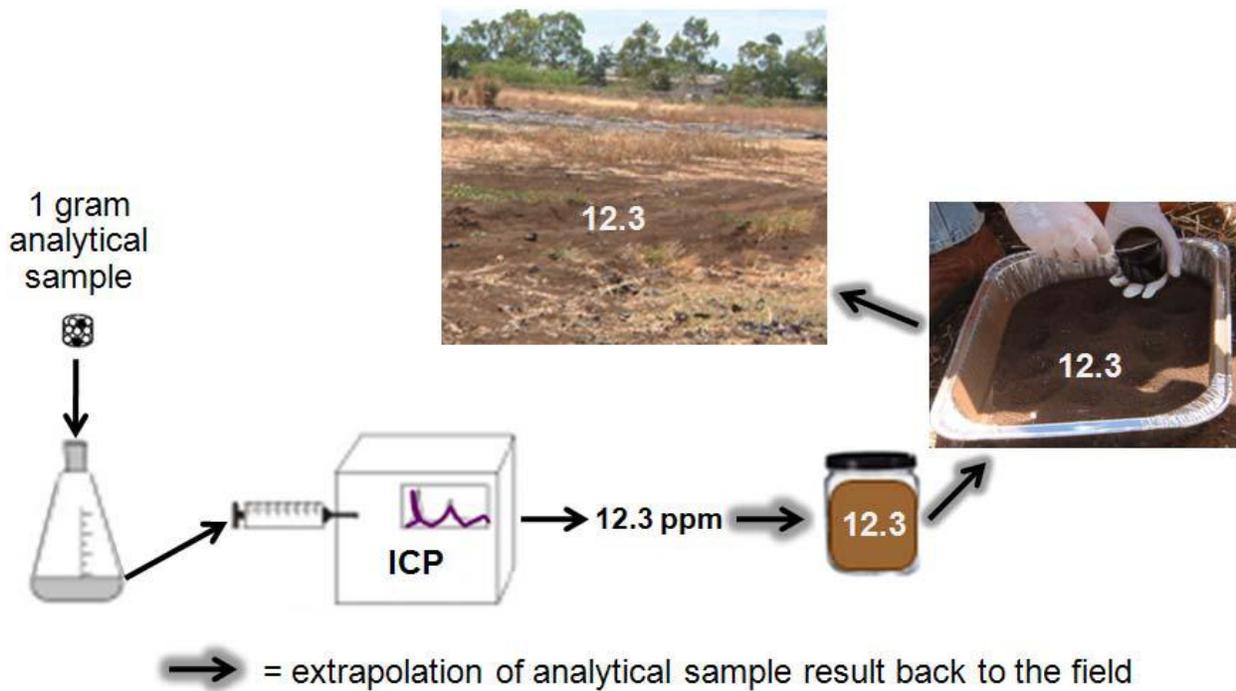
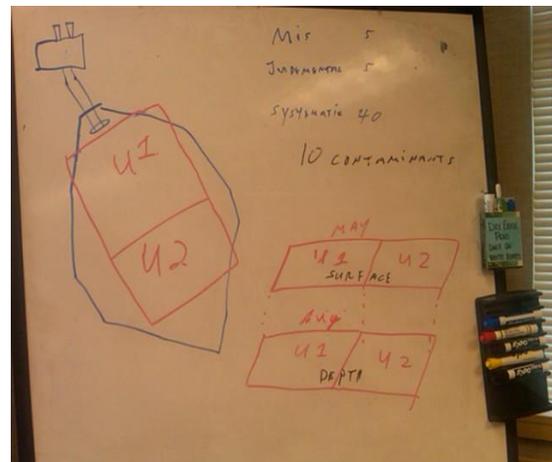




# A Comparison Study of Soil Sampling Techniques for Environmental Studies



Statistics Project  
 Spring Quarter 2011  
 By: Kelly Rogers



## **Hypothesis Tests Comparing MIS, Systematic, and Judgmental Sampling**

In 2008, Washington Department of Ecology in cooperation with DOE (Department of Energy) and CHPRC (CH2M Hill Plateau Remediation Company) collected two soil samples from a single location immediately adjacent to the Point of Discharge of the 216-S-19 Pond, a waste site of the 200-MG-1 Operable Unit. These samples were designed as “screening” in order to determine if the site would be a suitable location to conduct a comparison of three (Judgmental, Systematic Random, and Multi-Incremental) sampling designs. Based on the results of the Washington State Department of Ecology screening effort, COPCs (Chemical of Potential Concern) were selected and are the following: Chromium, Copper, Zinc, Mercury, Uranium-238, Uranium-233/234, Uranium-235, Plutonium-238, Plutonium-239/240, Americium-241, and Nitrate.

MIS sample points were selected by dividing each Decision Unit into grids with 100 units. One sample increment was collected from each grid unit for a total of 100 increments to comprise a single, multi-incremental “parent” sample. Four field replicate samples were also collected from each of the 100 grid-units in each Decision Unit.

Systematic Random sample points were selected using the 100-grid locations established in the MIS scheme above. Discrete sampling locations were proportioned out evenly within each Decision Unit using a random start point. In order to achieve a uniform distribution over each Decision Unit, 42 sample locations were identified rather than 40 as specified in the SAP.

Judgmental sample points were selected primarily based on field observations, professional judgment, and radiological field screening measurements. One location of highest expected (encountered) concentration will be selected, with the remaining four locations fanning out from that position. A total of five locations within each of the two Decision Units were identified and sampled.

Comparison testing of the mean concentration level of each of the elements listed above was done for these three different sampling techniques for two different decision areas on two different dates. Due to the nature of MIS sampling, the Central Limit Theorem applies, and this data can be assumed to be normally distributed as can the Systematic sampling data. The same assumption was made for the Judgmental sample data. However, any results involving Judgmental sampling should be viewed with caution as the assumption of normality is extremely questionable. All comparison tests were conducted using a Student’s t Distribution. The results for each test are summarized by element in various tables presented on the

following pages. All 132 hypothesis tests used the following general format, test statistic, significance level, and critical value.

### General Approach: Testing a Claim about Two Independent Population Means

**Claim:** There is no difference, when sampling the same area, between the mean element levels obtained from MIS sampling, Systematic sampling, and Judgmental sampling.

Hypothesis Test:

Test Statistic:

$$H_o : \mu_1 - \mu_2 = 0 \quad (\text{Claim})$$

$$H_1 : \mu_1 - \mu_2 \neq 0$$

Significance Level:  $\alpha = 0.05$

Critical Value:  $t_{0.05/2} = \pm 2.776$

Degrees of Freedom: 4

$$t^* = \frac{(\bar{x}_1 - \bar{x}_2) - (\mu_1 - \mu_2)}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$

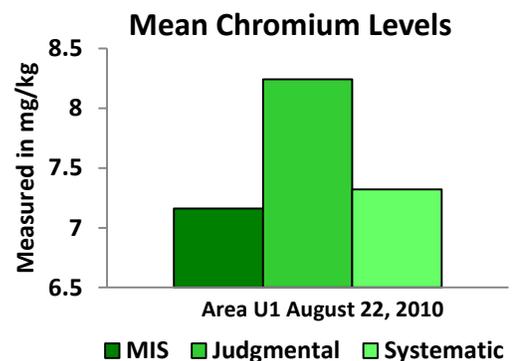
Each element section is also accompanied by a bar graph which provides a visual comparison of the three sampling techniques and a table displaying the sample statistics used each hypothesis test. The results of these hypothesis tests are presented in a table along with the outcomes and written conclusions for each set of comparisons.

### Area U1 for August 22, 2010

#### Comparison Tests Involving Chromium

#### Chromium Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	7.16	0.384707
Judgmental	8.24	0.559464
Systematic	7.3194444	1.4089144



## Chromium Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	-0.548	Fail to Reject $H_0$
MIS vs Judgmental	-3.557	Reject $H_0$
Systematic vs Judgmental	-2.683	Fail to Reject $H_0$

**Conclusion:** Since the test statistics for both the comparison of MIS and Systematic sampling as well as Systematic and Judgmental sampling (-0.548 and -2.683 respectively) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Chromium levels obtained from MIS and Systematic sampling as well as Systematic and Judgmental sampling. However, the test statistic for the comparison of MIS and Judgmental sampling (-3.557) is less than the critical value of -2.766, reject  $H_0$ . There is sufficient evidence to reject the claim that there is no difference between Chromium levels obtained from MIS and Judgmental sampling.

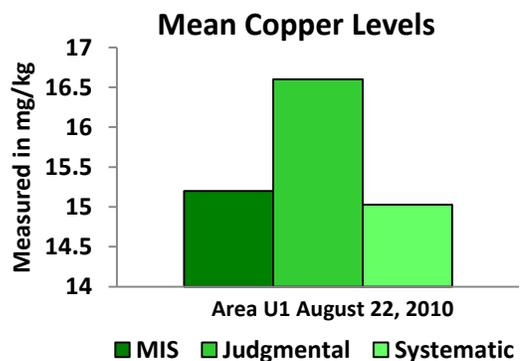
### Area U1 August 22, 2010

#### Comparison Tests Involving Copper

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#### Copper Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	15.2	1.6432
Judgmental	16.6	2.60077
Systematic	15.028	1.7966



## Copper Hypothesis Test Results

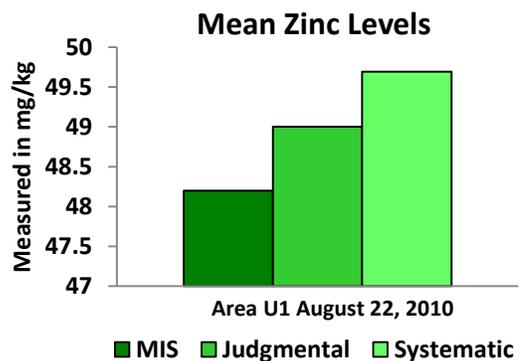
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	0.217	Fail to Reject $H_0$
MIS vs Judgmental	-1.016	Fail to Reject $H_0$
Systematic vs Judgmental	-1.306	Fail to Reject $H_0$

**Conclusion:** Since the test statistics in all three comparisons (0.217, -1.016, and -1.306) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Copper levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Zinc

### Zinc Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	48.2	1.095
Judgmental	49	2.345
Systematic	49.69	2.955



### Zinc Hypothesis Test Results

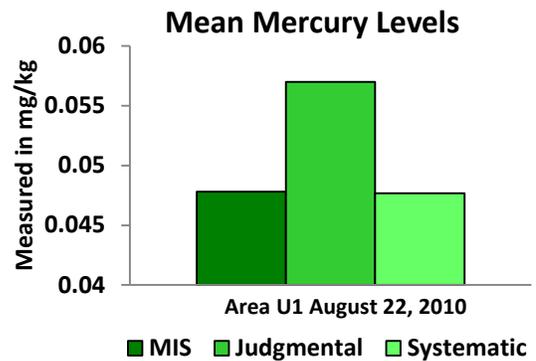
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	-2.145	Fail to Reject $H_0$
MIS vs Judgmental	-0.691	Fail to Reject $H_0$
Systematic vs Judgmental	0.596	Fail to Reject $H_0$

**Conclusion:** Since the test statistics in all three comparisons (-2.145, -0.691, and 0.596) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Zinc levels obtained from MIS, Systematic, and Judgmental sampling.

### Comparison Tests Involving Mercury

#### Mercury Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	0.0478	0.00602
Judgmental	0.057	0.01739
Systematic	0.04767	0.03079



#### Mercury Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	0.022	Fail to Reject $H_0$
MIS vs Judgmental	-1.118	Fail to Reject $H_0$
Systematic vs Judgmental	-1.001	Fail to Reject $H_0$

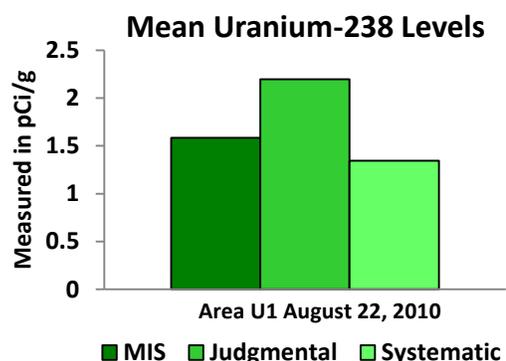
**Conclusion:** Since the test statistics in all three comparisons (0.022, -1.118, and -1.001) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Mercury levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Uranium-238

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### U-238 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	1.584	0.08532
Judgmental	2.196	1.52677
Systematic	1.34639	0.811



### Uranium-238 Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	1.692	Fail to Reject $H_0$
MIS vs Judgmental	-0.895	Fail to Reject $H_0$
Systematic vs Judgmental	-1.221	Fail to Reject $H_0$

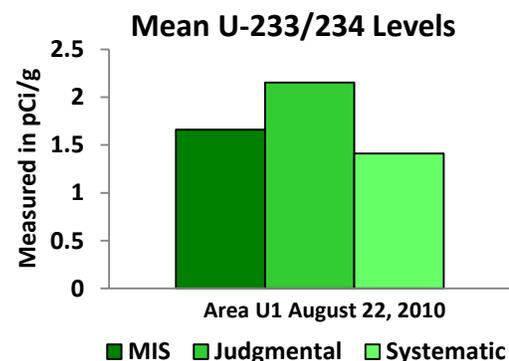
**Conclusion:** Since the test statistics in all three comparisons (1.692, -0.895, and -1.221) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Uranium-238 levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Uranium-233/234

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### U-233/234 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	1.662	0.09471
Judgmental	2.154	1.32022
Systematic	1.410556	0.815535



## Uranium-233/234 Hypothesis Test Results

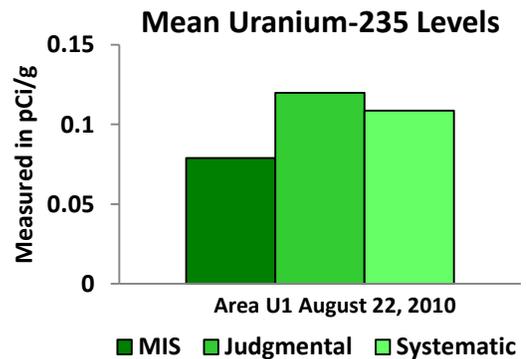
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	1.766	Fail to Reject $H_0$
MIS vs Judgmental	-0.831	Fail to Reject $H_0$
Systematic vs Judgmental	-1.227	Fail to Reject $H_0$

**Conclusion:** Since the test statistics in all three comparisons (1.766, -0.831, and -1.227) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Uranium-233/234 levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Uranium-235

### U-235 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.079	0.0157
Judgmental	0.1198	0.06423
Systematic	0.10856	0.21524



### Uranium-235 Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	-0.809	Fail to Reject $H_0$
MIS vs Judgmental	-1.380	Fail to Reject $H_0$
Systematic vs Judgmental	-0.245	Fail to Reject $H_0$

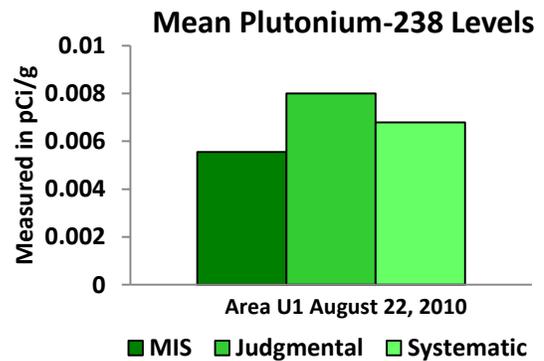
**Conclusion:** Since the test statistics in all three comparisons (-0.809, -1.380, and -0.245) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Uranium-235 levels obtained from MIS, Systematic, and Judgmental sampling.

### Comparison Tests Involving Plutonium-238

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#### Pu-238 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.00556	0.00433
Judgmental	0.008	0.0051
Systematic	0.00679	0.00474



#### Plutonium-238 Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	-0.588	Fail to Reject $H_0$
MIS vs Judgmental	-0.816	Fail to Reject $H_0$
Systematic vs Judgmental	-0.501	Fail to Reject $H_0$

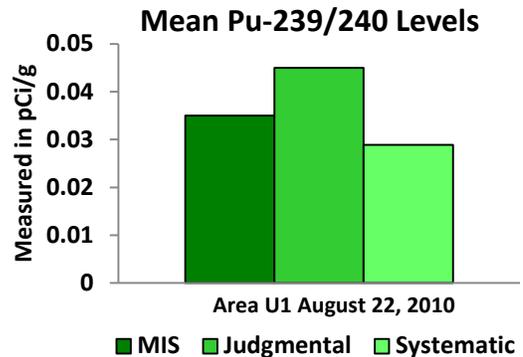
**Conclusion:** Since the test statistics in all three comparisons (-0.588, -0.816, and -0.501) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Plutonium-238 levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Plutonium-238

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### Pu-239/240 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.035	0.0081548
Judgmental	0.045	0.0310242
Systematic	0.0288889	0.0330414



### Plutonium-239/240 Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	0.925	Fail to Reject $H_0$
MIS vs Judgmental	-0.697	Fail to Reject $H_0$
Systematic vs Judgmental	-1.079	Fail to Reject $H_0$

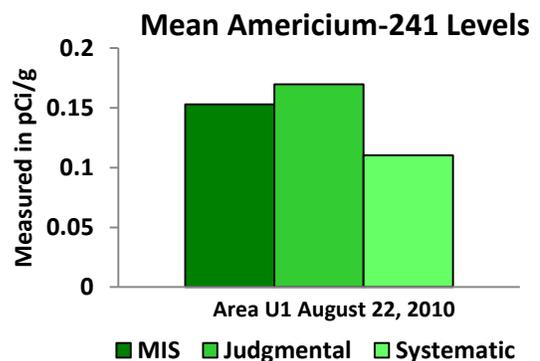
**Conclusion:** Since the test statistics in all three comparisons (0.925, -0.697, and -1.079) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Plutonium-239/240 levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Americium-241

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### Am-241 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.1528	0.02381
Judgmental	0.1696	0.11122
Systematic	0.11039	0.18687



### Americium-241 Hypothesis Test Results

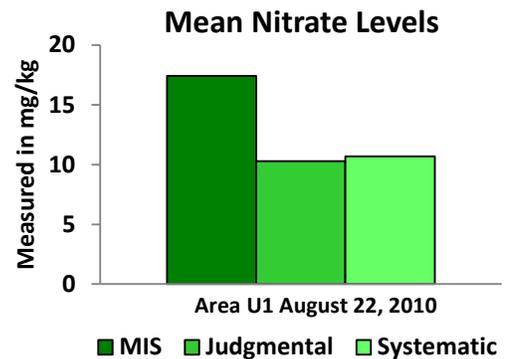
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	1.288	Fail to Reject $H_0$
MIS vs Judgmental	-0.330	Fail to Reject $H_0$
Systematic vs Judgmental	-1.009	Fail to Reject $H_0$

**Conclusion:** Since the test statistics in all three comparisons (1.288, -0.330, and -1.009) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Americium-241 levels obtained from MIS, Systematic, and Judgmental sampling.

### Comparison Tests Involving Nitrate

#### Nitrate Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	17.4	1.81659
Judgmental	10.28	11.4305
Systematic	10.6917	8.94943



#### Nitrate Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	3.950	Reject $H_0$
MIS vs Judgmental	1.376	Fail to Reject $H_0$
Systematic vs Judgmental	0.077	Fail to Reject $H_0$

**Conclusion:** Since the test statistic for the comparison of MIS and Systematic sampling (3.950) is greater than the critical value of 2.776, reject  $H_0$ . There is sufficient evidence to reject the claim that there is no difference between mean Nitrate levels obtained from MIS and Systematic sampling. However, the test statistic for the comparison of MIS and Judgmental sampling (1.376) as well as the comparison of Systematic and Judgmental sampling (0.077) are both greater than the critical value of -2.766 and less than the critical value of 2.766, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between Nitrate levels obtained from MIS and Judgmental sampling as well as Systematic and Judgmental sampling.

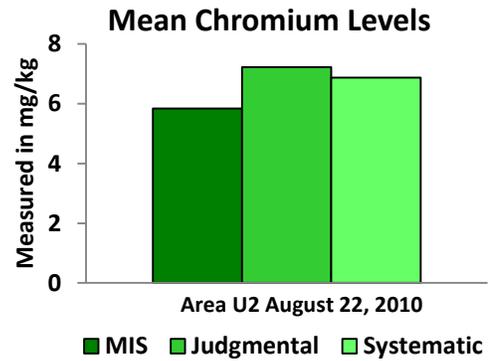
## Area U2 for August 22, 2010

### Comparison Tests Involving Chromium

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#### Chromium Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	5.84	1.2778889
Judgmental	7.22	0.6978539
Systematic	6.8641026	1.1157927



#### Chromium Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	-1.710	Fail to Reject $H_0$
MIS vs Judgmental	-2.119	Fail to Reject $H_0$
Systematic vs Judgmental	-0.990	Fail to Reject $H_0$

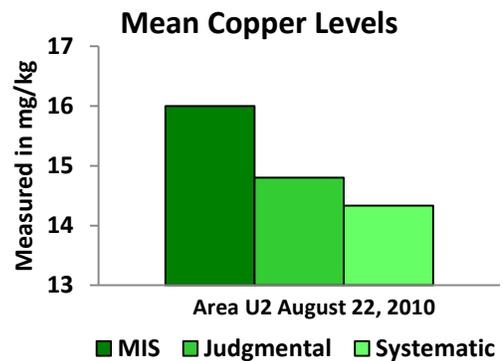
**Conclusion:** Since the test statistics in all three comparisons (-1.710, -2.119, and -0.990) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Chromium levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Copper

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### Copper Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	16	3.937003937
Judgmental	14.8	0.447213595
Systematic	14.333	1.447493681



### Chromium Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	0.939	Fail to Reject $H_0$
MIS vs Judgmental	0.677	Fail to Reject $H_0$
Systematic vs Judgmental	-1.525	Fail to Reject $H_0$

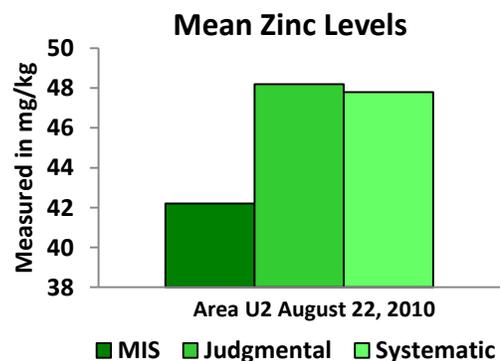
**Conclusion:** Since the test statistics in all three comparisons (0.939, 0.677, and -1.525) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Copper levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Zinc

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### Zinc Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	42.2	7.661592524
Judgmental	48.2	1.643167673
Systematic	47.79487179	2.054257289



## Zinc Hypothesis Test Results

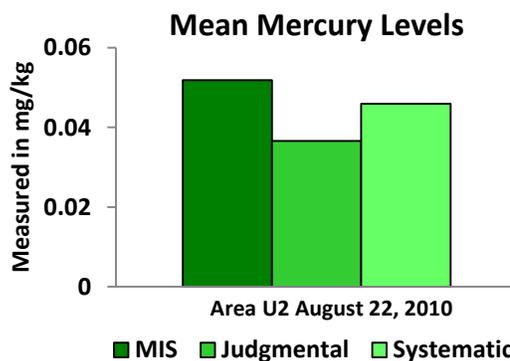
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	-1.625	Fail to Reject $H_0$
MIS vs Judgmental	-1.712	Fail to Reject $H_0$
Systematic vs Judgmental	-0.503	Fail to Reject $H_0$

**Conclusion:** Since the test statistics in all three comparisons (-1.625, -1.712, and -0.503) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Zinc levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Mercury

### Mercury Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	0.0518	0.01255786
Judgmental	0.0366	0.00585662
Systematic	0.045897436	0.02841126



### Mercury Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	0.817	Fail to Reject $H_0$
MIS vs Judgmental	2.453	Fail to Reject $H_0$
Systematic vs Judgmental	1.771	Fail to Reject $H_0$

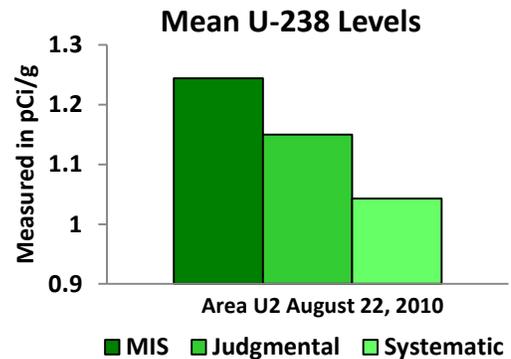
**Conclusion:** Since the test statistics in all three comparisons (0.817, 2.453, and 1.771) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Mercury levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Uranium-238

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### U-238 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	1.244	0.248253902
Judgmental	1.15	0.349857114
Systematic	1.042871795	0.582962993



### U-238 Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	1.387	Fail to Reject $H_0$
MIS vs Judgmental	0.490	Fail to Reject $H_0$
Systematic vs Judgmental	-0.588	Fail to Reject $H_0$

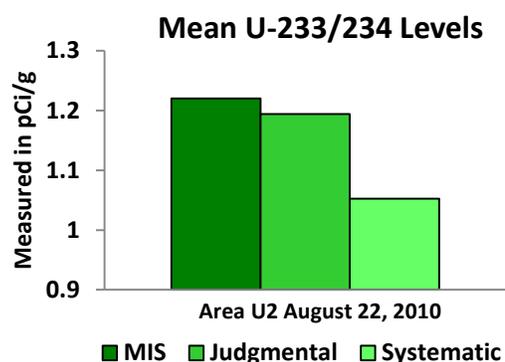
**Conclusion:** Since the test statistics in all three comparisons (1.387, 0.490, and -0.588) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Uranium-238 levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Uranium-233/234

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### U-233/234 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	1.22	0.230867928
Judgmental	1.194	0.292796858
Systematic	1.052358974	0.590635852



### U-233/234 Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	1.197	Fail to Reject $H_0$
MIS vs Judgmental	0.156	Fail to Reject $H_0$
Systematic vs Judgmental	-0.877	Fail to Reject $H_0$

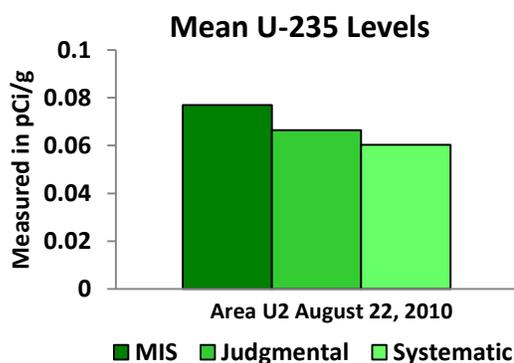
**Conclusion:** Since the test statistics in all three comparisons (1.197, 0.156, and -0.877) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Uranium-233/234 levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Uranium-235

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### U-235 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.077	0.02875
Judgmental	0.0664	0.02349
Systematic	0.06033	0.03966



## U-235 Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	1.162	Fail to Reject $H_0$
MIS vs Judgmental	0.638	Fail to Reject $H_0$
Systematic vs Judgmental	-0.494	Fail to Reject $H_0$

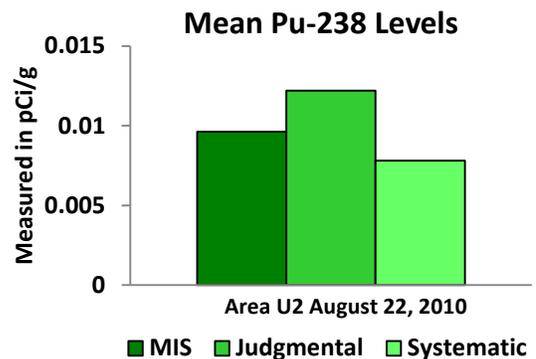
**Conclusion:** Since the test statistics in all three comparisons (1.162, 0.638, and -0.494) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Uranium-235 levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Plutonium 238

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### Pu-238 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.00962	0.007674764
Judgmental	0.0122	0.010497619
Systematic	0.007815325	0.005575205



### Pu-238 Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	0.509	Fail to Reject $H_0$
MIS vs Judgmental	-0.444	Fail to Reject $H_0$
Systematic vs Judgmental	-0.918	Fail to Reject $H_0$

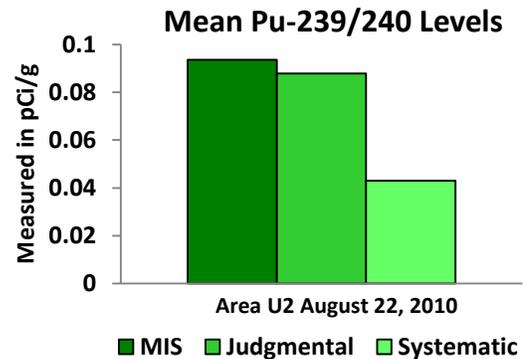
**Conclusion:** Since the test statistics in all three comparisons (0.509, -0.444, and -0.918) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Plutonium-238 levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Plutonium 239/240

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### Pu-239/240 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.0936	0.026726391
Judgmental	0.0878	0.102074483
Systematic	0.043069231	0.049786244



### Pu-239/240 Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	3.517	Reject $H_0$
MIS vs Judgmental	0.123	Fail to Reject $H_0$
Systematic vs Judgmental	-0.965	Fail to Reject $H_0$

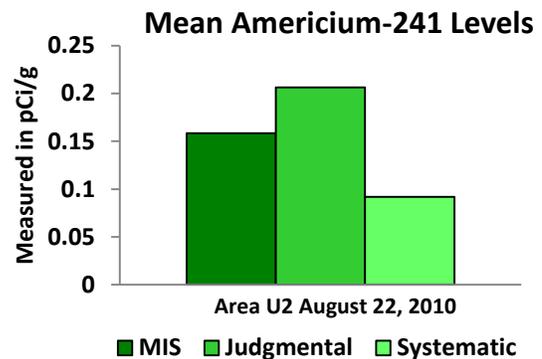
**Conclusion:** Since the test statistic for the comparison of MIS and Systematic sampling (3.517) is greater than the critical value of 2.776, reject  $H_0$ . There is sufficient evidence to reject the claim that there is no difference between mean Plutonium-239/240 levels obtained from MIS and Systematic sampling. However, the test statistic for the comparison of MIS and Judgmental sampling (0.123) as well as the comparison of Systematic and Judgmental sampling (-0.965) are both greater than the critical value of -2.766 and less than the critical value of 2.766, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between Plutonium-239/240 levels obtained from MIS and Judgmental sampling as well as Systematic and Judgmental sampling.

## Comparison Tests Involving Americium-241

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### Am-241 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.1586	0.029074043
Judgmental	0.2064	0.194401132
Systematic	0.092	0.090786331



### Americium-241 Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	3.415	Reject $H_0$
MIS vs Judgmental	-0.544	Fail to Reject $H_0$
Systematic vs Judgmental	-1.298	Fail to Reject $H_0$

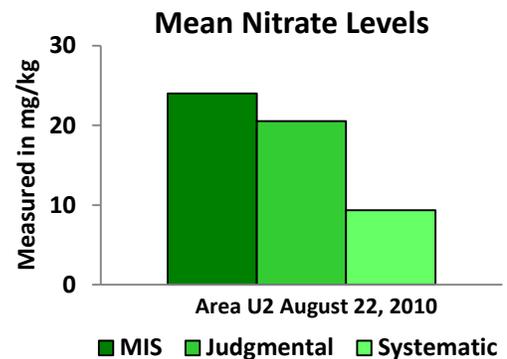
**Conclusion:** Since the test statistic for the comparison of MIS and Systematic sampling (3.415) is greater than the critical value of 2.776, reject  $H_0$ . There is sufficient evidence to reject the claim that there is no difference between mean Americium-241 levels obtained from MIS and Systematic sampling. However, the test statistic for the comparison of MIS and Judgmental sampling (-0.544) as well as the comparison of Systematic and Judgmental sampling (-1.298) are both greater than the critical value of -2.766 and less than the critical value of 2.766, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between Americium-241 levels obtained from MIS and Judgmental sampling as well as Systematic and Judgmental sampling.

## Comparison Tests Involving Nitrate

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### Nitrate Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	24	2.44989743
Judgmental	20.52	15.50603108
Systematic	9.374358974	5.217315197



### Nitrate Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	10.615	Reject $H_0$
MIS vs Judgmental	0.496	Fail to Reject $H_0$
Systematic vs Judgmental	-1.596	Fail to Reject $H_0$

**Conclusion:** Since the test statistic for the comparison of MIS and Systematic sampling (10.615) is greater than the critical value of 2.776, reject  $H_0$ . There is sufficient evidence to reject the claim that there is no difference between mean Nitrate levels obtained from MIS and Systematic sampling. However, the test statistic for the comparison of MIS and Judgmental sampling (0.496) as well as the comparison of Systematic and Judgmental sampling (-1.596) are both greater than the critical value of -2.766 and less than the critical value of 2.766, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between Nitrate levels obtained from MIS and Judgmental sampling as well as Systematic and Judgmental sampling.

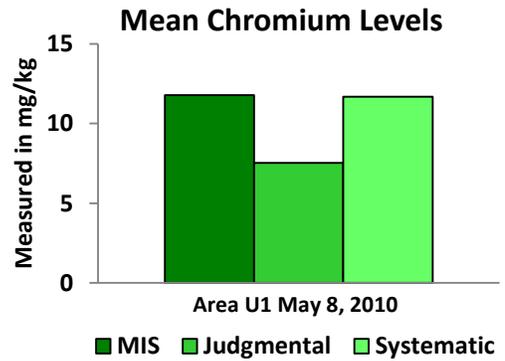
## Area U1 for May 8, 2010

### Comparison Tests Involving Chromium

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#### Chromium Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	11.78	4.334974
Judgmental	7.54	2.0231164
Systematic	11.68	11.338028



#### Chromium Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	0.038	Fail to Reject $H_0$
MIS vs Judgmental	1.982	Fail to Reject $H_0$
Systematic vs Judgmental	2.062	Fail to Reject $H_0$

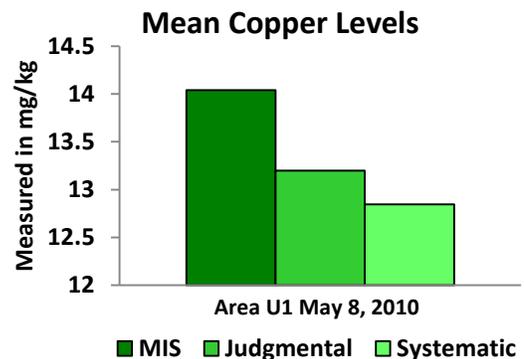
**Conclusion:** Since the test statistics in all three comparisons (0.038, 1.982, and 2.062) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Chromium levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Copper

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### Copper Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	14.04	4.930314392
Judgmental	13.2	3.271085447
Systematic	12.8475	8.555789388



### Chromium Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	0.461	Fail to Reject $H_0$
MIS vs Judgmental	0.317	Fail to Reject $H_0$
Systematic vs Judgmental	-0.177	Fail to Reject $H_0$

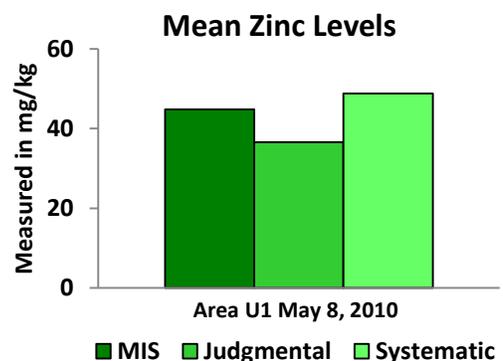
**Conclusion:** Since the test statistics in all three comparisons (0.461, 0.317, and -0.177) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Copper levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Zinc

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### Zinc Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	44.8	10.30533842
Judgmental	36.6	1.516575089
Systematic	48.8	3.472972568



## Zinc Hypothesis Test Results

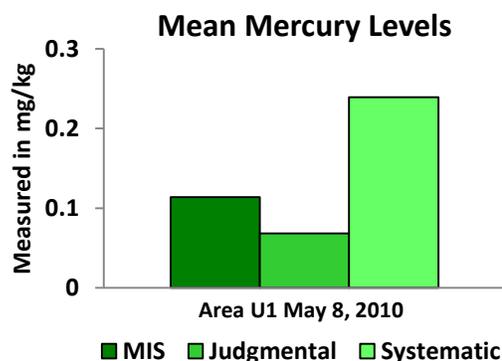
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	-0.862	Fail to Reject $H_0$
MIS vs Judgmental	1.760	Fail to Reject $H_0$
Systematic vs Judgmental	13.980	Reject $H_0$

**Conclusion:** Since the test statistics for both the comparison of MIS and Systematic sampling as well as Systematic and Judgmental sampling (-0.862 and 1.760 respectively) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Zinc levels obtained from MIS and Systematic sampling as well as Systematic and Judgmental sampling. However, the test statistic for the comparison of MIS and Judgmental sampling (13.980) is greater than the critical value of 2.766, reject  $H_0$ . There is sufficient evidence to reject the claim that there is no difference between Zinc levels obtained from MIS and Judgmental sampling.

## Comparison Tests Involving Mercury

### Mercury Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	0.1138	0.075816885
Judgmental	0.0686	0.050460876
Systematic	0.2394	0.823964519



## Mercury Hypothesis Test Results

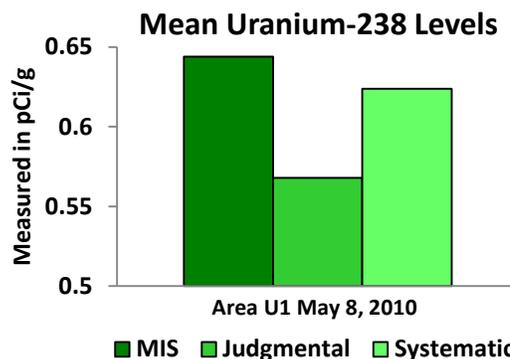
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	-0.933	Fail to Reject $H_0$
MIS vs Judgmental	1.110	Fail to Reject $H_0$
Systematic vs Judgmental	1.292	Fail to Reject $H_0$

**Conclusion:** Since the test statistics in all three comparisons (-0.933, 1.110, and 1.292) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Mercury levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Uranium-238

### Uranium-238 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.644	0.101882285
Judgmental	0.568	0.188069136
Systematic	0.62375	0.239311914



### Uranium-238 Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	0.342	Fail to Reject $H_0$
MIS vs Judgmental	0.795	Fail to Reject $H_0$
Systematic vs Judgmental	0.604	Fail to Reject $H_0$

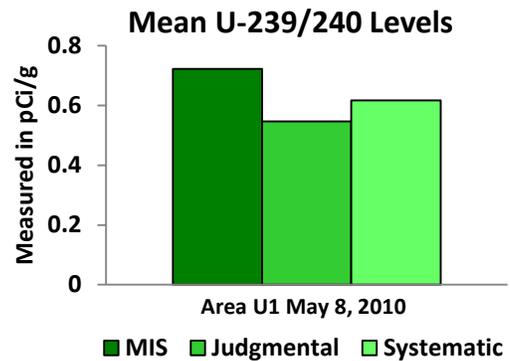
**Conclusion:** Since the test statistics in all three comparisons (0.342, 0.795, and 0.604) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Uranium-238 levels obtained from MIS, Systematic, and Judgmental sampling.

### Comparison Tests Involving Uranium-239/240

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#### U-239/240 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.722	0.163003067
Judgmental	0.546	0.087920419
Systematic	0.617	0.20600224



#### Uranium-239/240 Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	1.315	Fail to Reject $H_0$
MIS vs Judgmental	2.125	Fail to Reject $H_0$
Systematic vs Judgmental	1.391	Fail to Reject $H_0$

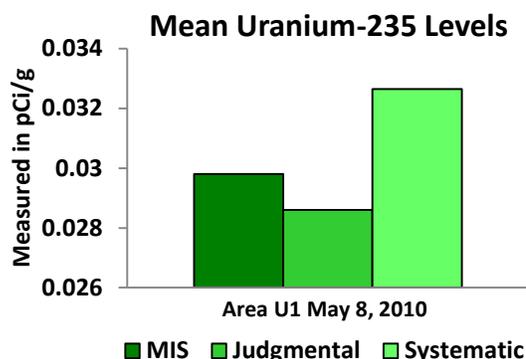
**Conclusion:** Since the test statistics in all three comparisons (1.315, 2.125, and 1.391) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Uranium-239/240 levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Uranium-235

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### Uranium-235 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.0298	0.01605
Judgmental	0.0286	0.0082
Systematic	0.03265	0.01642



### Uranium-235 Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	-0.373	Fail to Reject $H_0$
MIS vs Judgmental	0.149	Fail to Reject $H_0$
Systematic vs Judgmental	0.901	Fail to Reject $H_0$

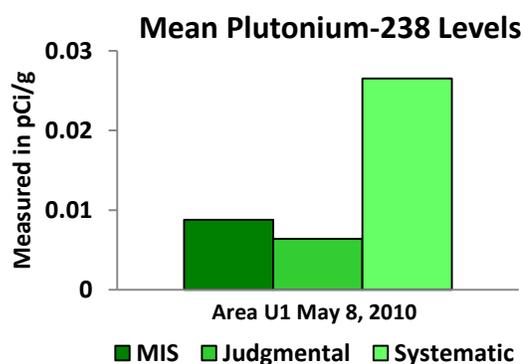
**Conclusion:** Since the test statistics in all three comparisons (-0.373, 0.149, and 0.901) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Uranium-235 levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Plutonium-238

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### Pu-238 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.0088	0.016300307
Judgmental	0.0064	0.01422322
Systematic	0.026515	0.097484072



## Plutonium-238 Hypothesis Test Results

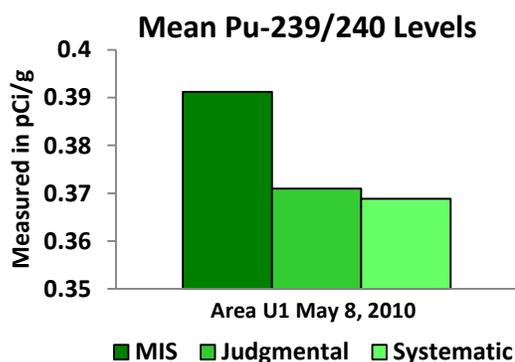
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	-1.039	Fail to Reject $H_0$
MIS vs Judgmental	0.248	Fail to Reject $H_0$
Systematic vs Judgmental	1.206	Fail to Reject $H_0$

**Conclusion:** Since the test statistics in all three comparisons (-1.039, 0.248, and 1.206) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Plutonium-238 levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Plutonium-239/240

### Pu-239/240 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.3912	0.459781687
Judgmental	0.371	0.485799341
Systematic	0.3688875	1.040721367



### Plutonium-239/240 Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	0.085	Fail to Reject $H_0$
MIS vs Judgmental	0.068	Fail to Reject $H_0$
Systematic vs Judgmental	-0.008	Fail to Reject $H_0$

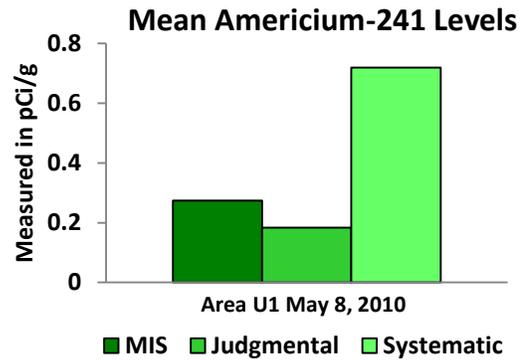
**Conclusion:** Since the test statistics in all three comparisons (0.085, 0.068, and -0.008) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Plutonium-239/240 levels obtained from MIS, Systematic, and Judgmental sampling.

### Comparison Tests Involving Americium-241

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#### Am-241 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.2738	0.158027529
Judgmental	0.184	0.216216327
Systematic	0.7188	2.734396349



#### Americium-241 Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	-1.016	Fail to Reject $H_0$
MIS vs Judgmental	0.750	Fail to Reject $H_0$
Systematic vs Judgmental	1.207	Fail to Reject $H_0$

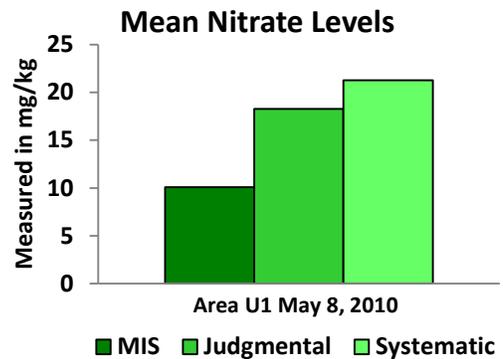
**Conclusion:** Since the test statistics in all three comparisons (-1.016, 0.750, and 1.207) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Americium-241 levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Nitrate

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### Nitrate Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	10.1	0.85732141
Judgmental	18.26	14.8740714
Systematic	21.255	17.39901191



### Nitrate Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	-4.016	Reject $H_0$
MIS vs Judgmental	-1.225	Fail to Reject $H_0$
Systematic vs Judgmental	0.416	Fail to Reject $H_0$

**Conclusion:** Since the test statistic for the comparison of MIS and Systematic sampling (-4.016) is less than the critical value of -2.776, reject  $H_0$ . There is sufficient evidence to reject the claim that there is no difference between mean Nitrate levels obtained from MIS and Systematic sampling. However, the test statistic for the comparison of MIS and Judgmental sampling (-1.225) as well as the comparison of Systematic and Judgmental sampling (0.416) are both greater than the critical value of -2.766 and less than the critical value of 2.766, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between Nitrate levels obtained from MIS and Judgmental sampling as well as Systematic and Judgmental sampling.

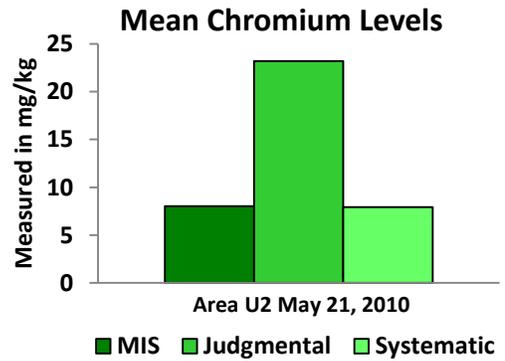
## Area U2 for May 21, 2010

### Comparison Tests Involving Chromium

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#### Chromium Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	8.04	1.7529974
Judgmental	23.18	27.583455
Systematic	7.9375	1.3590509



#### Chromium Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	0.126	Fail to Reject $H_0$
MIS vs Judgmental	-1.225	Fail to Reject $H_0$
Systematic vs Judgmental	-1.235	Fail to Reject $H_0$

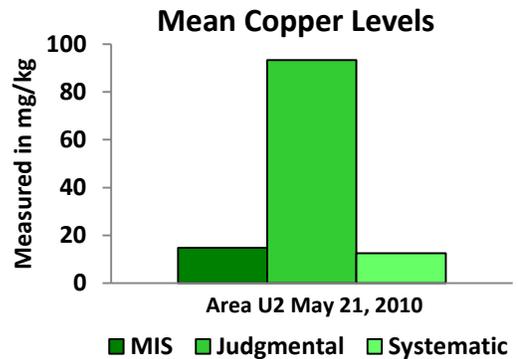
**Conclusion:** Since the test statistics in all three comparisons (0.126, -1.225, and -1.235) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Chromium levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Copper

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### Copper Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	14.8	3.271085447
Judgmental	93.38	151.3240629
Systematic	12.57	3.544819261



### Copper Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	1.423	Fail to Reject $H_0$
MIS vs Judgmental	-1.161	Fail to Reject $H_0$
Systematic vs Judgmental	-1.194	Fail to Reject $H_0$

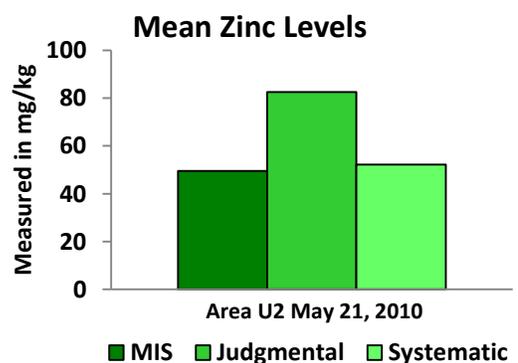
**Conclusion:** Since the test statistics in all three comparisons (1.426, -1.161, and -1.194) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Cropper levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Zinc

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### Zinc Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	49.6	4.878524367
Judgmental	82.6	60.85885309
Systematic	52.225	1.64062996



## Zinc Hypothesis Test Results

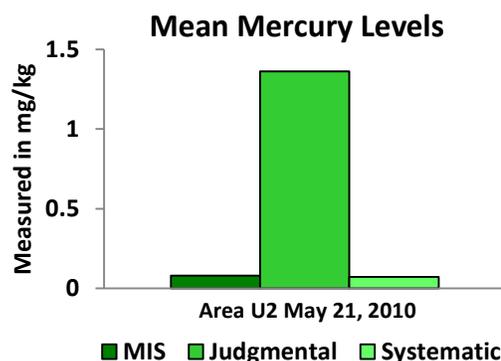
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	-1.195	Fail to Reject $H_0$
MIS vs Judgmental	-1.209	Fail to Reject $H_0$
Systematic vs Judgmental	-1.116	Fail to Reject $H_0$

**Conclusion:** Since the test statistics in all three comparisons (-1.195, -.209, and -1.116) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Zinc levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Mercury

### Mercury Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	0.0802	0.095334674
Judgmental	1.362	2.413442251
Systematic	0.07295	0.132357897



### Mercury Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	0.153	Fail to Reject $H_0$
MIS vs Judgmental	-1.187	Fail to Reject $H_0$
Systematic vs Judgmental	-1.194	Fail to Reject $H_0$

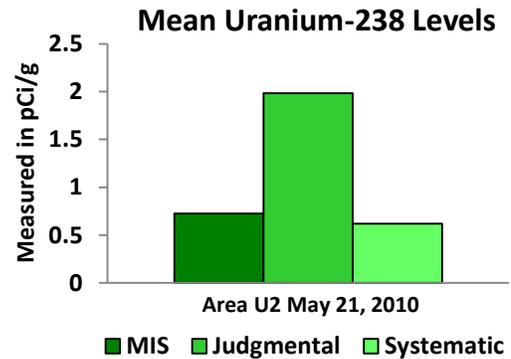
**Conclusion:** Since the test statistics in all three comparisons (0.153, -1.187, and -1.194) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Mercury levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Uranium-238

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### Uranium-238 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.728	0.28137164
Judgmental	1.984	2.30977921
Systematic	0.62175	0.293090408



### Uranium-238 Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	0.792	Fail to Reject $H_0$
MIS vs Judgmental	-1.207	Fail to Reject $H_0$
Systematic vs Judgmental	-1.317	Fail to Reject $H_0$

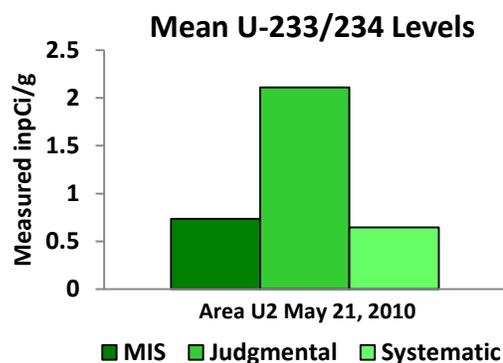
**Conclusion:** Since the test statistics in all three comparisons (0.792, -1.207, and -1.317) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Uranium-238 levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Uranium-233/234

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### U-233/234 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.736	0.267824569
Judgmental	2.11	2.355525419
Systematic	0.64825	0.291397055



### Uranium-233/234 Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	0.684	Fail to Reject $H_0$
MIS vs Judgmental	-1.296	Fail to Reject $H_0$
Systematic vs Judgmental	-1.317	Fail to Reject $H_0$

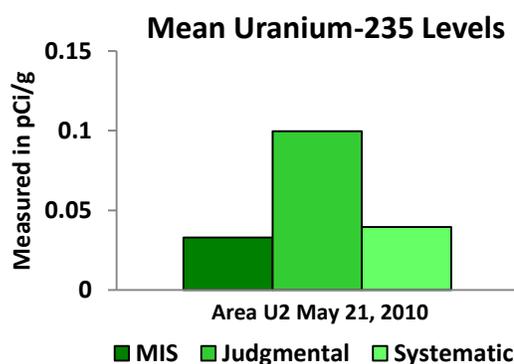
**Conclusion:** Since the test statistics in all three comparisons (0.684, -1.296, and -1.317) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Uranium-233/234 levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Uranium-235

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### Uranium-235 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.033	0.01393
Judgmental	0.0996	0.12777
Systematic	0.03955	0.02555



## Uranium-235 Hypothesis Test Results

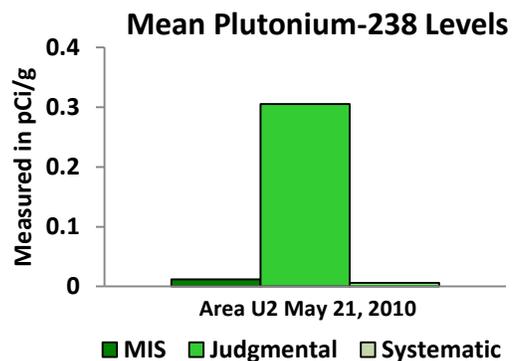
Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	-0.882	Fail to Reject $H_0$
MIS vs Judgmental	-1.159	Fail to Reject $H_0$
Systematic vs Judgmental	-1.048	Fail to Reject $H_0$

**Conclusion:** Since the test statistics in all three comparisons (-0.882, -1.159, and -1.048) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Uranium-235 levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Plutonium-238

### Plutonium-238 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.01188	0.009571155
Judgmental	0.3052	0.593421183
Systematic	0.0062175	0.013448151



### Plutonium-238 Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	1.185	Fail to Reject $H_0$
MIS vs Judgmental	-1.105	Fail to Reject $H_0$
Systematic vs Judgmental	-1.127	Fail to Reject $H_0$

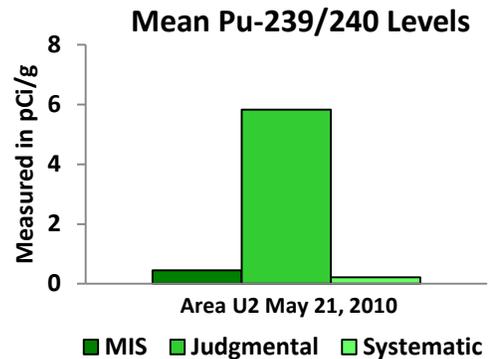
**Conclusion:** Since the test statistics in all three comparisons (1.185, -1.105, and -1.127) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Plutonium-238 levels obtained from MIS, Systematic, and Judgmental sampling.

### Comparison Tests Involving Plutonium-239/240

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#### Pu-239/240 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.4518	0.633552445
Judgmental	5.829	9.647604003
Systematic	0.22012	0.568582542



#### Plutonium-239/240 Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	0.779	Fail to Reject $H_0$
MIS vs Judgmental	-1.244	Fail to Reject $H_0$
Systematic vs Judgmental	-1.300	Fail to Reject $H_0$

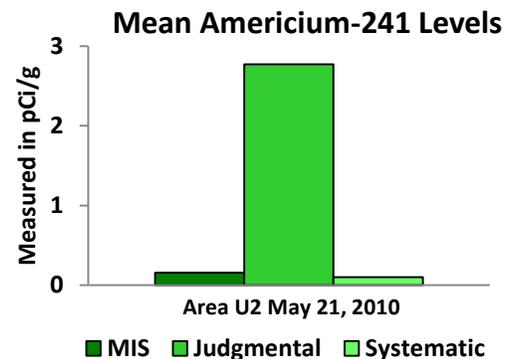
**Conclusion:** Since the test statistics in all three comparisons (0.779, -1.244, and -1.300) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Plutonium-239/240 levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Americium-241

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### Americium-241 Summary Statistics in pCi/g

Sampling Method	Mean	Standard Deviation
MIS	0.1562	0.134525834
Judgmental	2.772	5.363375383
Systematic	0.09988	0.180440889



### Americium-241 Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	0.846	Fail to Reject $H_0$
MIS vs Judgmental	-1.090	Fail to Reject $H_0$
Systematic vs Judgmental	-1.114	Fail to Reject $H_0$

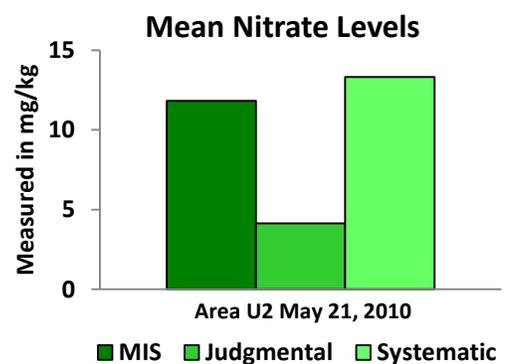
**Conclusion:** Since the test statistics in all three comparisons (0.846, -1.090, and -1.114) are greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Americium-241 levels obtained from MIS, Systematic, and Judgmental sampling.

## Comparison Tests Involving Nitrate

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### Nitrate Summary Statistics in mg/kg

Sampling Method	Mean	Standard Deviation
MIS	11.82	3.076036411
Judgmental	4.14	2.065913841
Systematic	13.315	13.17286547



## Nitrate Hypothesis Test Results

Hypothesis Test	Test Statistic	Outcome
MIS vs Systematic	-0.599	Fail to Reject $H_0$
MIS vs Judgmental	4.635	Reject $H_0$
Systematic vs Judgmental	4.027	Reject $H_0$

**Conclusion:** Since the test statistics for the comparison of MIS and Systematic sampling (-0.599) is greater than the critical value of -2.776 and less than the critical value of 2.776, fail to reject  $H_0$ . There is insufficient evidence to reject the claim that there is no difference between mean Nitrate levels obtained from MIS and Systematic sampling. However, the test statistics for both the comparison of MIS and Judgmental sampling as well as Systematic and Judgmental sampling (4.635 and 4.027 respectively) is greater than the critical value of 2.766, reject  $H_0$ . There is sufficient evidence to reject the claim that there is no difference between Nitrate levels obtained from MIS and Judgmental sampling as well as Systematic and Judgmental sampling.

### MIS and Systematic

- Nitrate for August 22, 2010 in area U1 (MIS mean: 17.4 mg/kg, standard deviation 1.81659 mg/kg Systematic: mean 10.6917 mg/kg, standard deviation 8.94943 mg/kg).
- Plutonium 239/240 for August 22, 2010 in area U2 (MIS mean: 0.0936 pCi/g, standard deviation 0.026726391 pCi/g Systematic: mean 0.043069231 pCi/g, standard deviation 0.049786244 pCi/g).
- Americium 241 for August 22, 2010 in area U2 (MIS mean: 0.1586 pCi/g, standard deviation 0.029074043 pCi/g Systematic: mean: 0.092 pCi/g, standard deviation 0.090786331 pCi/g)
- Nitrate for August 22, 2010 in area U2 (MIS mean: 24 mg/kg, standard deviation 2.44989743 mg/kg Systematic mean: 9.374358974 mg/kg, standard deviation 5.217315197 mg/kg)
- Nitrate for May 8, 2010 in area U1 (MIS mean: 10.1 mg/kg, standard deviation 0.85732141 mg/kg Systematic mean: 21.255 mg/kg, standard deviation 17.39901191 mg/kg)

### MIS and Judgmental

- Chromium for August 22, 2010 in area U1 (MIS mean: 7.16 mg/kg, standard deviation 0.384707 mg/kg Judgmental mean: 8.24 mg/kg, 0.559464 mg/kg)

- Nitrate for May 21, 2010 in area U2 (MIS mean 11.82 mg/kg, standard deviation 3.076036411 Judgmental mean: 4.14 mg/kg, standard deviation 2.065913841 mg/kg)

### **Systematic and Judgmental**

- Zinc for May 8, 2010 in area U1 (Systematic mean 48.8 mg/kg, standard deviation 3.472972568 kg/mg Judgmental 36.6 mg/kg, standard deviation 1.516575089 mg/kg)
- Nitrate for May 21, 2010 in area U2 (Systematic mean 13.315 mg/kg, standard deviation 13.17286547 Judgmental mean: 4.14 mg/kg, standard deviation 2.065913841 mg/kg)

### **Comparison Summary:**

For the data collected from areas U1 and U2, there were 9 cases where a statistical difference was detected between sampling methods. Four of these cases involved the Judgmental samples. Given the nature of Judgmental sampling and the questionable assumption of normality for Judgmental sampling data, these results should not be taken seriously.

There were five cases out of 44 that resulted in a statistical difference in sampling methods between MIS and Systematic. Two of these statistical differences came from the elements Plutonium 239/240 and Americium-241 collected in area U2 on August 22, 2010. Given the extremely low levels of concentrations of these two elements these results may be insignificant. The other three statistical differences involved the element Nitrate in areas U1 and U2 for the data collected on August 22, 2010 and for the area U2 data collected May 21, 2010.

Given the nature of hypothesis testing it would not be totally unexpected, when conducting multiple hypothesis tests, to reject  $H_0$  (a small percentage of times), when in fact it is true. That is, the significance level of 0.05 defines the probability of finding a statistical difference when one does not exist. The significance level states that this mistake will be made approximately 5% of the time. There were 44 hypothesis tests comparing MIS and Systematic sampling means for various elements. Of those, five detected a statistical difference. This represents approximately 11% of the total 44 tests. If the two tests involving Plutonium-239/240 and Americium-241 are ignored due to their low level radiation levels, there were only 3 out of 42 or approximately 7% of these comparison tests that resulted in a statistical difference. All three of these tests involved the element Nitrate. It is considered unusual that all three statistical differences between MIS and Systematic sampling occurred with the same element Nitrate. This fact should be further investigated.

**Appendix A**  
**Hanford Soil Samples Data Base**  
**Collected in May and August of 2010**