Variability in WET Results in a Municipal Wastewater Effluent

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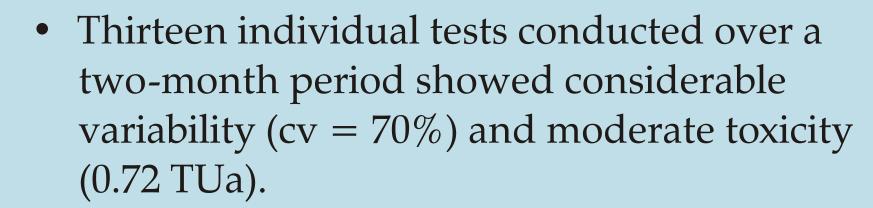
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Abstract

Inter- and intra-test variability in freshwater and marine acute and marine chronic WET test results were assessed in six species in a municipal wastewater effluent. The test species included the fathead minnow (Pimaphales promelas) and water flea (Ceriodaphnia dubia) freshwater acute tests, the East Coast mysid shrimp (Americamysis bahia) and inland silverside minnow (Menidia beryllina) marine acute tests, and the red abalone (Haliotis rufescens) larval development and purple sea urchin (Strongylocentrotus purpuratus) fertilization marine chronic WET tests. Inter-test variability was measured in tests conducted on separate samples collected between April and November 2002.

Disinfection of the effluent with chlorination-dechlorination was initiated on August 1, 2002. The variability in the pre- and post-disinfection samples were analyzed separately. Intra-test variability was determined by conducting separate tests on split samples (two pre-disinfection samples only). Variability was measured as the coefficient of variation (cv) among test results. The degree of variability depended on the species and effluent type (disinfected or non-disinfected). In disinfected effluent, toxicity magnitude and variability was reduced by approximately 50% for all species, except C. dubia for which variability almost doubled while magnitude decreased slightly. Intra-test variability ranged from 0% (H. rufescens and . purpuratus) - 116% (P. promelas) among test species. Intra-test variability was greatest in *P. promelas* ranging from 3% - 116% in the two samples tested and least in *S. purpuratus*, which was 0% in both samples. Correlation analysis indicated that test animal condition (as measured by reference toxicant test results) and differences in water quality parameters (pH and dissolved oxygen) can contribute to variability in WET test results.

Fathead Minnow



 Split-sample tests showed great variability in one sample (cv = 116%) with moderately-low toxicity (0.50 TUa), while the other sample showed very low variability (cv = 3%), but twice the toxicity (1.02 TUa).

| Table 5. Summary of Fathead Minnow (<i>Pimephales promelas</i>) Toxicity Results: Predisinfection samples, April-July, 2002. | | | | | | | | |
|--|--------------|------|-----------------------|-----------|--------------------------|--|--|--|
| Parameter | N | Mean | Standard Deviation | Range | Coefficient of Variation | | | |
| TUa | 13 | 0.72 | 0.50 | 0.00-1.20 | 70 | | | |
| Control Survival | 13 | 0.99 | 0.03 | 0.90-1.00 | 3 | | | |
| pH Mean | 13 | 6.99 | 0.12 | 6.73-7.20 | 2 | | | |
| DO Mean (mg/L) | 13 | 5.90 | 0.82 | 4.30-6.80 | 14 | | | |
| Ref. Tox. LC50 | 13 | 256 | 57.8 | 150-300 | 23 | | | |
| A. June 4, 2002 – Split-sample | | | | | | | | |
| Parameter | N | Mean | Standard Deviation | Range | Coefficient of Variation | | | |
| TUa | 4 | 0.50 | 0.58 | 0.00-1.00 | 116 | | | |
| Control Survival | 4 | 0.98 | 0.05 | 0.90-1.00 | 5 | | | |
| pH Mean | 4 | 7.03 | 0.11 | 6.87-7.13 | 2 | | | |
| DO Mean (mg/L) | 4 | 6.19 | 0.54 | 5.40-6.63 | 9 | | | |
| B. June 18, 2002 | - Split-samp | le | | | | | | |
| Parameter | N | Mean | Standard Deviation | Range | Coefficient of Variation | | | |
| TUa | 3 | 1.02 | 0.03 | 1.00-1.05 | 3 | | | |
| Control Survival | 3 | 1.00 | 0.00 | 1.00-1.00 | 0 | | | |
| pH Mean | 3 | 7.02 | 0.02 | 7.00-7.03 | <1 | | | |
| DO Mean (mg/L) | 3 | 5.45 | 0.90 | 4.50-6.13 | 17 | | | |

Water Flea

(Ceriodaphnia dubia)

- Thirteen individual tests conducted over a twomonth period showed low variability (cv = 16%).
- Split-sample tests showed low variability in
- Test endpoint (TUa) was consistent among all tests showing moderate toxicity, which is expected to demonstrate the greatest variability in results.

| Parameter | | | Standard Deviation | Range | Coefficient of Variation | | | |
|--------------------------------|--------------|-------|-----------------------|-----------|--------------------------|--|--|--|
| TUa | 13 | 1.27 | 0.20 | 0.82-1.49 | 16 | | | |
| Control Survival | 13 | 1.00 | 0.00 | 1.00-1.00 | 0 | | | |
| pH Mean | 13 | 8.22 | 0.17 | 8.00-8.55 | 2 | | | |
| DO Mean (mg/L) 13 | | 6.84 | 7.02 | 4.15-7.60 | 103 | | | |
| Ref. Tox. LC50 | 13 | 17.31 | 15.8 | 12.0-39.0 | 91 | | | |
| A. June 4, 2002 – Split-sample | | | | | | | | |
| Parameter | N | Mean | Standard Deviation | Range | Coefficient of Variation | | | |
| TUa | 4 | 1.37 | 0.08 | 1.33-1.49 | 6 | | | |
| Control Survival | 4 | 1.00 | 0.00 | 1.00-1.00 | 0 | | | |
| pH Mean | 4 | 8.19 | 0.03 | 8.15-8.20 | 13 | | | |
| DO Mean (mg/L) | 4 | 7.53 | 0.12 | 7.35-7.60 | 2 | | | |
| B. June 18, 2002 - | - Split-samp | le | | | | | | |
| Parameter | N | Mean | Standard Deviation | Range | Coefficient of Variation | | | |
| TUa | 3 | 1.33 | 0.16 | 1.18-1.49 | 12 | | | |
| Control Survival | 3 | 1.00 | 0.00 | 1.00-1.00 | 0 | | | |
| pH Mean | 3 | 8.45 | 0.10 | 8.35-8.55 | 1 | | | |
| DO Mean (mg/L) | 3 | 5.75 | 1.39 | 4.15-6.65 | 24 | | | |

Methods

- Testing was conducted using 24-hour flow-weighted composite final effluent samples.
- Effluent disinfection occurs at several points throughout the plant and at various stages of treatment. Bleach is added at a rate depending on the volume/flow of the waste stream and is de-chlorinated using sodium bisulfite prior to ocean release.
- Effluent chemistry for metals, trace organics, ammonia, and hardness were conducted.

| Table 1. Effluent Chemistry Ana | lytes and Analysis Methods. |
|--|---|
| Effluent Constituent | Method |
| Hardness | USEPA Method 130.2 |
| Ammonia | USEPA Method 350.1 |
| Mercury | USEPA Method 245.1 |
| Metals | USEPA Method 200.8 |
| Organochlorine Pesticides | USEPA Method 608 |
| Volatile Organic Compounds | USEPA Method 624 |
| Base/neutral and Acid Compounds | USEPA Method 625 |
| Organophosphate Pesticides | USEPA SW-846 Method 8141 |
| Gross Alpha and Beta Compounds Radioactivity | APHA Standard Methods 7110/USEPA Method 900 |
| 1,4-Dioxane | USEPA SW-846 Method 8270 (Modified for low-level testing in wastewater) |
| N-Nitrosodimethylamine | California DHS Low-level Analysis for NDMA Procedural Guidelines |

- The species and protocols used are listed in Table 1. All tests were conducted on split effluent samples for data comparability.
- Freshwater acute tests conducted without dilution credit. Permit limit = 1.5 TUa.
- Marine acute tests conducted with dilution credit of 10% that of the allowable chronic value (per California Ocean Plan). Permit limit = 5.7 TUa.
- Marine acute conducted with 180:1 dilution credit (per NPDES permit). Permit limit = 1.8 TUc.

| Table 2. Whole Effluent Toxicity | Test Species, Me | ethods, and Permit Lim | its. |
|---|---------------------|------------------------|--------------|
| Species | Test Type | Method | Permit Limit |
| Fathead Minnow 96-hour Survival (<i>Pimephales promelas</i>) | Freshwater Acute | EPA-600/4-85-013 | 1.5 TUa |
| Water Flea 48-hour Survival and Reproduction (<i>Ceriodaphnia dubia</i>) | Freshwater Acute | EPA/600/4-90/027F | 1.5.TUa |
| Inland Silverside Minnow 96-hour Survival (<i>Menidia beryllina</i>) | Marine Acute | EPA/600/4-90/027F | 5.7 TUa |
| East Coast Mysid Shrimp 48-hour Survival and Reproduction (<i>Americamysis bahia</i>) | Marine Acute | EPA/600/4-90/027F | 5.7 TUa |
| Red Abalone 48-hour Development (<i>Haliotis rufescens</i>) | Marine Chronic | EPA/600/R-95-136 | 1.8 TUc |
| Purple Sea Urchin Fertilization (Strongylocentrotus purpuratus) | Marine Chronic | EPA/600/R-95-136 | 1.8 TUc |

This information came out of monitoring data and was not

Conclusions & Discussion

- designed as a cause-effect research project, so no firm conclusions can be drawn from this study, though some relationships were suggested from the data.
- The results of this study demonstrate the concern in using WET test results with numerical limits for permit compliance. Depending on the test, the final result (TUa or TUc) can be extremely variable. Further, within-sample variability can be zero or as high as 116%. The exact cause of this tremendous variability within a single split-sample is not known.
- The variability in effluent ammonia and hardness was low in both pre-disinfection and disinfected samples. In general, variability in effluent metals was greater in disinfected effluent (13% vs. 37%), while organic compounds had greater variability in the effluent prior to disinfection (30% vs.20%).
- Changes in water quality parameters (pH and DO) in the test vessels over the test period also appear to have an effect on test results, either by acting directly on the test animal or by driving changes in effluent chemistry that influence toxicity. The classic example is the interaction between effluent pH drift and ammonia toxicity, but in this study it was suggested that changes in pH and DO within the effluent test samples affected chemistry, which may affect WET test results. Further, it also appears that the disinfection process has a dampening effect on effluent chemistry and toxicity, especially in the marine chronic tests.
- The chemistry and toxicity tests were conducted on splitsamples to insure comparability of the data, yet correlations of water quality parameters to effluent chemistry yielded different results for each toxicity test demonstrating that the individual test protocols have an effect on the effluent sample. These differences are due to test factors such as aeration vs. no aeration, test temperature, and duration of the test among the different test types and animals.

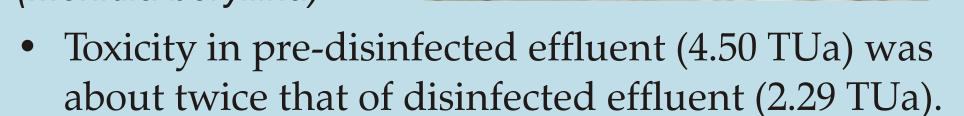
Introduction

Variability in (WET) tests has been the focus of attention by both regulators and the regulated community, including resulting in litigation (i.e., Edison Electric Institute et al. v. US EPA). The primary focus has been on freshwater WET tests, mainly those using the fathead minnow (Pimaphales promelas) using single reference toxicants.

The Orange County Sanitation District (OCSD) is a publicly owned treatment works (POTW) that serves 2.5 million people in central and northwest Orange County, California, treating an average of 243 million gallon per day (mgd) of approximately 80% residential and 20% industrial wastewater. All wastewater received advanced chemical primary treatment, while 50% also received full secondary treatment by either waste activated sludge or tricking filter technology. The blended (50:50 primary to secondary treated wastewater) final effluent is discharged into the Pacific Ocean via a 4.5 mile long ocean pipeline. In OCSD's National Pollution Discharge Elimination System (NPDES) discharge permit is a requirement to conduct acute and chronic whole effluent toxicity (WET) tests for the purpose of determining permit compliance. In August 2002, OCSD began disinfecting the effluent using bleach and then de-chlorinating with sodium bisulfite.

In the present study, we examined the variability in WET tests using both freshwater and marine species and acute and chronic test protocols using OCSD's final effluent. Testing was conducted on samples collected prior to disinfection (pre-disinfection) and post-disinfection (disinfected) to determine the effect of the disinfection process on chemistry and WET results. The purpose was to determine the variability in the species and tests required in OCSD's NPDES permit using the actual medium tested (final effluent, a complex mixture) in addition to a single reference toxicant.

Inland Silverside



• Moderate variability (cv = 49%) seen in predisinfection tests, while disinfected effluent variability was reduced by about half (cv = 24%).

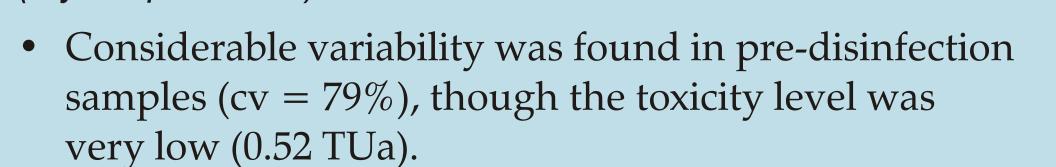
| Table 7. Summary of Inland Silverside Minnow (<i>Menidia beryllina</i>) Toxicity Results: A. Pre-disinfection samples, April-July, 2002, B. Disinfected samples, August-November 2002. | | | | | | | | | |
|--|--------|------|-----------------------|-----------|--------------------------|--|--|--|--|
| A. Pre-disinfection Parameter | n N | Mean | Standard Deviation | Range | Coefficient of Variation | | | | |
| TUa | 13 | 4.50 | 2.20 | 2.29-9.09 | 49 | | | | |
| Control Survival | 13 | 0.90 | 0.01 | 0.85-0.90 | 1 | | | | |
| pH Mean | 13 | 7.95 | 0.14 | 7.70-8.17 | 2 | | | | |
| DO Mean (mg/L) | 13 | 6.45 | 0.34 | 5.73-6.83 | 5 | | | | |
| Ref. Tox. LC50 | 13 | 180 | 44.1 | 74.0-223 | 25 | | | | |
| B. Disinfected | | | | | | | | | |
| Parameter | N | Mean | Standard Deviation | Range | Coefficient of Variation | | | | |
| TUa | 7 | 2.29 | 0.54 | 1.91-3.18 | 24 | | | | |
| Control Survival | 7 | 0.94 | 0.04 | 0.90-1.00 | 4 | | | | |
| pH Mean | 6 | 7.91 | 0.20 | 7.53-8.07 | 3 | | | | |
| DO Mean (mg/L) | 6 | 6.91 | 0.30 | 6.40-7.23 | 4 | | | | |
| Ref. Tox. LC50 | 7 | 144 | 47.7 | 96.0-225 | 33 | | | | |

 Split-sample tests showed moderate to considerable variability in both tests (cv = 36% and 66%).

 TUa was elevated in both samples indicating moderate to high toxicity. Table 8. Summary of Inland Silverside Minnow (Menidia beryllina) Toxicity Results:

| une 4, 2002 | | | | | | | | | | |
|--------------|----------|------|--------------------|-----------|--------------------------|--|--|--|--|--|
| arameter | N | Mean | Standard Deviation | Range | Coefficient of Variation | | | | | |
| | 4 | 5.86 | 2.13 | 3.66-8.04 | 36 | | | | | |
| rol Survival | 4 | 0.90 | 0.00 | 0.90-0.90 | 0 | | | | | |
| lean | 4 | 7.94 | 0.03 | 7.90-7.97 | <1 | | | | | |
| /lean (mg/L) | 4 | 6.41 | 0.11 | 6.27-6.53 | 2 | | | | | |
| une 18, 2002 | <u> </u> | | | | | | | | | |
| arameter | N | Mean | Standard Deviation | Range | Coefficient of Variation | | | | | |
| | 3 | 5.15 | 3.41 | 3.03-9.09 | 66 | | | | | |
| rol Survival | 3 | 0.90 | 0.00 | 0.90-0.90 | 0 | | | | | |
| lean | 3 | 8.14 | 0.02 | 8.13-8.17 | <1 | | | | | |
| /lean (mg/L) | 3 | 6.43 | 0.32 | 6.20-6.80 | 5 | | | | | |

Mysid Shrimp



 Disinfected effluent showed about three-times the toxicity (1.44 TUa; still very low), but only half the variability (cv = 36%).

| A. Pre-disinfection samples, April-July, 2002,B. Post-disinfection samples, August-November 2002. | | | | | | | | | |
|--|----|------|-----------------------|-----------|----------------------|--|--|--|--|
| A. | | | | | | | | | |
| Parameter | N | Mean | Standard Deviation | Range | Coefficie of Variati | | | | |
| TUa | 12 | 0.52 | 0.41 | 0.00-1.00 | 79 | | | | |
| Control Survival | 12 | 0.96 | 0.05 | 0.90-1.00 | 5 | | | | |
| pH Mean | 12 | 7.93 | 0.17 | 7.63-8.20 | 2 | | | | |
| DO Mean (mg/L) | 12 | 6.52 | 0.40 | 5.90-7.10 | 6 | | | | |
| Ref. Tox. LC50 | 12 | 29.3 | 9.29 | 10.0-43.0 | 32 | | | | |
| B. | | | | | | | | | |
| Parameter | N | Mean | Standard Deviation | Range | Coefficie of Variati | | | | |
| TUa | 4 | 1.44 | 0.52 | 1.00-2.03 | 36 | | | | |
| Control Survival | 4 | 0.99 | 0.03 | 0.95-1.00 | 3 | | | | |
| pH Mean | 4 | 7.96 | 0.56 | 7.90-8.03 | 7 | | | | |
| DO Mean (mg/L) | 4 | 6.18 | 0.48 | 5.60-6.63 | 8 | | | | |
| Ref. Tox. LC50 | 4 | 18.0 | 1.16 | 17.0-19.0 | 6 | | | | |

 Both rounds of split-sample testing showed considerable variability in test results (cv = 71% and 92%), but toxicity was very low in both samples.

| • | • | Tests, June 4, 1 Tests, June 18 | | | |
|------------------|---|------------------------------------|-----------------------|-----------|--------------------------|
| A. June 4, 2002 | | | | | |
| Parameter | N | Mean | Standard Deviation | Range | Coefficient of Variation |
| TUa | 4 | 0.59 | 0.42 | 0.00-0.94 | 71 |
| Control Survival | 4 | 0.90 | 0.00 | 0.90-0.90 | 0 |
| pH Mean | 4 | 7.92 | 0.06 | 7.87-7.97 | 1 |
| DO Mean (mg/L) | 4 | 6.53 | 0.08 | 6.43-6.63 | 1 |
| B. June 18, 2002 | | | | | |
| Parameter | N | Mean | Standard Deviation | Range | Coefficient of Variation |
| TUa | 3 | 0.50 | 0.46 | 0.00-0.91 | 92 |
| Control Survival | 3 | 1.00 | 0.00 | 1.00-1.00 | 0 |
| pH Mean | 3 | 8.15 | 0.04 | 8.13-8.20 | 1 |
| DO Mean (mg/L) | 3 | 6.50 | 0.53 | 6.10-7.10 | 8 |

Effluent Chemistry

• Rent chemistry analyses are presented in Tables 3 (Pre-disinfection samples) and 4 (disinfected samples).

• Differences in chemistry concentrations between pre-disinfection and post-disinfection effluent samples were tested with a two-sample t-test. Only three of 15 analytes tested showed differences. Pre-disinfection concentrations of antimony (Sb) (P = 0.01) and chromium (Cr) (P = 0.01) were greater than disinfected samples, while concentrations of Method 608 compounds were greater in the disinfected effluent (P<0.001).

Results

• It appears that the disinfection process has little effect on effluent chemistry, with but a few exceptions.

Purple Sea Urchin

(Strongylocentrotus purpuratus)

with no variability measured.

% Fert. = Percent fertilization.

Toxicity was consistently low in all tests conducted

Table 12 Summary of Purple Sea Urchin (Strongylocentrotus purpuratus)

A. Pre-disinfection samples, April-July, 2002,
B. Post-disinfection samples, August-November 2002.

 TUa
 5
 55.6
 0.00
 55.6-55.6
 0

 Control % Fert.
 5
 0.99
 0.02
 0.96-1.00
 2

 IC25 % Fert.
 5
 >1.80
 0.00
 >1.80->1.80
 0

 pH Mean
 5
 7.86
 0.09
 7.80-8.00
 1

 DO Mean
 5
 7.14
 0.22
 6.80-7.40
 3

 Ref. Tox. LC50
 5
 67.8
 15.4
 49.0-84.0
 23

A. Split-Sample Tests, June 4, 2002.

% Fert. = Percent fertilization

Table 13. Summary of Purple Sea Urchin (Stongylocentrotus purpuratus) Toxicity

 3
 1.80
 0.00
 1.80-1.80

 3
 8.00
 0.00
 8.00-8.00

 3
 6.43
 0.15
 6.30-6.60

• The significance of the effects, if any, seen in this study are not known at this time.

| Organics = μg/L. Coefficient of Variation (cv) = Percent. Standard | | | | | | | ganics = µg/ | Ammonia and H L. | | g/g: | iii iii otaii |
|---|----------|------|-----------------------|-----------|----------|--------------------------------|---------------|---------------------|-----------------------|-----------|---------------|
| Element | N | Mean | Standard Deviation | Range | CV | Element | N | Mean | Standard Deviation | Range | CV |
| A m m o n i a | 4 | 28.7 | 0.63 | 28.0-30.0 | 2 | Ammonia | 7 | 27.7 | 0.49 | 27.0-28.0 | 2 |
| Hardness | 4 | 355 | 12.4 | 340-380 | 4 | Hardness | 4 | 373 | 38.6 | 350-430 | 10 |
| Antimony (Sb) | 3 | 1.47 | 0.26 | 1.27-1.76 | 18 | Antimony (Sb) | 5 | 0.98 | 0.16 | 0.76-1.16 | 16 |
| Arsenic (As) | 3 | 1.84 | 0.72 | 1.07-2.50 | 39 | Arsenic (As) | 5 | 1.97 | 0.17 | 1.76-2.20 | 9 |
| Beryllium (Be) | 3 | 0.07 | 0 | 0.07-0.07 | 0 | Beryllium (Be) | 5 | 0.00 | 0.00 | 0.00 | 0 |
| Cadmium (Cd) | 3 | 0.08 | 0 | 0.08-0.08 | 0 | Cadmium (Cd) | 5 | 0.00 | 0.00 | 0.00 | 0 |
| Chromium (Cd) | 3 | 5.45 | 1.84 | 3.37-6.88 | 34 | Chromium (Cd) | <u> </u> | 2.57 | 0.30 | 2.19-3.01 | 12 |
| Copper (Cu) | 3 | 33.4 | 1.76 | 31.5-35.0 | 5 | Copper (Cu) | <u> </u> | 36.5 | 5.71 | 27.4-42.8 | 16 |
| Lead (Pb) | 3 | 1.37 | 0.12 | 1.23-1.47 | 9 | Lead (Pb) | 5 | 1.00 | 0.25 | 0.60-1.30 | 25 |
| Mercury (Hg) | 2 | 0.04 | NA 10.5 | 0.04-0.04 | N A | Mercury (Hg) | <u>5</u> 6 | 0.03 | 0.02 | 0.02-0.06 | 67 |
| Molybdenum (Mo) | 3 | 33.8 | 12.5 | 26.1-48.2 | 37 | Molybdenum (Mo) | 5 | 23.7 | 1.61 | 22.3-25.8 | 7 |
| Nickel (Ni) | 3 | 19.8 | 4.13 | 16.9-24.5 | 21 | Nickel (Ni) | | 25.5 | 5.87 | 19.0-32.8 | 23 |
| Selenium (Se) | <u> </u> | 4.14 | 0.55 | 3.56-4.66 | 13 | | 5 | | | 4.21-4.70 | 5 |
| Silver (Ag) | <u> </u> | 2.32 | 0.06 | 2.25-2.37 | 3 | Selenium (Se) | <u>5</u> | 4.47 | 0.22 | | |
| Thallium (TI) | 3 | 43.9 | 1.30 | 42.4-44.7 | 3 | Silver (Ag) | <u>5</u> | 1.26 | 1.24 | 0-2.86 | 98 |
| Zinc (Zn) Gross Alpha | <u> </u> | 43.9 | 1.30 | 42.4-44.1 | <u> </u> | Thallium (TI) | 5 | 0.24 | 0.53 | 0-1.19 | 221 |
| Radioactivity | 3 | 3.35 | 1.91 | 1.16-4.65 | 57 | Zinc (Zn) | 5 | 43.3 | 6.36 | 37.8-52.5 | 15 |
| Gross Beta | | | | | | Alpha | 4 | 3.93 | 1.05 | 2.75-5.16 | 27 |
| Radioactivity | 3 | 22.9 | 7.61 | 14.8-29.9 | 33 | Beta | 4 | 14.9 | 4.69 | 8.70-18.9 | 32 |
| USEPA Method | 1 | 0.20 | 0 | 0.20-0.20 | 0 | USEPA Method 608 Compounds | 4 | 1.29 | 0.25 | 0.91-1.45 | 19 |
| 608 Compounds | 4 | 0.20 | U | 0.20-0.20 | <u> </u> | USEPA Method | | | | | |
| USEPA Method | 4 | 725 | 314 | 440-1040 | 43 | 624 Compounds | 4 | 813 | 148 | 633-971 | 18 |
| 624 Compounds USEPA Method | | | | | | USEPA Method | | 400 | 00.0 | 04.0.405 | 4.0 |
| 625 Compounds | 4 | 152 | 24.0 | 126-179 | 16 | 625 Compounds | 4 | 128 | 63.2 | 61.9-195 | 49 |
| USEPA Method 8141 Compounds | 1 | 0 | NA | NA | NA | USEPA Method 8141 Compounds | 4 | 0.00 | 0.00 | 0.00 | 0 |
| 1,4-Dioxane* | 0 | NA | NA | NA | NA | 1,4-Dioxane | 2 | 5078 | 643 | 4623-5532 | 13 |
| NDMA* | 0 | NA | NA | NA | NA | NDMA | 2 | 60.9 | 5.87 | 56.7-65.0 | 10 |

Red Abalone



- There was low variability in pre=disinfection samples (cv = 25%), which was reduced to zero by disinfection.
- Toxicity was low to moderate in predisinfectiaon smples and consistently low in disinfected samples.

| Table 11. Summary of Red Abalone (<i>Haliotis rufescens</i>) Toxicity Results: A. Pre-disinfection samples, April-July, 2002, B. Post-disinfection samples, August-November 2002. C. Split-Sample Tests, June 18, 2002 %ND = Percent normal development | | | | | | | | | |
|---|---|-------|-----------------------|-------------|-----------------------------|--|--|--|--|
| A. Parameter | N | Mean | Standard Deviation | Range | Coefficient of Variation | | | | |
| TUc | 9 | 60.5 | 14.8 | 55.6-100 | 25 | | | | |
| Control % ND | 9 | 0.98 | 0.02 | 0.95-1.00 | 2 | | | | |
| IC25 | 9 | 1.74 | 0.19 | 1.22-1.80 | 11 | | | | |
| pH Mean | 9 | 7.94 | 0.12 | 7.75-8.10 | 2 | | | | |
| DO Mean (mg/L) | 9 | 6.48 | 0.57 | 5.90-7.50 | 9 | | | | |
| Ref. Tox. LC50 | 9 | 60.3 | 16.7 | 41.0-77.0 | 28 | | | | |
| B. Parameter | N | Mean | Standard Deviation | Range | Coefficient of Variation | | | | |
| TUc | 7 | 55.6 | 0.00 | 55.6-55.6 | 0 | | | | |
| Control % ND | 7 | 0.98 | 0.02 | 0.94-1.00 | 2 | | | | |
| IC25 | 7 | >1.80 | 0.00 | >1.80->1.80 | 0 | | | | |
| pH Mean | 7 | 7.74 | 0.11 | 7.55-7.90 | 1 | | | | |
| DO Mean (mg/L) | 7 | 6.00 | 0.49 | 5.50-6.65 | 8 | | | | |
| Ref. Tox. LC50 | 7 | 38.0 | 6.95 | 25.0-43.0 | 18 | | | | |
| C. June 18, 2002 Parameter | N | Mean | Standard Deviation | Range | Coefficient of Variation | | | | |
| TUc | 3 | 55.6 | 0.00 | 55.6-55.6 | 0 | | | | |
| Control ND | 3 | 0.98 | 0.00 | 0.98-0.98 | 0 | | | | |
| IC25 | 3 | 1.80 | 0.00 | 1.80-1.80 | 0 | | | | |
| pH Mean | 3 | 8.10 | 0.10 | 8.00-8.20 | 1 | | | | |
| DO Mean (mg/L) | 3 | 5.98 | 0.10 | 5.90-6.10 | 2 | | | | |