2014 DoD Environmental Monitoring Data Quality Workshop
Lessons Learned – FUDS MMRP RIs

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Bomb Target

- Target area is 222 acres
- High-altitude bombing (horizontal), dive bombing, target strafing, and emergency landing activities.
- MK19, MK23, M38A1, MK5 practice bombs, 20mm TP strafing
- MC sampling biased to areas of MEC, pre- and post-BIP (1 location)
- Soil sampling (8 locations): 0-6” and 6-24” bgs: explosives and metals
- All explosives ND (including pre- and post-); all metals within background
- **MC is not a problem at this site**

Former Army Post

- NFA from EE/CA: Area 1, 600 acres; Area 2, 799 acres; Area 3 (lock and dam area), 1305 acres;
- Area 4: residential/agricultural, 50 MD items, no MEC
- Area 5: 180 acres residential/agricultural; no MEC/MD NFA
- Area 6: residential/agricultural; no MEC/MD NFA
- Area 7: 27 acres; no MEC/MD NFA
- Soil, sediment, surface water and groundwater: explosives and Sb, Ba, Cu, Pb, Hg
- Discrete and ISM (triplicate), biased toward anomalies identified in the EE/CA
- Sampling in Area 4 and Area 6: explosives ND; Ba and Hg elevated – assumed to be due to gas production well drilling.
- **Elevated detections of metals determined to not be munitions related…no MC problem at these sites**

Range Complex

- § 14,075 acres
- § 31 MEC: 14 - 2.36” rockets, 20 - 60mm mortars, 1 rifle grenade, 30 cal magazines
- § 16 ISM soil, 3 SW/Sed couples
- § Explosives ND
- § Metals within acceptable concentrations
- § **Another site without MC problems**

Former Army Post

- 37,035 acres
- Site characterizations, records searches, EE/CAs, removal actions resulted in 5 MRSs
- 777 anomalies: MD only at 228, UXO at 2 (4.2" mortar, MKII Livens projectile)
- 35 soil samples (biased to UXO/MD), 15 Background soil
- 4 MRSs: no HH or Eco risks expected.
- 1 MRS: post-BIP indicated a "localized unacceptable risks to HH due to TNT and RDX at concentrations greater than the human health screening values"
- FS recommended removal of MC contaminated soil: "the contaminated area is approximately 10 feet across and only shallow soils are contaminated"
- **Really? Who are you protecting? This is a non-issue…**

Range Complex/Maneuver Areas

- 11,353 acres; agriculture, forestry, mining, industrial, commercial, recreational and residential
- 7 MRSs 65,726 anomalies/6,303 investigated
- 73 MDEH detonated on-site
- 3 MRSs – NFA; 3 realigned and 3 created (FS recommended)
- SW, Sed, surface soil (0-1'), subsurface soil (1-2') – biased to MDEH locations
- 3-nitrotoluene in one SW sample; perchlorate upstream and on-site below 15 ug/L; Mn above screening levels; no COPCs/COPECs in sed; no COPCs/COPECs in surface soil; Mn > background in subsurface soil
- No HH or Eco risks shown; NFA for MC
- **Exceedance of screening levels does not mean that risks exist. That's why we do risk assessments…**

CA Manufacturing Plant

- 1918-1919 large-scale manufacturing of mustard agent and magnesium arsenide production.
- History: unknown quantity of mustard agent was disposed on-site by burial.
- 2003: EE/CA to characterize N&E of CA/ABP/magnesium arsenide.
- 22 anomalies investigated and extensively sampled
- ND for CA/ABP; elevated As and Mg concentrations, correlation coefficient study indicated other than DoD sources are possible.
- **NDAI recommended**

Bombing and Gunnery Range

- 7,455 acres
- 9 MRSs
- Coastal defense, live fire training, aerial bombing, direct-fire rockets, small arms and 37 mm artillery
- M38 100-pound (lb.) Sand Filled Practice Bomb, M48 Practice 20-lb. Fragmentation Bomb, M54 4-lb. Incendiary Bomb, Practice 5" High Velocity Air Rocket (HVAR) Warhead, M69 6-lb. Incendiary Bomb, M57 General Purpose Old-Style (GPOS) 250 lb. Bomb, M63, 37 mm Projectile, Mk4, 2.75" Rocket, M16, Smoke Grenade
- Recreational, commercial and/or residential
- 33 surface soil (ISM, 11 in triplicate); 20 SW and Sed (+10 ea for perchlorate)
- Explosives, Sb, Ba, Cd, Cu, Pb, Hg, Zn, perchlorate - all results below RSLs
- **No MC risks indicated**

Artillery Impact Areas

- 4 MRSs (1 not investigated due to ROE)
- 466 anomalies investigated: 49 MD, 1 2.75" rocket w/demolition charge
- 28 soil samples, 7 sediment samples analyzed for explosives and metals (Sb, Ba, Cr, Cu, Pb, Hg, Zn)
- Explosives ND (dup had TNB and NT<< RSLs); metals >BG, but below RSLs
- **NFA for MC as no risks shown for HH or Eco receptors**

Pilot Training Airfield

- 649 acres after realignment (162 investigated for the RI)
- M47, AN-MK23, and M38 practice bombs (4,809 total)
- EE/CA: 144 surface soil samples, 12 “deeper” soil samples – all within state background levels
- Samples taken to evaluate MC from anomalies: 240 subsurface samples – explosives ND, white phosphorus (9 samples)< screening levels, Pb and Zn approx. background.
- **NFA for MC**

CA Test Area

- 66 acres
- Testing of decontamination of beach sands using marine and fresh water
- Chemical Warfare Board documents 1943 and 1944 found relative to prior activities at the site
- RI became desktop
- **NDAI**

PBR

- § 234 acres
- § Water-filled bombs, MK23, flares
- § 88 MEC (MK23s) and 325 MD
- § Biased soil (ISM and discrete), sediment, GW – explosives (including PETN and NG) and Sb, Cu, Pb, Ni, Zn
- § Sb, Pb and Zn > eco screening levels
- § Risk assessment showed no HH or Eco risks.
- § **FS for MEC only**

Gunnery Range

- 22,400 acres, 10 MRAs **(MRSs?)**
- Aerial bombing, strafing, and air-to-ground rocketry. Undeveloped; unpaved roadway system (unrestricted access)
- 100# HE bombs, MK23, 20mm TP, practice rockets (2.25”, 2.75”, 5”), small arms
- 3 T&E species present
- 11,337 anomalies investigated
- 39 biased samples for explosives and metals in soils (0-2” and 2-12”)
- Pre- and post-BIP samples at 2 locations
- All explosives were ND; metals below R9 PRGs **(?)** and within background
- **No risk assessment for MC required**
- **FS for MEC only**

Multi-Use Area

- 2,111 acres; 2 MRSs; residential and commercial use.
- Rifle training range; Toxic Gas Yard; pistol range
- Simulated anti-tank mines, demolition equipment, small arms anti-aircraft firing, rifle grenades, bazooka, frag grenades, aircraft signal flares, ground-fired munitions and simulated 300# bomb detonations.
- 2,244 anomalies investigated at MRS01: 99 MD; no MEC/UXO
- 26 anomalies investigated at MRS02: 2 MD; no MEC/UXO
- 69 soil (0-2”), 8 soil (0-2” and 10-12”), 4 GW; explosives and selected metals
- Ba, Sb, and Cr above background
- No HH or Eco risks shown
- **FS for MEC only**

CA Testing Area

- 8.8 acres, 1 MRS
- During SI: no CA/ABP were detected
- RI investigated 19 anomalies; 3 test pits
- No MEC, MD, CAIS found (all cultural debris); No MC samples taken
- **NDAI**

Gunnery Range

- 33,621 acres; 6 MRSs
- Impact area/safety zone anti-aircraft artillery
- 90mm HE, 90mm AP, 120mm HE (previous EOD response found 37mm and 75mm projectiles)
- MC sampling biased to high density MD
- Soil (ISM), sediment and surface water: explosives (including PETN and NG), Sb, Cu, Pb, Zn and Hg
- Explosives were ND; metals below screening levels
- No HH or Eco risks
- **No MC concerns**

PBR

- 15,246 Acres
- 2 MRSs
- M38A2 practice bombs, 100-lb AN-M30 GP HE
- 896 anomalies, 10-36” deep
- IS used for MC (Biased toward MEC/MD):
  - 16-2 acre SUs (100 increments each)
  - 9-1/4 acre SUs (50 increments each)
- No detects for energetics
- No potential for risks
- **Cool…MC is not a problem…we’re done!!**

Multi-Purpose Range

- 9,210 acres, 1 MRS
- MEC found: 4-105mm (HE and smoke), 4-37mm (HE), M17A1 illum
- Excessive MD found: 37mm, 57mm, 75mm, 105mm, and 155mm); mortars (60mm and 81mm HE and white phosphorus); 2.36-inch rockets; hand grenades, rifle grenades, expended fuzes
- Samples (biased toward MEC/MD) taken of surface water, sediment, groundwater and soil, both IS (energetics) and composite (metals)
  - Soil: Cu and Mn exceeded screening values
  - SW: Mn exceeded screening value
  - Sed: Mn exceeded screening value
- **Unable to confirm results**
- Post BIP:
  - 1,3,5-TNB; 2,4,6-TNT, RDX and HMX exceeded screening values
- **Unable to confirm results**
- **Conclusion: no release of MC at the MRS**

Range Complex

- 51,088.06 acres, 6 OOUs (MRSs?)
- MEC: small arms ammunition, 20 to 155mm projectiles, mortars, rockets, grenades, and up to 500-pound bombs
- Biased (based on DGM and EE/CA) samples taken of surface water, sediment, groundwater and soil, both IS (29 SUs) and composite (26 samples); extensive analyte list
- OOU 2
  - Soil MDCs did not exceed HH screening values
  - Soil 95% UCL did not exceed eco screening values
  - Sed: slight exceedance for eco, WOE indicated negligible potential for risks
  - SW: Pb above AWQC (no confirmation)
- Other OOUs: "Further characterization of the sites designated OOU-3, OOU-4, OOU-5 and portions of OOU-6 is needed in order to determine the nature and extent of MEC and MC contamination in those areas."
- **Huh? This is an RI…nature and extent is required by NCP**

Artillery Range

- 30,618 acres
- 8,474 anomalies (DGM), 1,503 intrusively investigated
- MEC items included one 3” AP, Mk29 with an MkII Mod 9 Fuze, and eleven 37mm MkII
- Based on minimal EE/CA data, RI only sampled for perchlorate in groundwater
- Not detected in any sample
- **No MC risks**

Naval Auxiliary Air Facility

- 42,000 acres
- 39 investigation areas (AOCs, AOIs)
- >80 discrete and MI samples of surface soils, subsurface soils, surface waters, and sediments (biased on MEC/MD)
- MC concentrations were above action levels in soil
- Sb, Cu, Zn concentrations >action levels and BG in sediment
- Cu, Hg, Zn, 2,4-DNT, 2,6-DNT concentrations >action levels and BG in sediment from demolition craters
- 2,4-DNT and 2,6-DNT >action levels and BG in discrete and MI surface soil samples at or adjacent to demolition craters
- "This report does not include a Baseline Risk Assessment (BRA) for MC"
- **Huh? This is an RI…BRA is required by NCP**

Artillery Range

- 1,781-acre (land and water), 182-acre primary target area
- Current owner: USFWS
- 192 anomalies were intrusively investigated, 16 MEC
- Biased surface soil, surface water, sediment, and groundwater
- **pre- and post-detonation** soil samples
- Ambient samples (explosives and metals)
- RDX detected in soil > protection of groundwater level; no risk
- Soil
  - Ba, Cr, Cu, Zn < HH screening levels
  - Cr > ESV but within background
- SW
  - Ba, Sb, Cu, Hg < HH screening levels
  - Cu, Hg > ESV; no risk
- Sed
  - Cu < HH screening levels and ESV

Artillery Range(cont.)

- GW
  - Al, Sb, Ba, Cd, Cr, TNT, HMX < HH screening levels
- Risk Assessment showed no risks
- FS
  - evaluate "mitigation of risk" where two samples had Zn > ESV
  - Post-BIP found TNT > protection of GW
- **If BRA shows no risks, do not evaluate mitigation of MC risks in FS.**
- **Don't take pre-BIP samples…they mean nothing.**

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"Range Complex"

- 12,483 Acres, 3 MRSs
- 23,539 geophysical anomalies; 8,626 were intrusively investigated
- MEC found: M50 incendiary bombs, 20# practice and frag. Bombs, 500# incendiary bombs, 2.36" HEAT rockets, fuzes, bursters
- TCRA: 283 MEC and 1,497 MD
- 64 soil samples from surface to 4-feet bgs; explosives and 17 metals
- 98 soil samples from 6 to 22 inches bgs; explosives and 17 metals
- Ba, Cu > screening values
- "These locations were revisited to collect soil samples around the original locations in an effort to determine the extent of contamination. In all instances, the contamination extent was local (less than one meter from original position)"
- FS: remediate MC contaminated soils
- **Remediation of localized contamination is not necessary!!**

Multi-Purpose Range

- 59,000 acres, 19 MRSs
- 4,244 anomalies; 2,557 investigated
- 12 MEC: one M6 2.36-inch HEAT rocket, one 2.36-inch practice rocket, nine M49A2 60mm mortars, and an M9 rifle grenade
- IS for soil and discrete groundwater
  - Ba, Cr, Cu, Pb, Sr, Zn, explosives, perchlorate
  - Explosives were ND, perchlorate was ND; metals below screening levels
- Pre- and Post-BIP found Cu, TNT, A-DNTs > screening values
- "However, the MC contamination resulting from these isolated demolition events is anticipated to be minimal and highly localized and, based on this and comparison with risk-based screening values, the risk assessment determined that these concentrations of MC present no unacceptable risks to human health or the environment"
- **That's correct…no risk means no remediation!!!**

Beach Area

- § MEC on beach due to replenishment (dredging)
- § TCRA along 3,700 foot section of beach
- § Sampling to assess presence or absence of explosives, metals and SVOCs
- § "negligible to nonexistent threat from MC"
- § **Done and gone…**

Island Range

- 3,276 acres; almost entirely comprised of salt marsh
- 8 tons of MD removed, primarily JATO bottles (perchlorate)
- 476 anomalies investigated; mostly aluminum cans; 14 50# bombs and MK25 flare
- Surface and subsurface wetland sediment, surface water, stream/pond sediment
- Explosives were ND, perchlorate detected in site and background surface water; metals were within background
- Cancer risks were acceptable; HI < 1
- **No harm…no foul**

PBR

- 18,030 acres; 3 MRSs
- MEC used: 100-pound practice bombs, incendiary flares, and possibly 100-pound GP HE bombs
- 2,053 anomalies; 429 investigated
- Collected surface soil samples for Cu and Pb (to evaluate avian receptors) from 5 DUs (200m x 200m) with triplicates from 2 DUs
- 10 subsurface samples for Sb, Cu, Pb, Zn and explosives
- One Post-BIP for Sb, Cu, Pb, Zn and explosives
- Surface Soil:
  - Cu, Pb were below HH and eco screening levels
  - Explosives were ND; metals below HH screening values; Zn > ESV, but attributed to deteriorating metal pipe
- Subsurface Soil:
  - Zn > ESV, incomplete pathway to subsurface soil; metals within background
- **Another good job!!!!**

Multi-Use Area

- 2,011 acres; state owned public park
- 10 MRAs (MRSs?)
- Soil sampling (surface and subsurface) at 5 MRAs
- MDCs < HH screening values
- "chemicals detected at the MRAs are considered not to pose a significant risk to ecological receptors at any level"
- **Seems like we're getting the picture…**

Troop Training Area

- 71,000 acres
- Wildlife refuge (USFWS)
- 25 AOIs
- 9,042 anomalies; 2,982 investigated (71% cultural debris)
- No samples exceeded screening levels for HH or eco
- No risks
- **This one was easy…**

Naval Bombing/Rocket Range

- 1,800 acres
- 2,029 anomalies; 1,254 investigated (miniature practice bombs)
- Phase I: 26 samples for Fe, Pb, Ti, Zn
  - All < screening levels except for Fe (23,300 vs 23,000)
- Phase II: 21 samples for Fe, Pb, Ti, Zn (one sample to confirm previous Fe detect)
  - All within background
- **Why sample for metals when all that was found was miniature practice bombs?**

Impact Area

- 19,833 acres (remote, mountainous and undeveloped)
- 105 anomalies; 6-10” deep; MPPEH (some were perforated, some BIP, all MD)
- 5 site soil samples and 3 Pre- and Post-BIP
  - Nitrobenzene, 4-Am-2,6-DNT, 2-NT, HMX, NG
  - All significantly < HH screening values
- Sediment: 4-Am-2,6-DNT, HMX < HH screening values
- All samples < ESVs
- **No risks to worry about.**

UPDATE: MORE RIs

- Review of 27 RIs (not included in previous slides) showed:
  - Sampling for explosives and select metals using discrete, 7-point wheel and ISM methods.
  - Biased to CMUAs or VSP generated schemes.
  - All MC found within background, below screening levels, or exceedances were localized to single sample area.
- FS for MEC only.
- MC is generally not a concern for FUDS!

RI Lessons Learned Summary

- For an RI, CERCLA requires determination of nature and extent…and performance of a baseline risk assessment.
- No need for Pre-BIP sampling.
- Base the need for MC cleanup on RISKS.
- Risk is based on the average concentration within the exposure area.
- Sample for reasonably expected MC…or deal with the consequences.

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Laboratory Control Samples using 8330B Appendix A

How can we use ground LCSs for ISM methods other than explosives?

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QSM 5.0

- **Method 8330B is the only reference for ISM sampling.**
- **Appendix A is not mentioned in the document.**
- **How do you apply Appendix A to other analyses?**

QSM 5.0 Method 8330B

A solid reference material containing all reported analytes must be prepared (e.g., ground and subsampled) and analyzed in exactly the same manner as a field sample. Results may not be reported without a valid LCS. Flagging is only appropriate in cases where the samples cannot be reanalyzed.

Sample Prep by 8330B

- Be aware of what you are agreeing to do.
- Where do you get the LCS?
- Do you process the LCS through the entire method?
- How do you evaluate the LCS?

LCS Data

- PAHs
- Metals
- Perchlorate
- Picric Acid

PAH LCS

- Solid standards purchased from ERA
- Control limits not based on ground material
- 10-gram subsamples
- Soxhlet extraction by Method 3540C

PAHs

- 2-Methyl-Naphthalene
- Acenaphthylene
- Acenaphthene
- Fluorene
- Phenanthrene
- Anthracene
- Benz(a)anthracene
- Benzo(a)pyrene
- Benzo(g,h,i)perylene

Experimental Design for PAHs

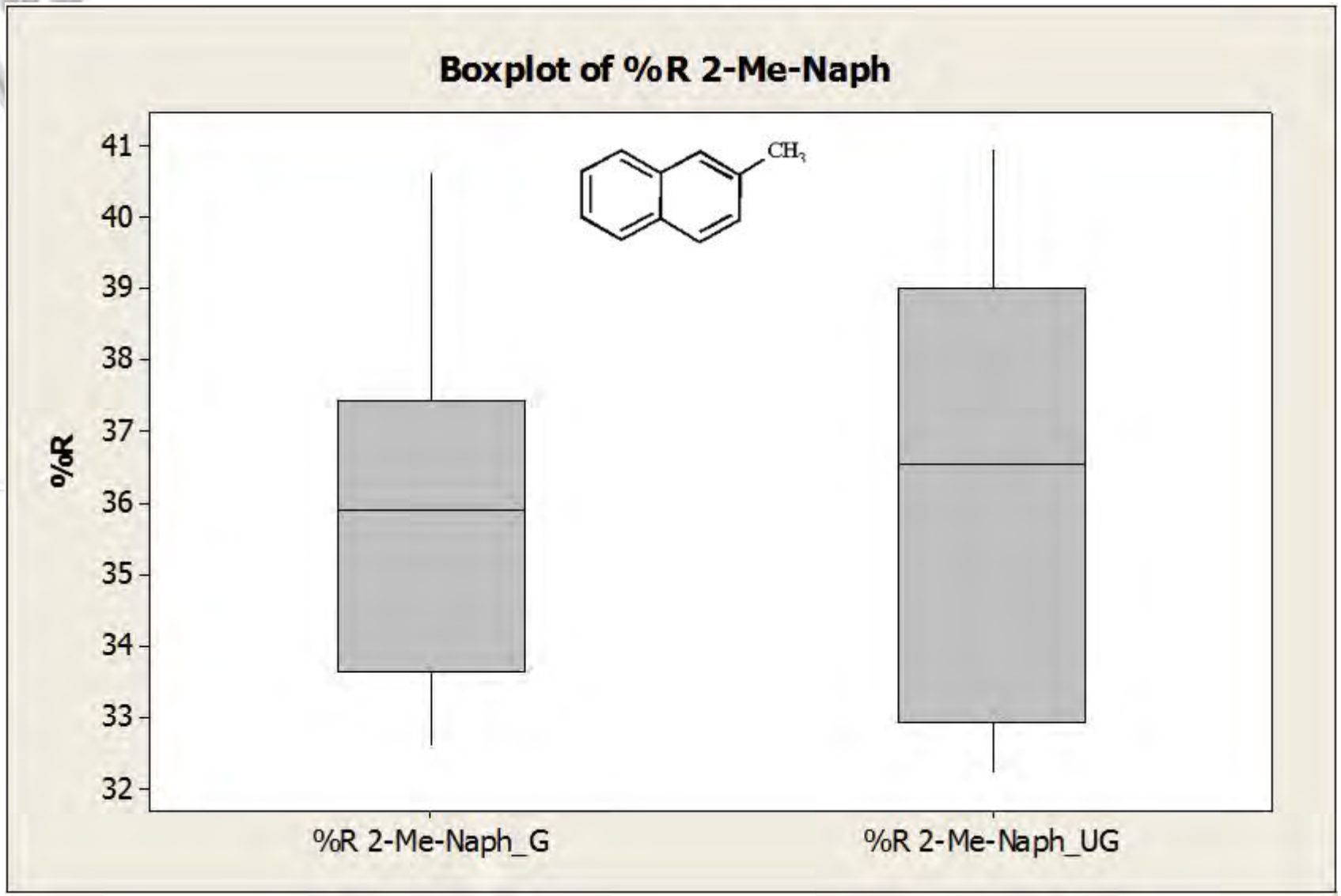
- One LCS subsampled 10 times w/o grinding
- Same LCS ground and subsampled 10 times

% RSDs for 9 PAHS

- Ground (G): 4% – 9%
- Unground (UG): 9% – 20%

Ground (G) vs. Unground (UG) LCS replicates

	Var(UG) > Var(G)?	Mean(UG) > Mean(G)
• 2-Me-Naph	No	No
• Acenapthylene	**Yes**	**Yes**
• Acenaphthene	No	**Yes**
• Fluorene	No	No
• Phenanthrene	No	No
• Anthracene	No	**Yes**
• Benz(a)anthracene	No	No
• Benzo(a)pyrene	**Yes**	No
• Benzo(g,h,i)perylene	**Yes**	No


Boxplot of %R 2-Me-Naph
%R
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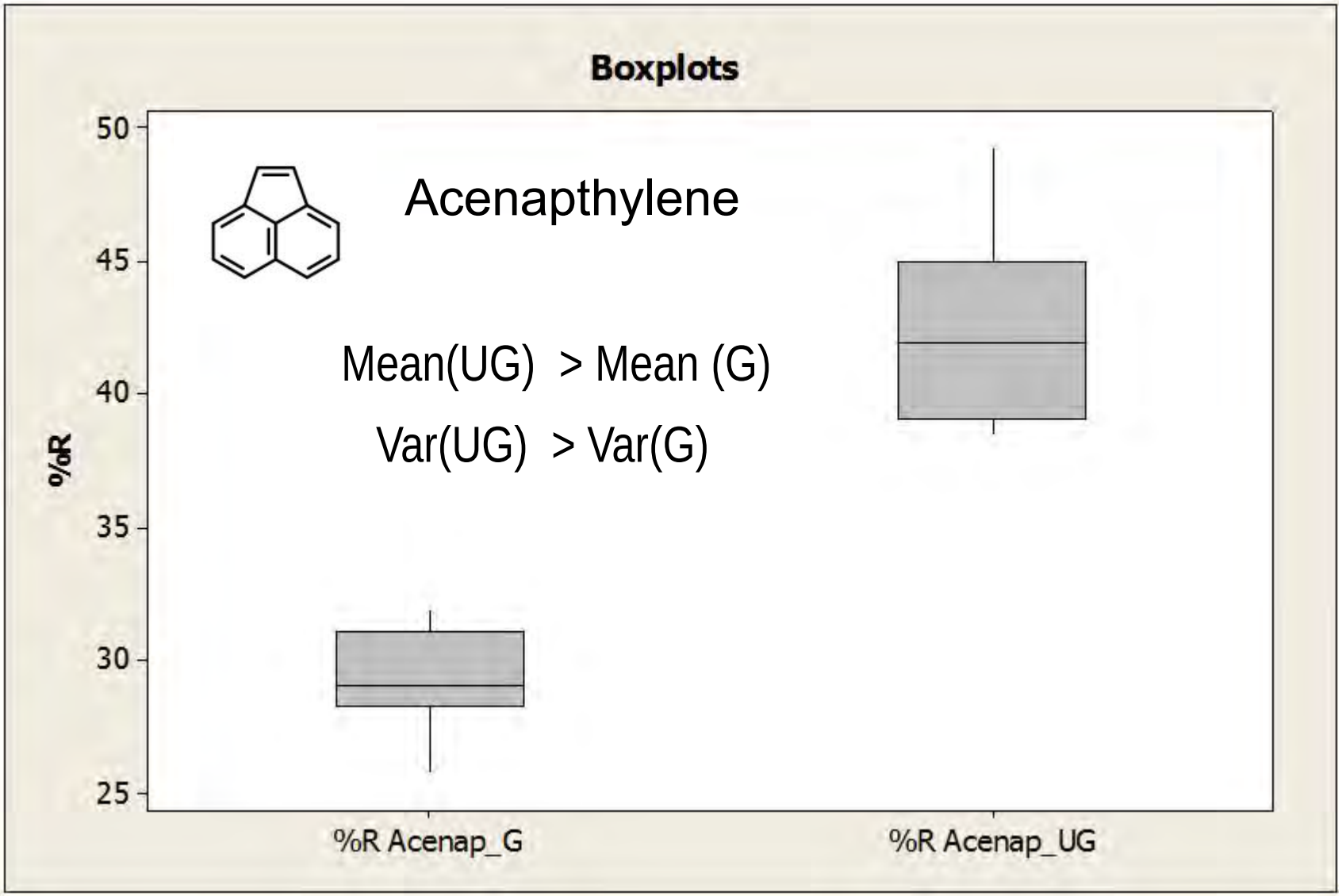
CH3
%R 2-Me-Naph_G
%R 2-Me-Naph_UG


Boxplots
Acenapthylene
Mean(UG) > Mean (G)
Var(UG) > Var(G)
%R
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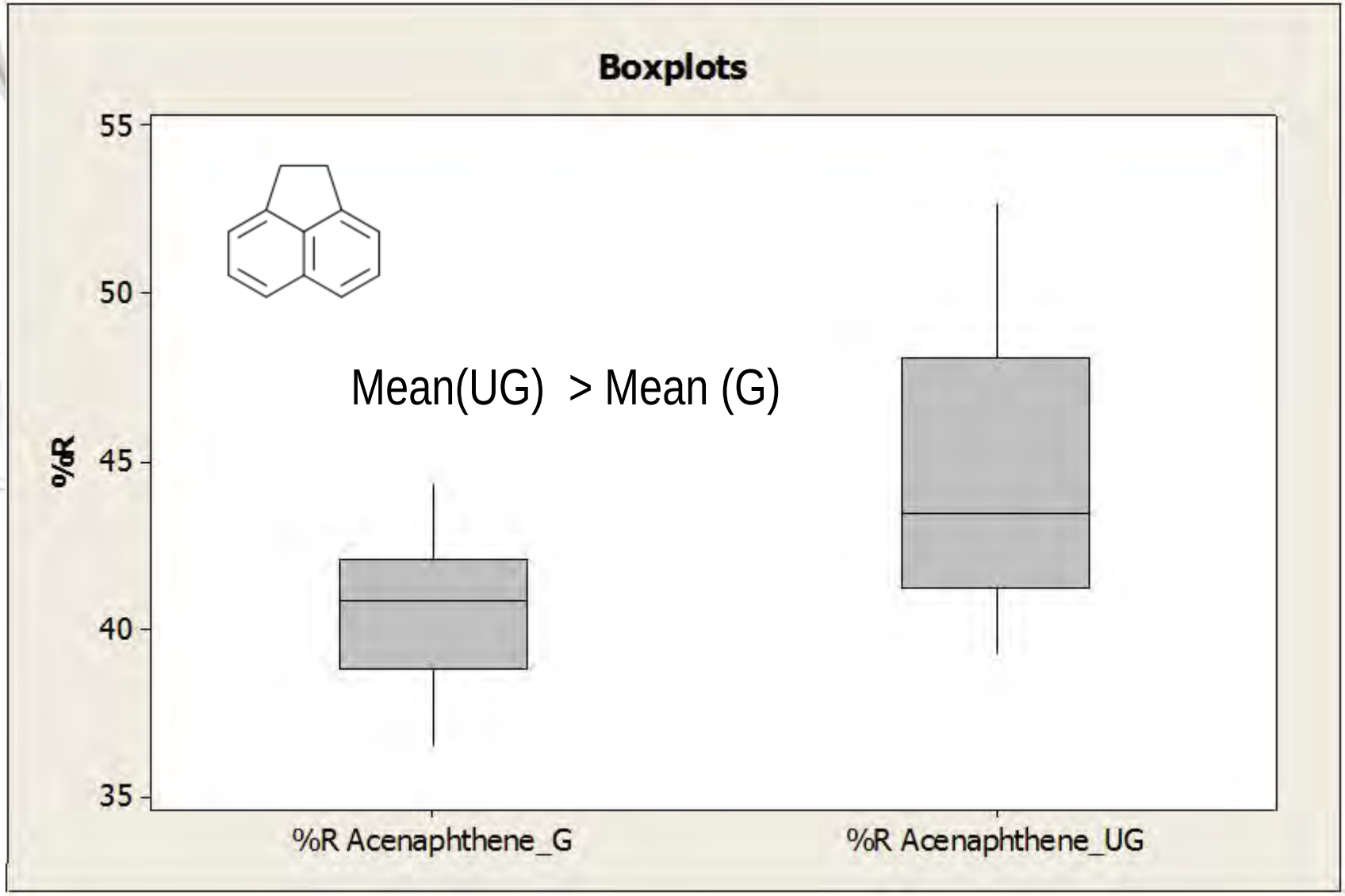
%R Acenap_UG


Boxplots
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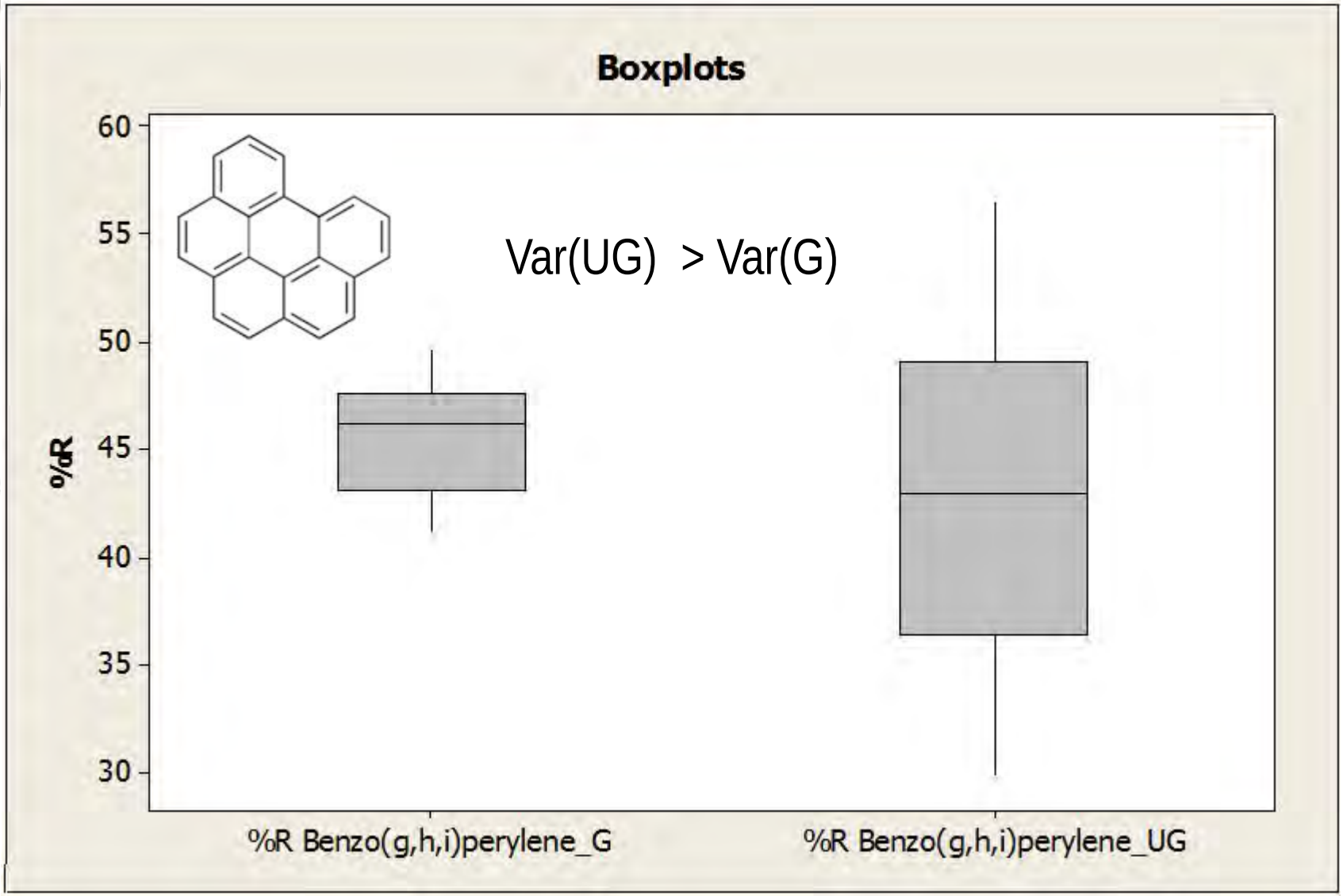
%R
Mean(UG) > Mean (G)
%R Acenaphthene_G
%R Acenaphthene_UG


Boxplots
Var(UG) > Var(G)
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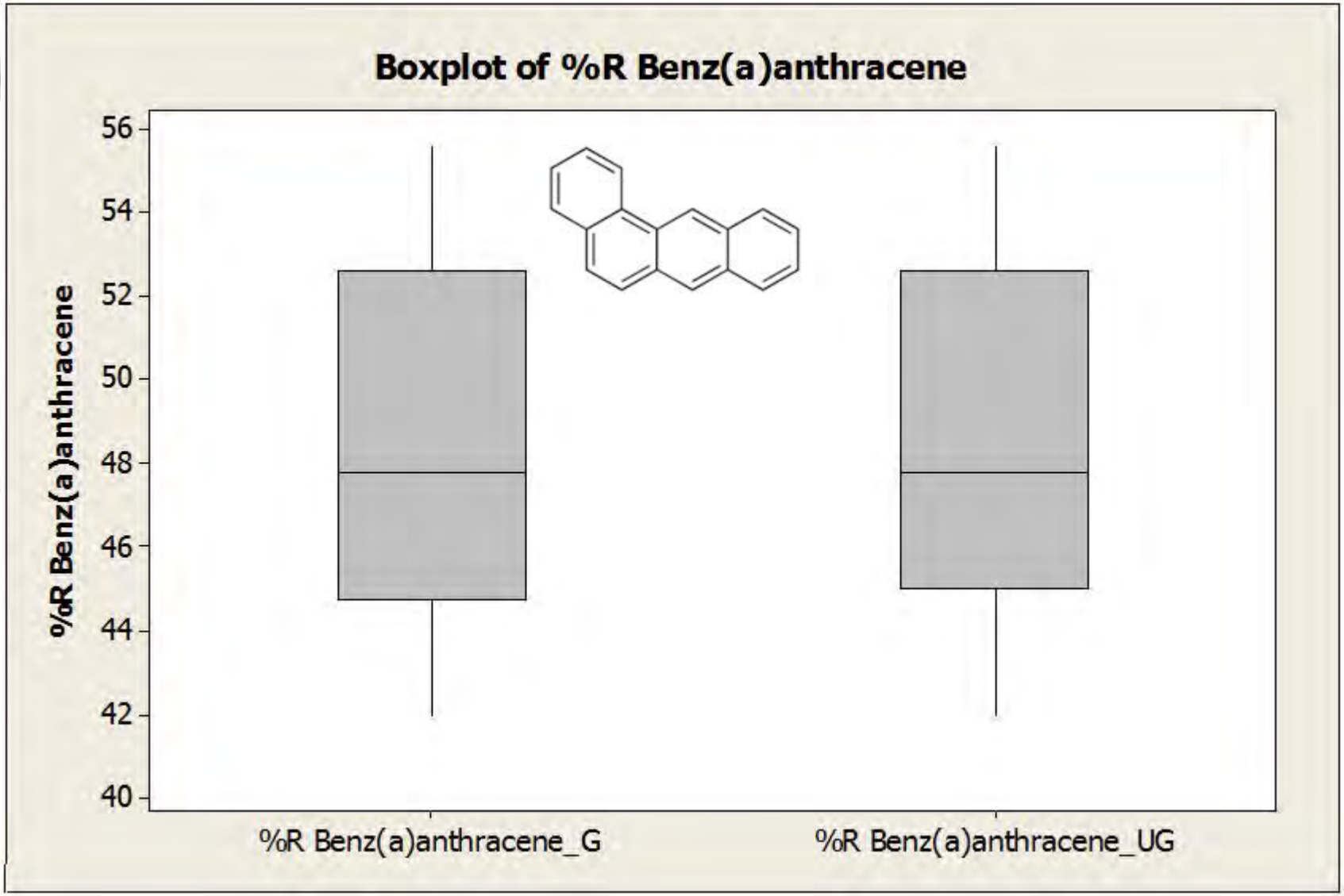
%R Benzo(g,h,i)perylene_G
%R Benzo(g,h,i)perylene_UG


Boxplot of %R Benz(a)anthracene
%R Benz(a)anthracene
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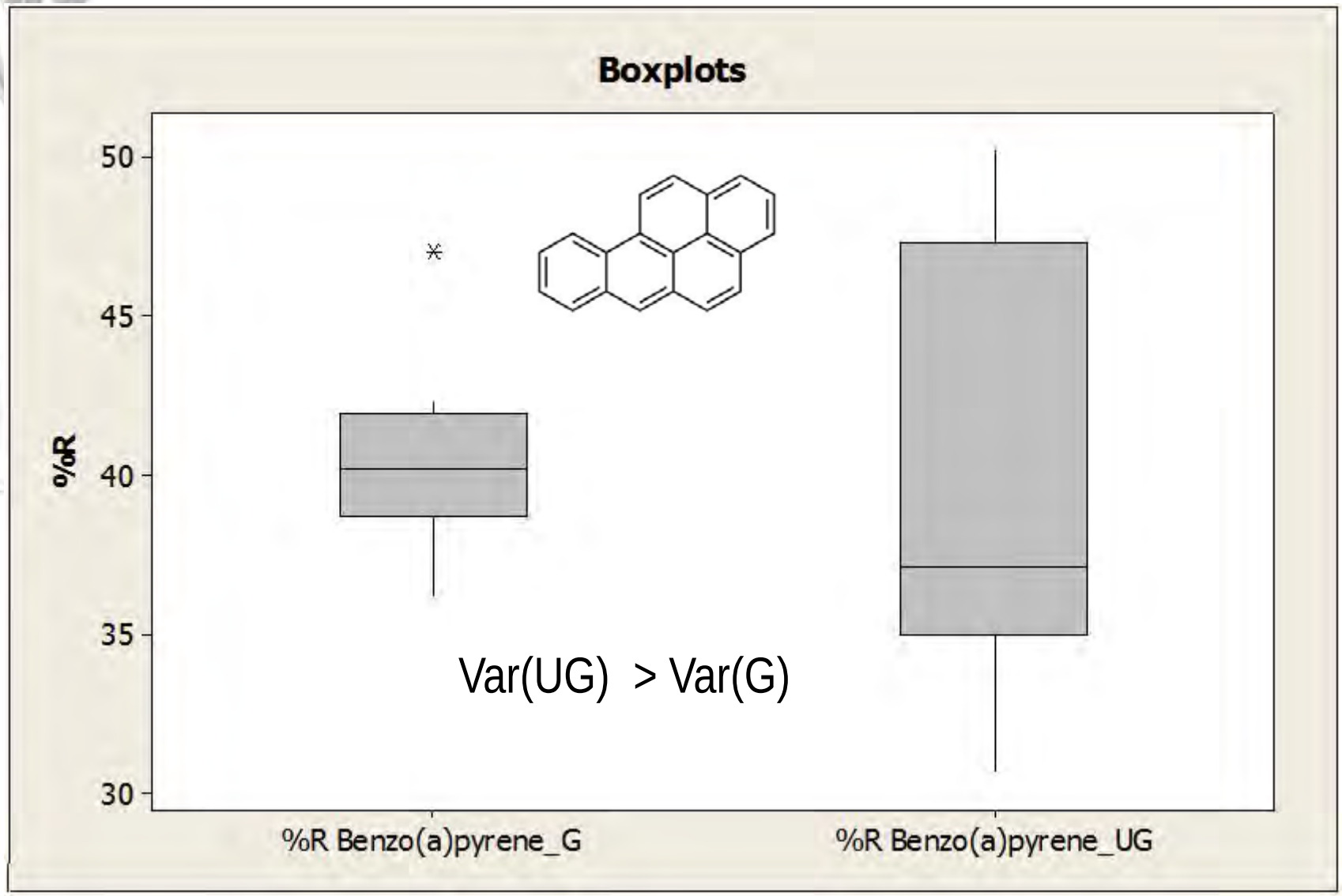
%R Benz(a)anthracene_G
%R Benz(a)anthracene_UG


Boxplots
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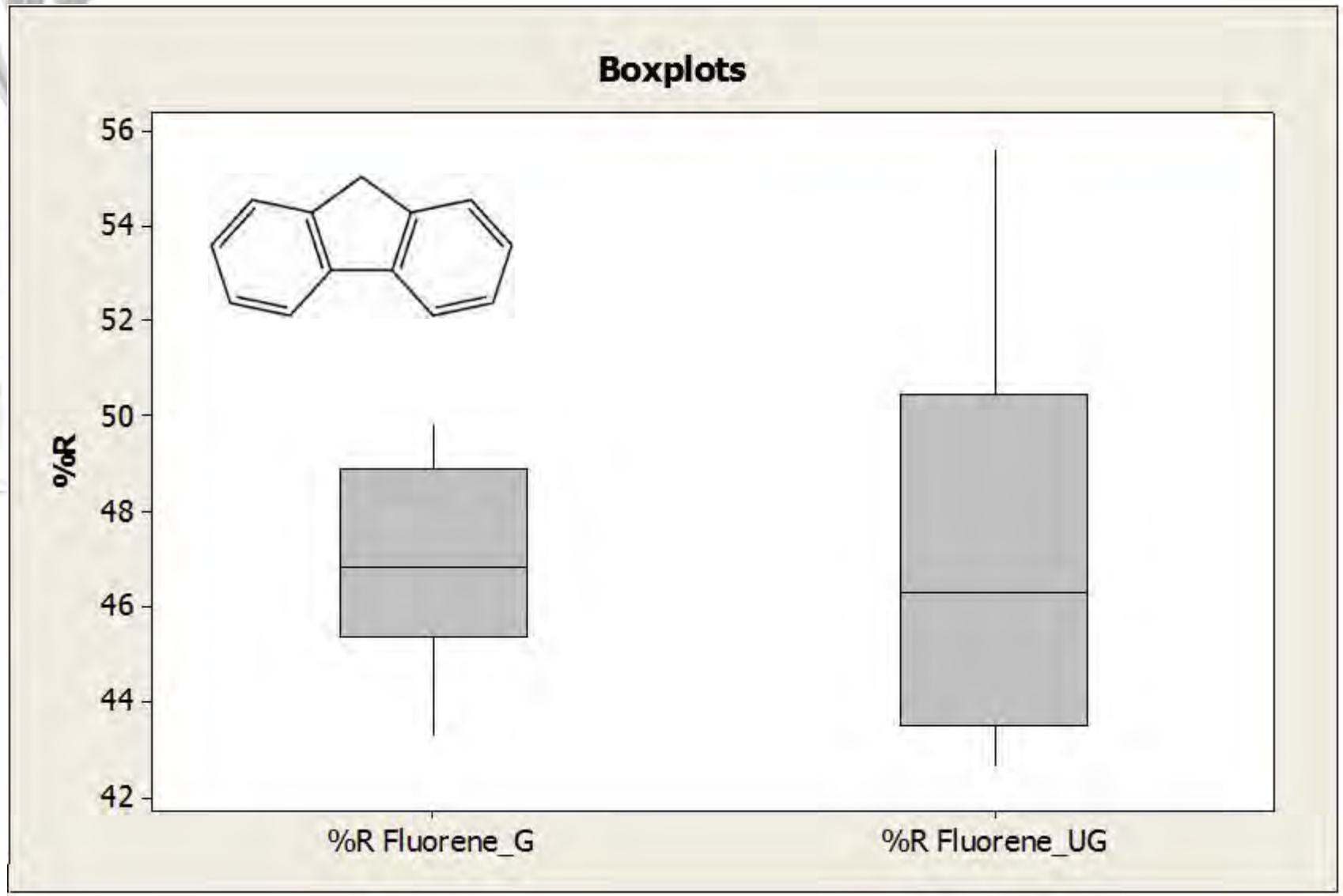
Var(UG) > Var(G)
%R Benzo(a)pyrene_G
%R Benzo(a)pyrene_UG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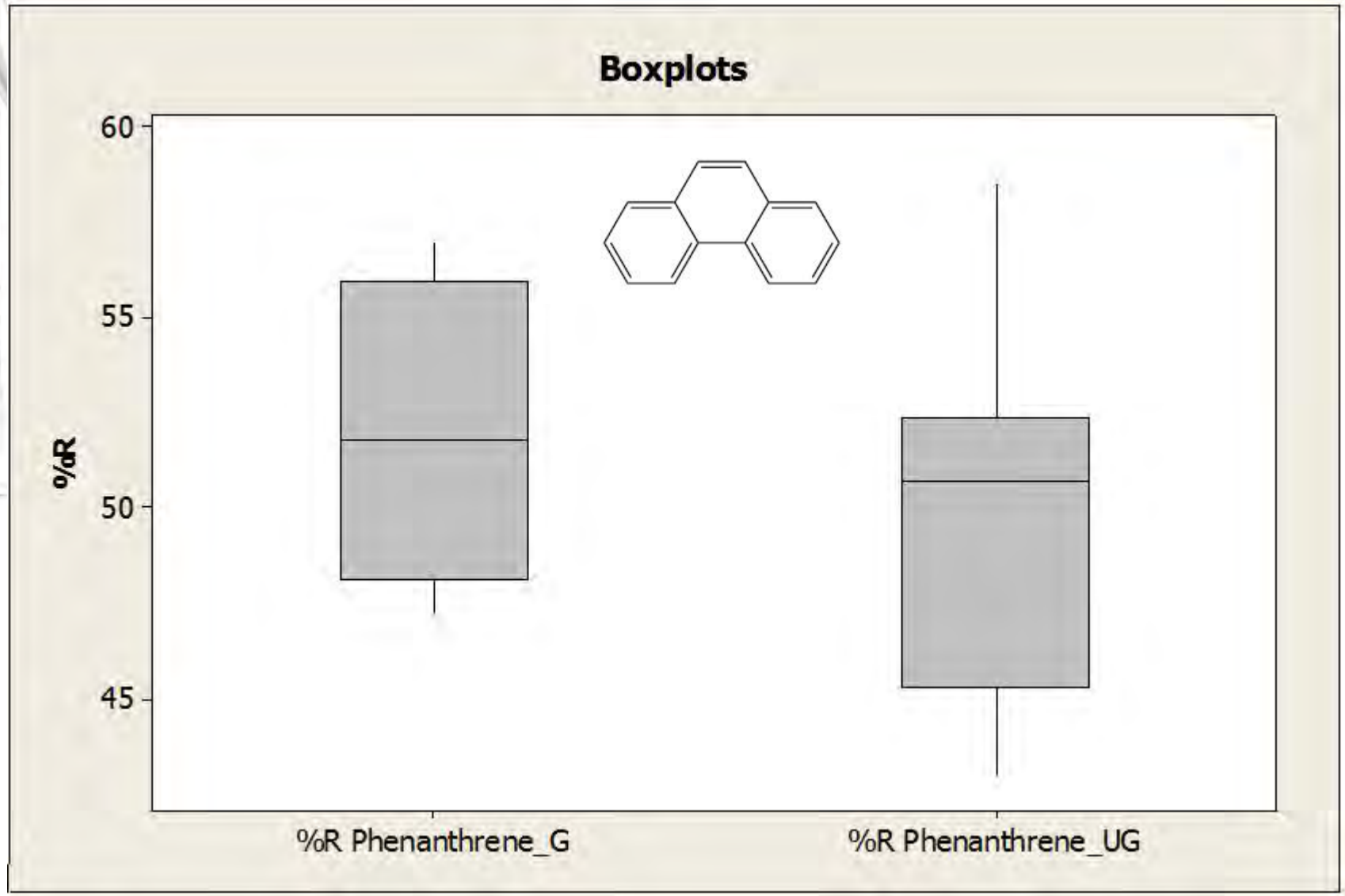
%R Fluorene_G
%R Fluorene_UG


Boxplots
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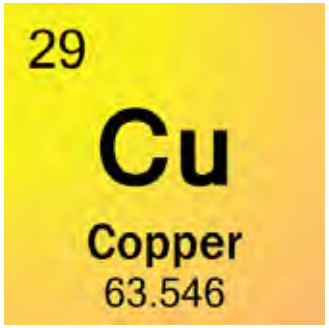
%R
%R Phenanthrene_G
%R Phenanthrene_UG

Metals LCS

- 500 g well characterized for metals
- 500 g spiked with Cu, Pb, Zn and Sb
- Pellets < 2 mm were added to desired concentration for each metal
- Entire sample ground

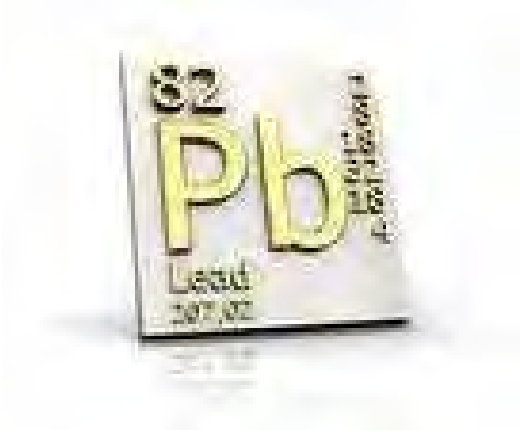
Metals

- LCS ground and n = 15 subsample replicates analyzed
- 2 g subsamples digested by Method 3050B
- n = 8 LCSs ground and analyzed once
- Total n = 23



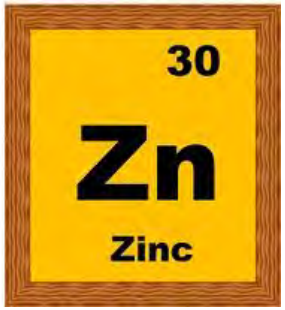
Copper

n	Mean	StDev	Min	Median	Maximum
15	**74.77**	12.58	**56.30**	73.10	**107.00**
8	**70.86**	17.22	**37.70**	75.10	**90.30**
23	73.41	14.09	37.70	73.10	107.00



Lead

n	Mean	StDev	Minimum	Median	Maximum
8	**88.88**	15.34	**75.50**	83.25	**117.50**
15	**76.05**	13.85	**59.25**	71.50	**98.75**
23	80.51	15.36	59.25	76.75	117.50

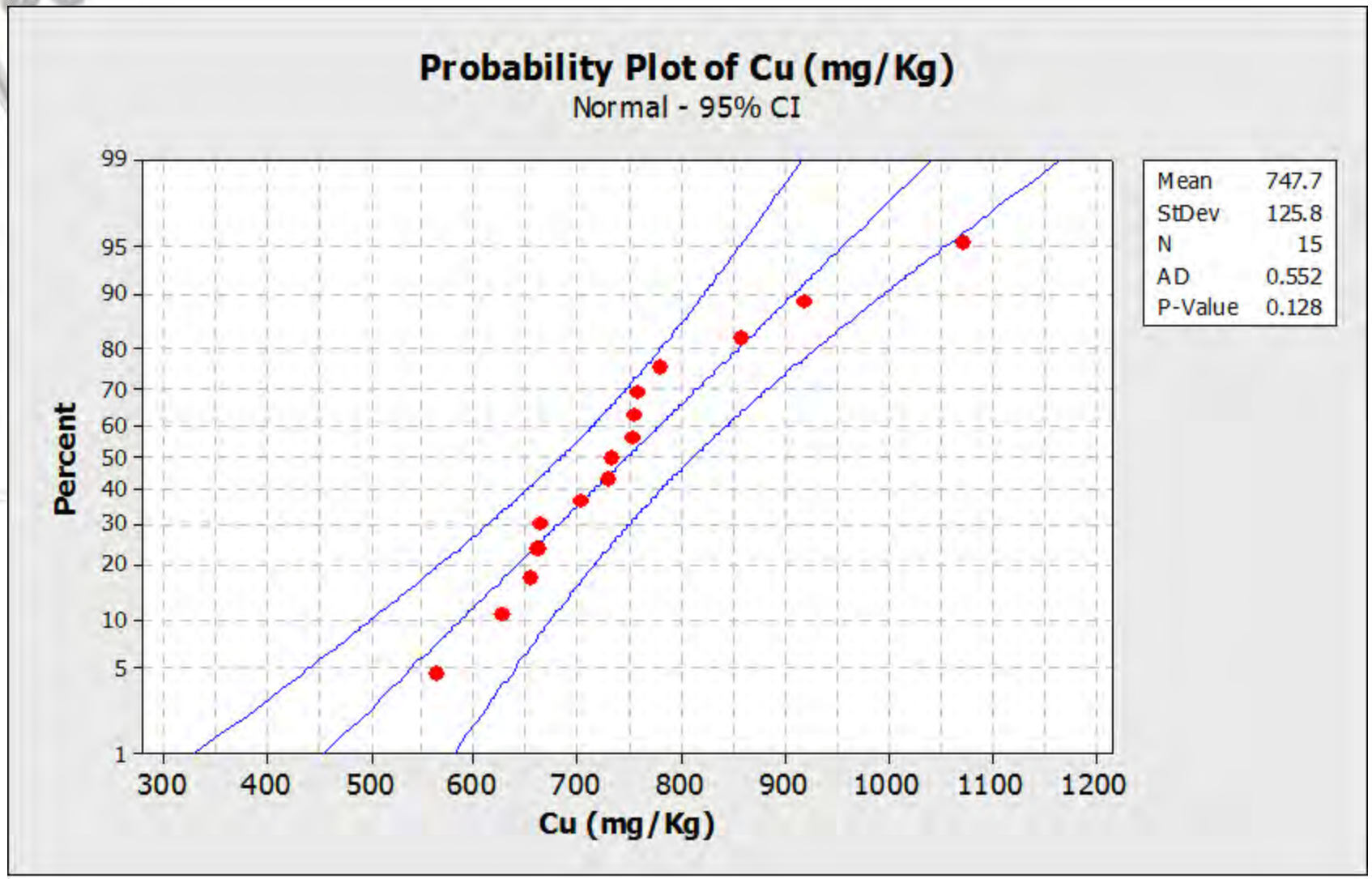


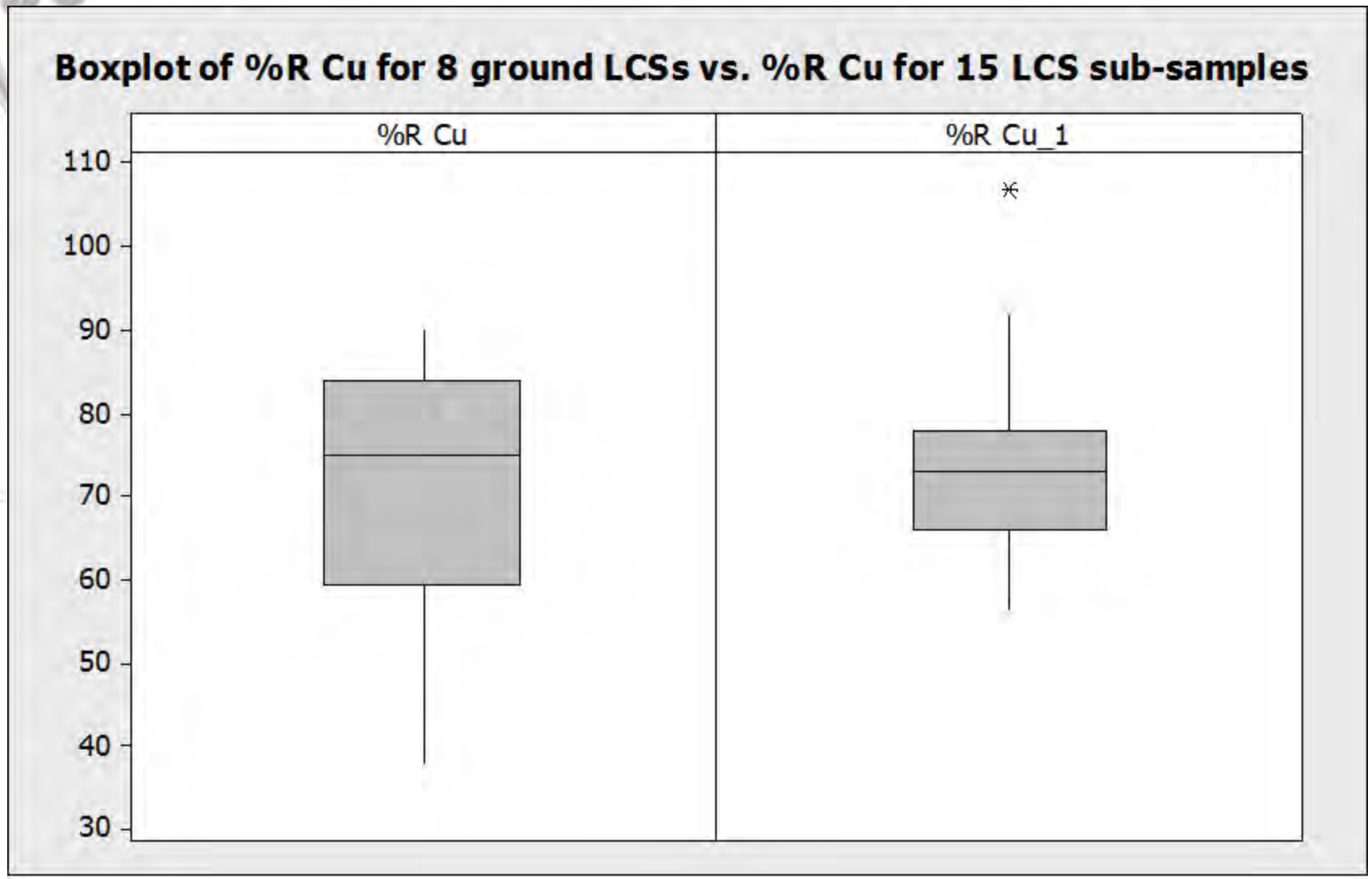
Zinc

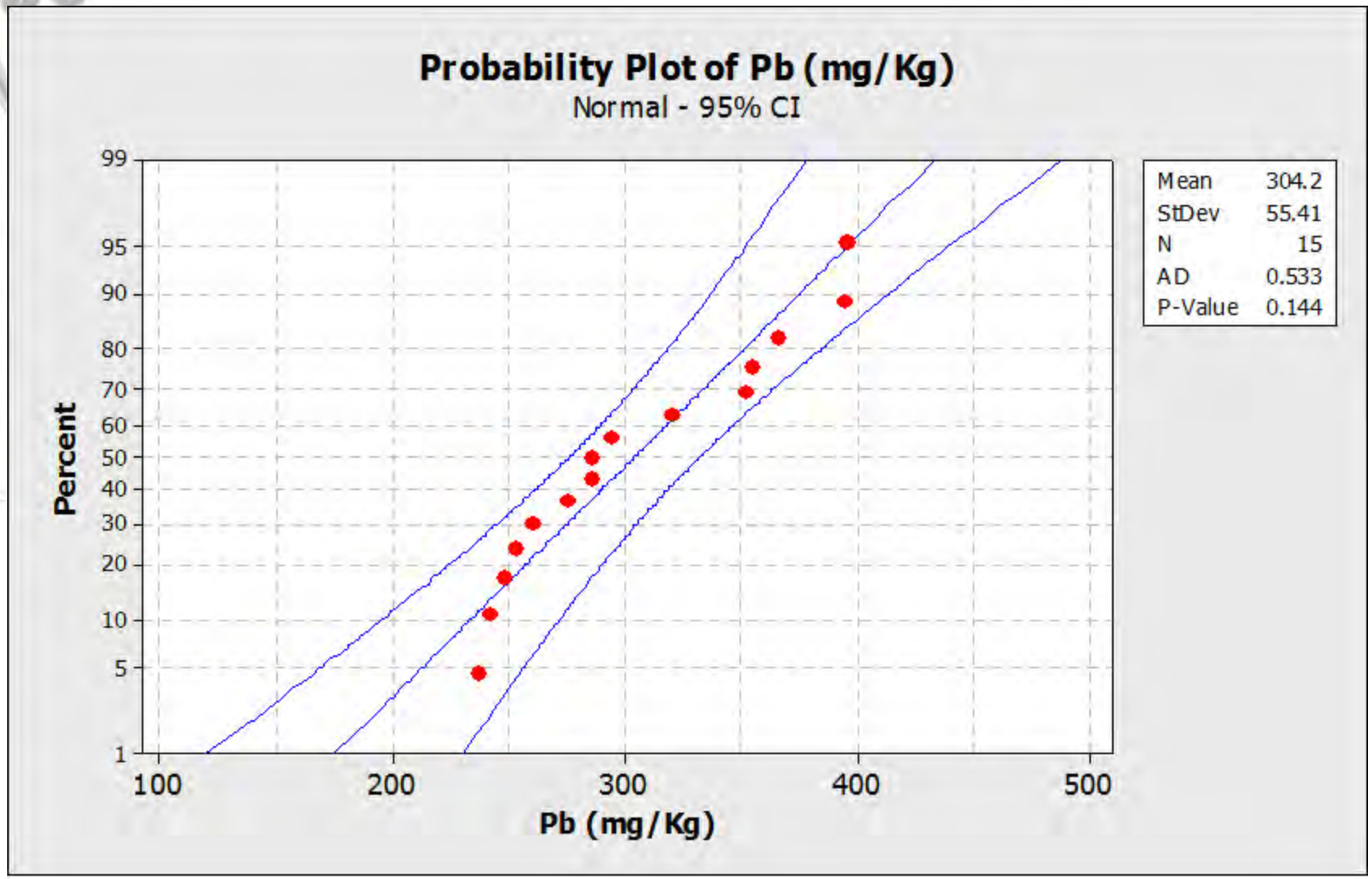
N	Mean	StDev	Minimum	Median	Maximum
8	**62.66**	27.20	**23.10**	70.15	**104.00**
15	**61.69**	12.93	**45.70**	58.10	**89.10**
23	62.03	18.50	23.10	62.70	104.00

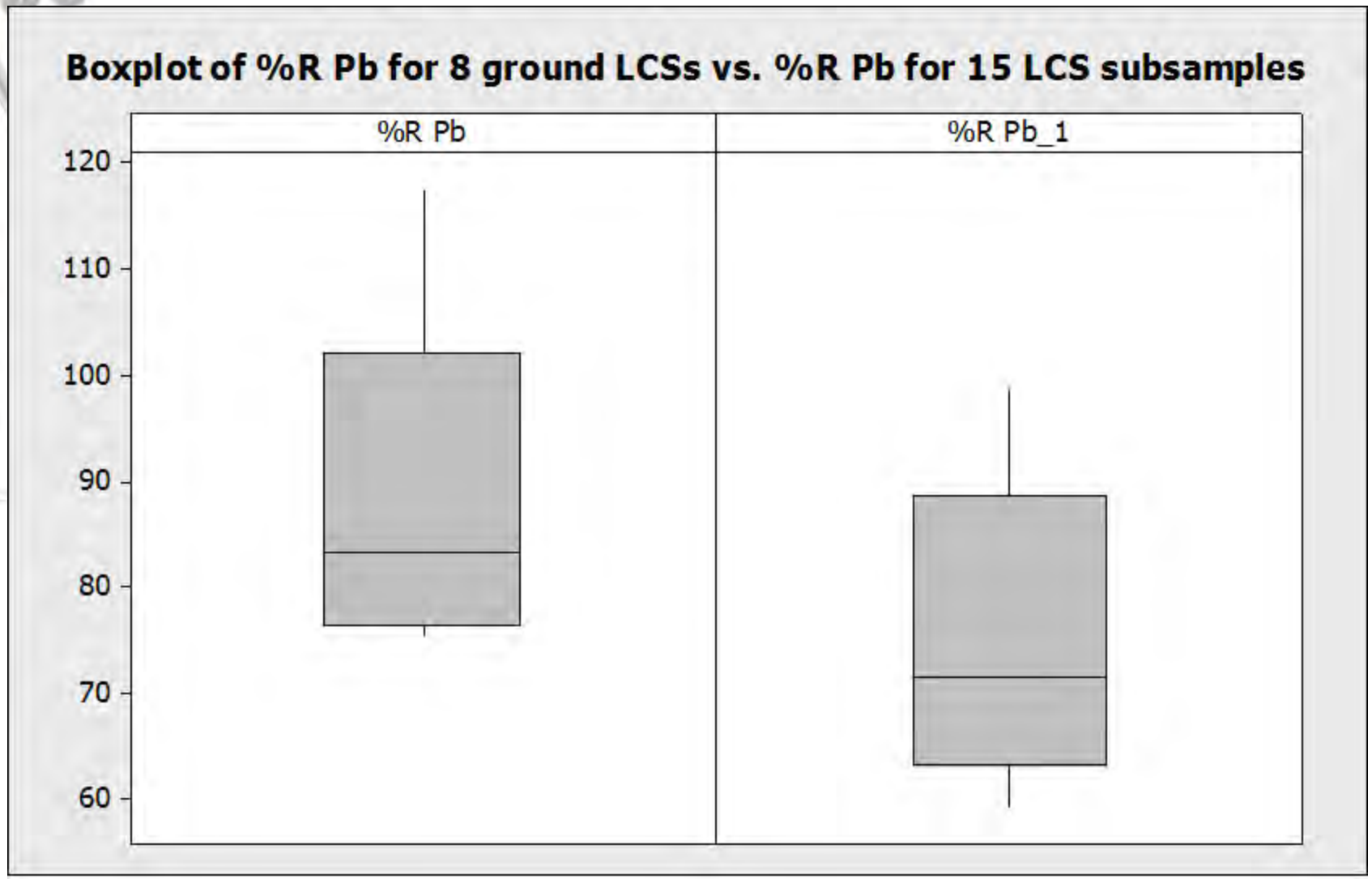
Antimony

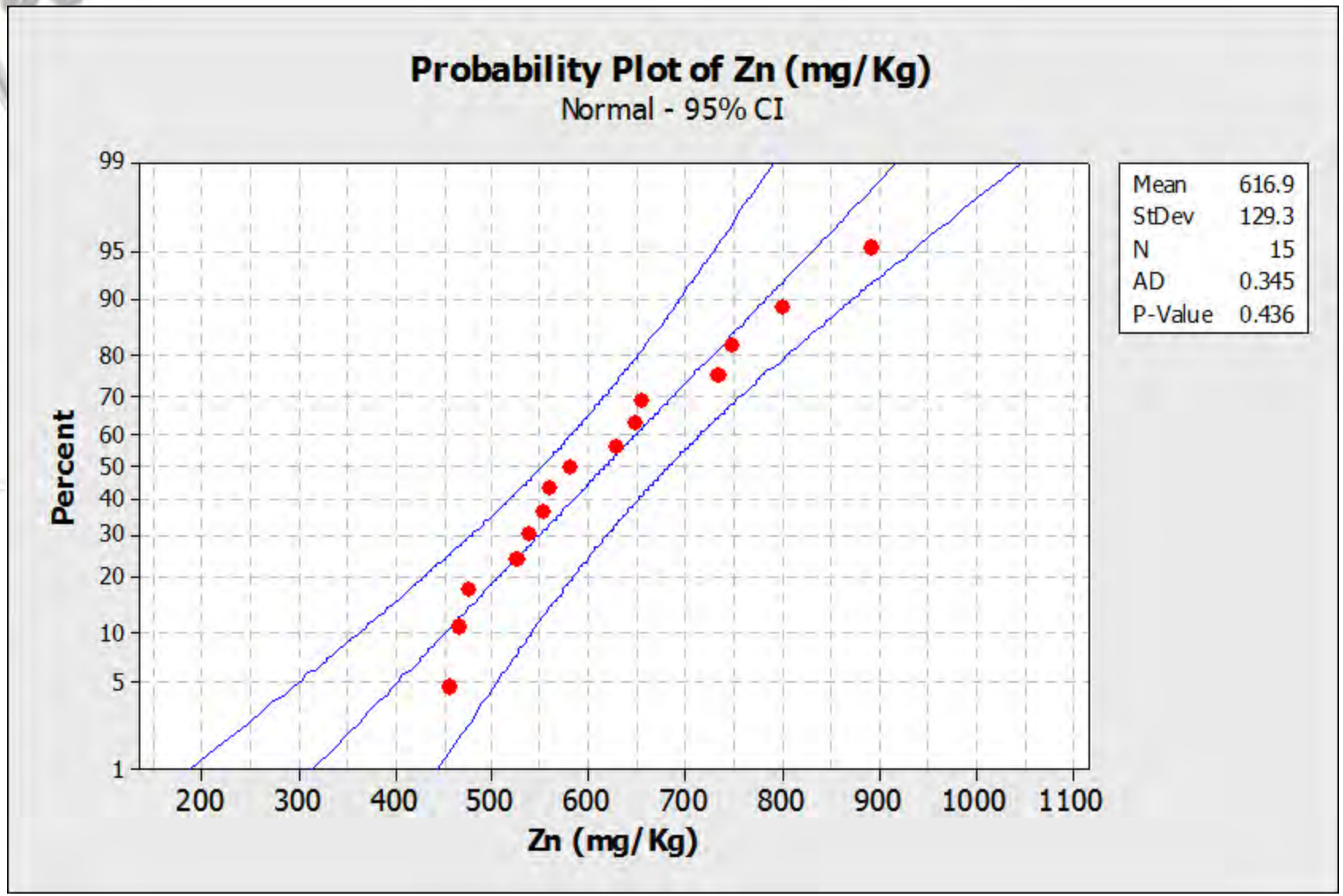
N	Mean	StDev	Min	Median	Maximum
15	**14.415**	2.751	**11.025**	14.225	**19.025**
8	**73.16**	4.20	**68.50**	72.38	**79.50**

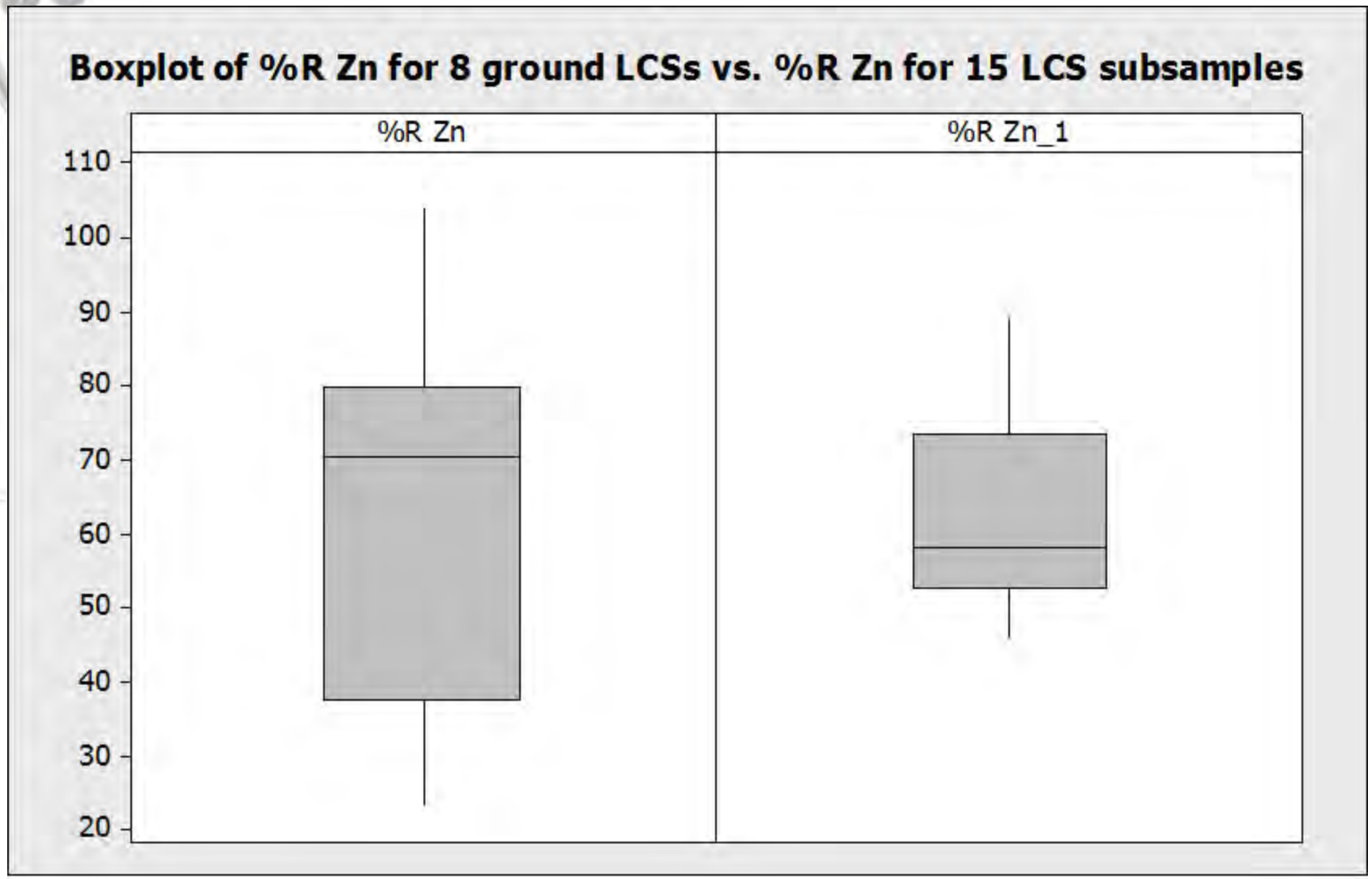

Probability Plot of Cu (mg/Kg)
Normal - 95% CI
Percent
99
95
90
80
70
60
50
40
30
20
10
5
1
300
400
500
600
700
800
900
1000
1100
1200
Cu (mg/Kg)
Mean 747.7
StDev 125.8
N 15
AD 0.552
P-Value 0.128

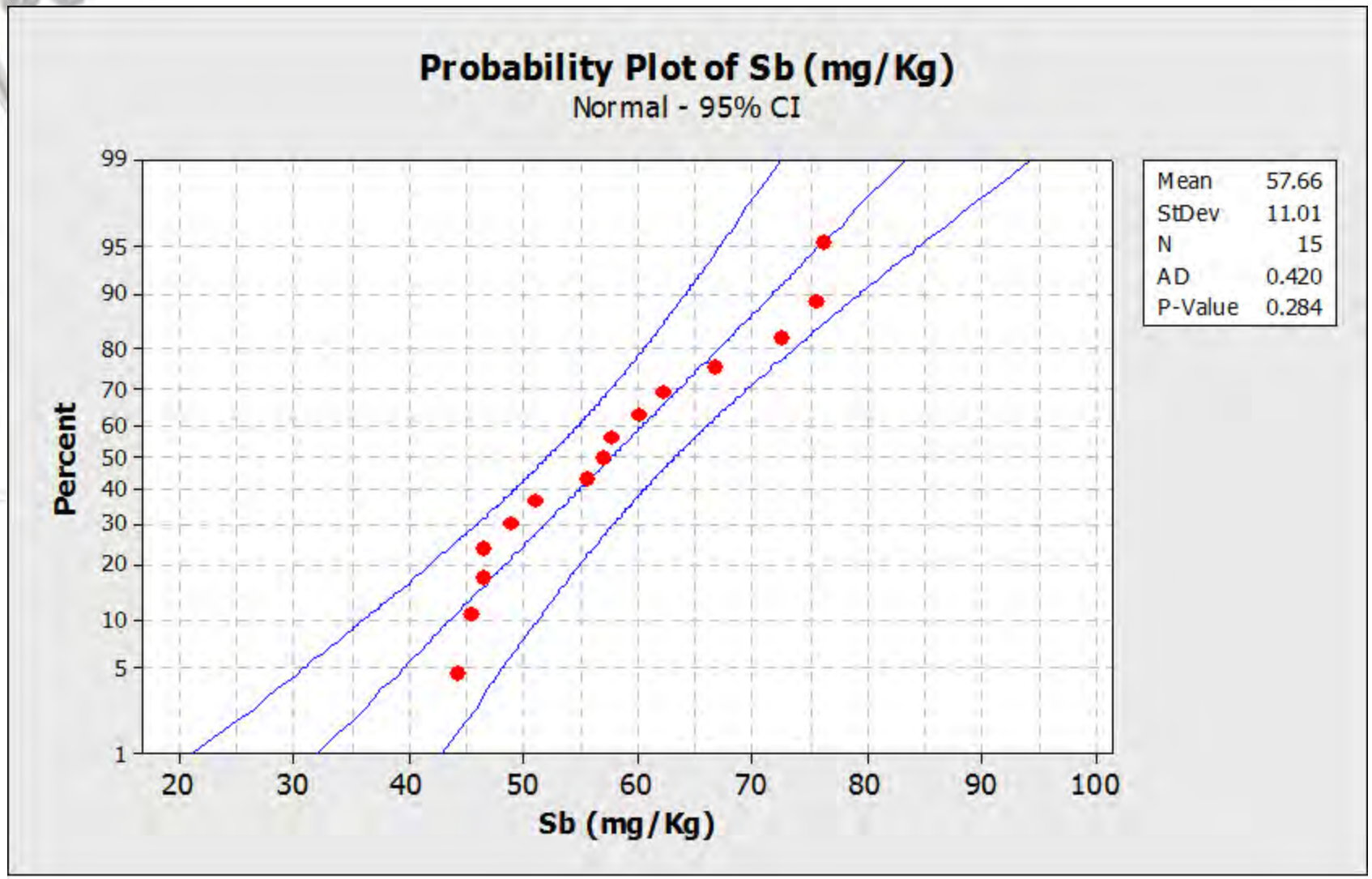

Boxplot of %R Cu for 8 ground LCSs vs. %R Cu for 15 LCS sub-samples
%R Cu
%R Cu_1
110
100
90
80
70
60
50
40
30

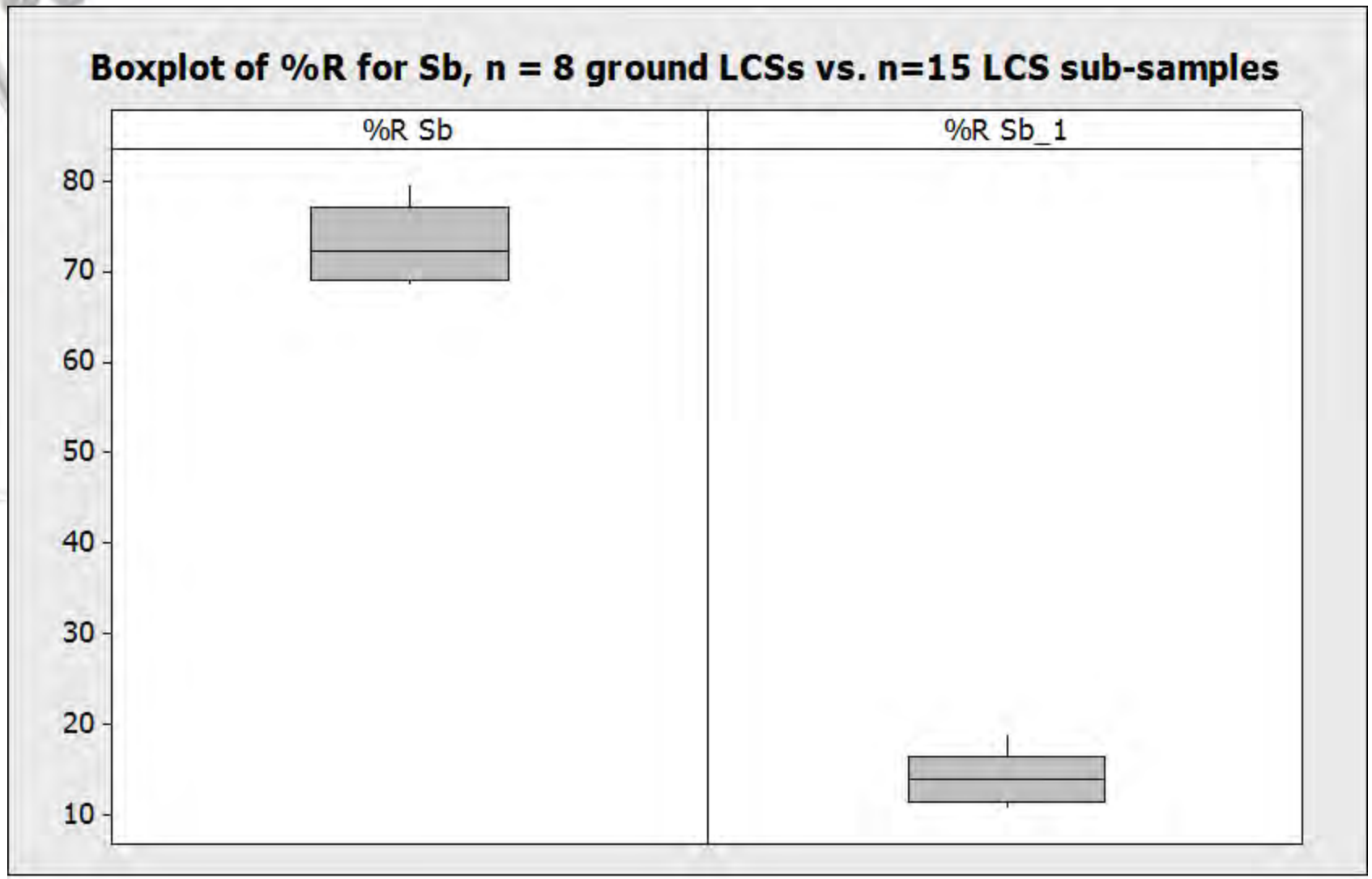

Probability Plot of Pb (mg/Kg)
Normal - 95% CI
Percent
99
95
90
80
70
60
50
40
30
20
10
5
1
100
200
300
400
500
Pb (mg/Kg)
Mean 304.2
StDev 55.41
N 15
AD 0.533
P-Value 0.144


Boxplot of %R Pb for 8 ground LCSs vs. %R Pb for 15 LCS subsamples
%R Pb
%R Pb_1
120
110
100
90
80
70
60


Probability Plot of Zn (mg/Kg)
Normal - 95% CI
Percent
99
95
90
80
70
60
50
40
30
20
10
5
1
200
300
400
500
600
700
800
900
1000
1100
Zn (mg/Kg)
Mean 616.9
StDev 129.3
N 15
AD 0.345
P-Value 0.436


Boxplot of %R Zn for 8 ground LCSs vs. %R Zn for 15 LCS subsamples
%R Zn
%R Zn_1
110
100
90
80
70
60
50
40
30
20

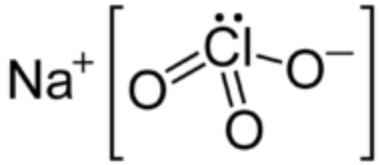

Probability Plot of Sb (mg/Kg)
Normal - 95% CI
Percent
99
95
90
80
70
60
50
40
30
20
10
5
1
20
30
40
50
60
70
80
90
100
Sb (mg/Kg)
Mean 57.66
StDev 11.01
N 15
AD 0.420
P-Value 0.284


Boxplot of %R for Sb, n = 8 ground LCSs vs. n=15 LCS sub-samples
%R Sb
%R Sb_1
80
70
60
50
40
30
20
10

Control Limits for Metals

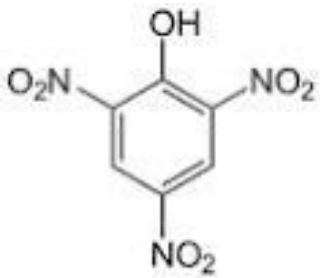
Metal	Control Limits*
Cu	104% - 41%
Pb	115% - 60%
Zn	101 - 26%
Sb	68% - 80%

* 95th percentile – 5th percentile, *n* = 23 for Cu, Pb, and Zn; *n* = 8 for Sb



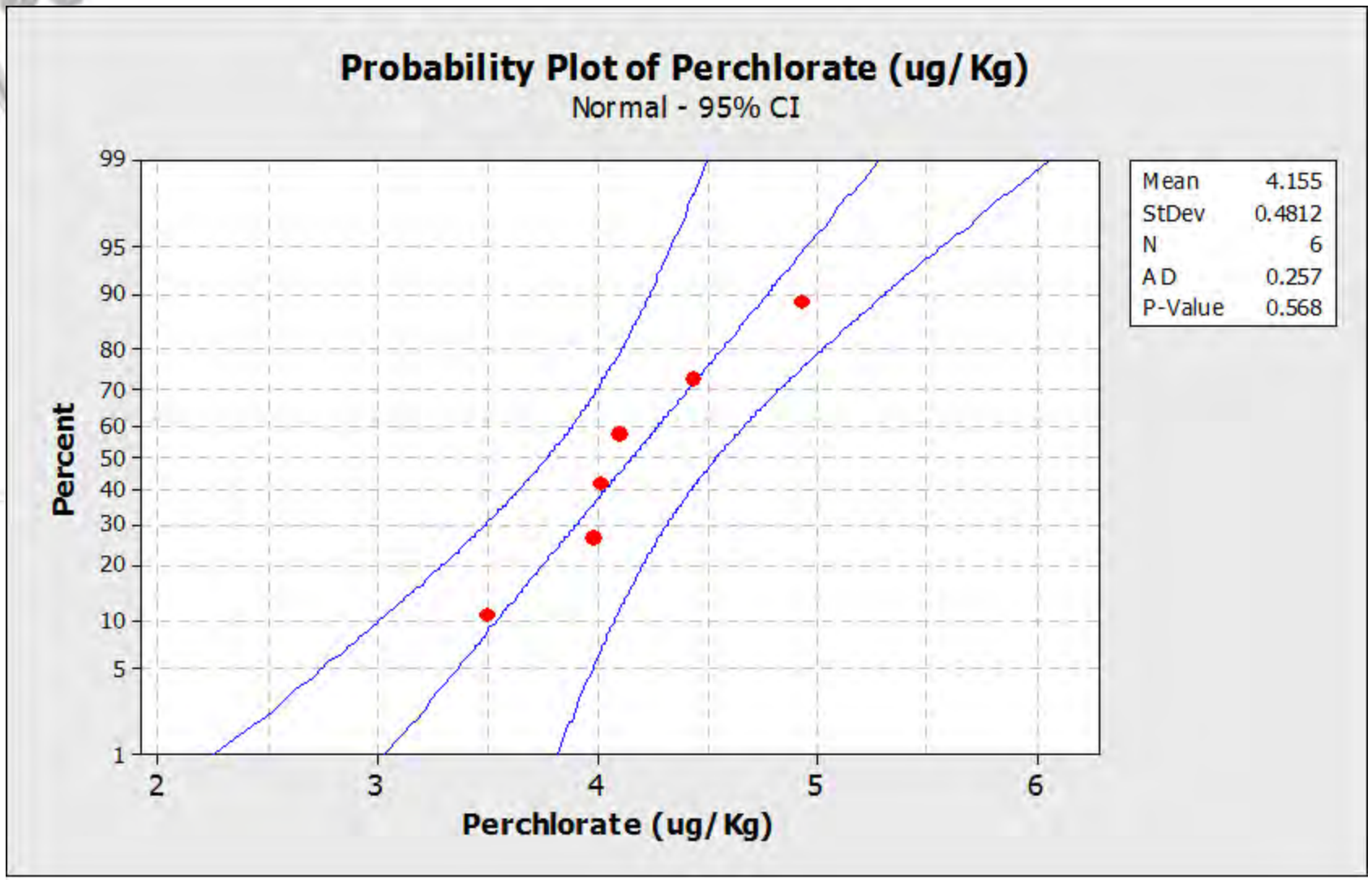
Perchlorate

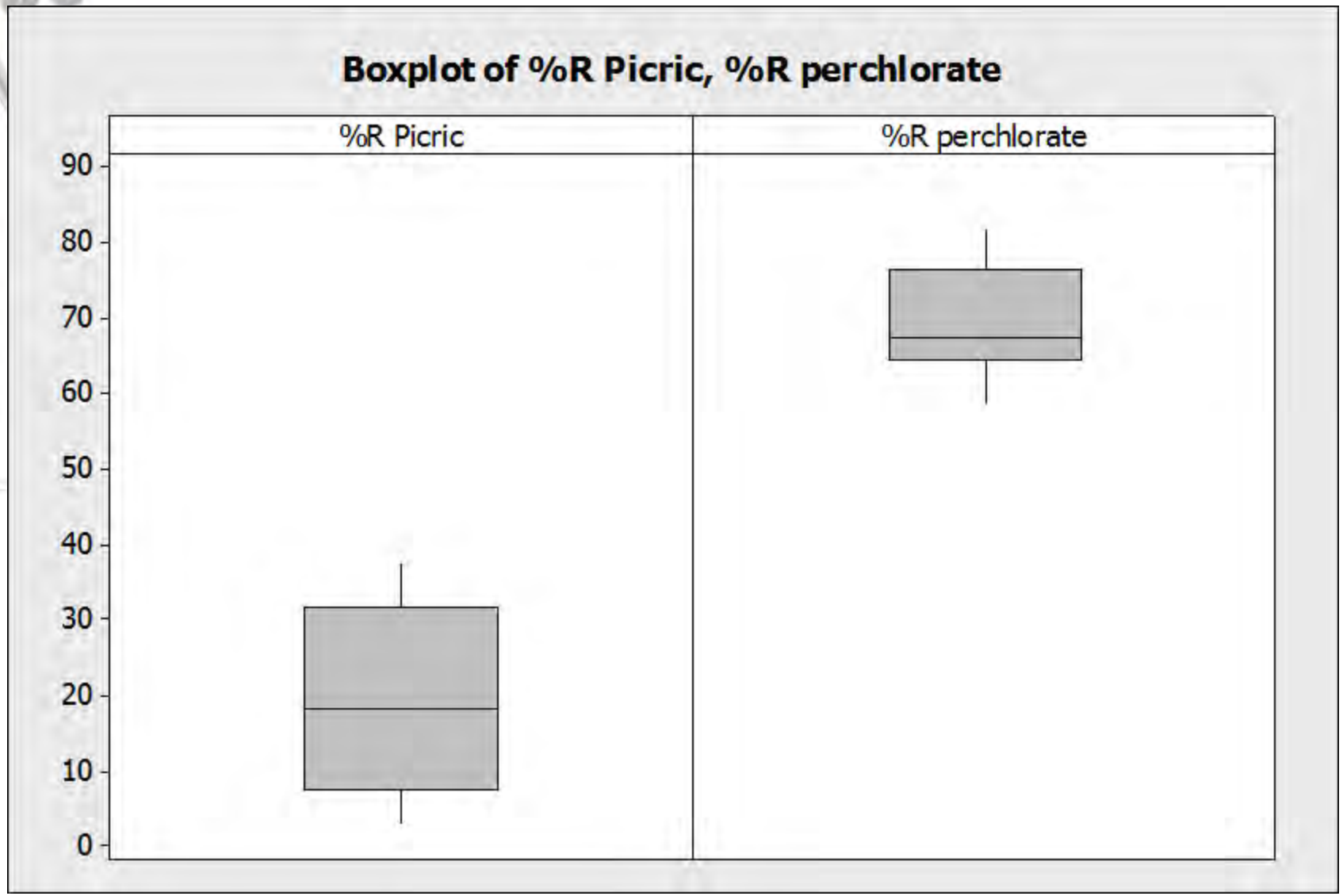
- LCS prepared inhouse
- 1 g extracted per method



Picric Acid

- LCS prepared in house
- 10 grams extracted


Probability Plot of Perchlorate (ug/Kg)
Normal - 95% CI
Percent
99
95
90
80
70
60
50
40
30
20
10
5
1
2
3
4
5
6
Perchlorate (ug/Kg)
Mean 4.155
StDev 0.4812
N 6
AD 0.257
P-Value 0.568


Boxplot of %R Picric, %R perchlorate
%R Picric
%R perchlorate
90
80
70
60
50
40
30
20
10
0

Control Limits

Analyte	%RSD	Mean %R	Control Limits*
Picric Acid	70%	19%	Not calculated.
Perchlorate	12%	69%	55% - 85%

* mean ± 2 s, rounded to nearest 5%, *n* = 6

Conclusions

- PAHs – Grinding is best for precision but recoveries are lower for some analytes
- Metals – Grinding helps but needs more work
- Perchlorate – Grinding looks OK but limited data
- Picric Acid – Limited data, but don’t grind

Special Thanks

Thomas Georgian for his slides and insight

Brian Jordan for allowing us to use his data

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MUNITIONS CONSTITUENTS GUIDANCE UPDATE

Deborah Walker

Project Manager

US Army Engineering and Support Center, Huntsville

Environmental and Munitions Center of Expertise (EM CX)

2014 DoD Environmental Monitoring Data Quality Workshop

9 April 2014

US Army Corps of Engineers

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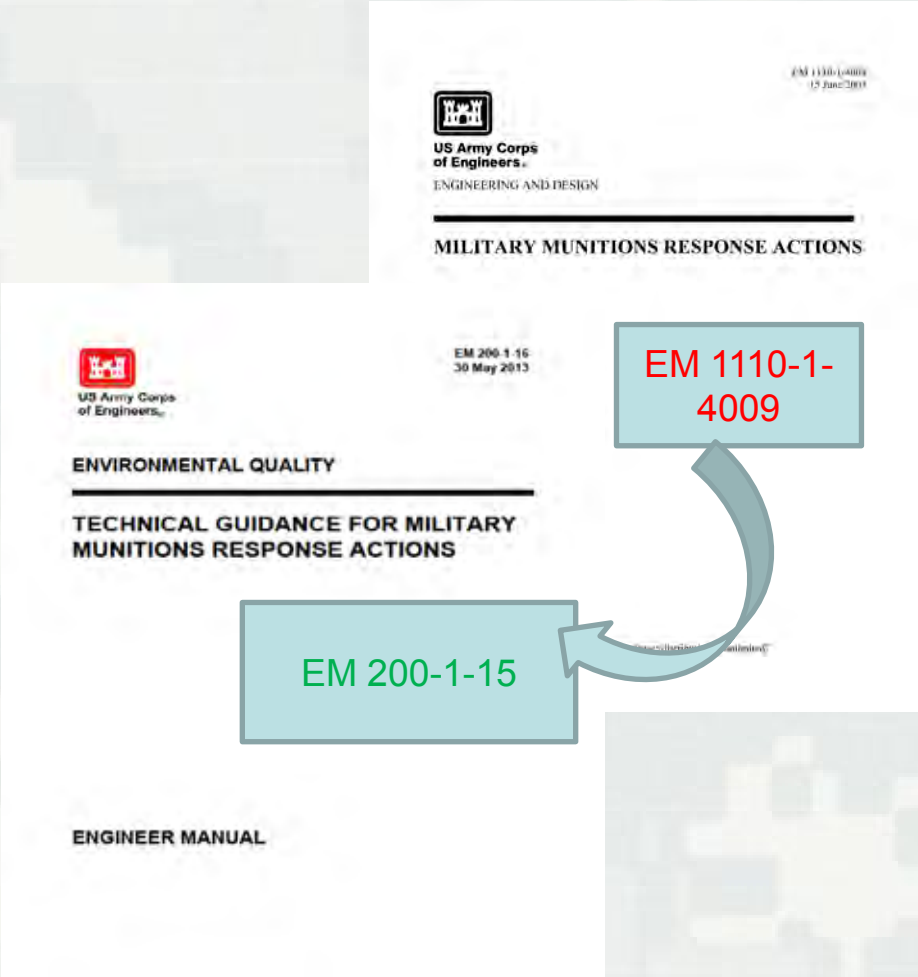
EM CX Interim Guidance Document 14-01, 20 December 2013

- Engineering Knowledge Online Link - Must Have USACE CAC to Download
- Draft EM 200-1-15 – Technical Guidance for Military Munitions Response
- Transition from using EM 1110-1-4009 to EM 200-1-15, which is in final stages of publication (estimated April 2014)

Reason for Update



- Reflect changes to DoD and USACE policies
- Reflect current trends/advances/changes to MR technology/techniques
- Eliminate redundancies with other guidance
- Improve consistency with other guidance
- Update terminology and guidance references
- Reflect USACE organizational changes
- Update pub number from “Engineering and Design” to “Environmental Quality”

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Update Process

EM 1110-1-4009 (2007) *Military Munitions Response Actions*

EM 200-1-15 (2013) *Technical Guidance for Military Munitions Response Actions*

User Questionnaire

SME Interviews/Review Available Guidance

Draft à SME Review

Draft Final à SME/NAOC Review

Final/Editorial Review

Publication 2013

TOC Comparison (>100 pages of new content)

Key Enhancements and Additions

EM 1110-1-4009 TOC

- 1. Project Planning and Execution
- ~~2. Project Contracting Requirements~~
- 3. Site Visit
- 4. Work Plans
- 5. Geospatial Data Systems
- 6. Geophysical Planning Strategies for Response Actions
- 7. Site Characterization
- 8. Geophysical Investigation
- 9. Quality Control of Geophysical Systems and Related Operations
- 10. MC Sampling
- ~~11. Blast and Fragment Protection~~
- 12. Risk Characterization
- ~~13. Quality Assurance Surveillance Plan (QASP)~~
- ~~14. COE MPPEH Inspection, Certification, and Final Disposition Procedures~~

EM 200-1-15 TOC

- **1. Introduction**
- 2. Project Planning and Execution
- 3. Site Visits
- 4. Project Planning Documents
- 5. Geospatial Data and Systems
- 6. Geophysical Investigation Methodologies
- 7. MC Characteristics and Analytical Methodologies
- 8. Site Characterization Strategies
- 9. Planning Strategies for Remedial or Removal Actions
- **10. MC Planning Considerations for Remedial or Removal Actions**
- 11. Quality Control
- 12. Hazard and Risk Assessment
- **13. Project Reporting Requirements**

Project Flow

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Updated Guidance Document References

Prior Document No.	New Document No.	Document Title
EP 75-1-4	EP 200-1-18	Environmental Quality: Five-year Reviews of Military Munitions Response Projects
EP 1110-1-24	EP 200-1-20	Land Use Controls
EP 1110-3-8	EP 200-3-1	Environmental Quality: Public Participation Requirements for Defense Environmental Restoration Program
EM 1110-1-4007	EM 200-1-23	Safety and Health Aspects of Hazardous, Toxic, and Radioactive Waste Remediation Technologies
EM 1110-1-4009	EM 200-1-15	Military Munitions Response Actions
EM 1110-1-1200	EM 200-1-12	Conceptual Site Models for Environmental and Munitions Projects
EM 1110-1-4000	EM 200-1-17	Monitoring Well Design, Installation, and Documentation at Hazardous, Toxic, and Radioactive Waste Sites
EM 1110-1-4014	EM 200-1-16	Environmental Quality: Environmental Statistics
ER 1110-1-263	ER 200-1-7	Chemical Data Quality Management for Environmental Cleanup

Content Crosswalk Table

Table 1-2: Information Locations by Topic Area

General Topic Area	Specific Topic	Relevant Section(s)
Geophysical investigation	Advanced EMI Sensors	6.3.7.3; Table 6-1
	Advanced EMI Tools and Surveys	6.3.5
	Analog Tools and Surveys	6.3.3
	Anomaly Classification	6.6.1
	Anomaly Classification – Anomaly Parameters	6.6.5
	Anomaly Classification – Anomaly Resolution	6.6.9; Table 6-6
	Anomaly Classification – Classifier Rules	6.6.7
	Anomaly Classification – Cued Data	6.6.4
	Anomaly Classification – Dig List	6.6.8
	Anomaly Classification – Selection	6.6.2; Figure 6-31; Figure 6-32
	Anomaly Classification – Training Data	6.6.6
	Data Analysis – Classification	6.6
	Data Analysis – Overview	6.6.1
	Deployment Platforms / Airborne	6.5.3; Figure 6-28
	Deployment Platforms / Man Portable	6.5.1; Figure 6-26
	Deployment Platforms / Multiple Instrument Arrays	6.5.2; Figure 6-27
	Deployment Platforms / Underwater Systems	6.5.4; Figure 6-29

MC Aspects – Where are they?
EM 200-1-15: Table of Contents

1. Introduction
2. **Project Planning and Execution**
3. Site Visits
4. **Project Planning Documents**
5. **Geospatial Data and Systems**
6. Geophysical Investigation Methodologies
7. **MC Characteristics and Analytical Methodologies**
8. **Site Characterization Strategies**
9. Planning Strategies for Remedial or Removal Actions
10. **MC Planning Considerations for Remedial or Removal Actions**
11. **Quality Control**
12. **Hazard and Risk Assessment**
13. **Project Reporting Requirements**

- Appendices
  - **App. A – References**
  - **App. B – QASP Template**
  - **App. C – Sample Discipline-Specific QA Reports**
  - **App. D – Chemical / Physical Properties of MC**
- Glossary

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Chapter 2 - Project Planning and Execution

- Technical Project Planning (TPP)
- Data Quality Objectives (DQOs)
- Use of Uniform Federal Policy – Quality Assurance Project Plan (UFP QAPP) and EM 200-1-2 in TPP process
- CSM Development per EM 200-1-12 UPDATED 28 December 2012

Where are you taking the samples and Why?
What are the analytes and Why?
What are you doing with the data?

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UFP-QAPP/EM Crosswalk

Worksheet Number(s)	Worksheet Title	CIO 2106-G-05 QAPP Guidance Section[a]		Potential Applicability		EM 200-1-15 Section
		Section	Title	MEC	MC	
1, 2	Title and Approval Page	2.2.1	Title, Version, and Approval/Sign-Off	•	•	NA
3, 5	Project Organization and QAPP Distribution	2.2.3	Distribution List	•	•	2.1; 2.2
		2.2.4	Project Organization and Schedule			
4, 7, 8	Personnel Qualifications and Sign-off Sheet	2.2.1	Title, Version, and Approval/Sign-Off	•	•	2.1.4; 6.2.1, 8.2.5.1
		2.2.7	Special Training Requirements and Certification			
6	Communication Pathways	2.2.4	Project Organization and Schedule	•	•	2.1; 2.2
9	Project Planning Session Summary	2.2.5	Project Background, Overview, and Intended Use of Data	•	•	2.2
10	Conceptual Site Model	2.2.5	Project Background, Overview, and Intended Use of Data	•	•	2.2.4.1.3, 12.2
11	Project Data Quality Objectives	2.2.6	Data/Project Quality Objectives and Measurement Performance Criteria	•	•	2.2.4; 5.3; 9.2; 11.3
12	Measurement Performance Criteria	2.2.6	Data/Project Quality Objectives and Measurement Performance Criteria	•	•	5.3.7; 11.3; Tables 11-3 through 11-6

Chapter 4 - Project Planning Documents

- § Quality Assurance Surveillance Plan (QASP)
- § UFP-QAPP

Document TPP Decisions

  - ► Recommended Minimum Standard Operating Procedures (SOPs):
    - MC sample collection procedures
    - Hazardous material shipping, if needed (applies to certain MC samples, x-ray fluorescence [XRF] sources, EXPRAY™ kits, etc.)
    - Chemistry data management
    - MC data review
    - Analytical laboratory SOPs
  - ► No separate Field Sampling Plan required
  - ► UFP-QAPP now for MC **AND** MEC

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Chapter 4 - Project Planning Documents

Avoid project pitfalls!

- Environmental Protection Plan
  - Ensure adequate planning in place for ecological and cultural resources
- Waste Management Plan
  - Ensure adequate planning in place to address generation, management, and disposal of various waste streams, which may include environmental sampling related investigation-derived waste (IDW), Munitions Debris (MD), material contaminated with chemical agent, and the solutions used for decontaminating equipment contaminated with chemical agent.
- Risk/Hazard Assessment Planning
  - Ensure adequate planning for data collection in place to support execution of risk/hazard assessment

Chapter 5: Geospatial Data and Systems

- § Environmental Sample Data
  - ► Accuracy requirement specified ±0.3m
- § GIS Data Format, Transfer, and Storage
  - ► Ensure environmental sample data is addressed in this discussion

Plan ahead so that Geospatial Data and MC Data can be smoothly coordinated

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Chapter 7 – MC Characteristics and Analytical Methodologies

Major Subsections

- MC sources
- MC overview and analytical instrumentation
- Primary explosives
- Secondary explosives
- Propellants
- Metals
- CAs and ABPs
- Riot control agents
- Incendiaries
- Smokes and obscurants
- Other MC
- PAHs
- Info sources to ID MC in munitions

Enhancements

- Focus on MC characteristics – MC sampling guidance moved to other chapters (8, 10)
- References to analytical methods updated
- Information from latest USACE MC training materials included
- MC quality management moved to QC chapter (11)
- MC sampling considerations moved to separate Site Characterization Chapter (8)

Additions

- MC physical properties provided in appendix D

Chapter 7 – MC Characteristics and Analytical Methodologies

- Sources of MC in Munitions
- MC Analytical Laboratory Instrumentation
- Identifying MC in Munitions
  - Common Operations Reports
  - Technical Manuals and other historic documents
  - Munition Items Disposition Action System (MIDAS) https://midas.dac.army.mil/ (requires CAC and registration; contractors require DoD sponsor)
  - MVS Munitions Database (recently taken off line)

Identify what is in the Munitions at YOUR Site and Sample Based on THOSE Munitions

Chapter 7 – MC Characteristics and Analytical Methodologies

- Types of MC
  - Primary Explosives
  - Secondary Explosives
  - Propellants
  - Metals
  - Chemical Agents and Agent Breakdown Products
  - Riot Control Agents
  - Incendiaries
  - Smokes and Obscurants
  - Other Types of Munitions Constituents
  - Polynuclear Aromatic Hydrocarbons (not MC)

Not Just Explosives and Metals

- Text provides some or all of the following for each type:
  - Specific compounds within each type
  - Fixed/field laboratory test information
  - Historical use in munitions
  - Limited environmental fate and transport characteristics
  - Limited sampling recommendations, primarily for compounds where sampling is not recommended

Chapter 7 – MC Characteristics and Analytical Methodologies: Metals in Munitions Compilation

Metal	Occurrence in Munitions	CERCLA Hazardous in Elemental Form	Are Compounds Hazardous Substances?	Common Oxidations States
Aluminum (Al)	Incendiaries, composition explosives, propellants, pyrotechnics (powdered Al), and rocket cases (alloys)	No	Only certain compounds	Al(0); Al(III)
Antimony (Sb)	Alloys with Pb in small arms bullets (99% Pb, 1% Sb) and in pyrotechnics	Yes	Yes	Sb(0); Sb(III); Sb(V)
Copper (Cu)	Cartridge cases (brass), bullet jackets (e.g., gilding metal), pyrotechnics, and bronze gun barrels	Yes	Yes	Cu(0); Cu(I); Cu(II)
Iron (Fe)	Present as steel in cases and projectiles, incendiaries, and pyrotechnics	No	No	Fe(0); Fe(II); Fe(III)
Lead (Pb)	Small arms bullets, primary explosives, primer compositions	Yes	Yes	Pb(0); Pb(II); Pb(IV)
Magnesium (Mg)	Incendiaries, pyrotechnics (photoflash), tracers, and armor piercing bullets	No	No	Mg(0); Mg(II)
Zinc (Zn)	Cartridge cases (brass) bullet jackets (e.g., gilding metal), HC smoke-filled munitions, and pyrotechnics	Yes	Yes	Zn(0); Zn(II)

Before you take the sample: What munitions were on the site and what metals were part of their makeup?

Table 7-9, IGD 14-01 (See EM for less commonly occurring metals)

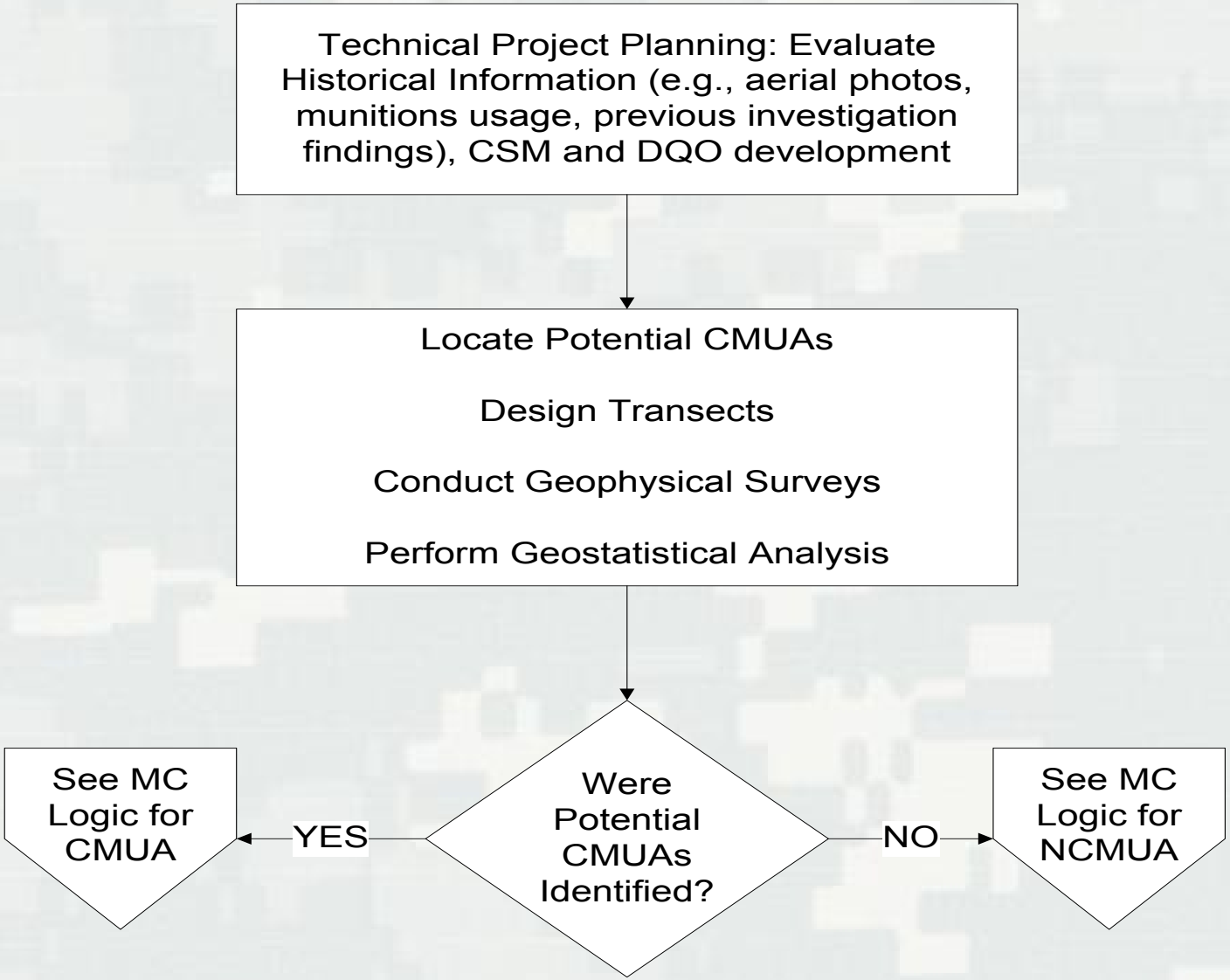
Chapter 8 – Site Characterization Strategies

Major Subsections	Enhancements	Additions
• Overview/Goals/Objectives • Planning considerations • Statistical tools • Locating concentrated munitions use areas • Characterizing CMUAs • Characterizing NCMUAs • Characterizing SA ranges • MC sampling and analysis • MRS delineation	• Planning considerations for MEC and MC characterization • MC sampling tied to MEC • New Terminology (CMUA and NCMUA)	• Site characterization decision logic diagrams • Statistical tools (VSP, UXO Estimator) • Incremental sampling guidance • Planning for chemical data QC • Characterization of CMUAs and NCMUAs • Small arms range characterization • MRS Delineation

Terminology

- Concentrated Munitions Use Area (CMUA)
  - High likelihood of finding MEC and high amount of MD from historical munitions use and fragmentation.
  - Entire MRS or areas within MRSs
  - Examples
    - Target areas on ranges
    - Explosion sites
    - OB/OD
    - Potentially disposal sites where munitions have been disposed of over a relatively large area (i.e., not small, isolated burial pits).
- Non-Concentrated Munitions Use Area (NCMUA)
  - Low amount of MD and UXO due to limited historical munitions use and fragmentation.
  - May be entire MRSs (e.g., training or maneuver areas) or they may be a portion of an MRS outside of a CMUA (e.g., buffer area)

Characterization Logic



Simplified Version of Figure 8-1.
IGD 14-01

Site Characterization Strategies

- Sample based on identifying either a source or a release of MC
- Coordinate sampling strategy with all data including geophysical results
- Consider whether sampling can be done during intrusive operations
- Collect samples where the evidence of munitions is the strongest during the MEC anomaly investigation (intrusive operations)

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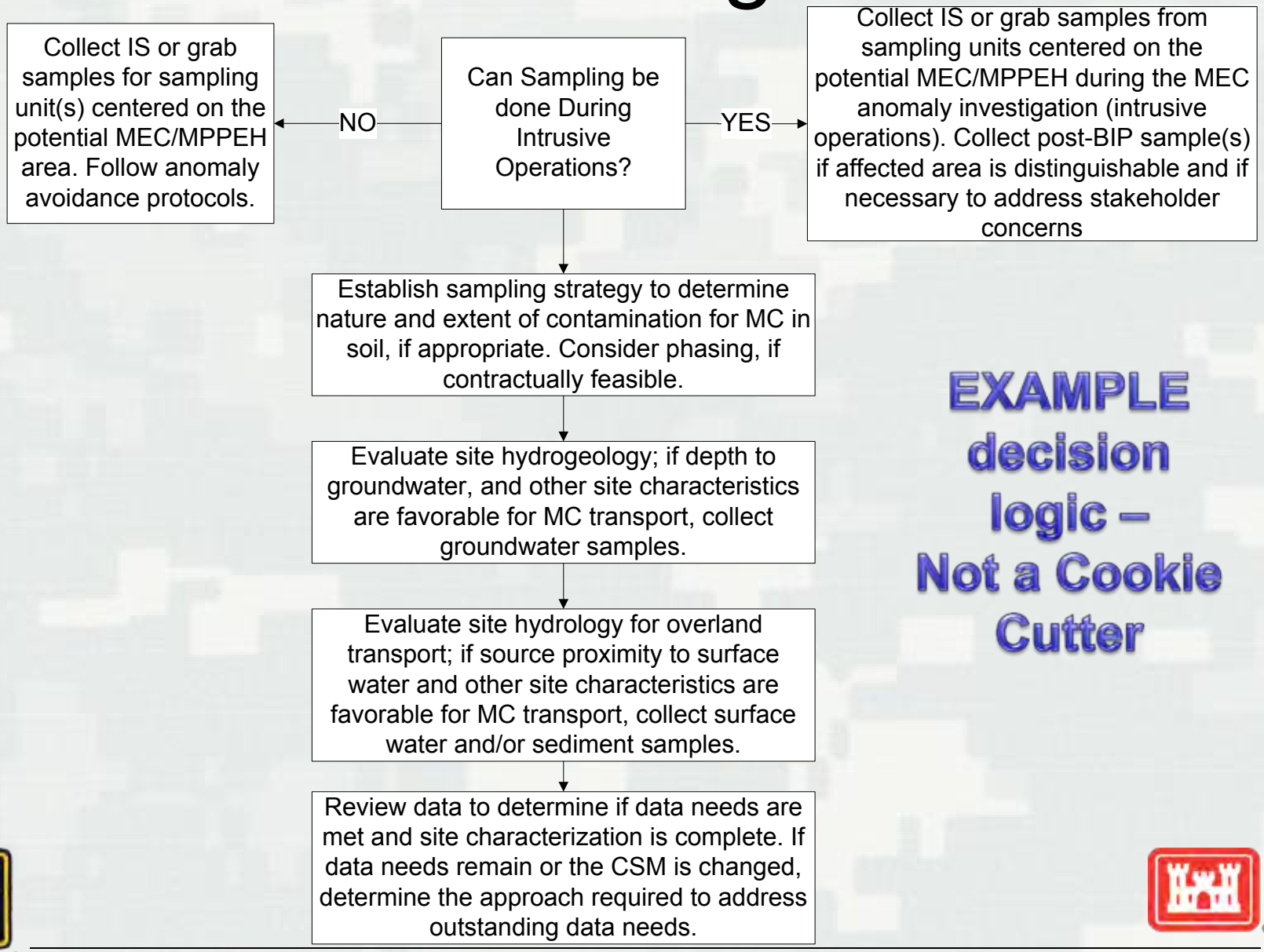
Characterization Logic - CMUAs



EXAMPLE decision logic – Not a Cookie Cutter

Simplified Version of Figure 8-2. IGD 14-01

Chapter 8 – Site Characterization Strategies

§ Small Arms Ranges

- ► Example Decision Logic Diagrams
  - Presence or Absence
  - Nature and Extent
- ► If MEC or MPPEH (other than small arms) is present, must characterize MEC, not just MC

Can you find a berm or shot fall area?

§ Non-Concentrated Munitions Use Areas

- ► Consider:
  - Types of munitions used
  - Frequency of use
  - Area over which the munitions were used

If no concentrated sources of MC are present, recommend not sampling!

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Chapter 8 – Site Characterization Strategies: Sampling and Analytical Considerations

- § MRS Layout
- § MEC Depth
- § Munition Composition
- § Condition of any MPPEH
- § Timing for MC Sample Collection if MEC or MD are Present
- § Background Conditions
- § Regulatory Requirements
- § Chemical-specific Screening Levels, ARARs, and TBCs
- § Analytical Issues with Energetics
- § Site Hydrology and Hydrogeology
- § MC Sampling Resources

We can't just run out and start putting dirt in jars!

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Chapter 8 – Site Characterization Strategies: Surface Water Sampling

- Surface water sampling for MC must be accompanied by documentation of the characteristics of the surface water body, such as:
  - Size and shape
  - Depth
  - Flow rate (if applical
  - pH
  - Temperature
  - Conductivity
  - Dissolved oxygen
  - Turbidity

- If surface water has low hardness and ecological receptors (and low ecological risk screening criteria corresponding to the low hardness), use of the "clean hands" sampling method (EPA 1669) and trace metals analysis (e.g., EPA 1638,) may be appropriate.

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Chapter 8 – Site Characterization Strategies: Blow-in-Place Sampling

- Pre-detonation soil sampling is not recommended
- Post-BIP Sampling
  - May be required on a site-specific basis during site characterization activities to determine if a release has occurred as a result of BIP detonation
  - If post-BIP samples are collected, specific DQOs should be established during the TPP process to define the specific uses of the data
  - Recommend IS sampling be used unless there are state or local requirements to the contrary
  - See EM for further recommendations

Chapter 8 – Site Characterization Strategies: Use of Incremental Sampling

- **IS is not mandated at the guidance level**
- During acquisition process, the USACE PDT should make an initial evaluation regarding its use, considering factors such as regulatory acceptance of IS, the lack of published IS laboratory sample processing methods for analytes other than explosives, and the availability of accredited commercial laboratory services, to determine if IS is the best method for the project.
- If the USACE PDT determines that IS is the best choice, the SOW/ PWS should specify its use.

§ For performance-based contracts, the contractor may recommend an alternate approach during the proposal phase for government consideration.

§ During TPP, as the project's DQOs are established, if it is concluded that the initial determination should be changed (i.e., IS is selected when discrete is in the SOW/PWS or vice versa), contracting personnel should be consulted for direction.

§ If IS is determined to be required, the PDT should include personnel knowledgeable and experienced in the design of IS.

IS is a tool in our tool box.

Chapter 8 – Site Characterization Strategies: Background Conditions

- Naturally occurring or anthropogenic background concentrations of metals, perchlorate, fuel oil, PAHs, or other compounds unrelated to munitions may exceed risk screening levels/ regulatory limits
- The use of published regional background data for evaluation of potential MC-related contamination is not recommended.
- Adequate and defensible background determination is key to successful site characterization if MC investigation includes these parameters.
- Each environmental medium should be evaluated to establish background values.

If it isn't from a DoD source, DoD cannot legally spend your tax dollars to clean it up.

Chapter 8 – Site Characterization Strategies: Key Requirements for MC Sampling at CWM Sites

- Incremental sampling is not recommended
- Environmental media samples must be handled differently than standard samples:
  - Onsite lab screens for agent before they are shipped offsite
  - Offsite lab performs total analysis for agent/breakdown products
  - If total analysis is Non-Detect, the sample can be released for commercial laboratory analysis.

Headspace Sample ≥ Short term Exposure Limit (STEL) or Extraction Sample ≥ Hazardous Waste Control Limit (HWCL)
Decontaminate to below HWCL (unless other more stringent level applies), then package and ship to TSDF for appropriate treatment or disposal IAW applicable laws and regulations

Extraction Sample < HWCL but ≥ appropriate Health Based Environmental Screening Level (HBESL)
Disposed of as hazardous waste per federal, state, interstate, and local laws and regulations or treated by an approved, licensed treatment or disposal facility to the appropriate level.

Extraction Sample < appropriate HBESL
May be used or disposed of per federal, state, interstate, and local laws and regulations (e.g., returned to the hole or disposed of as non-contaminated, non-hazardous material)

Laboratory limit of quantitation must be below HBESL

Chapter 10 – MC Planning Considerations for Remedial/Removal Actions: Small Arms Ranges

- Recommended Design Parameters*
  - Grain-size distribution of soil
  - Clay content
  - Organic content
  - Soil pH
  - Contaminant form
  - Contaminant distribution vs. grain-size

*In addition to nature and extent

- Soil Treatment Technologies
  - Soil Screening
  - Excavation and Disposal
  - Soil Washing
  - Solidification/ Stabilization
  - Chemical Extraction

Effective characterization planning can improve cleanup design process

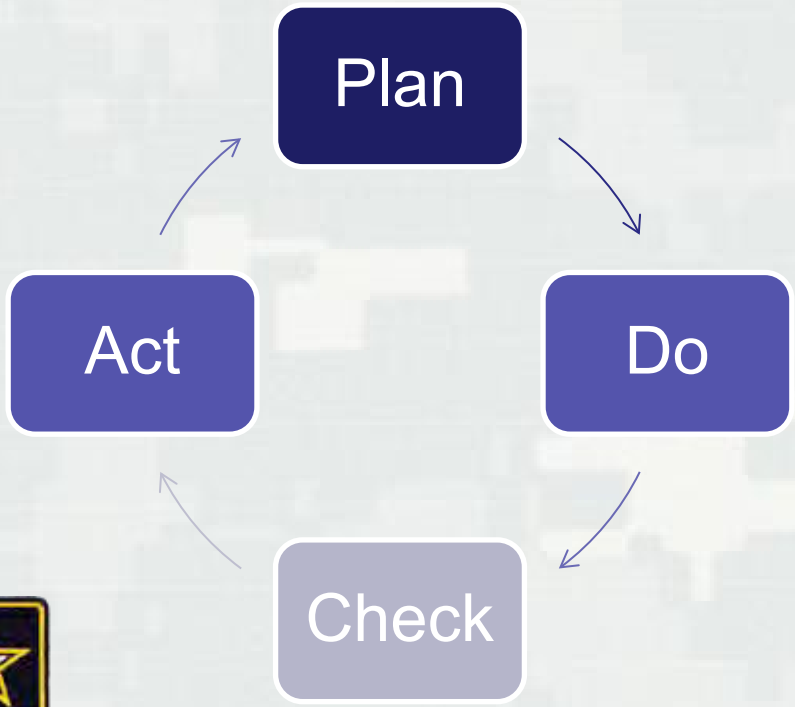
Chapter 10 – MC Planning Considerations for Remedial/Removal Actions: Energetics and Perchlorate

- Soil
  - In-situ biological treatment
    - Vadose zone bioremediation
    - Phytoremediation
  - Ex-situ biological
    - Composting
    - Landfarming
  - Alkaline Hydrolysis
  - Leaching from Vadose Zone Soils
- Groundwater
  - In-situ biological treatment
    - Enhanced anaerobic bioremediation
    - Phytoremediation
  - Ex-situ Treatment
    - Granular Activated Carbon
    - Ion Exchange
    - Fluidized Bed Reactor

Treatment for these MC has rarely been necessary at former ranges

Chapter 11 – Quality Control

§ Focus on QC performance IAW project-specific UFP-QAPP to meet project DQOs



"It is easier to do a job right than to explain why you didn't." – Martin Van Buren

Chapter 12 – Hazard and Risk Assessment: Munitions Constituent Risk Assessment

- Human Health Risk Assessment
  - Selecting MC COPCs
  - Exposure assessment
  - Toxicity assessment
  - Risk characterization
  - Evaluation of uncertainties and limitations
- Ecological Risk Assessment
  - Screening Level ERA (SLERA)
  - Baseline ERA (BERA)

Risk assessment for MC = Risk assessment for HTRW

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Chapter 13 – Project Reporting Documents

§ Reporting Guidance for:

- ▶ Cultural and Biological Resources Field Surveys
- ▶ Cultural Resource Monitoring
- ▶ Biological Avoidance
- ▶ MC Data Deliverables
  - Field Reporting
  - Analytical Laboratory Electronic Data
  - Chemical Data Final Report

Check PWS/SOW for Contract-specific Requirements

Appendices

- App. A – References
- App. B – QASP Template
- App. C – Sample Discipline-Specific QA Reports
  - Examples of reports to meet QASP requirements
- App. D – Chemical / Physical Properties of MC
- Glossary

Appendix D - Chemical/Physical Properties Of Munitions Constituents

§ MC Classes:

- Primary Explosives
- Secondary Explosives, Co-Contaminants, and Breakdown Products
- Chemical Agents and Agent Breakdown Products
- Riot Agents and Smokes

Provided to help support MC fate and transport discussions

§ Parameters

- Compound
- Chemical Formula
- Abbreviation
- CAS Number
- Molecular Weight
- Melting Point (°C)
- Boiling Point (°C)
- Vapor Pressure (mm Hg)
- Water Solubility (mg/L)
- Log K_{ow}
- K_{oc}
- Henry's Law constant (atm-m^3/mole)

Appendix D – Chemical/Physical Properties of Primary Explosives

Table D-1: Chemical/Physical Properties of Primary Explosives

Compound	Chemical Formula	Abbreviation	CAS Number	Molecular Weight	Melting Point (°C)	Boiling Point (°C)	Vapor Pressure (mm Hg)	Water Solubility (mg/L)	Log K_{ow}	K_{oc}	Henry's Law constant (atm-m^3/mole)
Lead azide	N_6-Pb	LA	13424-46-9	291.24	190 (decomp)[a]	350 (explodes)[a]	U [d]	230 @ 18°C[a]	1.47 (est.)[g]	U [d]	U [d]
Mercury fulminate	C_2-Hg-N_2-O_2	-	628-86-4	284.62	210 (explodes)[f]	NA [d]	0.000612 @ 25°C (est.)[b]	100 @ 15.5°C[a]	-4.83 (est.)[b]	11.1 (est.)[b]	U [d]
Diazodinitrophenol	C_6-H_3-N_4-O_5	DDNP	4682-03-5	211.11	230.43 (est.)[b]	538.16 (est.)[b]	1.95×10^{-12} @ 25°C (est.)[b]	630.5 @ 25°C (est.)[b]	2.09 (est.)[b]	NA [d, e]	2.86×10^{-9} (est.)[b]
Lead styphnate	C_6-H-N_3-O_8-Pb	-	15245-44-0	468.3	235 (decomp)[a]	260-310 (explodes)[c]	2.65×10^{-9} @ 25°C (est.)[b]	Practically insoluble in water [a]	1.06 (est.)[b]	3010 (est.)[b]	3.58×10^{-11} (est.)[b]
Tetracene	C_{18}-H_{12}	-	92-24-0	228.30	357[b]	399 (est.)[b]	2.49×10^{-9} [b]	0.00151 @ 25°C [b]	5.76 [b]	6.46×10^{5} [b]	5.01×10^{-6} (est.)[b]
Potassium dinitrobenzofuroxane	K-C_6-H_4-N_4-O_6	KDNBF	42994-94-5	265.20	210 (explodes)[c]	NA [d]	U [d]	2,450 @ 30°C[c]	0.99 (est.)[g]	U [d]	U [d]
Lead mononitroresorcinate	C_6-H_5-N-O_4-Pb	LMNR	51317-24-9	364.32	U [d]	U [d]	U [d]	U [d]	1.31 (est.)[g]	U [d]	U [d]

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Questions?

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MUNITIONS CONSTITUENTS WEBINAR

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US Army Corps of Engineers

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Time Slot	*Topic*	*Presenter*
1300 - 1310	Welcome & Introduction	Dwayne Ford, EM CX; Jean Balent, EPA
1310 - 1330	Keynote Speaker	Glenn Marks, Omaha Design Center
1330 - 1400	Qualitative Identification of Explosives to Avoid False Positive Results	Andrea Sansom, URS
1400 - 1430	Proposed Changes for USEPA Method 3050B, Metals Digestion, Incorporating Incremental Sampling Methodology	Jay Clausen, ERDC-CRREL
1430 - 1445	*Intermission*	
1445 - 1515	MC at MRSs -Where's the Beef?	Cliff Opdyke, Baltimore District
1515 - 1545	Munitions Constituents as Emerging Contaminants	Anita Meyer, EM CX
1545 - 1615	Assessing the Fate of Munitions Constituents with TREECS™	Billy Johnson and Mark Dortch, ERDC- EL
1615 - 1645	Questions and Open Discussion	Deborah Walker, EM CX

Munitions Constituents Webinar Registration

- Military Munitions Support Services - Munitions Constituents
- http://clu-in.org/conf/tio/register/new.cfm?date=733
- April 24, 2014
- 1:00 PM - 4:45 PM, EDT
- FREE
- Not restricted to government or contractor attendance