Naturally Occurring Radioactive Material (NORM) Wastes from Oil Exploration

S. Landsberger
Nuclear Engineering Teaching Lab
University of Texas
Austin, Texas, USA

Collaborators in a Two Year Effort

S. G. Landsberger, G. George
Enviroklean Product Development, Inc. (EPDI)
Houston, Texas

G. Kuzmin, D. Millsap, K. Dayman, C. Lu
University of Texas

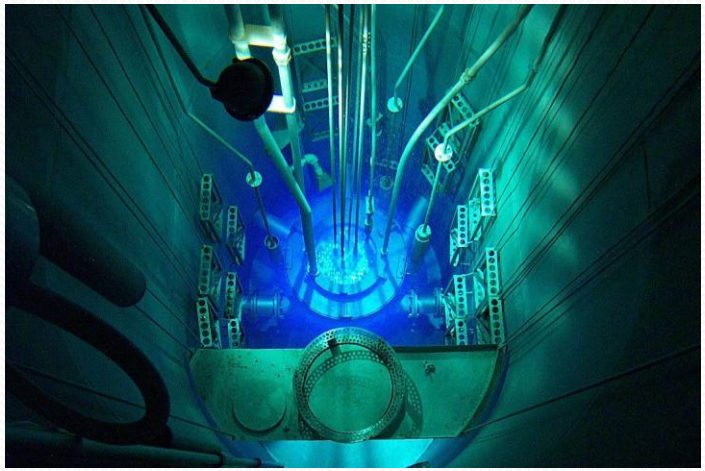
D. Tamalis, J. Louis-Jean, G. Dort, and T. Dudley
Florida Memorial University
Miami Gardens, Florida

Outline

- Energy Needs
- NORM and TENORM in Oil Fields
- Passive Counting
- Neutron Activation Analysis
- Worker Safety Training
- Conclusions

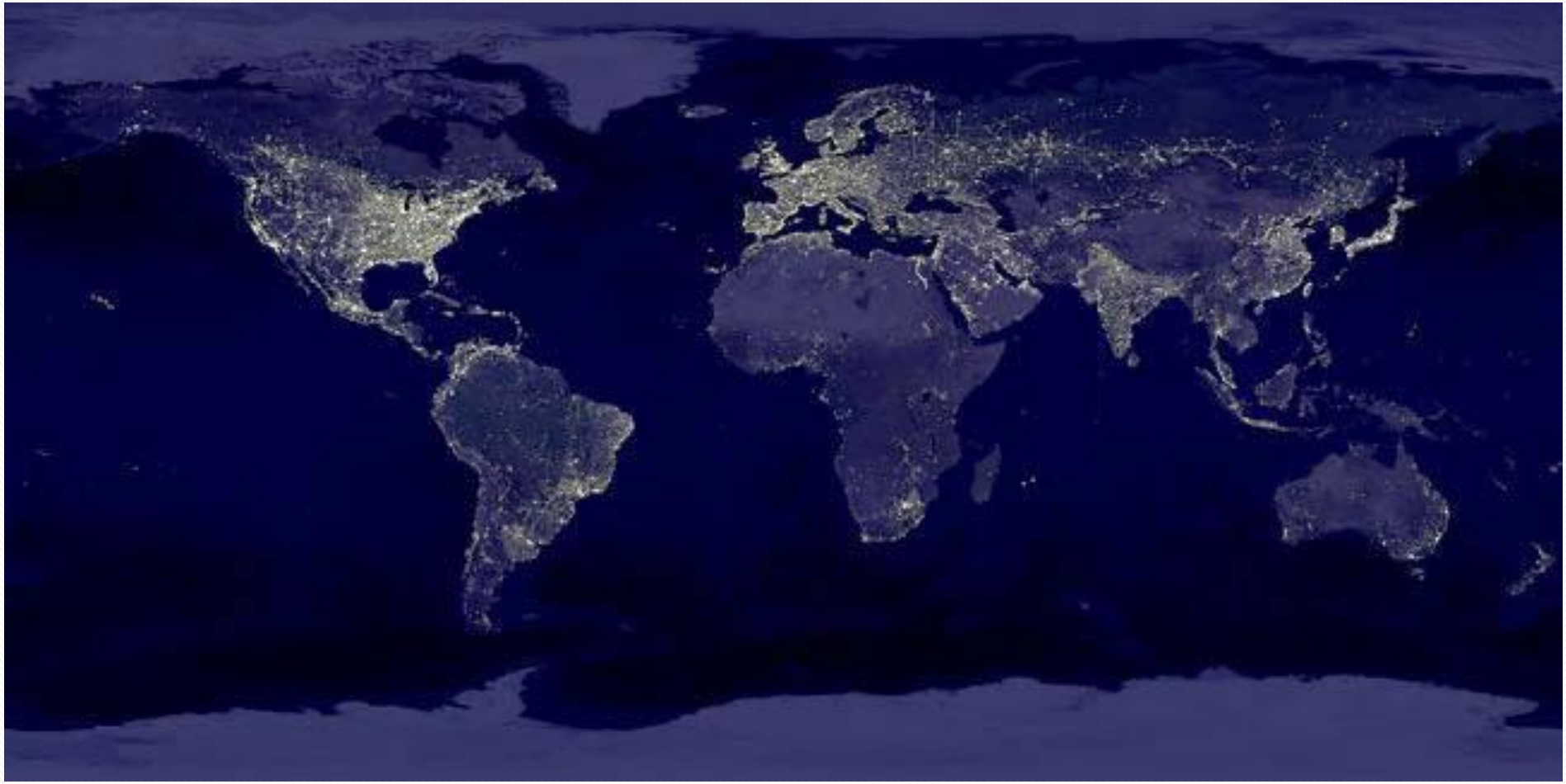
University-Industry Collaboration

Nuclear Engineering Teaching Lab



Enviroklean Product Development, Inc.
A State of Texas Licensed "NORM"
Decontamination Company and
Chemical Manufacturer

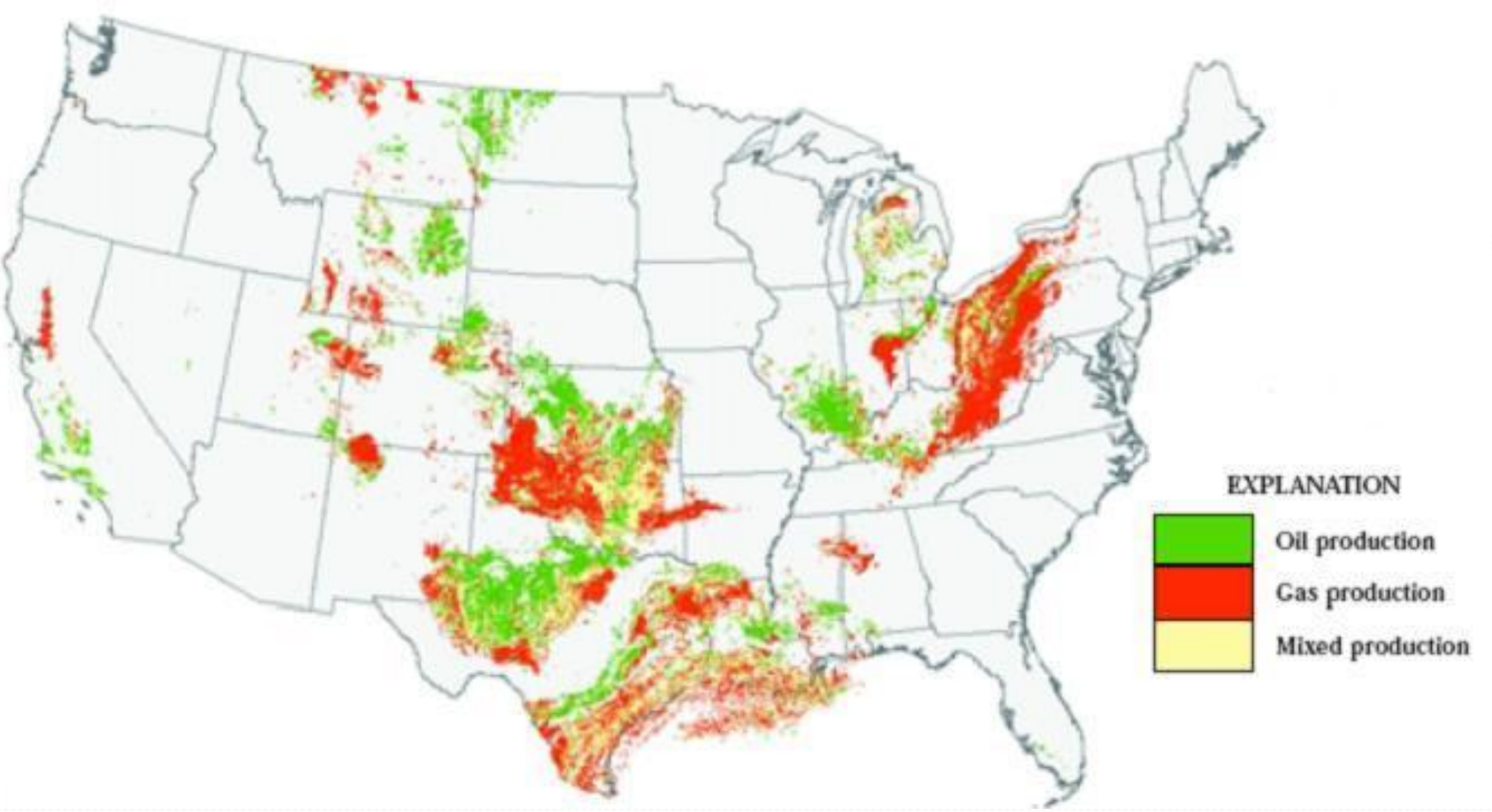
World Energy Needs



North Dakota Fracking

NORM/TENORM in Oil Fields

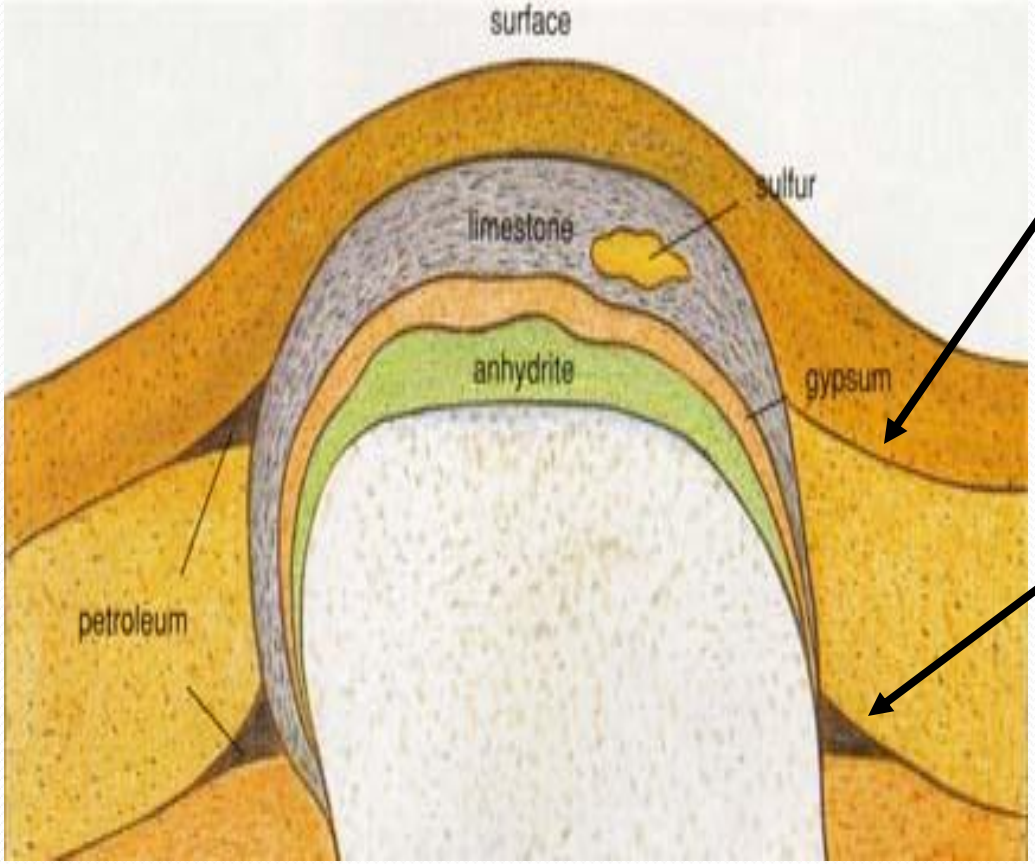
- ~85 million barrels of oil each day is produced
  - ~every 12 days 1 billion barrels is produced/consumed
  - ~31 billion barrels a year
  - USA uses about 25% of oil production
- Expanding economies of BRIC, Southeast Asia and Middle East
- Much more oil and gas maybe needed for the foreseeable future



Arial distribution in the continuous United States producing oil and gas wells through 1994.

(US Department of the Interior, 1999)

Geological Information



Uranium and Thorium collect between layers of sandstones.

Hydrocarbons collect in “traps” made by faults and shales.

www.loyno.edu/lucec/images/saltdome.jpg

Geological Information

- ^{238}U and ^{232}Th are naturally present in the Earth's crust and mantle.
- Found in small amounts and can be significant components in other minerals
- Geologic Locations
  - Shales tend to absorb radionuclides and act as traps for hydrocarbons.
  - Deposits can be located at the boundaries of sandstone layers.

Geological Information

- Decay products of ^{238}U and ^{232}Th are ^{226}Ra ($t_{1/2}$ = 1630 years) and ^{228}Ra ($t_{1/2}$ = 5.8 years) respectively
- ^{238}U and ^{232}Th are insoluble and usually remain in place in the formation.
- ^{226}Ra and ^{228}Ra are more soluble than their parents and are mobilized by liquid
- Uranium, Thorium, and Radium “have an affinity for crude oil”

Oil and Gas Wells

- Three phases of oil and gas wells will be discussed.
  - Drilling and Workover Operations
  - Production
  - Abandonment

How Norm Is Brought to the Surface

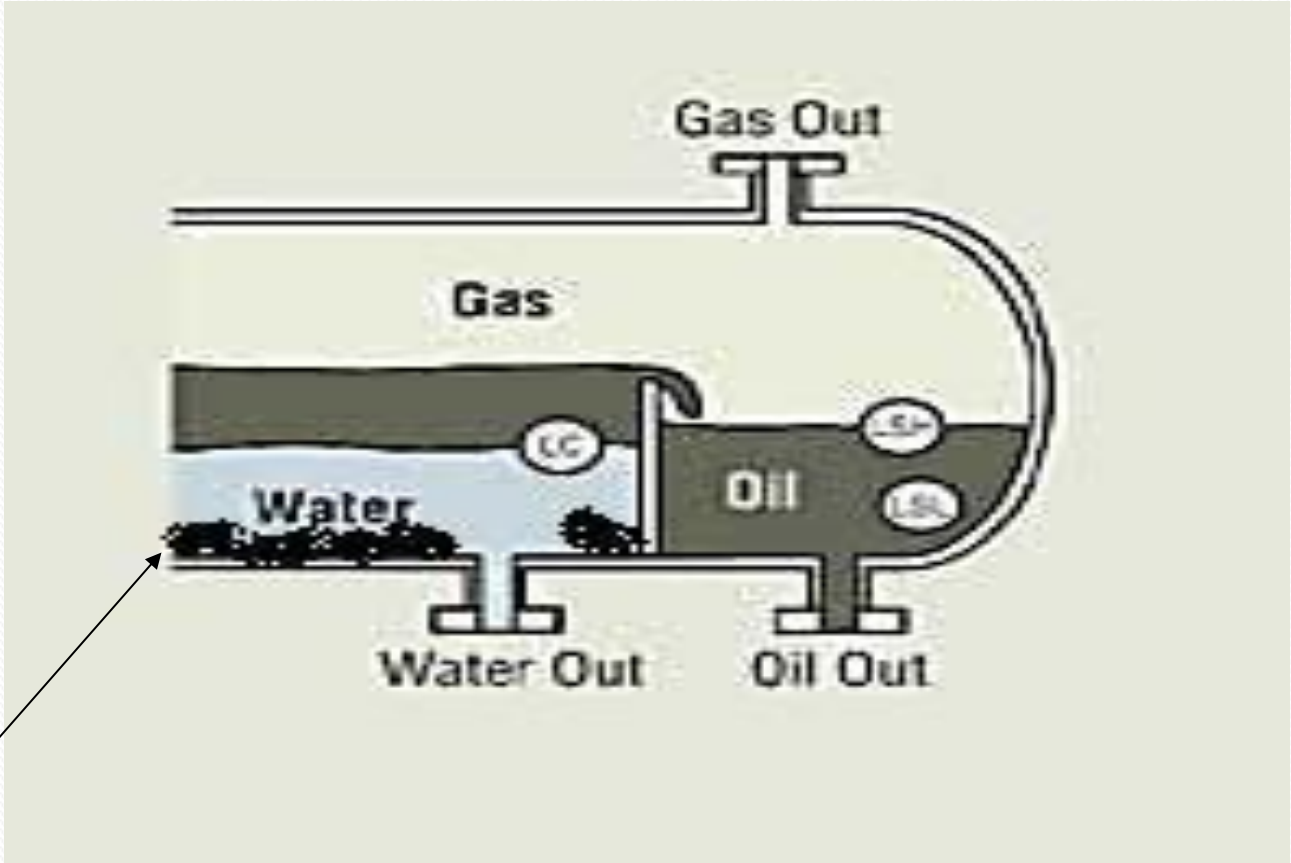
- NORM is brought up to the surface by the transport of gas and oil products
- Produced water
- Drilling mud and sludge
- Evaporation ponds and pits

Drilling and Workover Operations

Drilling mud (a liquid used to lubricate the bit, bring cuttings to the surface, and hold back the formation) also come in contact with NORM and can be contaminated.

Pipes with Radioactive Scale in the Oil Field

Formation of Radioactive Sludge in Production Equipment

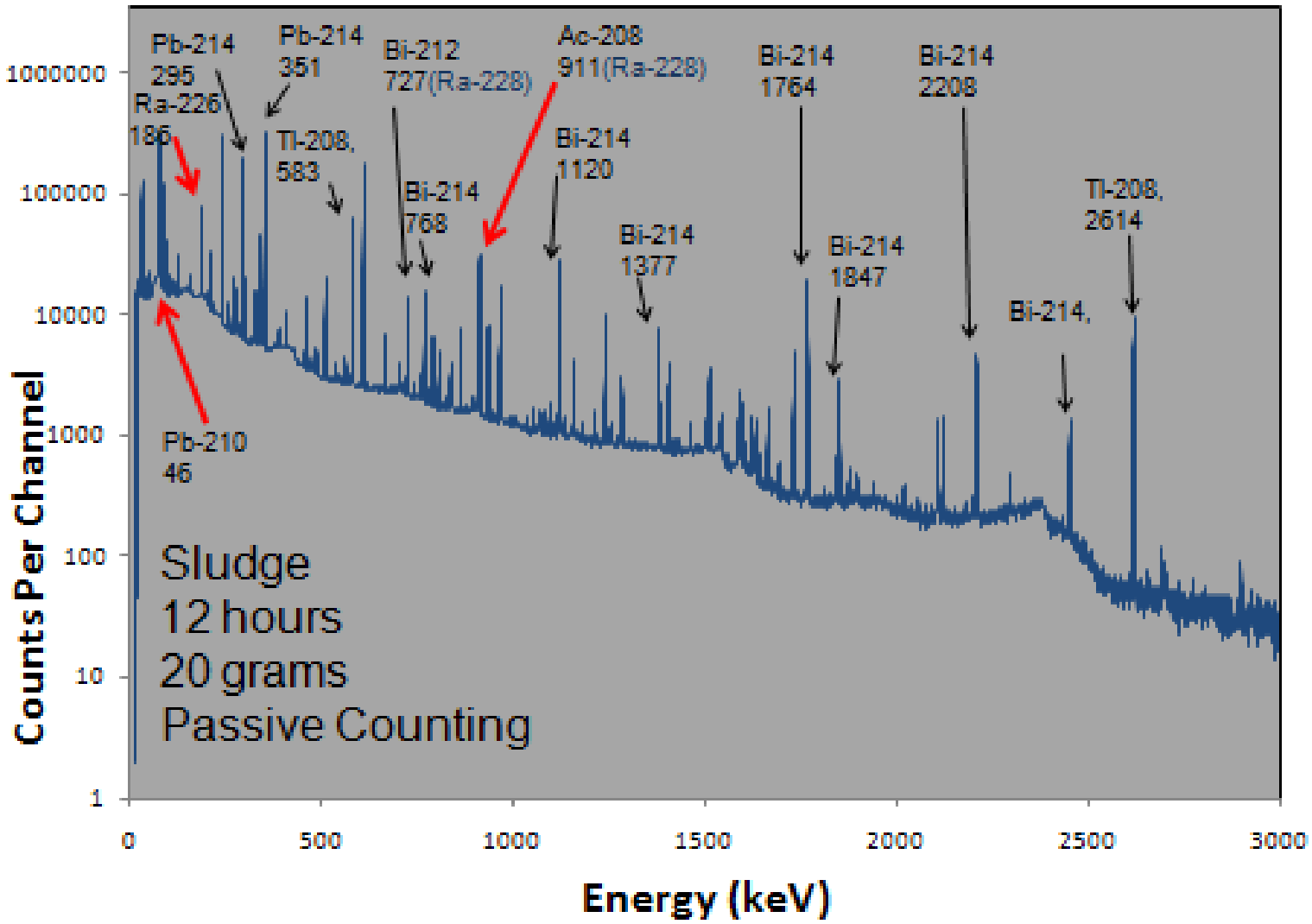


Sludge

250 µm Sieve

Low Level Gamma Counting

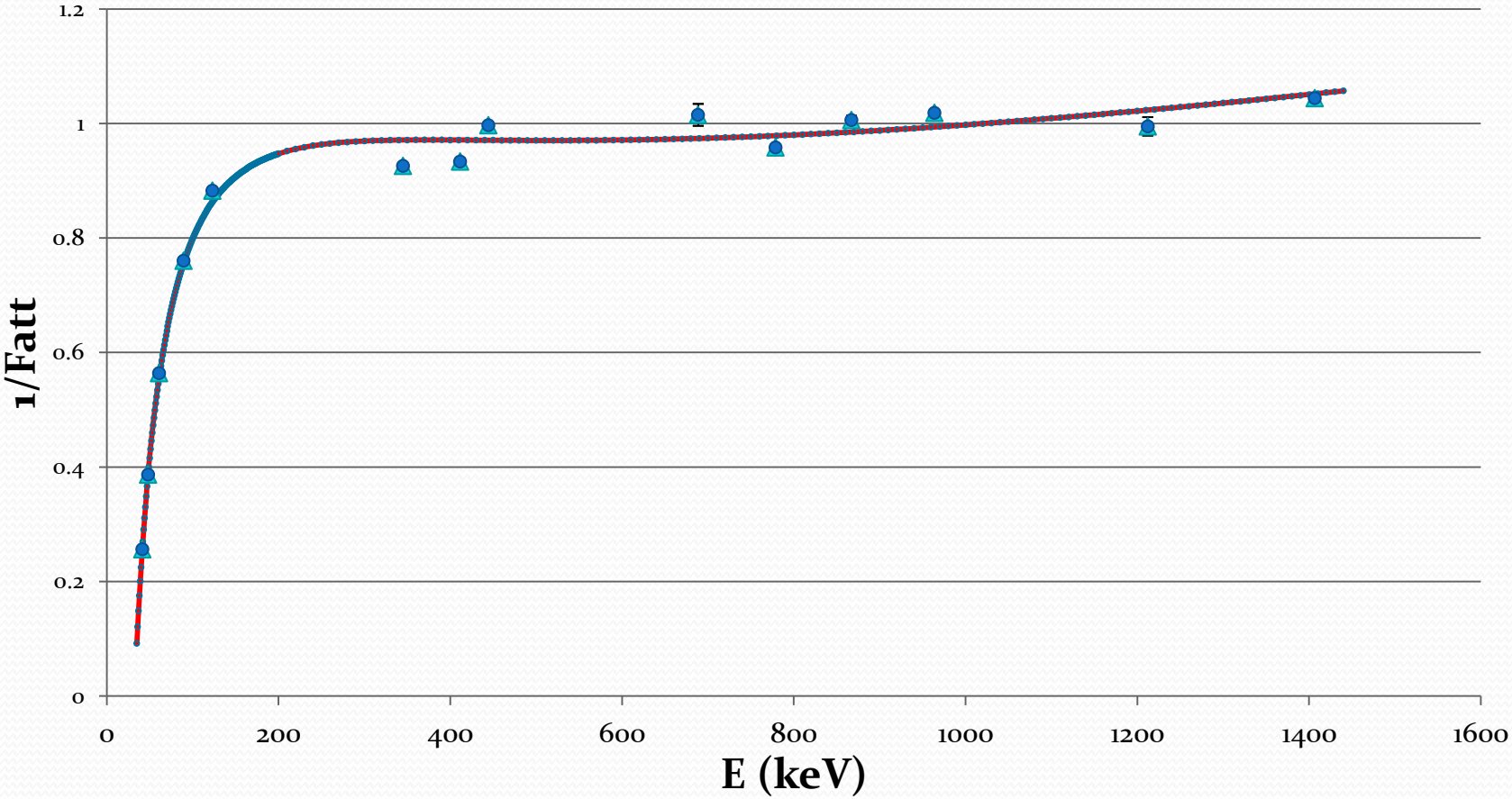
Small Sample Size
20 grams


Pb-214
295
Ra-226
186
Pb-214
351
Bi-212
727(Ra-228)
Ac-208
911(Ra-228)
Bi-214
1764
Bi-214
2208
Tl-208,
583
Bi-214
768
Bi-214
1120
Tl-208,
2614
Bi-214
1377
Bi-214
1847
Bi-214,
Pb-210
46
Sludge
12 hours
20 grams
Passive Counting
Counts Per Channel
1000000
100000
10000
1000
100
10
1
0
500
1000
1500
2000
2500
3000
Energy (keV)

Interferences

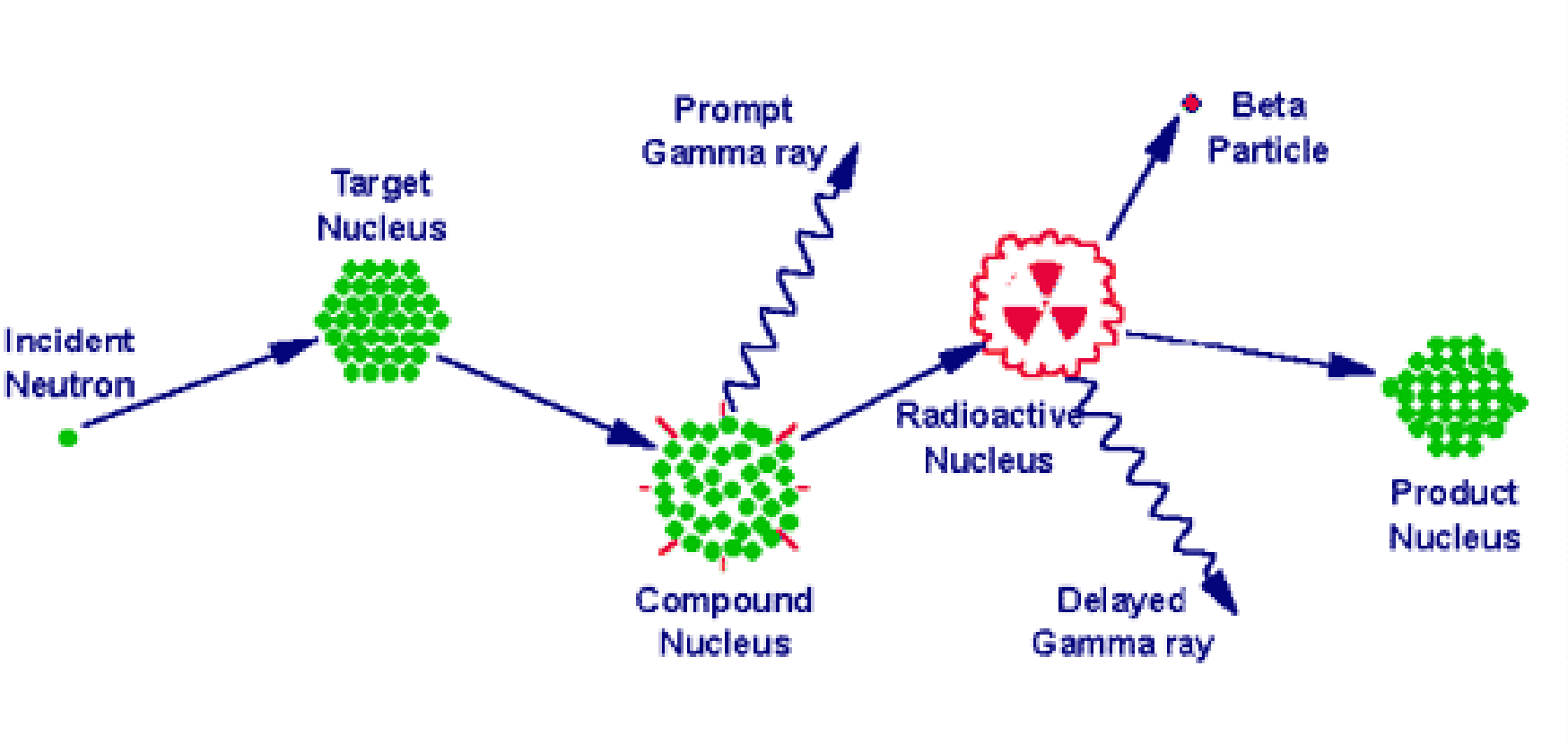
- 185.2 keV gamma-ray of ^{235}U on the 186.2 keV of ^{226}Ra
- Uranium is from one to many orders of magnitude less radium
- Negligible effect
- coincidence summing
- Negligible for ^{226}Ra and ^{210}Pb
- 9% effect for the 911 keV photon for ^{228}Ac used to determine ^{228}Ra

Self-Attenuation vs Gamma-Ray Energy



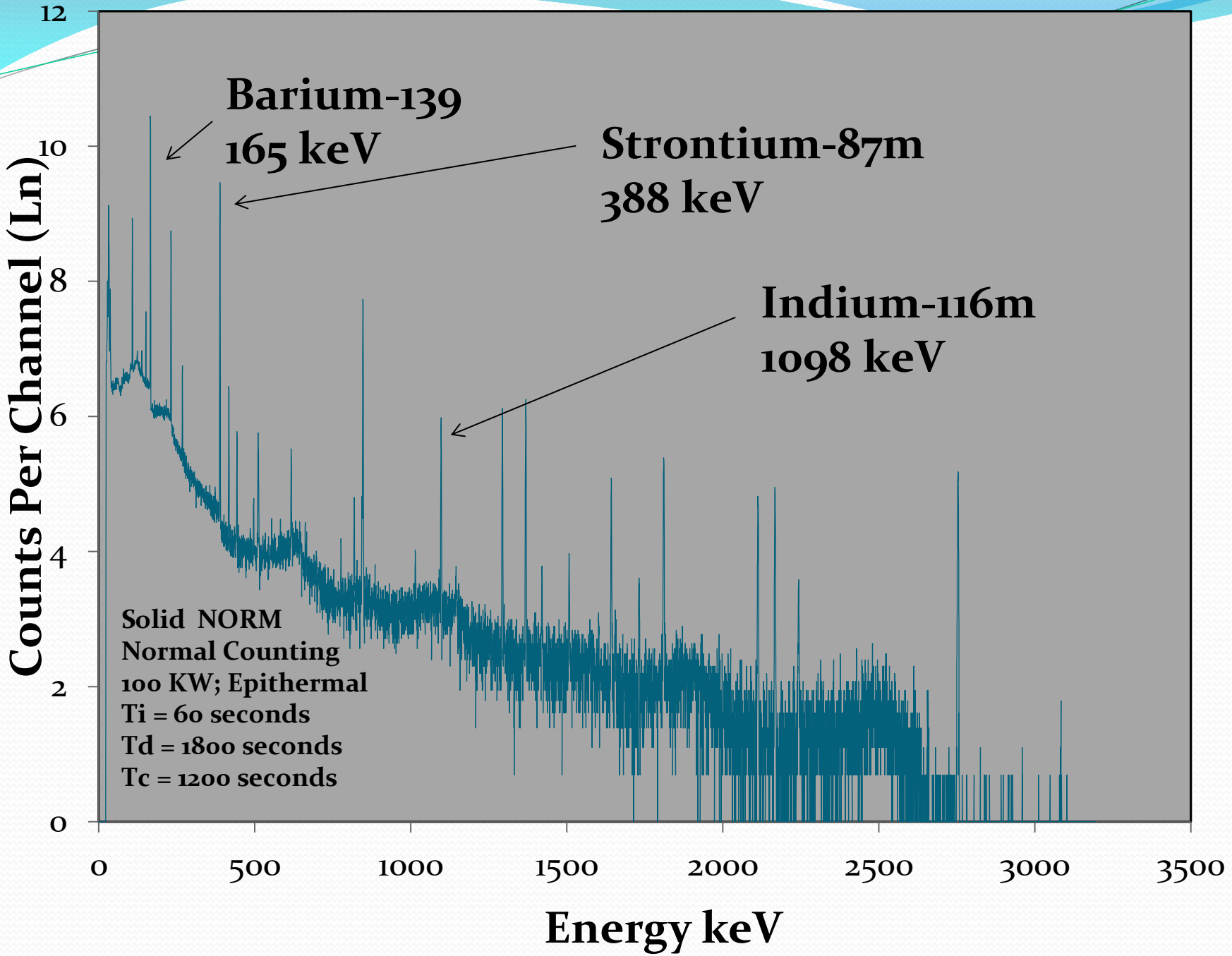
	Sludge (Bq/kg)	Scale (Bq/kg)	Soil (Bq/kg)	Water (Bq/L)
^{210}Pb	5148 ± 222	1370 ± 74	22, 889 ± 740	815 ± 37
^{226}Ra	59,000 ± 300	2630 ± 148	65,296 ± 3296	1481 ± 74
^{228}Ac (^{228}Ra)	28,501 ± 1493	565 ± 40	154 ± 12	251 ± 16

Neutron Activation Analysis



Group II Elements

Group	1	2	3	4	5	6	7
Period 1	1 H						
2	3 Li	4 Be					
3	11 Na	12 Mg					
4	19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn
5	37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc
6	55 Cs	56 Ba	57 La	72 Hf	73 Ta	74 W	75 Re
7	87 Fr	88 Ra	89 Ac	104 Rf	105 Db	106 Sg	107 Bh


Barium-139
165 keV
Strontium-87m
388 keV
Indium-116m
1098 keV
Solid NORM
Normal Counting
100 KW; Epithermal
Ti = 60 seconds
Td = 1800 seconds
Tc = 1200 seconds
Counts Per Channel (Ln)
0
2
4
6
8
10
12
0
500
1000
1500
2000
2500
3000
3500
Energy keV

Results for NORM Ba, Ca, Sr and In

	Barium (%)	Calcium (%)	Strontium (%)	Indium (µg/g)
Soil	18.54 ± 0.64%	5.97 ± 0.09%	1.95 ± 0.07%	0.033 ± 0.003
Scale	1.68 ± 0.06%	4.61 ± 0.11%	1.09 ± 0.04%	1.27 ± 0.02
Solid	22.04 ± 0.76%	1.50 ± 0.05%	5.28 ± 0.20%	0.88 ± 0.01

Element	Concentration
Aluminum (%)	0.53 ± 0.02
Barium (µg/g)	8936 ± 717
Bromine (µg/g)	223± 11
Calcium (%)	11.2 ± 0.7
Chlorine (%)	6.41 ± 0.48
Chromium (µg/g)	53 ± 2
Cobalt (µg/g)	14.6 ± 0.6
Indium (µg/g)	1.64 ± 0.08
Iron (%)	24.9 ± 0.5
Manganese (µg/g)	1053 ± 38

Nickel (µg/g)	54 ± 9
Scandium (µg/g)	0.21± 0.02
Silicon (%)	1.08 ± 0.14
Sodium (%)	3.24 ± 0.09
Strontium (µg/g)	12484 ± 1389
Uranium (µg/g)	0.08 ± 0.02
Vanadium (µg/g)	ND*
Zinc (µg/g)	288 ± 8

Ratio	Scale	Seawater
Cl/Na	1.97	1.8
Br/Cl	3.5×10^{-3}	6.2×10^{-3}
I/Cl	5×10^{-4}	3.3×10^{-6}

Who Can Benefit from NORM Training

- Employees working with NORM
  - Either with decontamination or maintenance of equipment in the oil and gas field
- Employees of Oil and Gas Companies
  - Anyone from a field worker to an executive
- Teaching emergency procedures of the company is important
- During the class each person should know the basic emergency procedures that happen on job site

Personal Protective Equipment (PPE)

- Gloves, fire retardant clothing, hard hat, safety glasses, steel toed boots, mask, self contained breathing apparatus, H2S monitor, TLD badge

Teaching Health Risks from NORM Exposure

- It is important to stress the importance of health effects when working with NORM both to the worker and the general public

- The radionuclides that pose the most risk in the oil and gas field are ^{226}Ra, ^{228}Ra, ^{222}Rn and ^{210}Pb
  - More detail on the specific side effects is presented

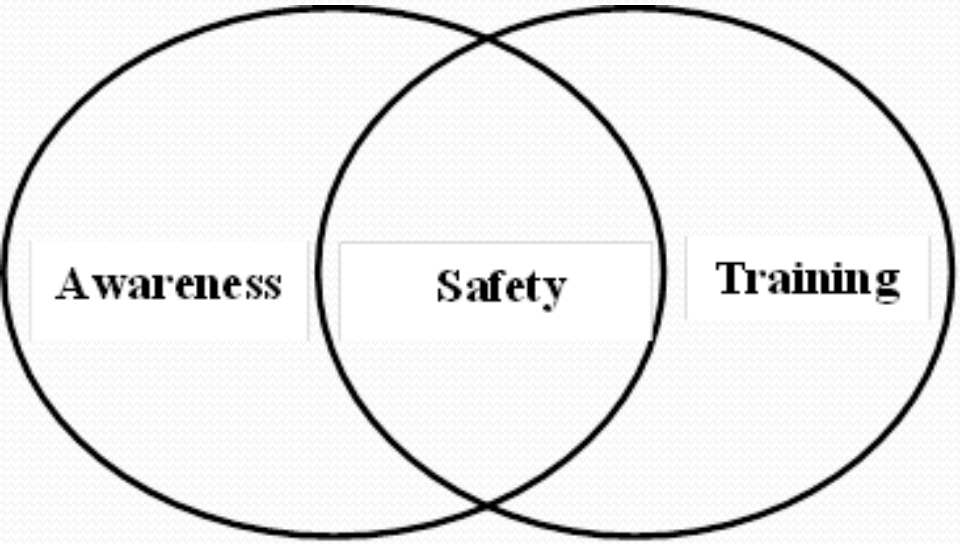
- "Frisking Out" is also revisited during this part of the course

Obstacles of Training in Texas Oil and Gas Field

- English may not be the first language of the participants in the class

- There is a variety of educations levels
  - Which means teaching to all levels of education
  - It is critical to go over the basics of radiation including basic chemistry

Overall Educational Goals



- Continual Education
- workers are continuing to be reinforced with the key points they learned during the training
- On the job site training
- keep up with any changing laws or regulations from state government agencies