



Which Liquid Scintillation Counting Prep Technique Can We Count On?

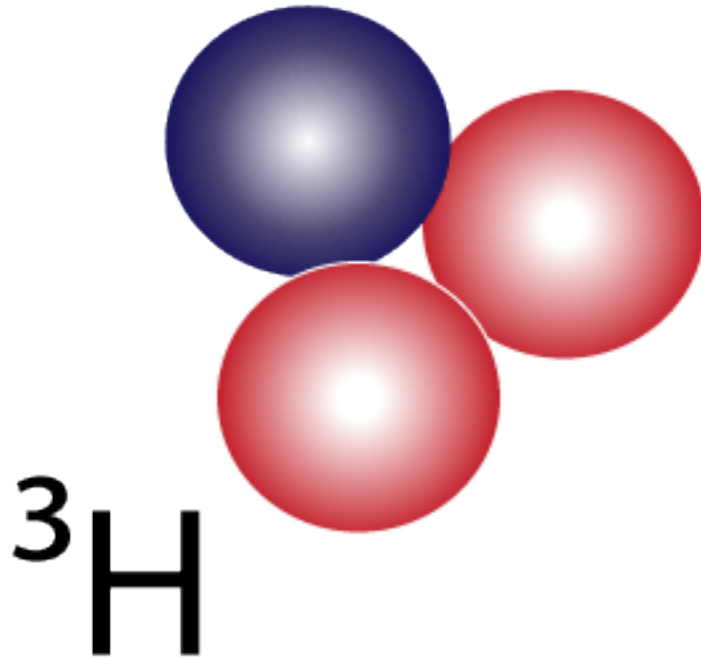
Katherine Guo

Mentors: Amber Kenney, Meka
Francis, Eric Korzeniowski

Matt Quinn

Tritium

- What is tritium?



Why's

- Why is this important to Fermilab?
- Why do we have to?
- ALARA THAT'S WHY

Liquid Scinti-what?

- Liquid Scintillation Counting
- Did I stutter
- Cocktails (not the fun kind)
- How the machine does the thing
- CPM>>DPM>>Activity



Figure 1A.1a Passing through scintillation fluid, a single beta particle gives rise to multiple, nearly simultaneous emissions of light. These photons are registered by the photomultiplier tube as one pulse of energy. The magnitude of this light pulse corresponds to the number of photons.

$$\text{bkgd}_{\text{avg}} = \frac{(\text{bkgd } 1 + \text{bkgd } 2 + \text{bkgd } 3 + \text{bkgd } 4)}{4}$$

$$\delta\text{bkgd} = \sqrt{\frac{(\text{bkgd } 1 - \text{bkgd}_{\text{avg}})^2 + (\text{bkgd } 2 - \text{bkgd}_{\text{avg}})^2 + (\text{bkgd } 3 - \text{bkgd}_{\text{avg}})^2 + (\text{bkgd } 4 - \text{bkgd}_{\text{avg}})^2}{4 - 1}}$$

$$\text{cpm}_{\text{avg}} = \frac{(\text{cpm } 1 + \text{cpm } 2)}{2}$$

$$\delta\text{cpm} = \sqrt{\frac{(\text{cpm } 1 - \text{cpm}_{\text{avg}})^2 + (\text{cpm } 2 - \text{cpm}_{\text{avg}})^2}{2 - 1}}$$

$$\text{cpm}_{\text{net}} = \text{cpm}_{\text{avg}} - \text{bkgd}_{\text{avg}}$$

$$\delta\text{cpm}_{\text{net}} = \sqrt{(\delta\text{cpm})^2 + (\delta\text{bkgd})^2}$$

$$\text{eff}_{\text{avg}} = \frac{(\text{eff } 1 + \text{eff } 2)}{2}$$

$$\delta\text{eff} = \sqrt{\frac{(\text{eff } 1 - \text{eff}_{\text{avg}})^2 + (\text{eff } 2 - \text{eff}_{\text{avg}})^2}{2 - 1}}$$

$$\text{dpm} = \frac{\text{cpm}_{\text{net}}}{\text{eff}_{\text{avg}}}$$

$$\delta\text{dpm} = \text{dpm} \left[\sqrt{\left(\frac{\delta\text{eff}}{\text{eff}_{\text{avg}}}\right)^2 + \left(\frac{\delta\text{cpm}_{\text{net}}}{\text{cpm}_{\text{net}}}\right)^2}\right]$$

$$\text{Activity} = \frac{\text{dpm} \pm \delta\text{dpm}}{\text{LSC Conv. Factor}}$$

3.7E+10 decays per second/ Ci

3.7E+10 dps/Ci * 60 seconds/min = 2.22E+12 dpm/Ci

2.22E+12 dpm/Ci * 1.0E-12 Ci/pCi = 2.22 dpm/pCi

If our sample is 2.5ml:

2.5ml * 2.22dpm/pCi = 5.5 dpm ml/pCi

What is my Purpose?

- To improve or affirm the effectiveness of Fermilab's tritium testing methods
- Basically, an epic quest for the “best” method

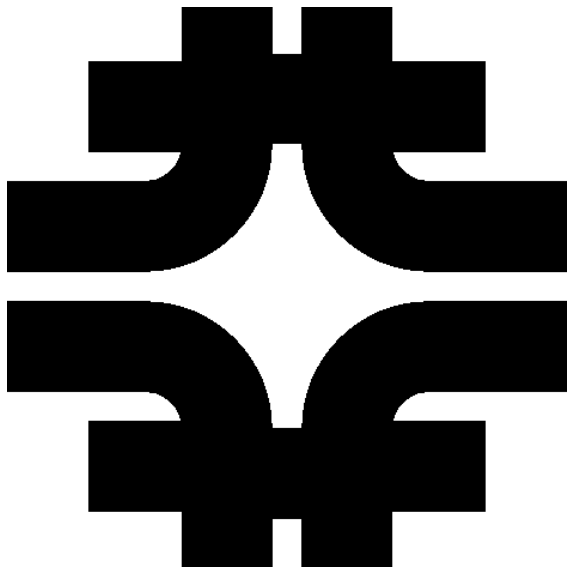


A Tale of Two Procedures

- Fermilab Procedure 210 of the Radionuclide Analysis Facility vs. EPA Method 906.0
- Fermilab: filter the sample
- EPA: oxidize everything in the water with an alkaline solution, then distill the sample

A Closer Look

- Treating the more complex and intensive EPA procedure as the gold standard
- Not really a competition, just seeing if the shortcut is acceptable



EPA Limits

- Surface Water Standards for DOE Facilities: 1900 pCi/mL
- Sewer water: 9500 pCi/mL
- Federal Drinking Water Standards: 20 pCi/mL
- Tritium concentrations in Indian Creek at site boundary: 1-3 pCi/mL
- Tritium concentrations in sanitary sewer water pumped to Batavia: 1-8 pCi/mL

WHAT DOOOO?




- Take samples
- Prep samples
- Count samples

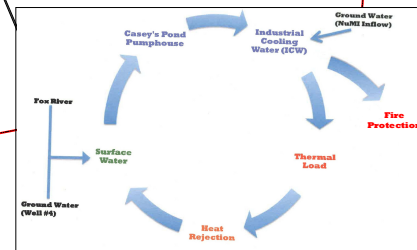
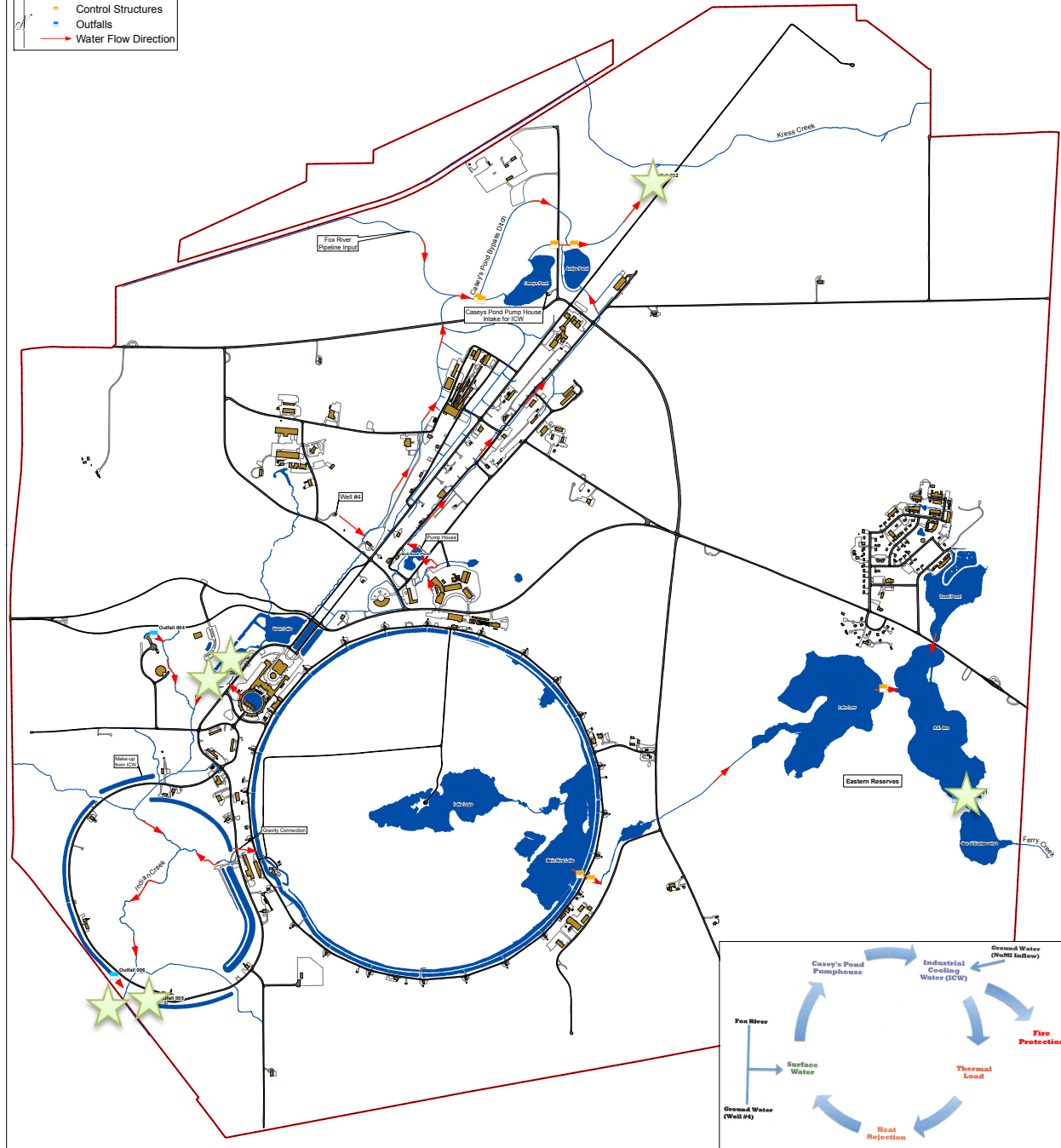
Sampling Locations



Fermilab Surface Water Flow/Control Map

Legend

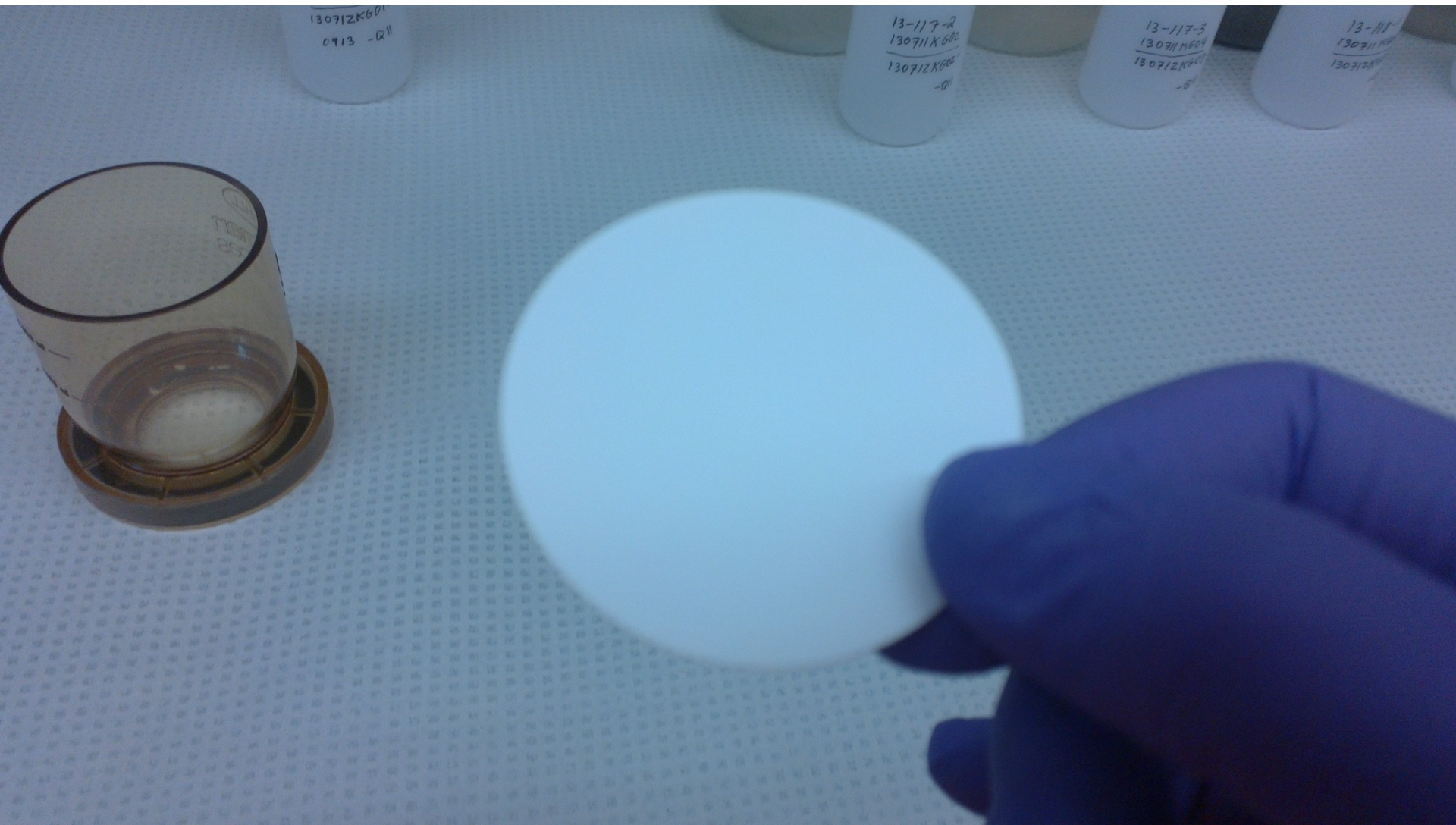
-  Control Structures
-  Outfalls
-  Water Flow Direction



Procedures in Graphic Detail

- *GRAPHIC I SAY*

Current Fermilab Method

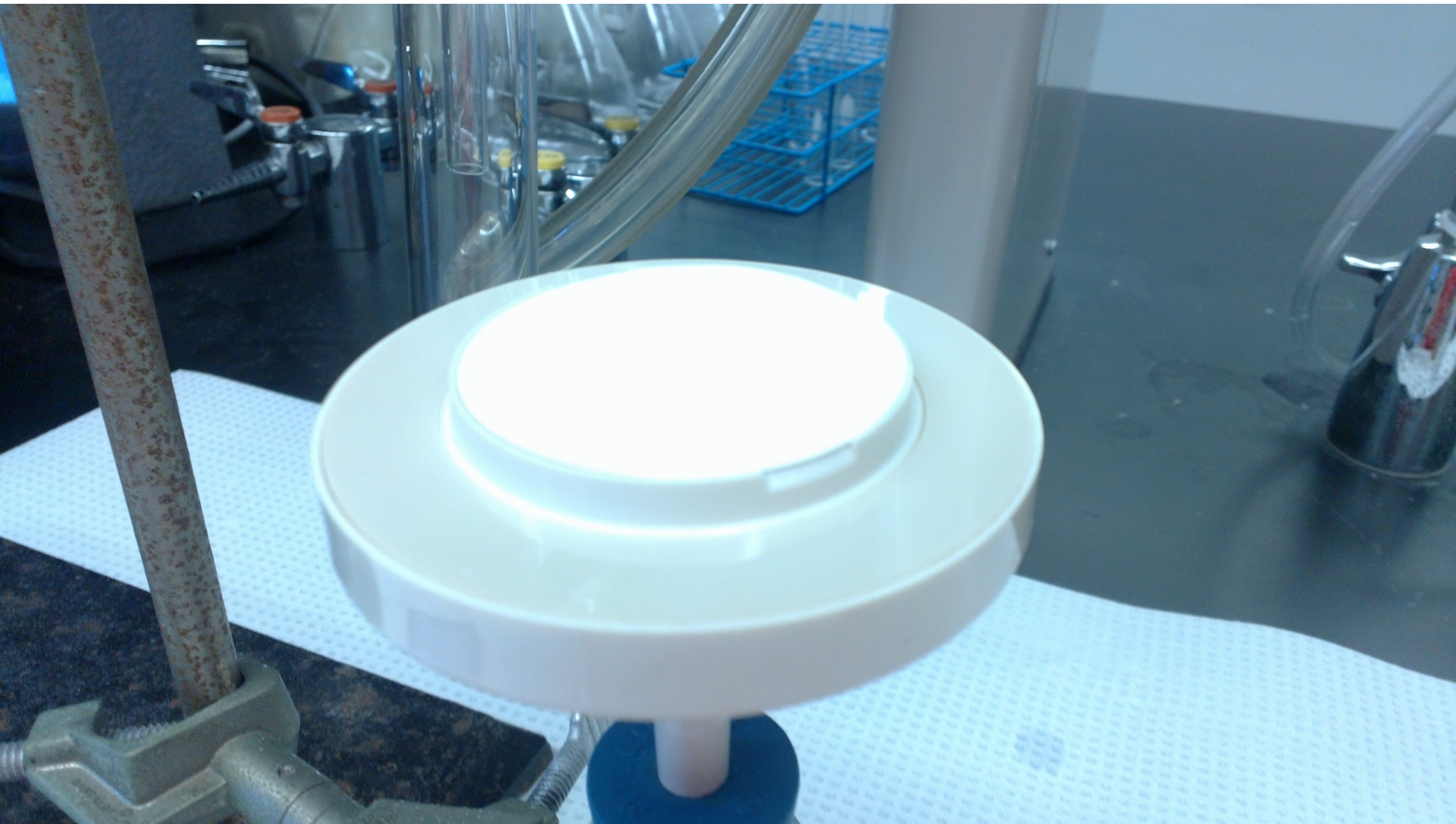


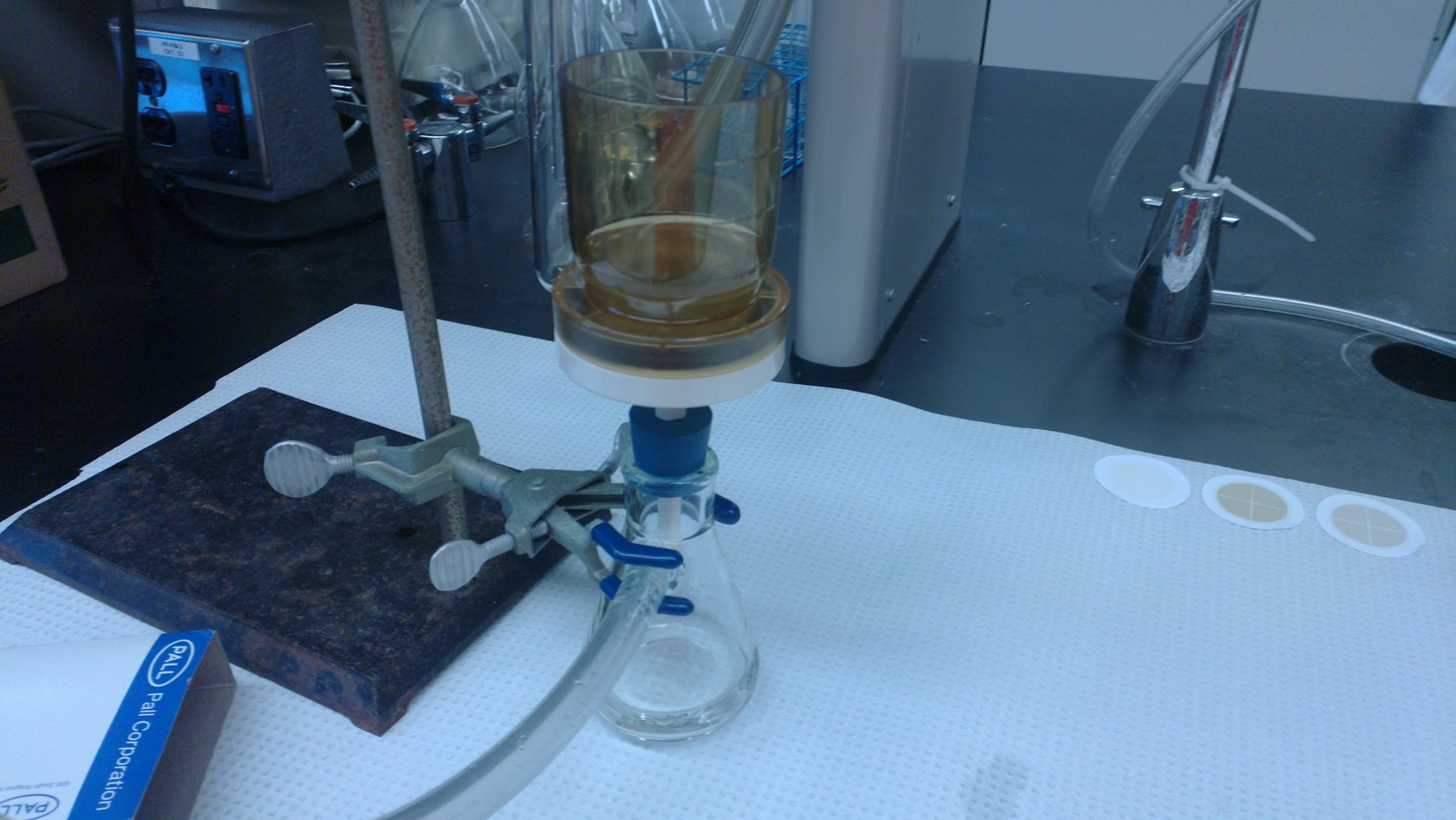
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0913 -R11

13-117-2
130711K602
130712K606
-R11

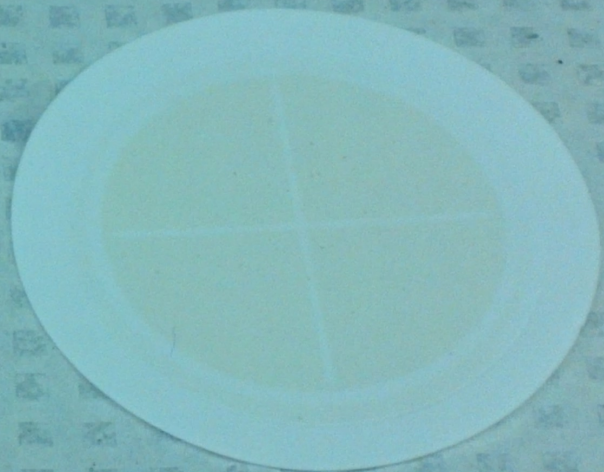
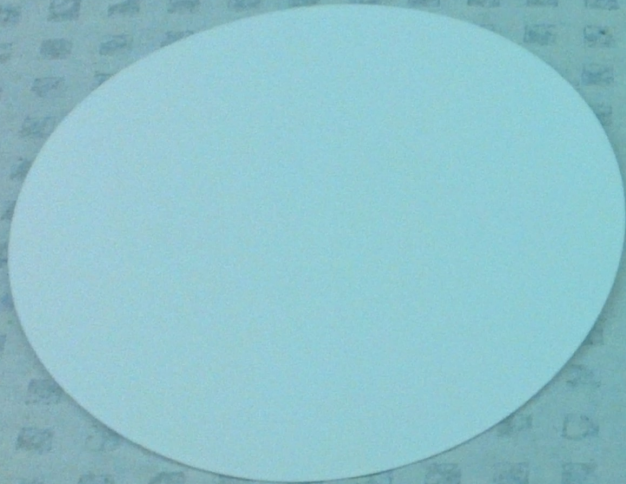
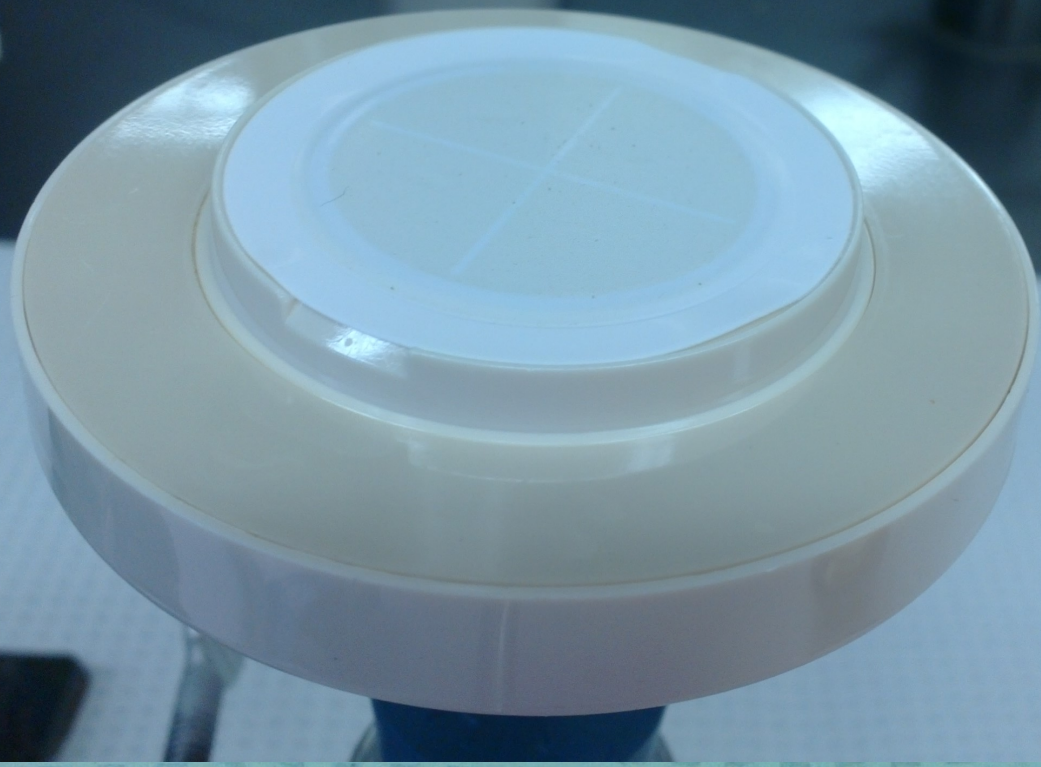
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130711K604
130712K603
-R11

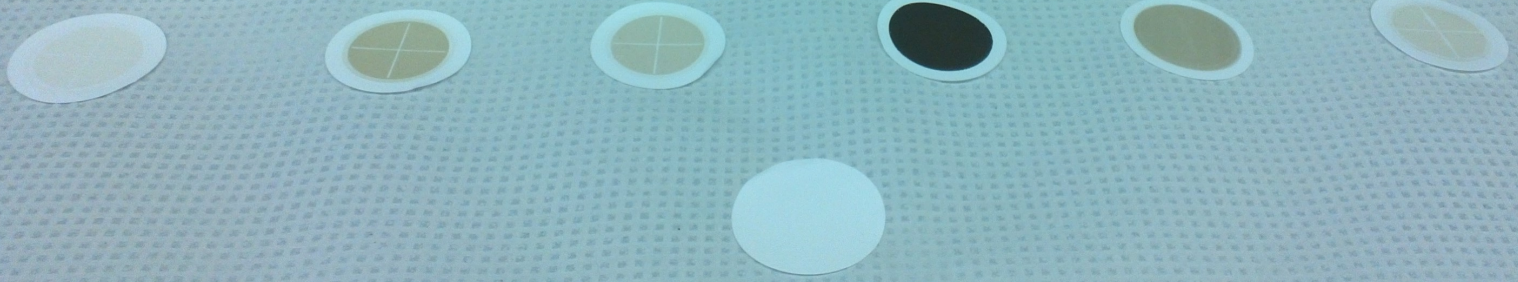
13-118
130711K605
130712K601





PALL Pall Corporation





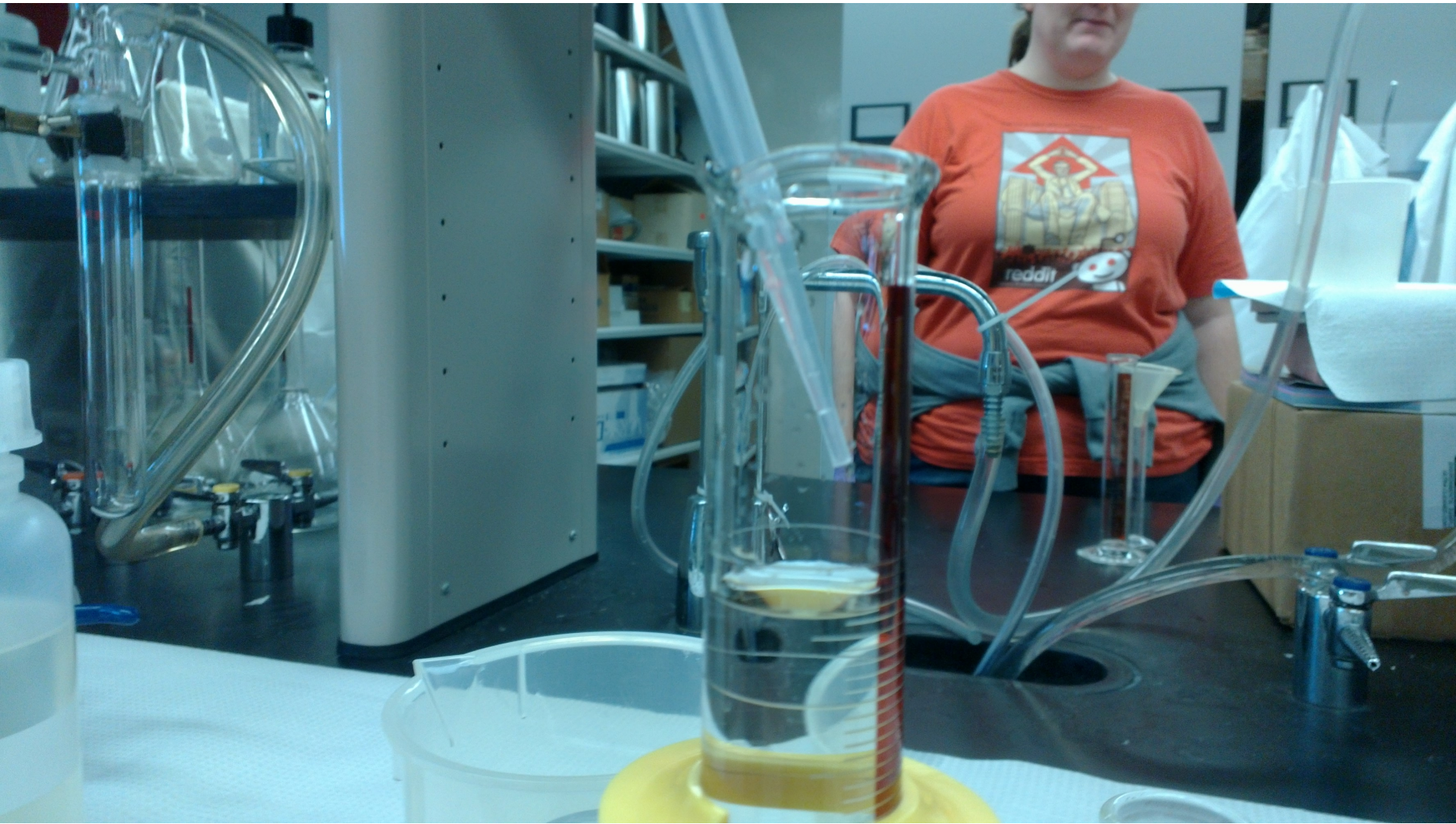
EPA Method 906.0

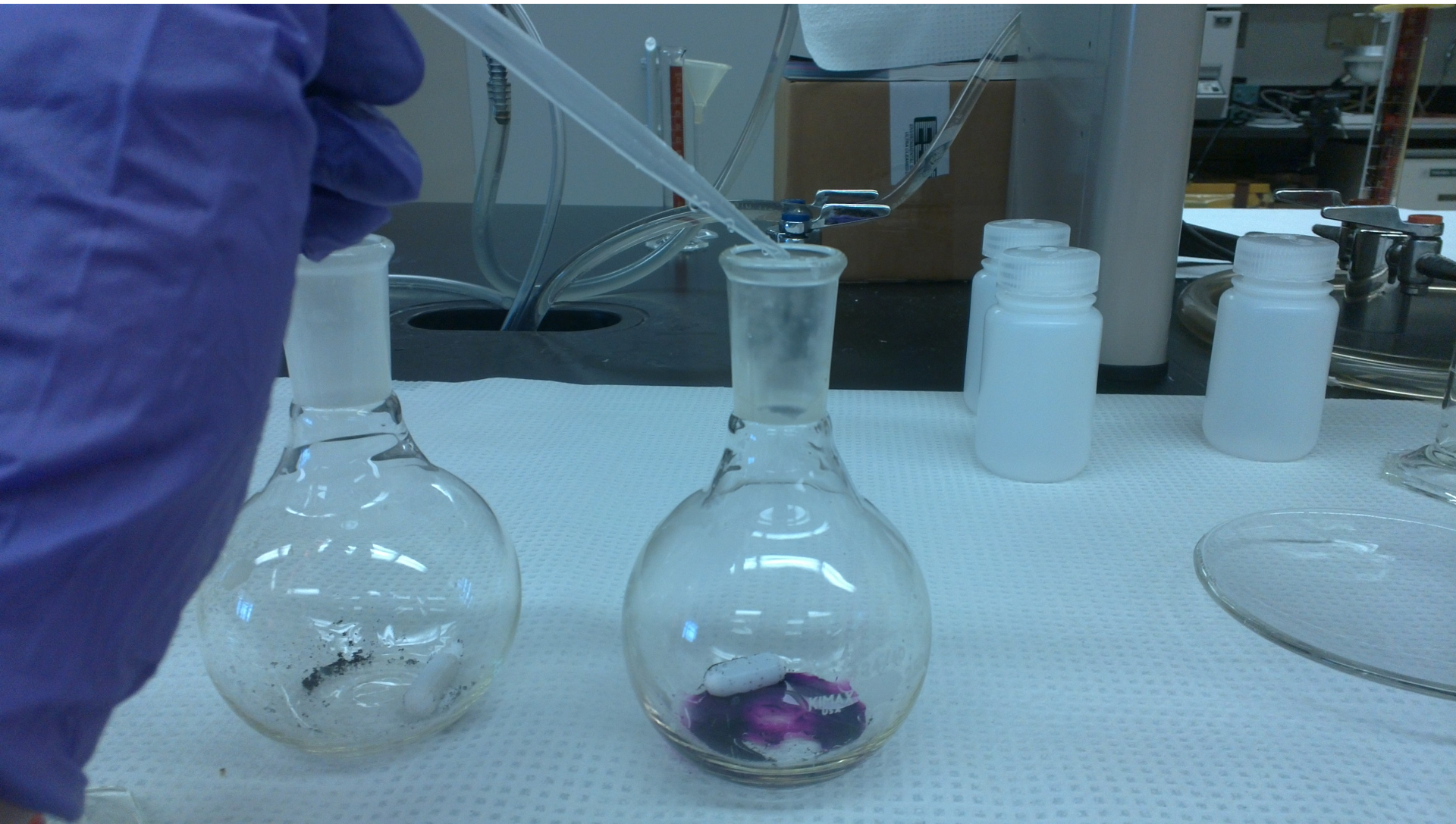


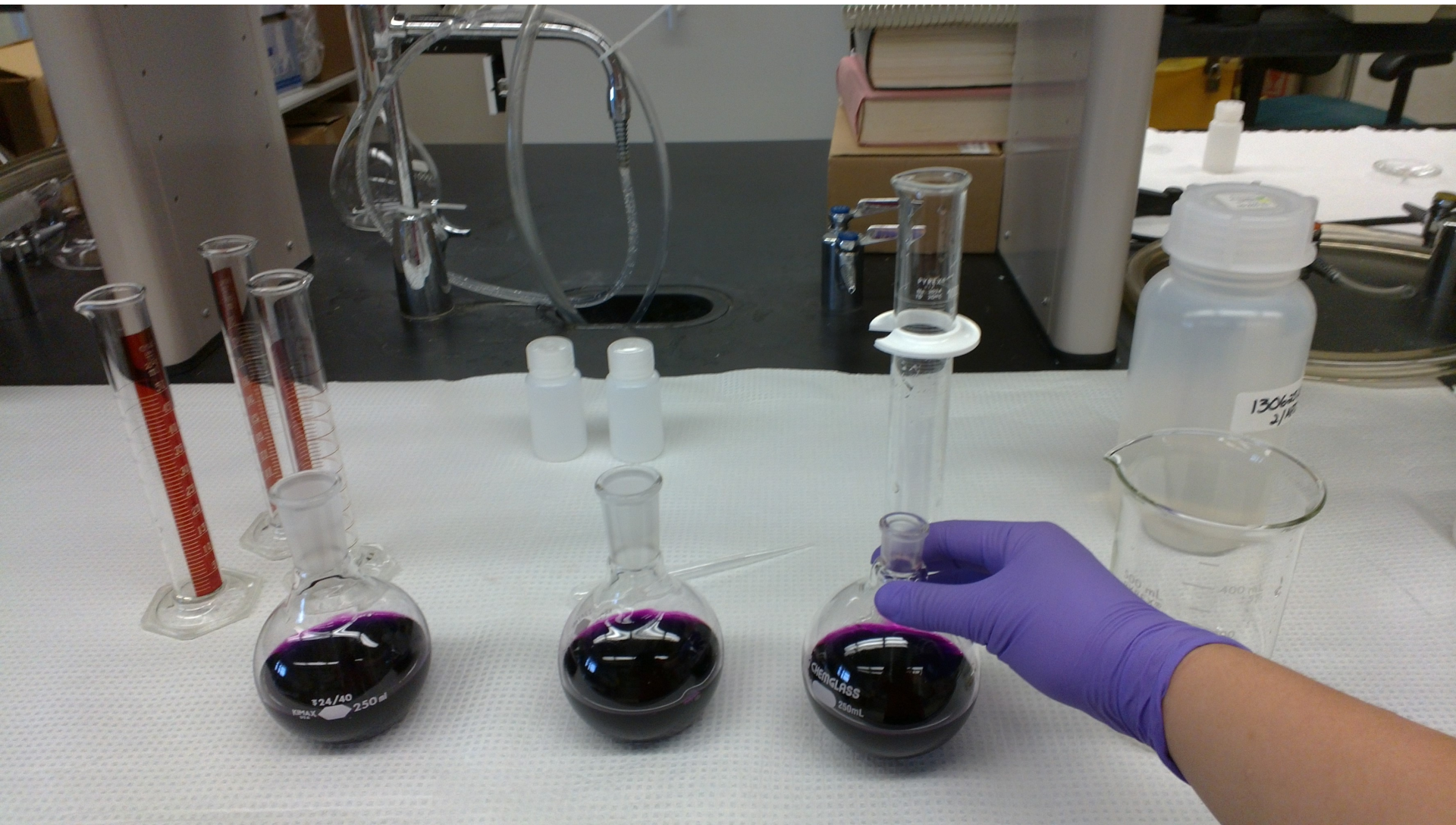


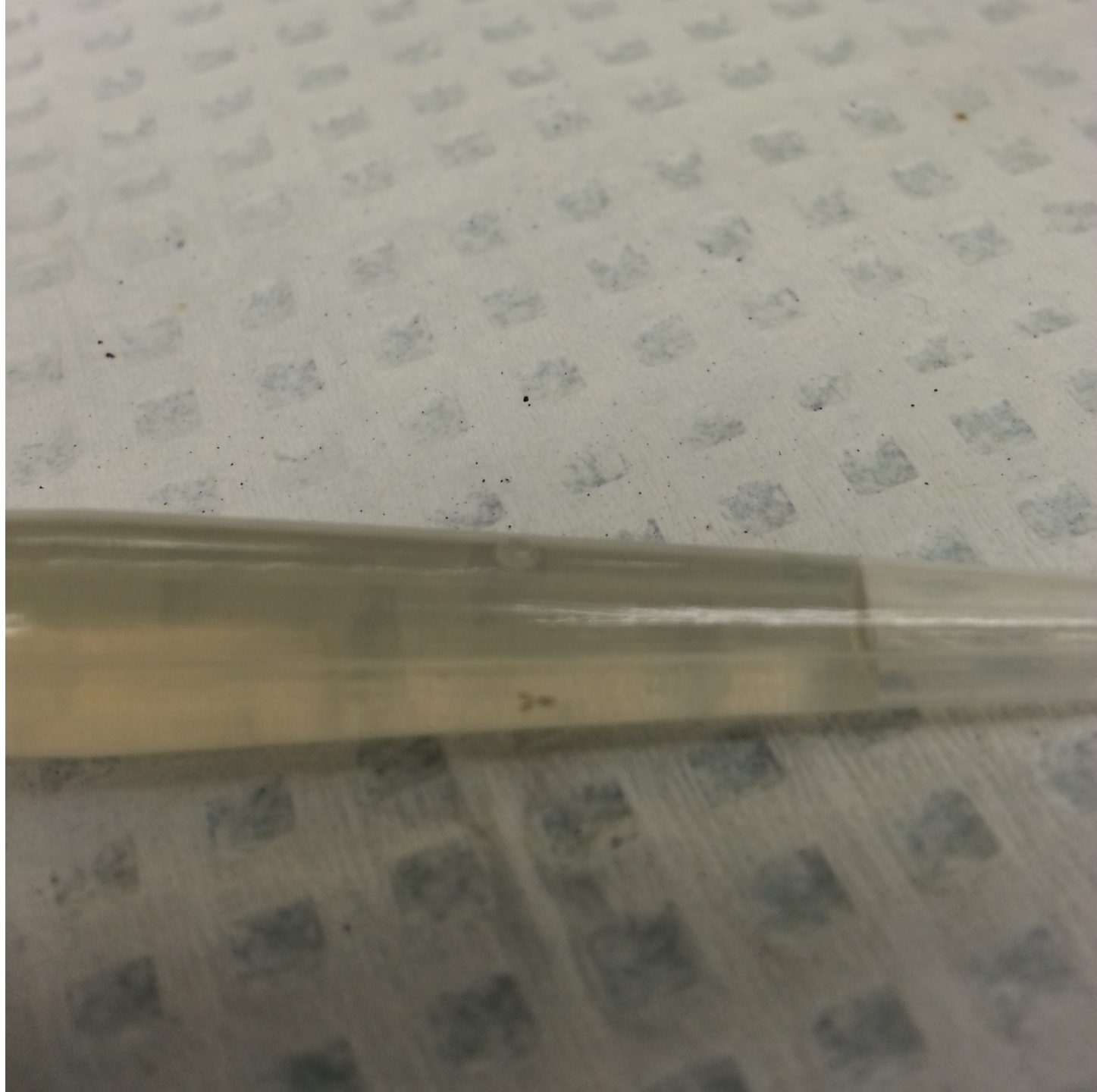


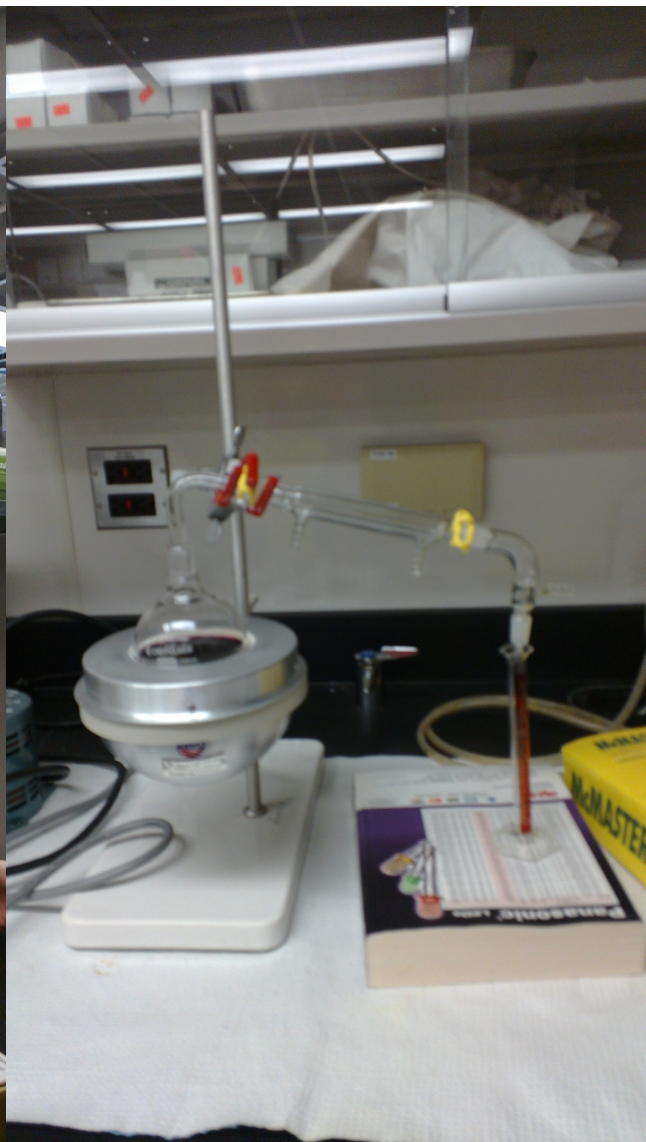
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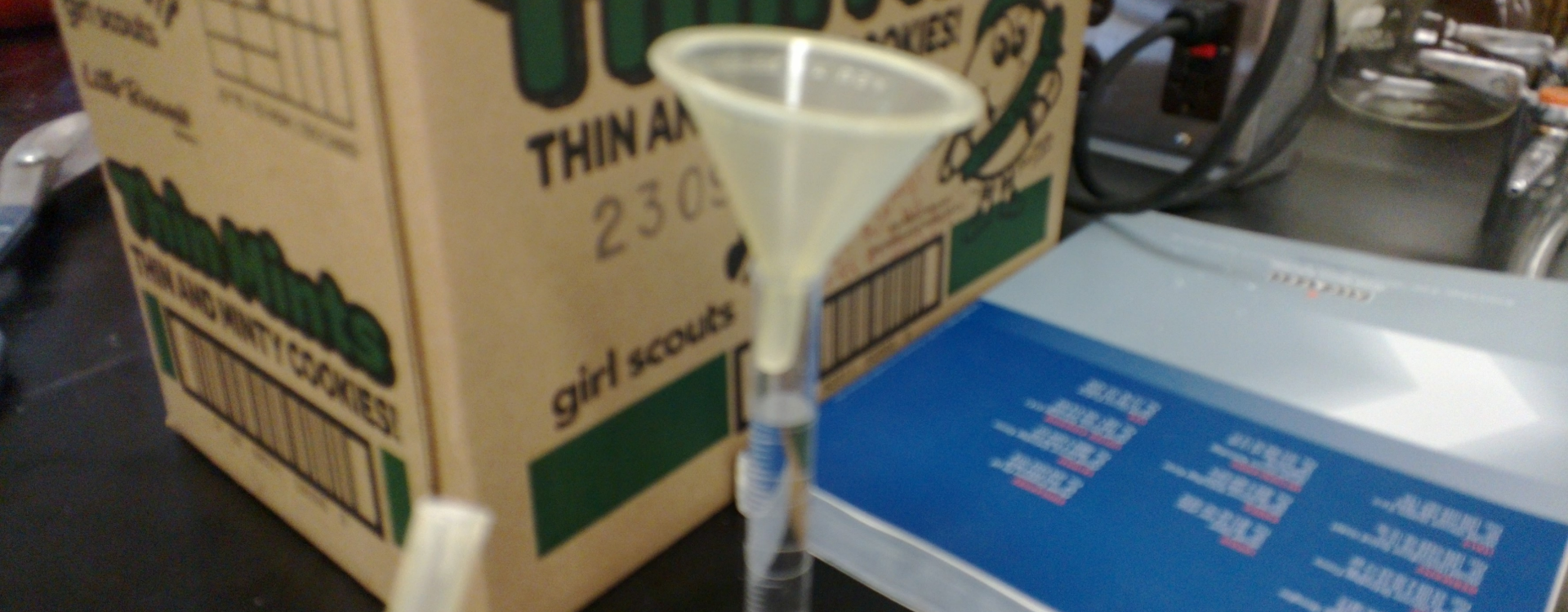












A Very Brief Overview of What Happens Post-Prep

Sample Prep, Old_130723-D.xlsm MF

Prep: Sample set made up in antistatic vials using 10.0 mL of Ultima Gold AB cocktail and 2.5 mL of sample material.
 Static controller is - ON / QEP All vials have been wiped off with distilled water prior to loading into the LSC.
 Made-up: 7/22/13 19:20 Put in LSC: 7/22/13 20:40 Started: Run#: 130723-D
 LSC: () 2260XL () 2750LL/AB, (x) 3170TR/SL Notes: 120 min. Protocol#: 9

Sample ID #	Vial No.	Tray No.	Work Req. Number	Sample Prep.	Report To:	Sample Description:
Blank	1	101	Bkgd.	--	--	Distilled Water
1206-1-L06	2	102	QA	--	--	LSC Spike @ 1.45 pCi/mL
130711KG05	3	103	13-118	Dist.	RAF	Outfall 003 - 906.0 (1)
130711KG05	4	104	13-118	Dist.	RAF	Outfall 003 - 906.0 (2)
130711KG05	5	105	13-118	Dist.	RAF	Outfall 003 - 906.0 (3)
1206-1-001	6	106	QA	--	--	LSC Spike @ 1.93 pCi/mL
130711KG05	7	107	13-118	--	RAF	Outfall 003 - No prep (1)
130711KG05	8	108	13-118	--	RAF	Outfall 003 - No prep (2)
130711KG05	9	109	13-118	--	RAF	Outfall 003 - No prep (3)
1206-1-002	10	110	QA	--	--	LSC Spike @ 4.83 pCi/mL
130711KG06	11	111	13-118	Dist.	RAF	Outfall 002 - 906.0 (1)
130711KG06	12	112	13-118	Dist.	RAF	Outfall 002 - 906.0 (2)
130711KG06	13	201	13-118	Dist.	RAF	Outfall 002 - 906.0 (3)
1206-1-002	14	202	QA	--	--	LSC Spike @ 4.83 pCi/mL
130711KG06	15	203	13-118	--	RAF	Outfall 002 - No prep (1)
130711KG06	16	204	13-118	--	RAF	Outfall 002 - No prep (2)
130711KG06	17	205	13-118	--	RAF	Outfall 002 - No prep (3)
Blank	18	206	Bkgd.	--	--	Distilled Water
	19	207				
	20	208				
	21	209				
	22	210				
	23	211				
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Sample Prep, Old_130712-A.xlsm MF

Prep: Sample set made up in antistatic vials using 10.0 mL of Ultima Gold AB cocktail and 2.5 mL of sample material.
 Static controller is - ON / QEP All vials have been wiped off with distilled water prior to loading into the LSC.
 Made-up: 7/22/13 11:40 Put in LSC: 7/22/13 12:20 Started: Run#: 130712-A
 LSC: () 2260XL () 2750LL/AB, (x) 3170TR/SL Notes: 60 min. Protocol#: 13

Sample ID #	Vial No.	Tray No.	Work Req. Number	Sample Prep.	Report To:	Sample Description:
Blank	1	101	Bkgd.	--	--	Distilled Water
1206-1-L06	2	102	QA	--	--	LSC Spike @ 1.45 pCi/mL
130711KG01	3	103	13-117	Filter 0.45 um	EPG	MI Pond C (1)
130711KG01	4	104	13-117	Filter 0.45 um	EPG	MI Pond C (2)
130711KG01	5	105	13-117	Filter 0.45 um	EPG	MI Pond C (3)
1206-1-001	6	106	QA	--	--	LSC Spike @ 1.93 pCi/mL
130711KG02	7	107	13-117	Filter 0.45 um	EPG	Kidney Pond (1)
130711KG02	8	108	13-117	Filter 0.45 um	EPG	Kidney Pond (2)
130711KG02	9	109	13-117	Filter 0.45 um	EPG	Kidney Pond (3)
1206-1-002	10	110	QA	--	--	LSC Spike @ 4.83 pCi/mL
130711KG04	11	111	13-117	Filter 0.45 um	EPG	Indian Creek Boundary (1)
130711KG04	12	112	13-117	Filter 0.45 um	EPG	Indian Creek Boundary (2)
130711KG04	13	201	13-117	Filter 0.45 um	EPG	Indian Creek Boundary (3)
9701-3-003	14	202	QA	--	--	LSC Spike @ 7.51 pCi/mL
1206-1-004	15	203	QA	--	--	LSC Spike @ 48.3 pCi/mL
Blank	16	204	Bkgd.	--	--	Distilled Water
	17	205				
	18	206				
	19	207				
	20	208				
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	23	211				
	24	212				

120 Min. Re-Run - Protocol #13

Sample Prep, Old_130712-B.xlsm MF

Prep: Sample set made up in antistatic vials using 10.0 mL of Ultima Gold AB cocktail and 2.5 mL of sample material.
 Static controller is - ON / QEP All vials have been wiped off with distilled water prior to loading into the LSC.
 Made-up: 7/22/13 12:45 Put in LSC: 7/22/13 13:05 Started: Run#: 130712-B
 LSC: () 2260XL () 2750LL/AB, (x) 3170TR/SL Notes: Protocol 28 80 min Protocol#: 28

Sample ID #	Vial No.	Tray No.	Work Req. Number	Sample Prep.	Report To:	Sample Description:
Blank	1	101	Bkgd.	--	--	Distilled Water
1206-1-L06	2	102	QA	--	--	LSC Spike @ 1.45 pCi/mL
130711KG03	3	103	13-118	Filter 0.45 um	EPG	Outfall 001 (1)
130711KG03	4	104	13-118	Filter 0.45 um	EPG	Outfall 001 (2)
130711KG03	5	105	13-118	Filter 0.45 um	EPG	Outfall 001 (3)
1206-1-001	6	106	QA	--	--	LSC Spike @ 1.93 pCi/mL
130711KG05	7	107	13-118	Filter 0.45 um	EPG	Outfall 003 (1)
130711KG05	8	108	13-118	Filter 0.45 um	EPG	Outfall 003 (2)
130711KG05	9	109	13-118	Filter 0.45 um	EPG	Outfall 003 (3)
1206-1-002	10	110	QA	--	--	LSC Spike @ 4.83 pCi/mL
130711KG06	11	111	13-118	Filter 0.45 um	EPG	Outfall 002 (1)
130711KG06	12	112	13-118	Filter 0.45 um	EPG	Outfall 002 (2)
130711KG06	13	201	13-118	Filter 0.45 um	EPG	Outfall 002 (3)
9701-3-003	14	202	QA	--	--	LSC Spike @ 7.51 pCi/mL
1206-1-004	15	203	QA	--	--	LSC Spike @ 48.3 pCi/mL
Blank	16	204	Bkgd.	--	--	Distilled Water
	17	205				
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	23	211				
	24	212				

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120 Min Re-Run - Protocol # 47

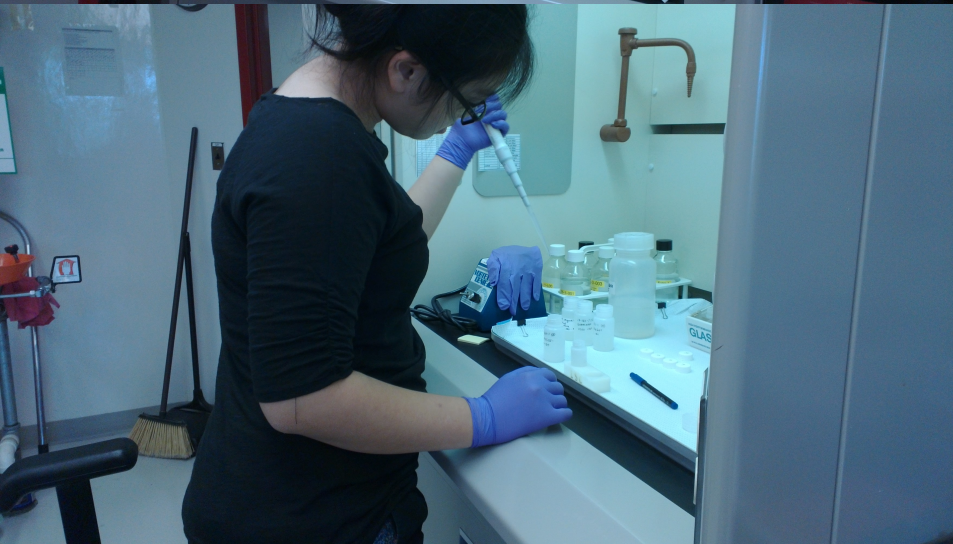
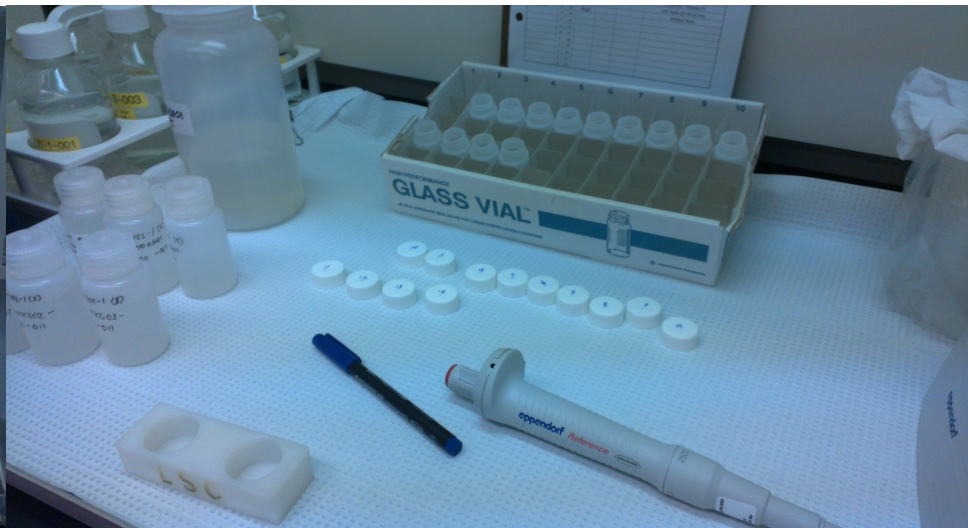
Sample Prep, Old_130723-C.xlsm MF

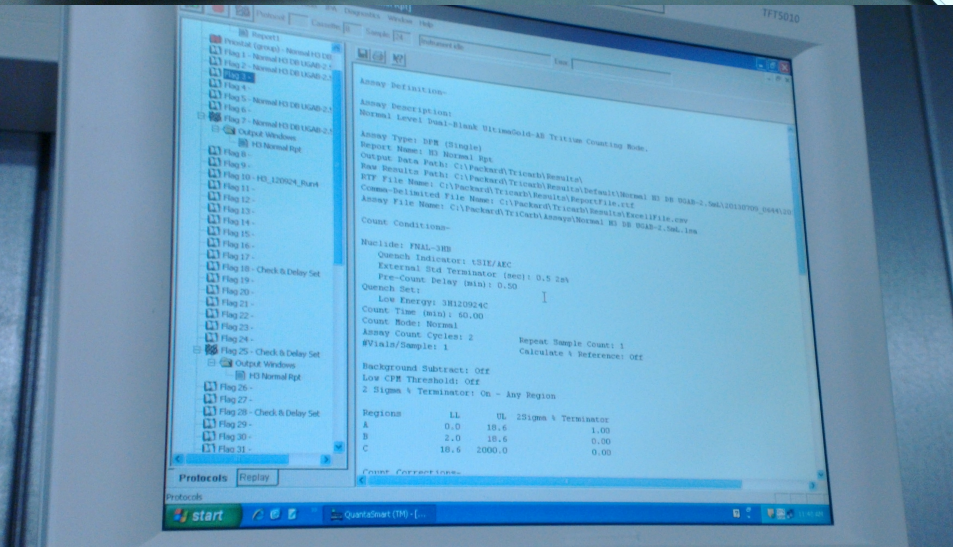
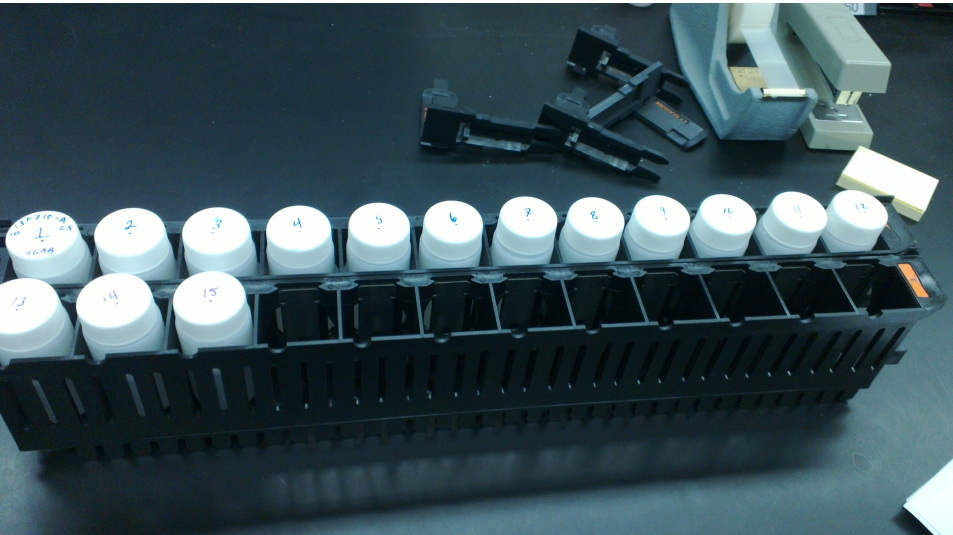
Prep: Sample set made up in antistatic vials using 10.0 mL of Ultima Gold AB cocktail and 2.5 mL of sample material.
 Static controller is - ON / QEP All vials have been wiped off with distilled water prior to loading into the LSC.
 Made-up: 7/22/13 19:20 Put in LSC: 7/22/13 20:40 Started: Run#: 130723-C
 LSC: () 2260XL () 2750LL/AB, (x) 3170TR/SL Notes: 120 min. Protocol#: 14

Sample ID #	Vial No.	Tray No.	Work Req. Number	Sample Prep.	Report To:	Sample Description:
Blank	1	101	Bkgd.	--	--	Distilled Water
1206-1-L06	2	102	QA	--	--	LSC Spike @ 1.45 pCi/mL
130711KG04	3	103	13-117	Dist.	RAF	Indian Creek Bdry - 906.0 (1)
130711KG04	4	104	13-117	Dist.	RAF	Indian Creek Bdry - 906.0 (2)
130711KG04	5	105	13-117	Dist.	RAF	Indian Creek Bdry - 906.0 (3)
1206-1-001	6	106	QA	--	--	LSC Spike @ 1.93 pCi/mL
130711KG04	7	107	13-117	--	RAF	Indian Creek Bdry - No prep (1)
130711KG04	8	108	13-117	--	RAF	Indian Creek Bdry - No prep (2)
130711KG04	9	109	13-117	--	RAF	Indian Creek Bdry - No prep (3)
1206-1-002	10	110	QA	--	--	LSC Spike @ 4.83 pCi/mL
130711KG03	11	111	13-118	Dist.	RAF	Outfall 001 - 906.0 (1)
130711KG03	12	112	13-118	Dist.	RAF	Outfall 001 - 906.0 (2)
130711KG03	13	201	13-118	Dist.	RAF	Outfall 001 - 906.0 (3)
1206-1-002	14	202	QA	--	--	LSC Spike @ 4.83 pCi/mL
130711KG03	15	203	13-118	--	RAF	Outfall 001 - No prep (1)
130711KG03	16	204	13-118	--	RAF	Outfall 001 - No prep (2)
130711KG03	17	205	13-118	--	RAF	Outfall 001 - No prep (3)
Blank	18	206	Bkgd.	--	--	Distilled Water
	19	207				
	20	208				
	21	209				
	22	210				
	23	211				
	24	212				

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RESULTS

- Fermilab's procedure was quite consistent with EPA's 906.0
- Both treatments proved more effective than no preparation at all...

Home | Layout | Tables | Charts | SmartArt | Formulas | Data | Review

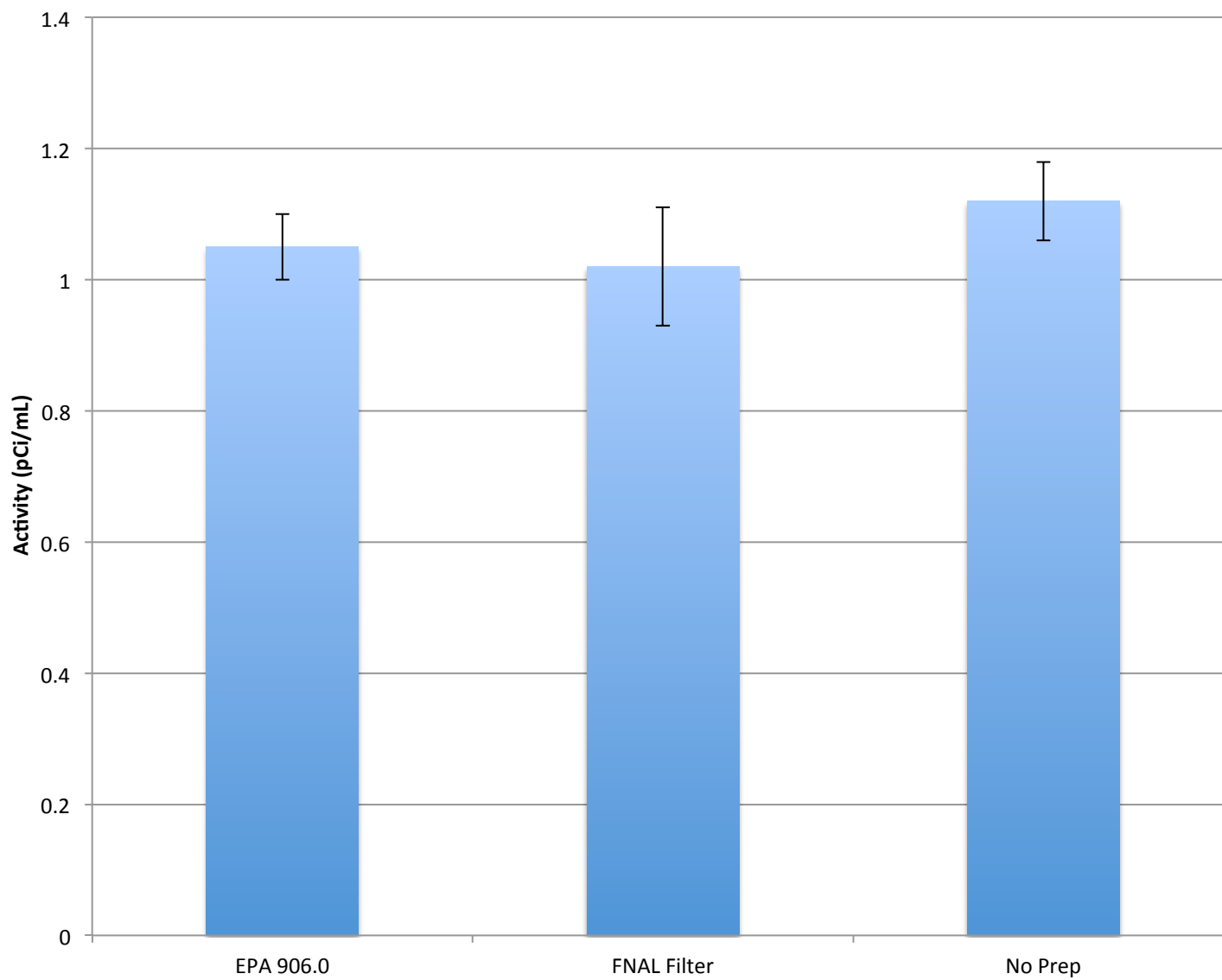
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Formula Bar: =AVERAGE(G4:G6,I4:I6)

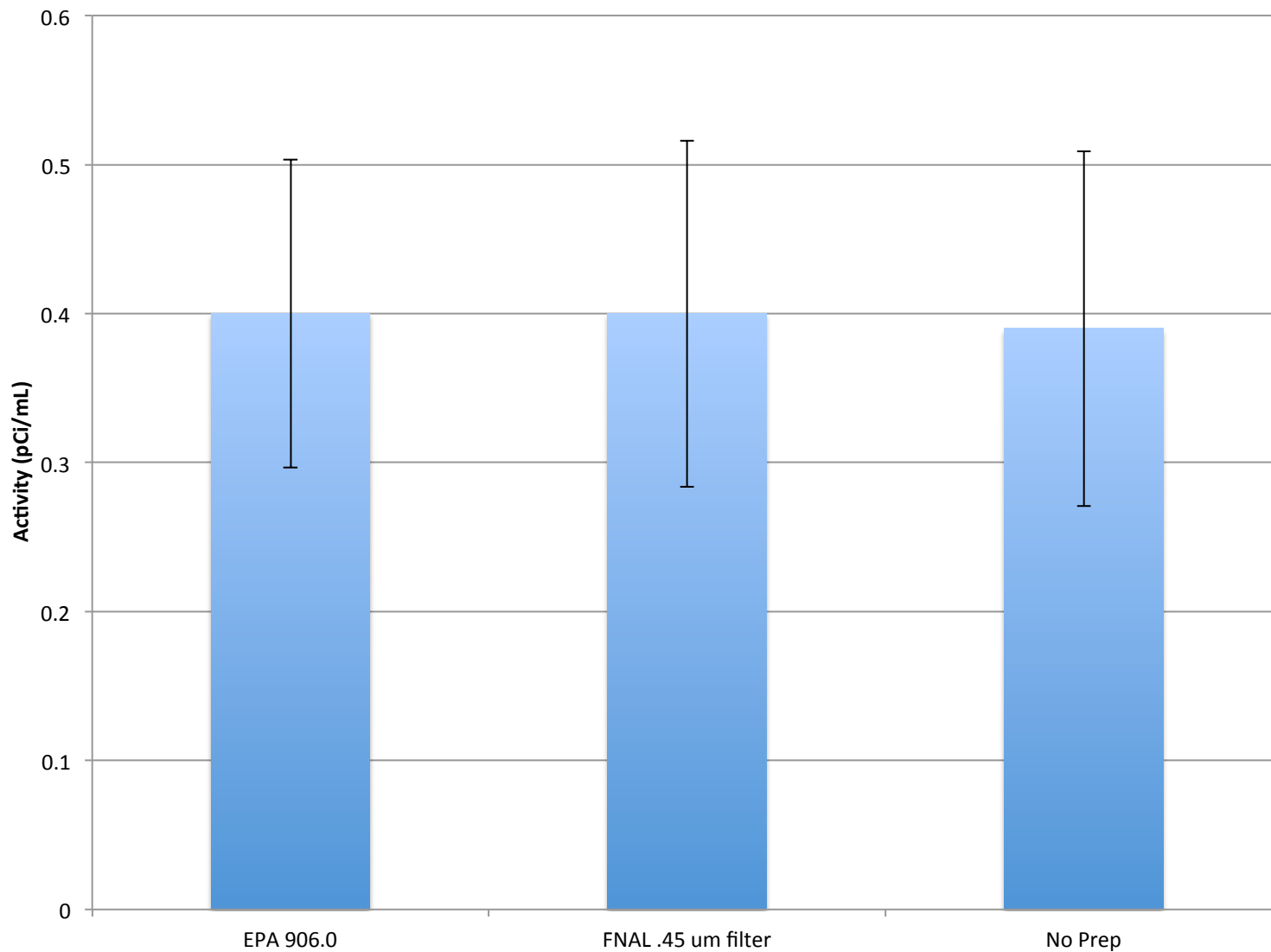
Calibration Data: CPMA & Efficiencies												
Dist. #	Spike - 906.0 Dist.				Dist. H2O + Spike				Raw H ₂ O - 906.0 Dist.			
1	626.88	43.77	635.02	43.96	637.85	44.25	637.28	44.79	3.00	44.27	2.96	44.33
2	633.15	44.06	632.53	44.50	637.31	44.26	636.57	44.74	2.86	44.18	2.65	44.42
3	639.58	44.10	635.53	44.72	636.80	44.04	640.19	44.51	2.79	44.22	2.86	44.34
Run Avg	633.20	43.98	634.36	44.39	637.32	44.18	638.01	44.68	2.88	44.22	2.82	44.36
Run SD	6.35	0.18	1.61	0.39	0.53	0.12	1.92	0.15	0.11	0.05	0.16	0.05
Total CPMA Avg	633.78				637.67				2.85			
Total CPMA Avg - Bkg	630.93				634.81				n/a			
Total CPMA and Bkg Error	4.19				1.32				0.11			
Total Region A Eff Avg	44.19				44.43				44.29			
Total Region A Eff SD	0.36				0.30				0.09			
Activity (pCi/mL)	257.28				257.43				1.16			
±	2.68				1.81				0.05			
13-102 (Outfall 002 - Kress Creek Transfer Ditch): CPMA & Efficiencies												
Bkg Data	2.54	43.50	2.94	44.52	2.54	43.50	2.94	44.52	2.54	43.50	2.94	44.52
	2.58	44.03	2.82	44.30	2.58	44.03	2.82	44.30	2.58	44.03	2.82	44.30
Avg Bkg Data	2.72		44.09		2.72		44.09		2.72		44.09	
±	0.19		0.44		0.19		0.44		0.19		0.44	
Dist. #	906.0 Dist.				0.45 um Filter				No Prep			
1	3.70	44.24	3.99	44.52	3.44	44.16	3.55	44.02	3.57	43.79	3.97	43.85
2	3.61	44.16	3.59	44.49	3.59	43.97	3.98	44.24	3.69	43.86	3.37	44.24
3	3.54	44.03	3.79	44.14	3.89	44.41	3.78	44.62	3.57	44.23	3.87	44.31
Run Avg	3.62	44.14	3.79	44.38	3.64	44.18	3.77	44.29	3.61	43.96	3.74	44.13
Run SD	0.08	0.11	0.20	0.21	0.23	0.22	0.22	0.30	0.07	0.24	0.32	0.25
Total CPMA Avg	3.70				3.71				3.67			
Total CPMA Avg - Bkg	0.98				0.99				0.95			
Total CPMA												

Instrument: PerkinElmer TriCarb 3170 liquid scintillation counter
 Count time: 120 mins.
 Count window: 0-18.6 keV
 2σ Terminator: 1%
 Vials: 20 mL Antistatic Polyethylene
 LSC Cocktail: PerkinElmer Ultima Gold AB
 Sample/Cocktail: 2.5 mL/10 mL

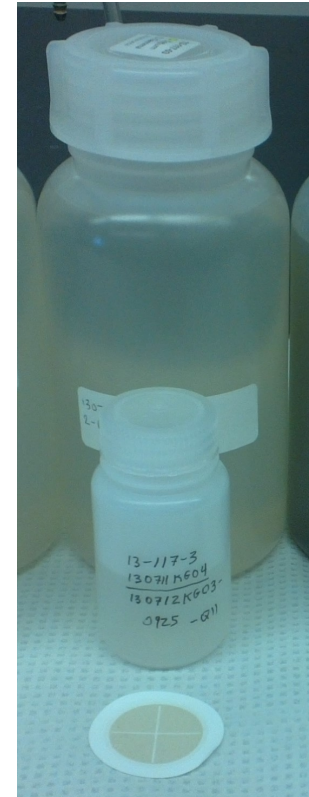
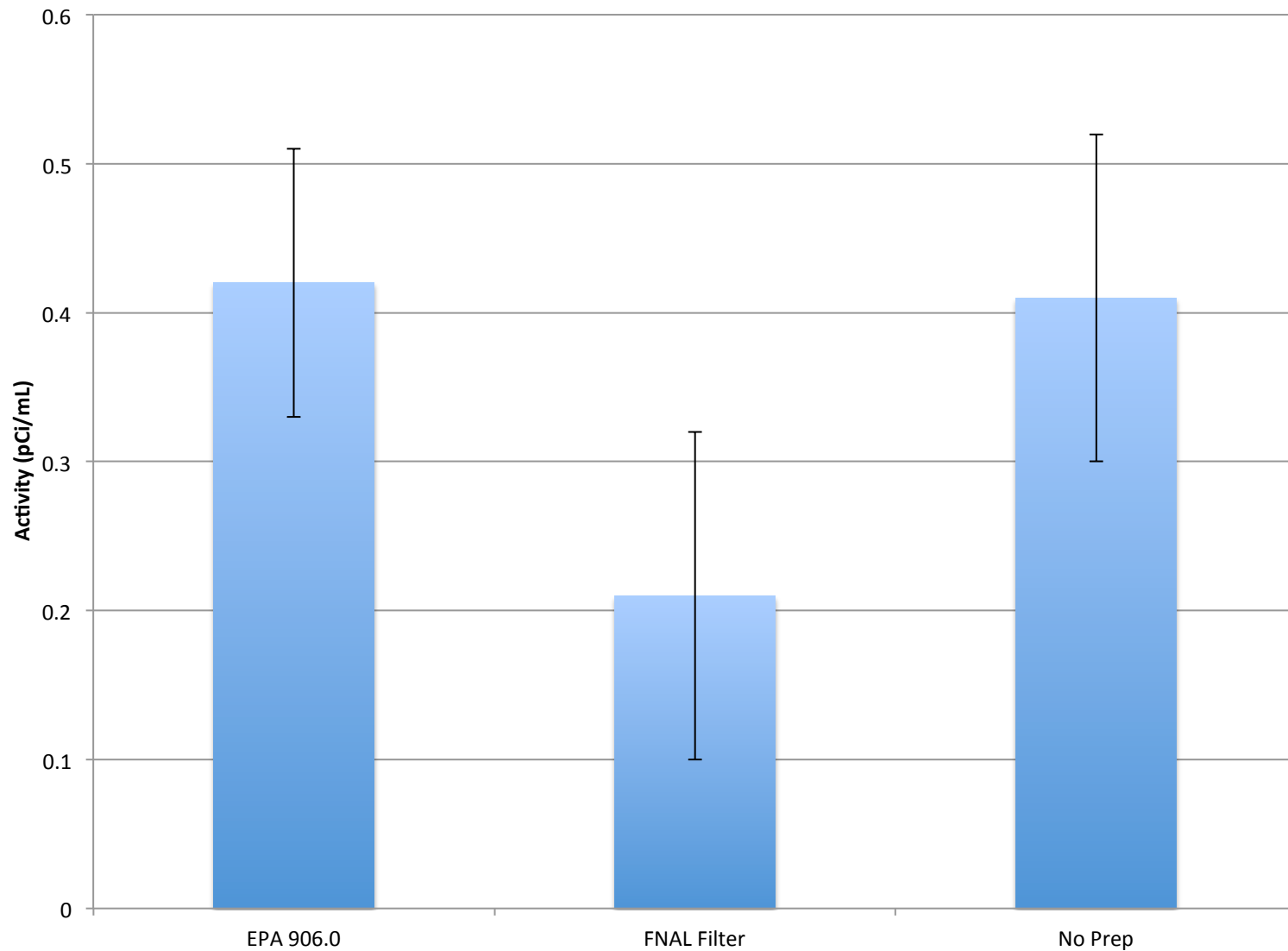
MI Pond C Tritium Activity



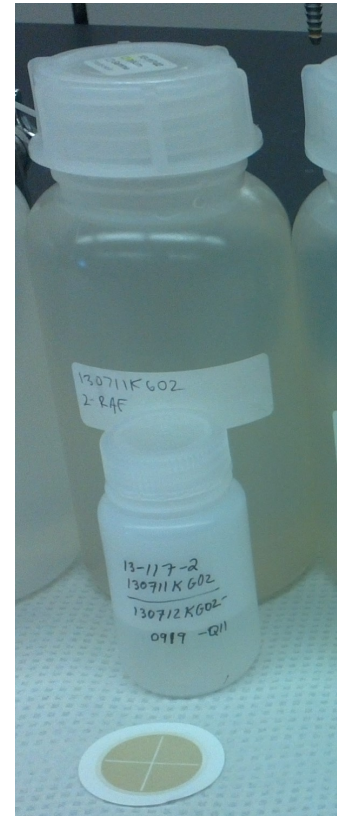
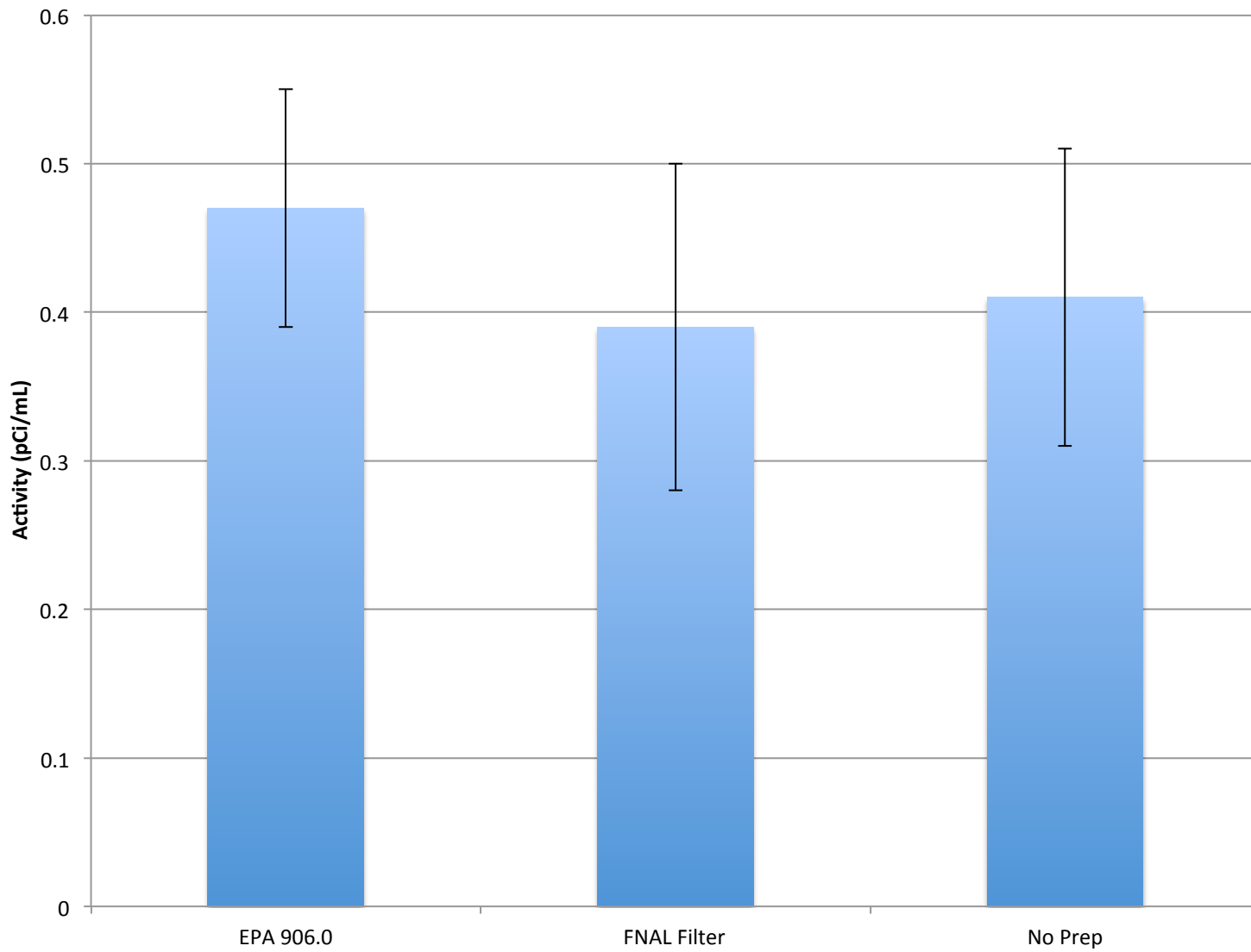
Outfall 002 Kress Creek Tritium Activity



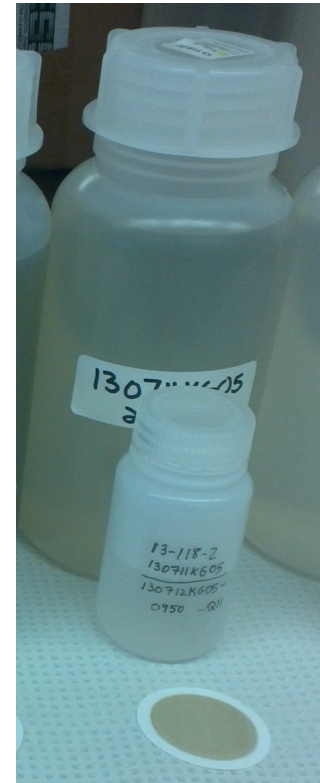
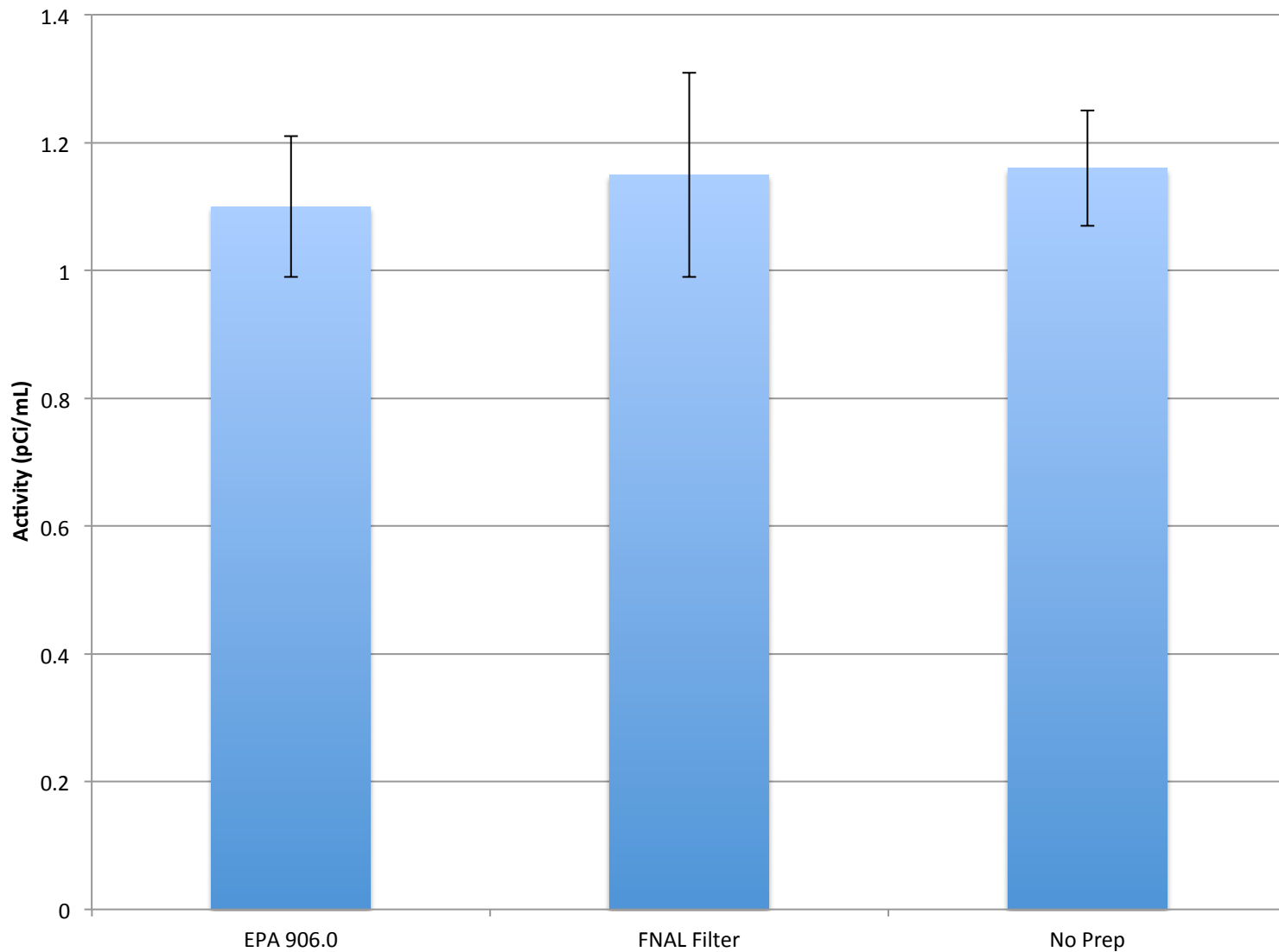
Indian Creek Boundary Tritium Activity



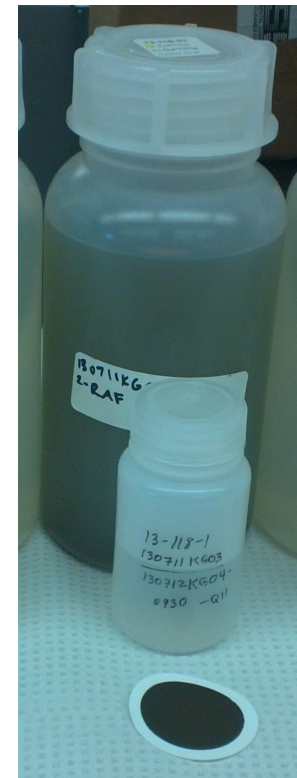
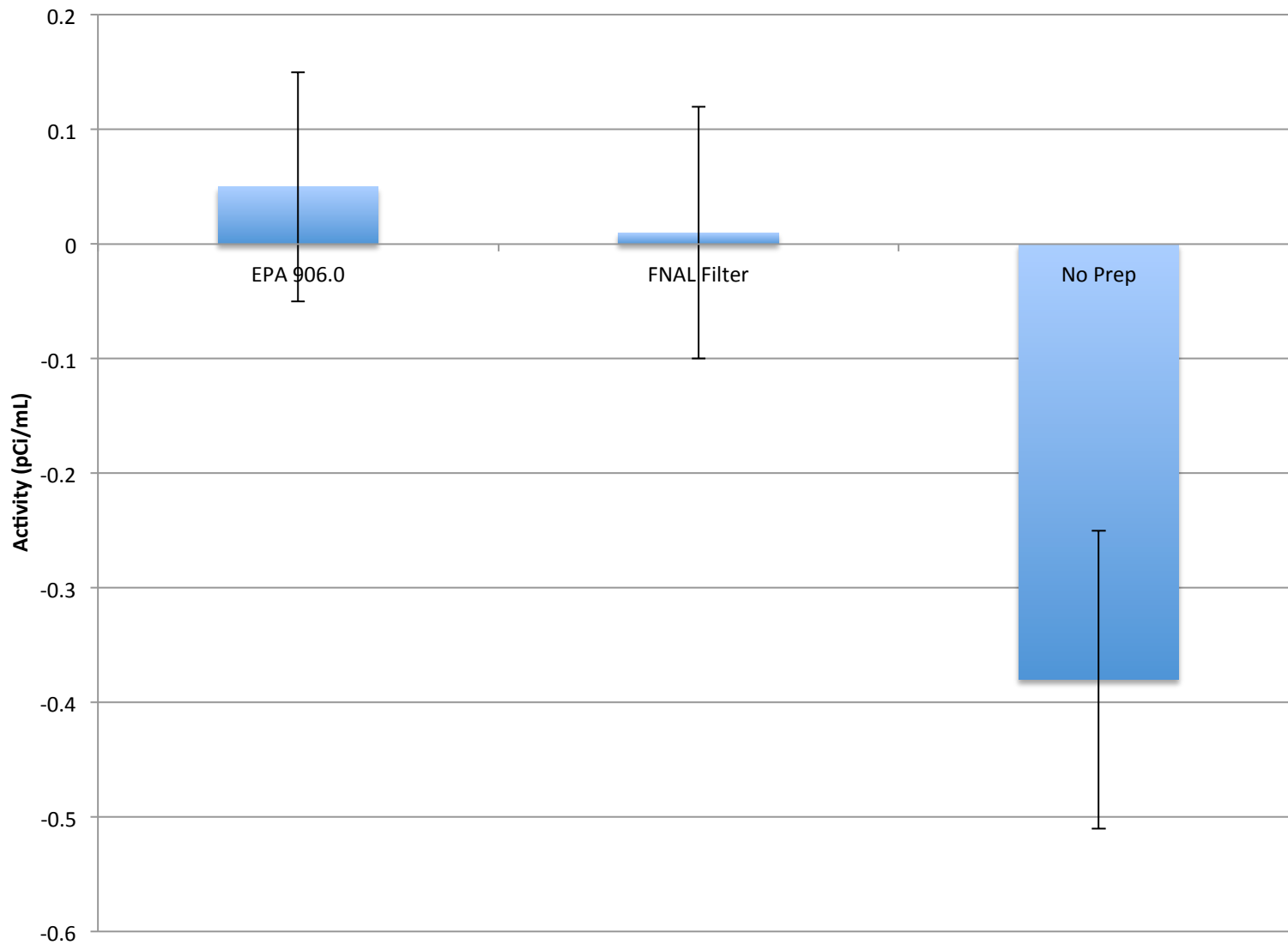
Kidney Pond Tritium Activity



Indian Creek Spillway Outfall 003 Tritium Activity



Ferry Creek Spillway Outfall 001 Tritium Activity



The Verdict

- 906.0 is quite time consuming and difficult to carry out exactly
- Consider that we are testing surface water, which is relatively clean
- Therefore...

Significance to Education

- This experience I had at Fermilab was a bird's-eye view
- Why do we sample here at Fermi?
- <3

Questions?