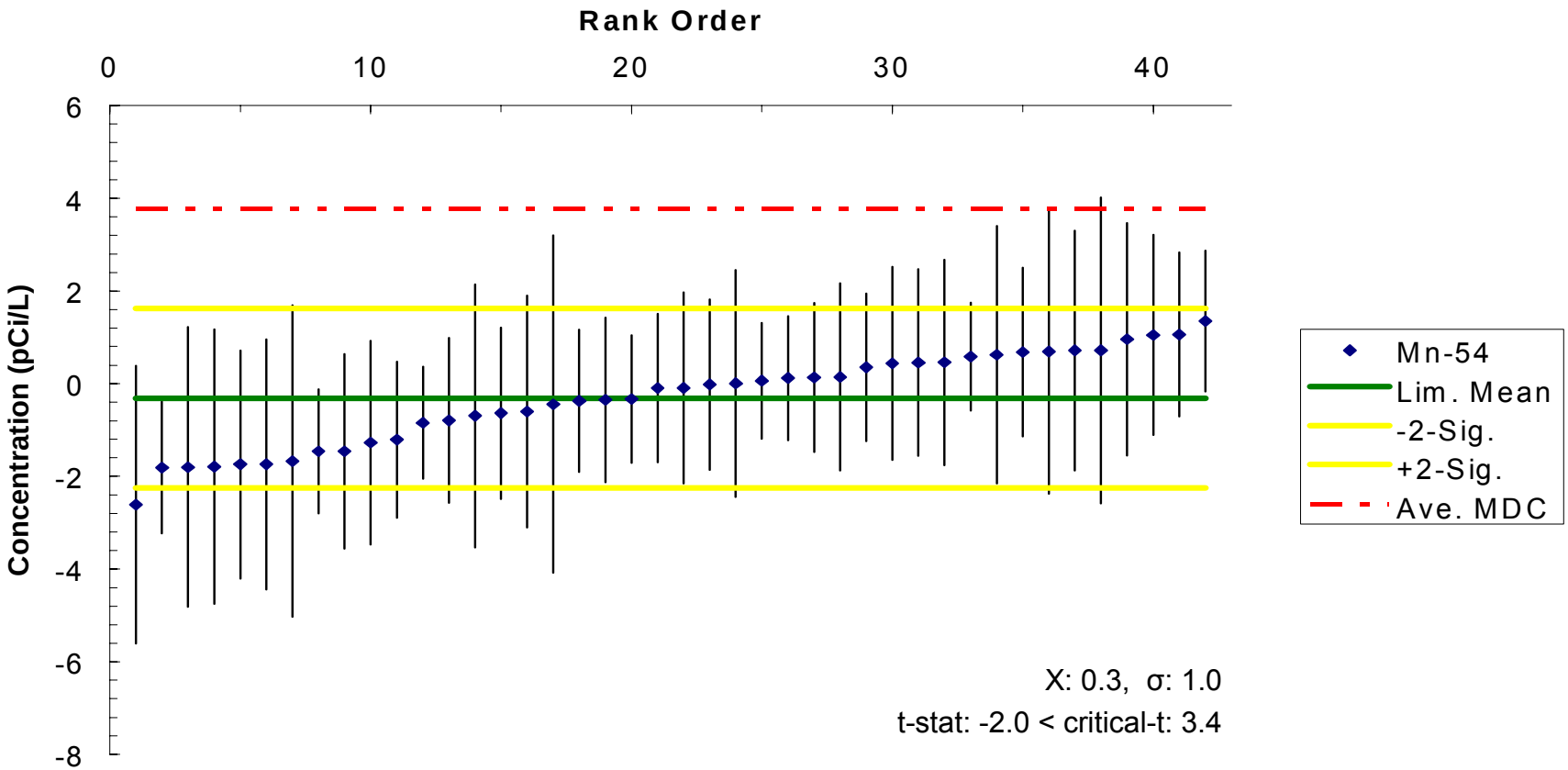
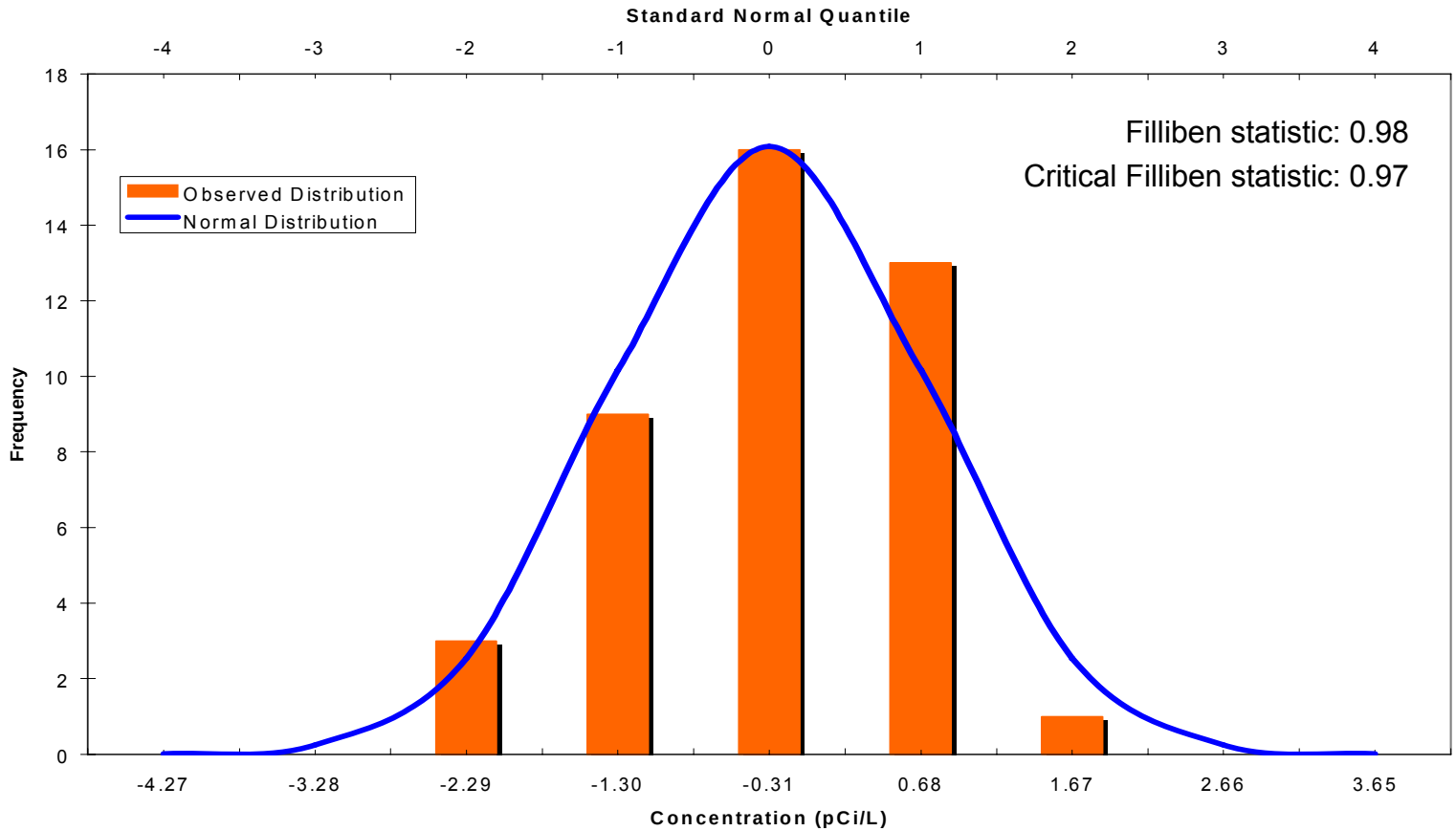
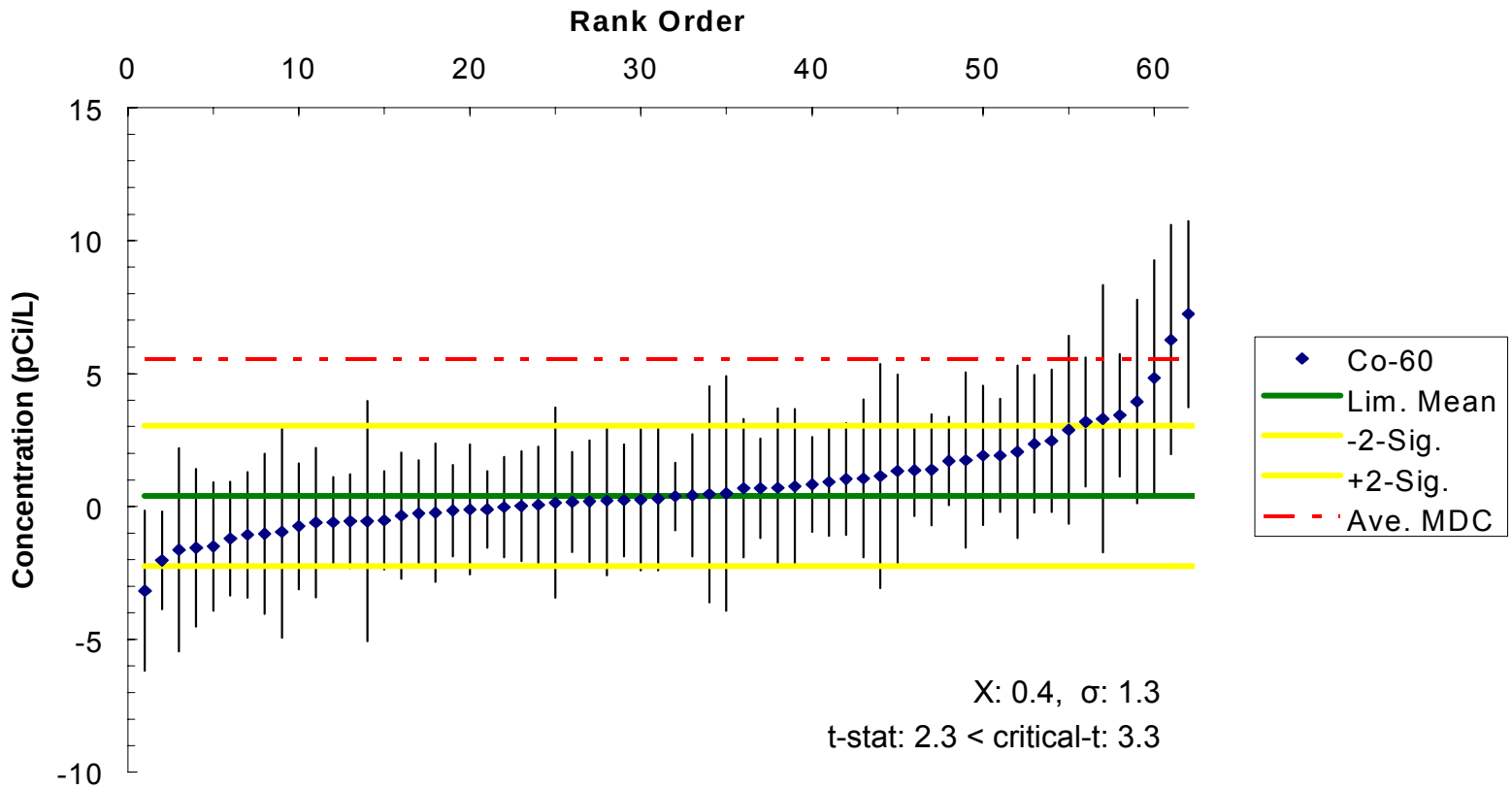
Mn-54 Rank Order for Sep-2004



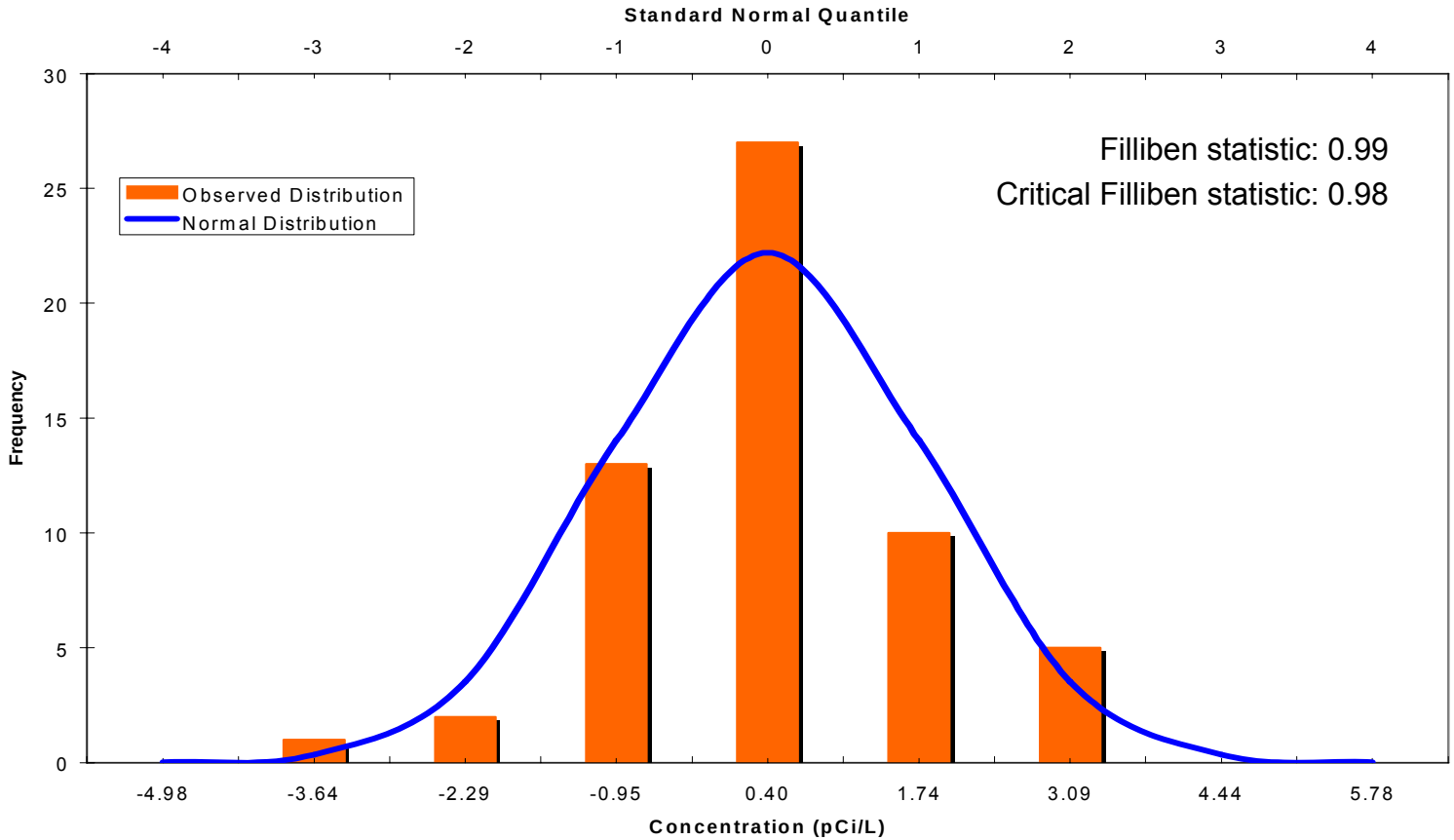
Mn-54 Normality Plot for Sep-2004



Co-60 Rank Order for Dec-2004



Co-60 Normality Plot for Dec-2004



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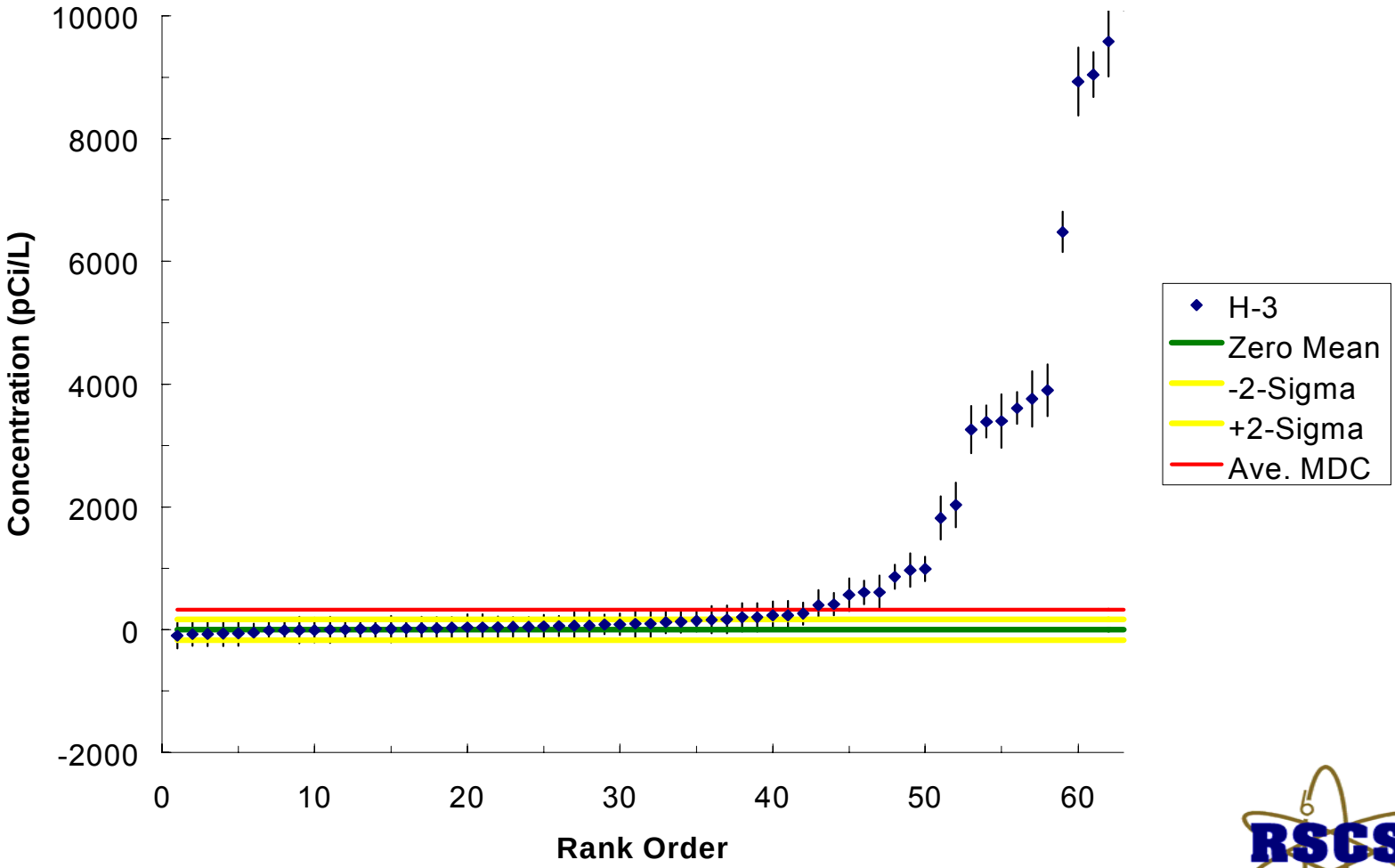
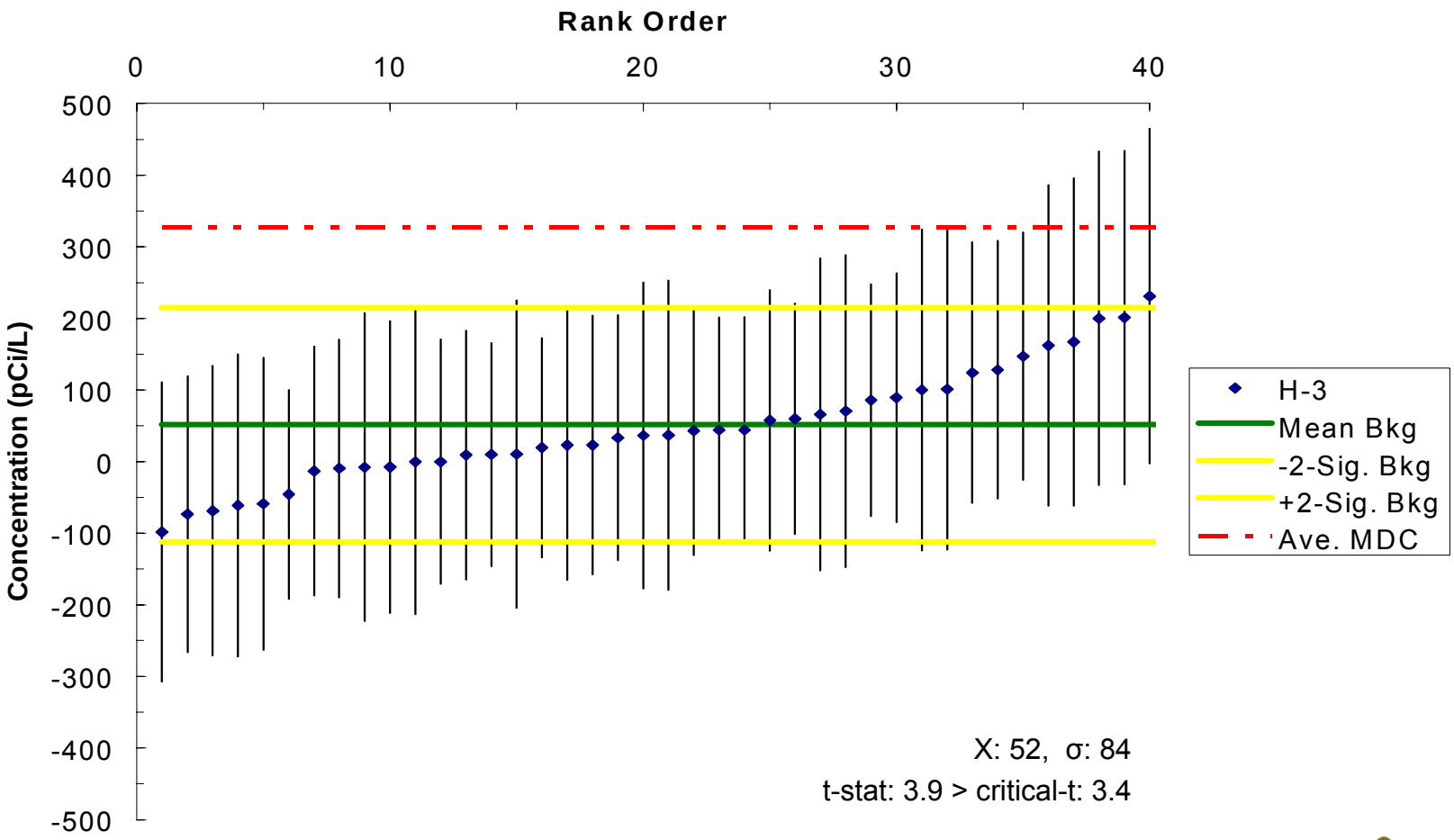
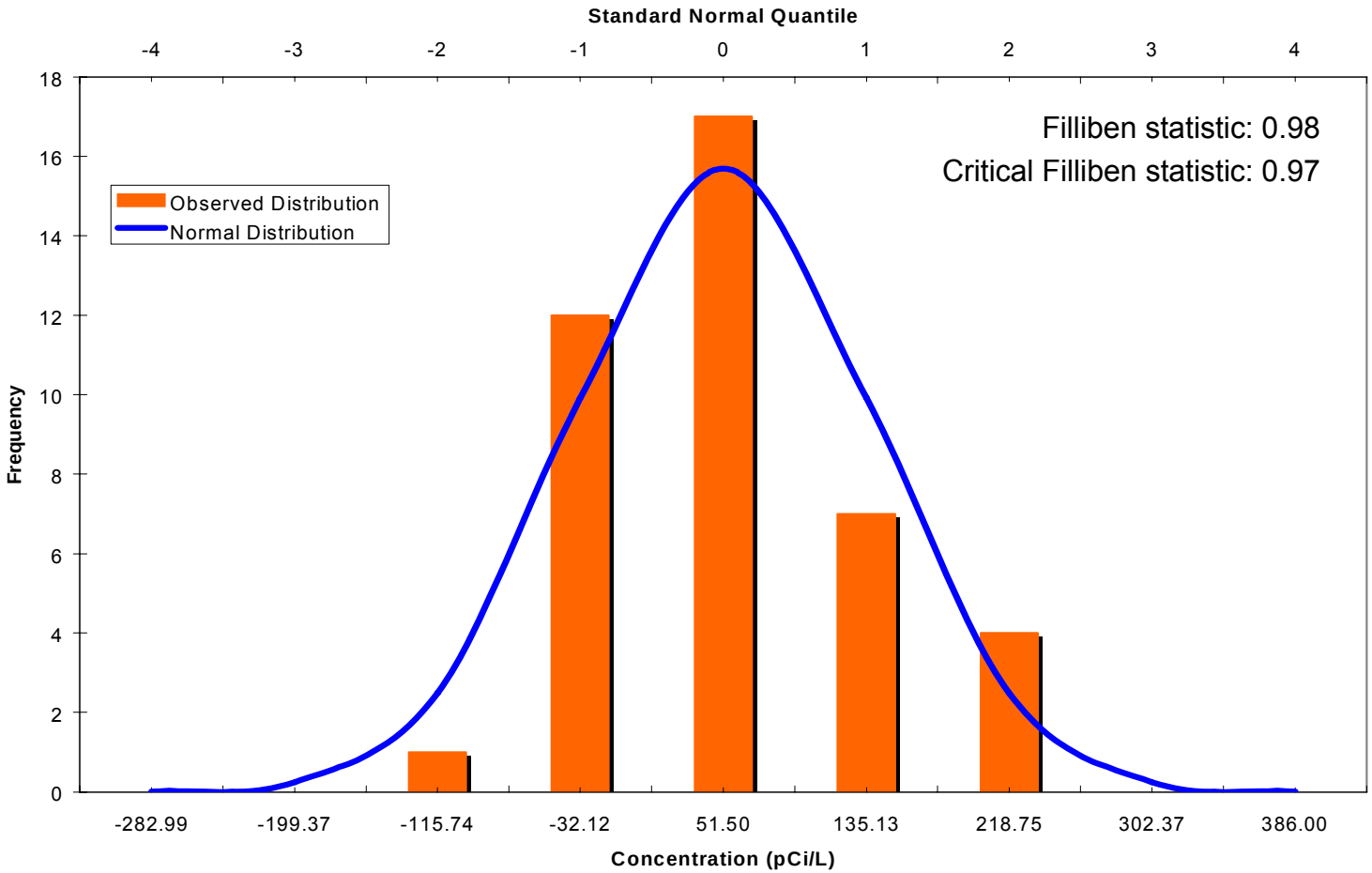
H-3 Rank Order for Dec-2004



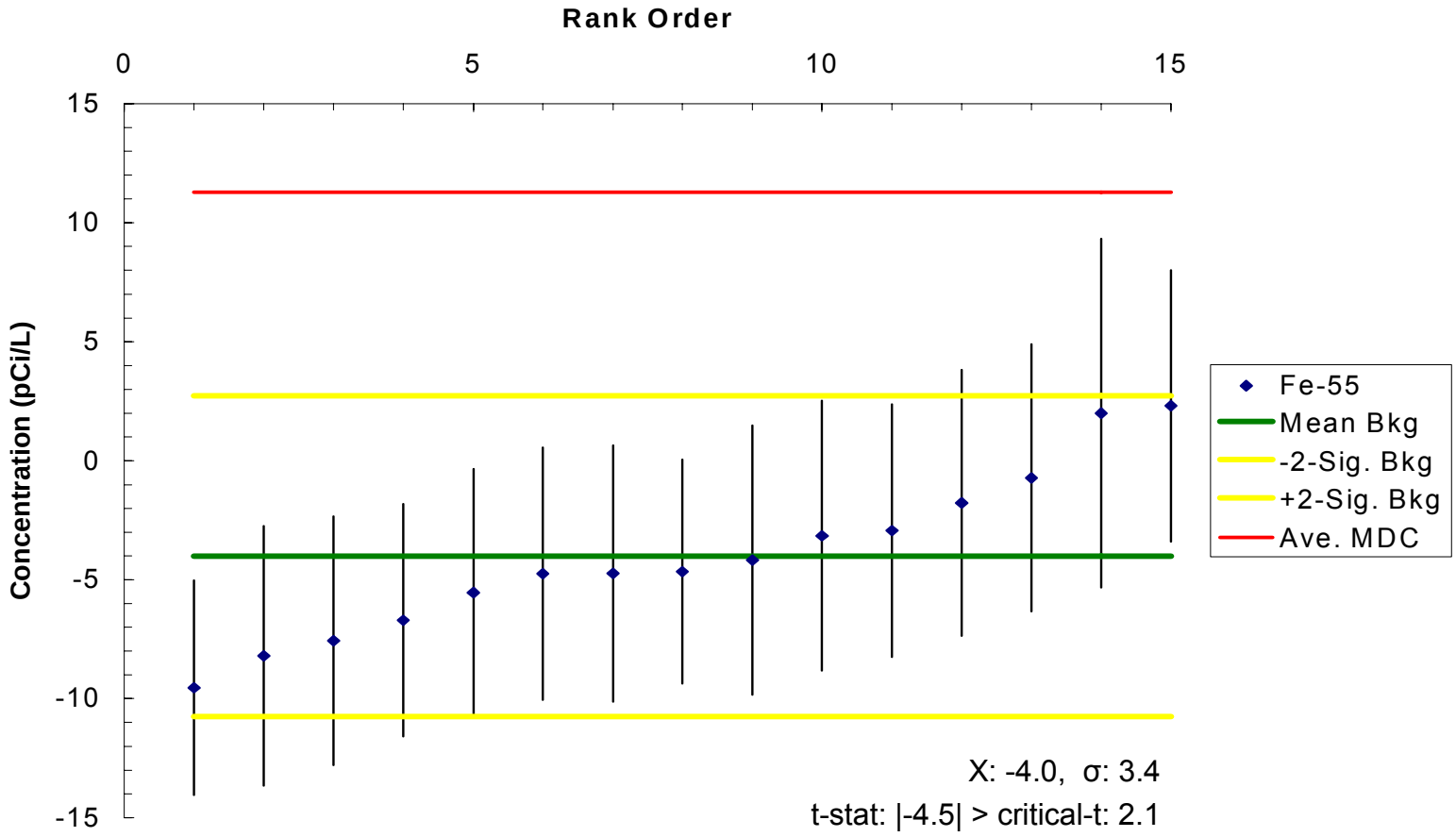
H-3 Rank Order for Dec-2004 (Baseline)



H-3 Normality Plot for Dec-2004 (Baseline)



Fe-55 Rank Order for Sep-2002



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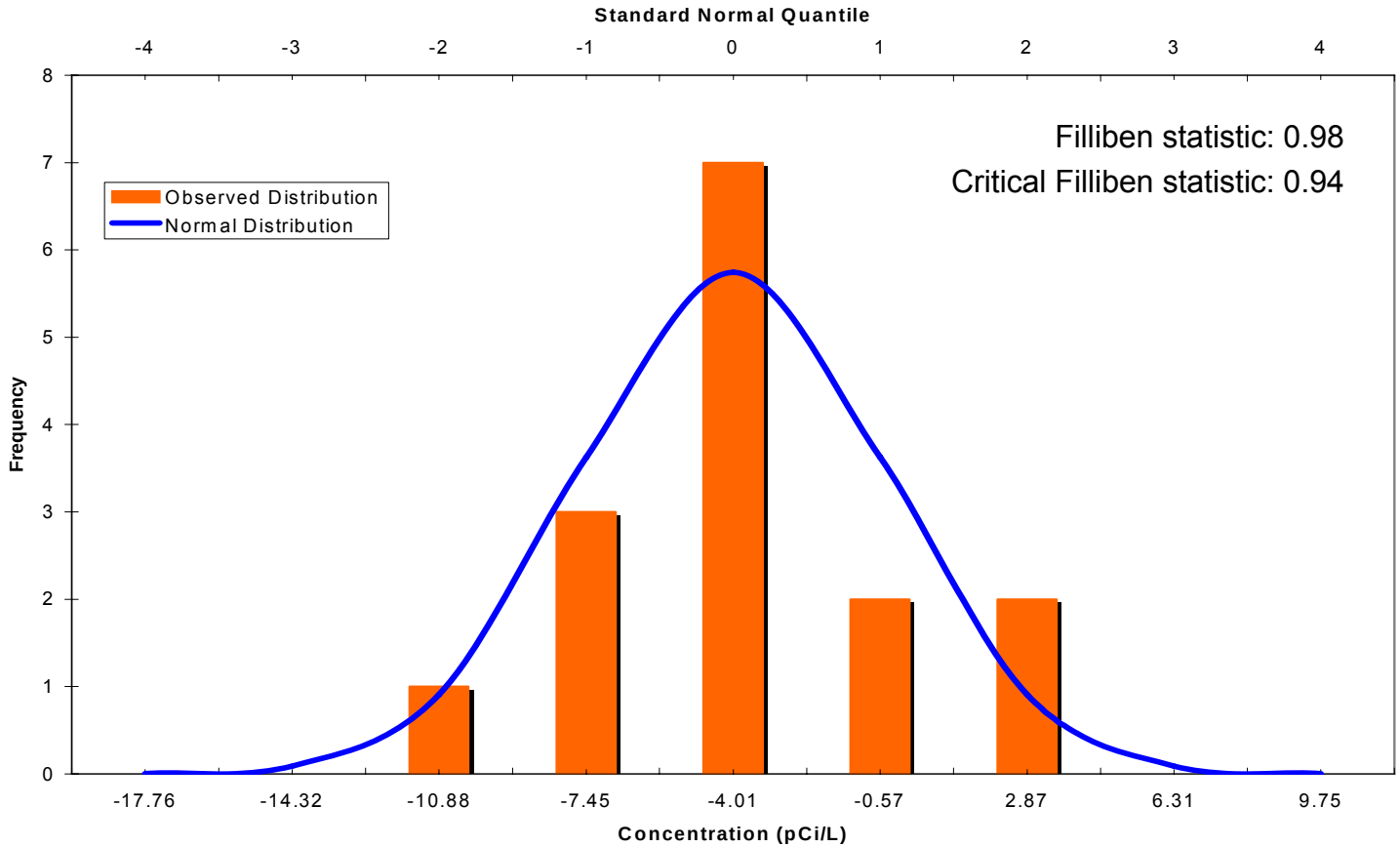
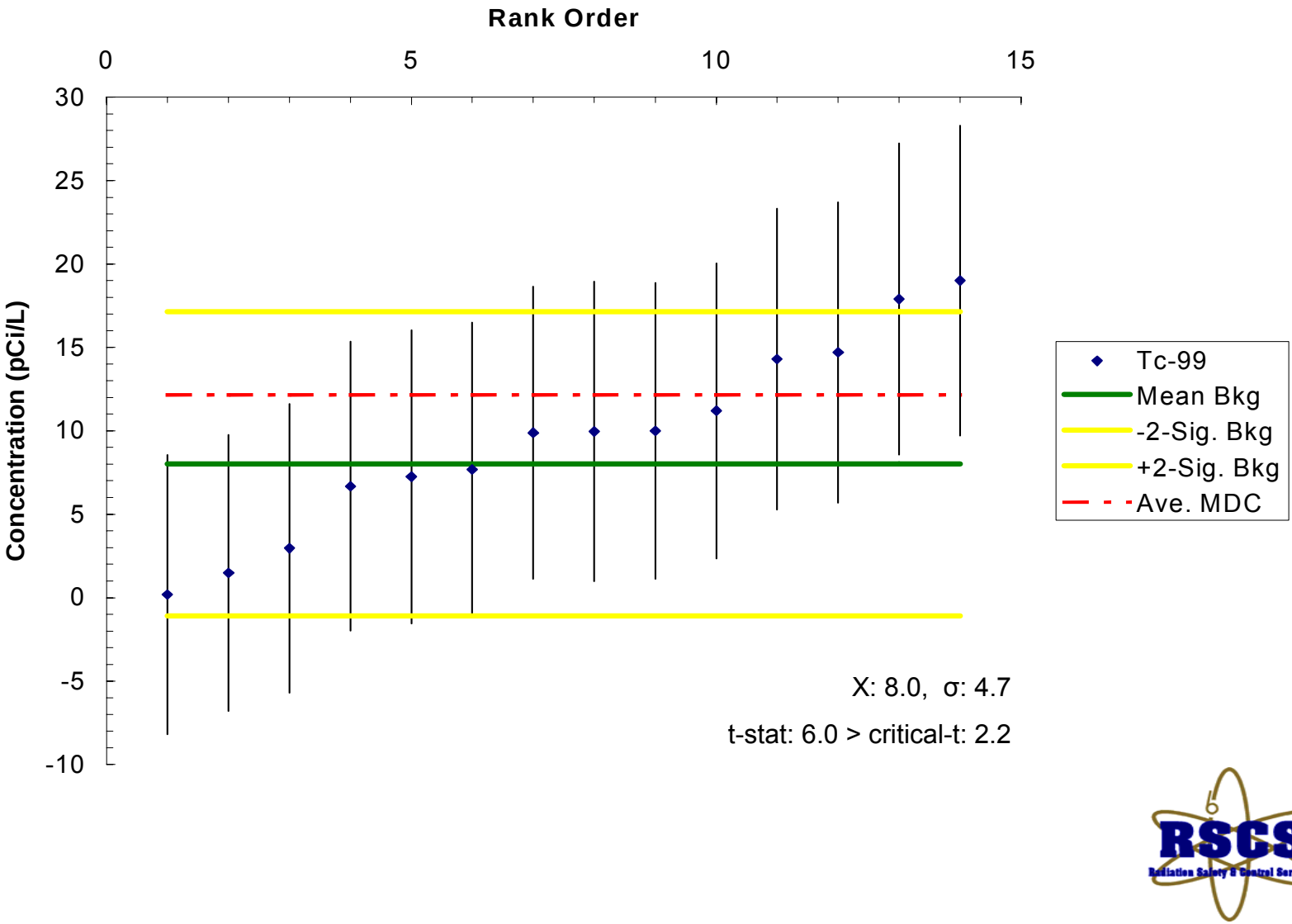
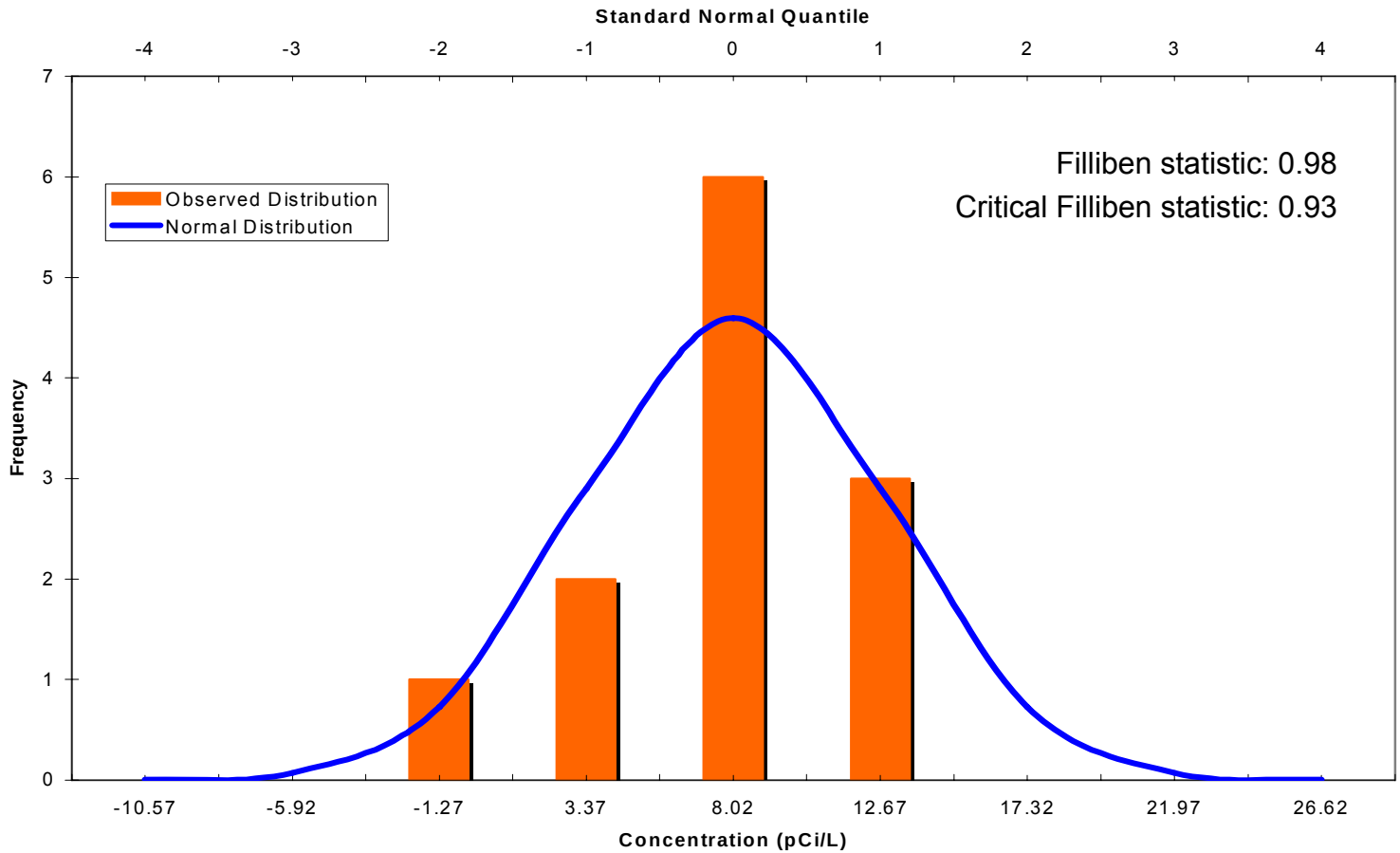
Fe-55 Normality Plot for Sep-2002



Tc-99 Rank Order for Dec-2002



Tc-99 Rank Order for Dec-2002



Sr-90 Rank Order for Jun-2003

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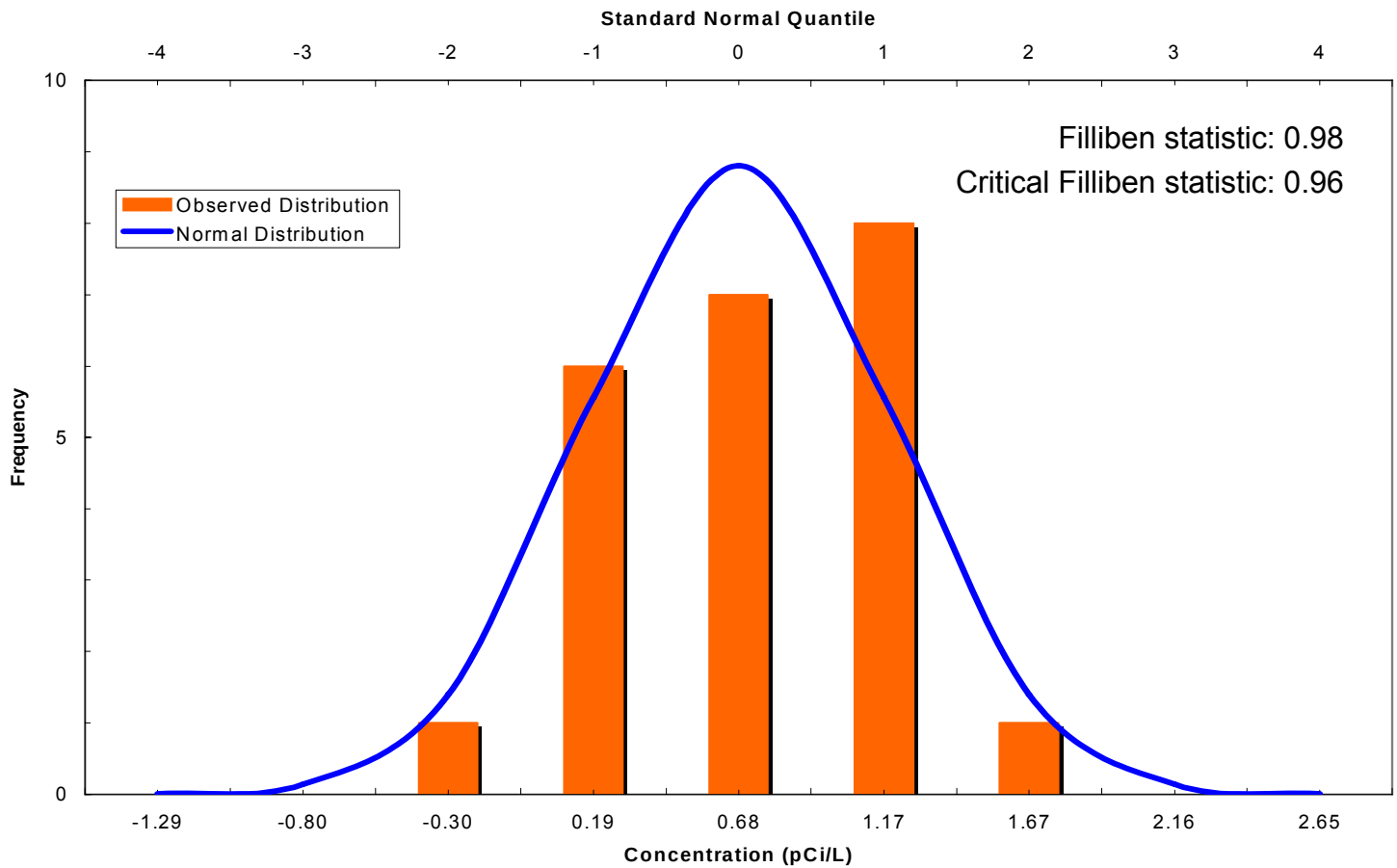
Sr-90 Normality Plot for Jun-2003



Conclusions

- Impact of analytical bias on detection decisions
- Include impact of analytical bias
  - Propagate additional uncertainty
  - Add impact to MDC (positive bias)
- Greater impact expected for non-ideal matrices (soil, concrete, bedrock)

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