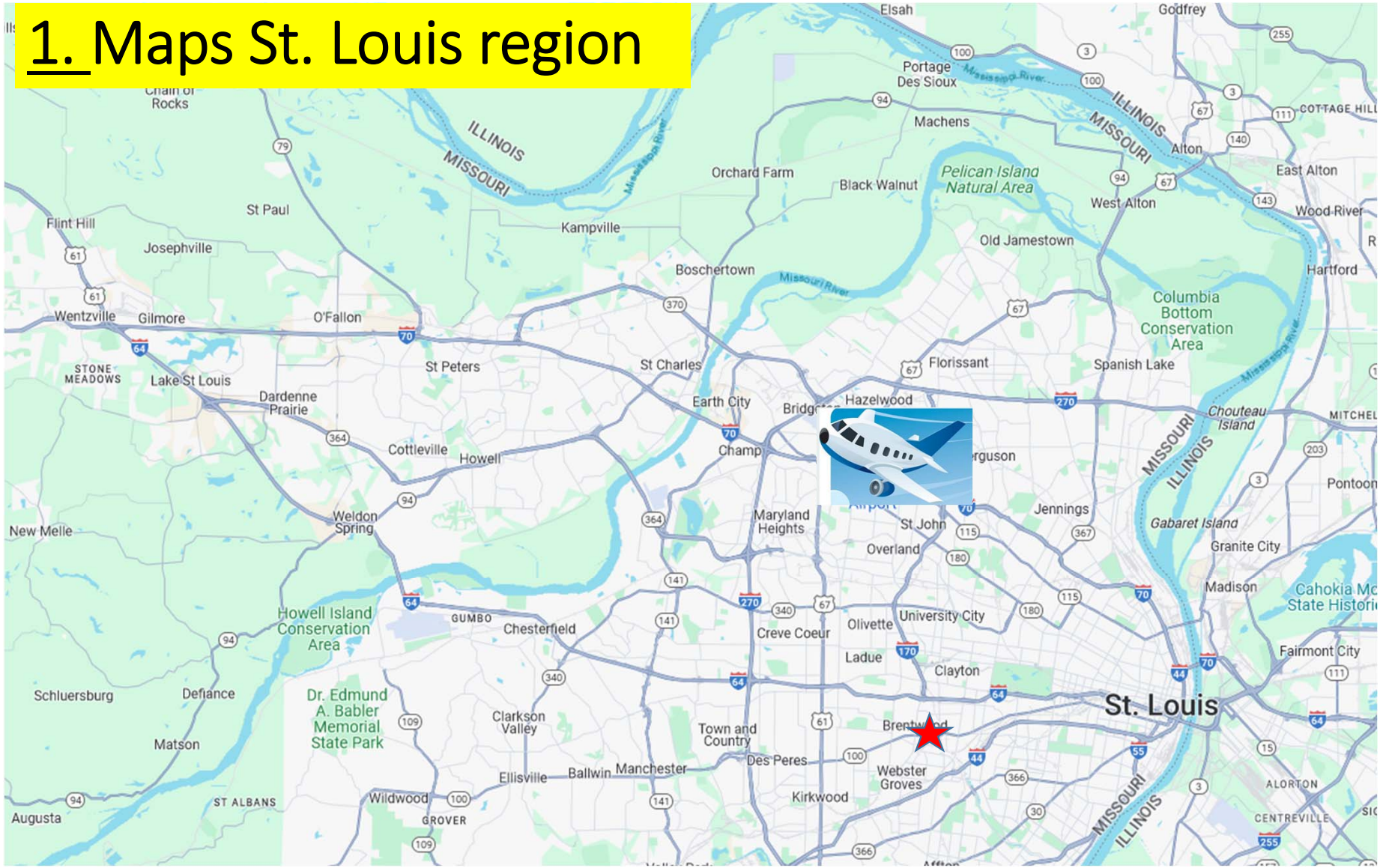
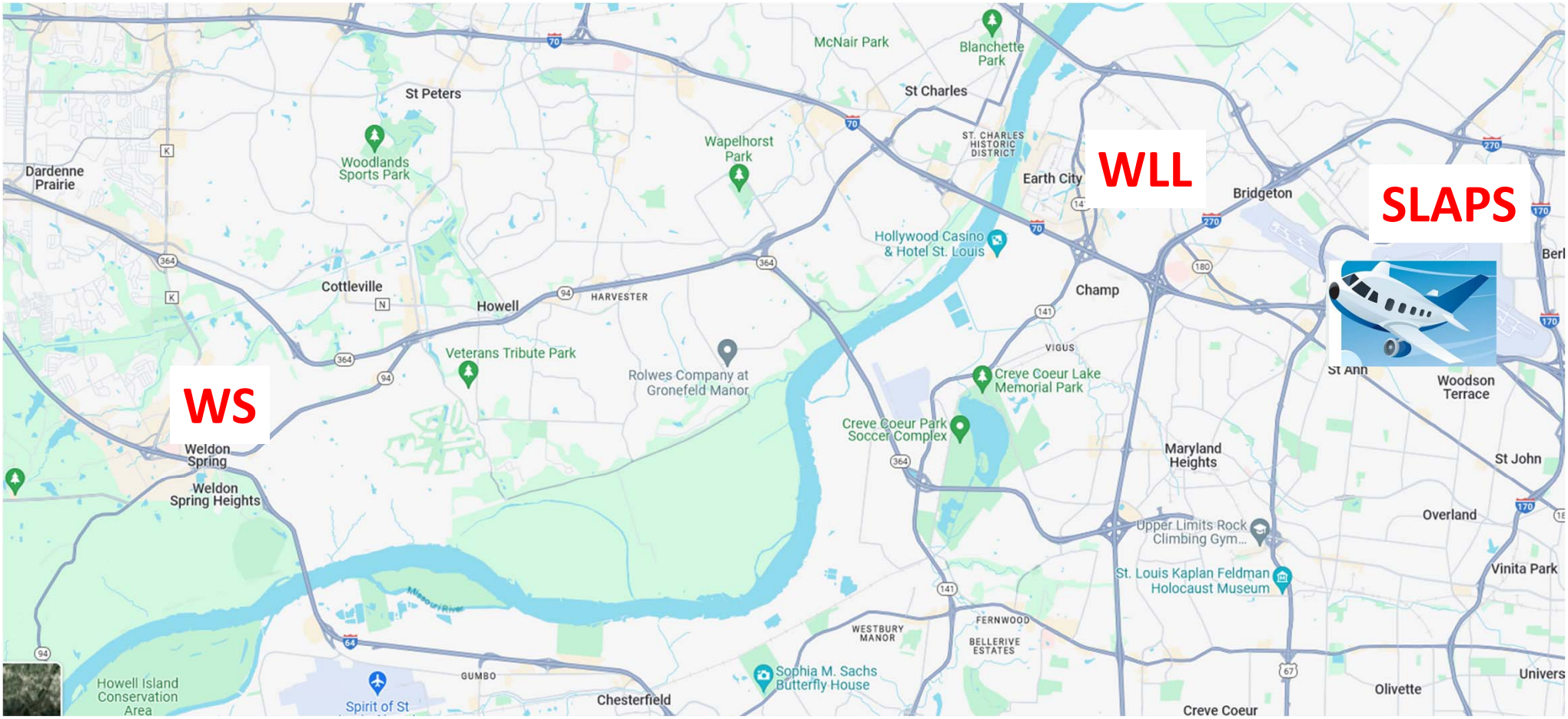
St. Louis Legacy Waste and Radiation Health Effects: Maps, units, human redistribution, clean-up criteria, false & real problems Part II: L. G. Sobotka

1. **Maps (WS, WLL, SLAPS, CWC, and Jana)**
2. **Some units, natural exposure and its variation, and various questions**
3. **How humans redistribute natural radiation**
4. **Some basic Nuclear Science:**
   - **a) the Chart of the Nuclides, b) α, β, γ radiation**
   - **c) Natural decay chains, and d) secular equilibrium and its breaking.**
5. **The Mallinckrodt^{++} story from "Belgian Congo" Ore → reactors (elsewhere)**
6. **Clean-up USACE agenda: clean-up criteria**
7. **Examples: of 1 false problem and several real problems**
8. **Conclusions & issues of contention.**

1. Maps St. Louis region



St. Louis midrange blowup



Weldon Spring (WS) engineered disposal site

Abbreviated history

➔**1941 – 1945** WS Ordnance works (17,232-acres)
Ultimately split into :
Busch Conservation area
St. Charles county ➔ Frances Howell SD
WS disposal cell (interpretive center)

➔**1957** Mallinckrodt (MCW), under AEC contract moves U processing from StL to WS.

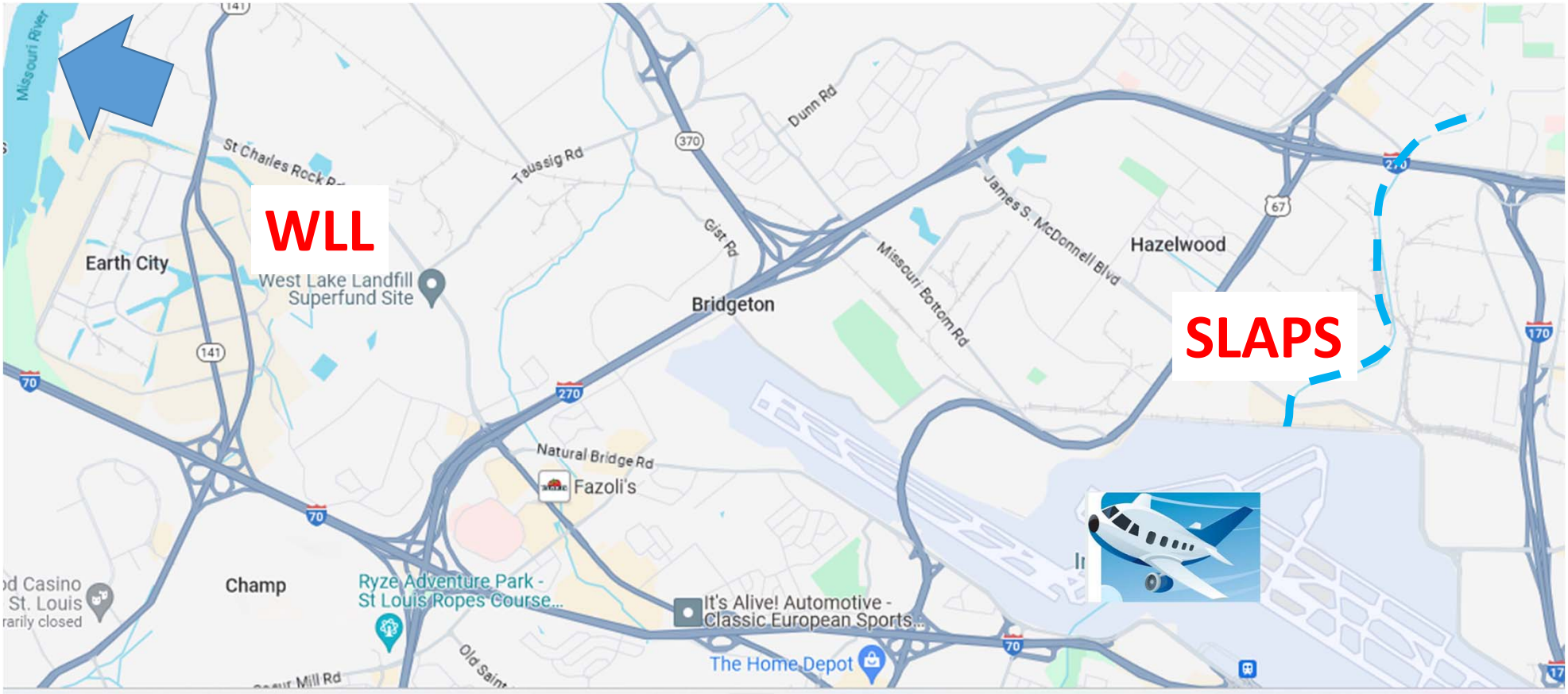
➔ **1957-1966** MCW processing plant for U and Th

➔ **1985** transferred to DOE

➔ **2001** Completion of 41-acre disposal cell

Ordnance works ➔ U processing plant ➔ Conservation area + disposal cell + school
This is not the focal point of present concern.
The history is not circuitous & and not the site of trucked waste from other sites.

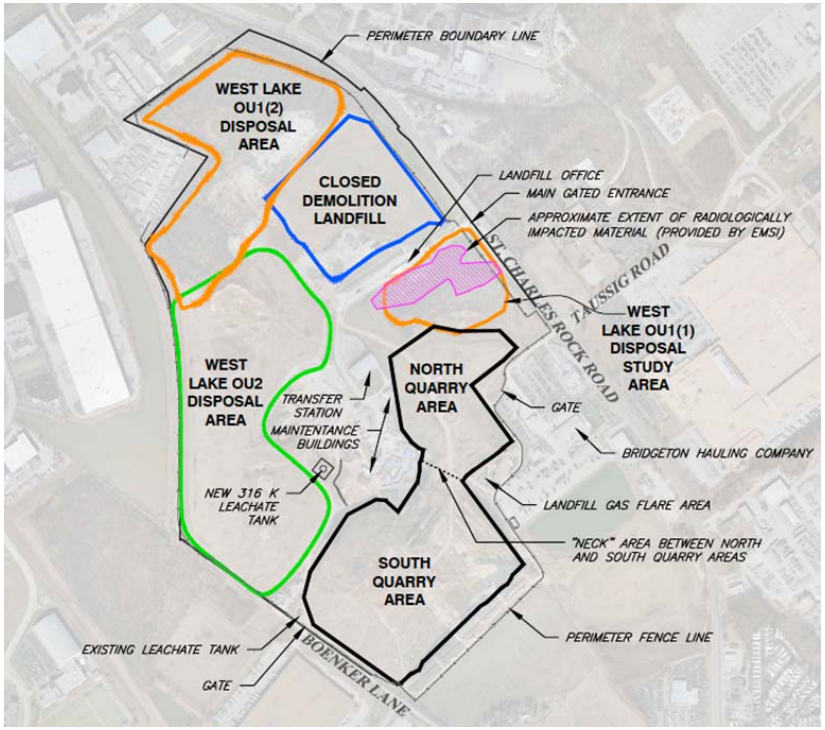
St. Louis blowup



Water flow from WLL W to Missouri River

Cold Water creek runs N, through communities, ultimately to MR

West Lake Landfill (WLL) Bridgeton
Most complicated history



1973 WLL received mixed MCW radioactive material as a cover for municipal wastes

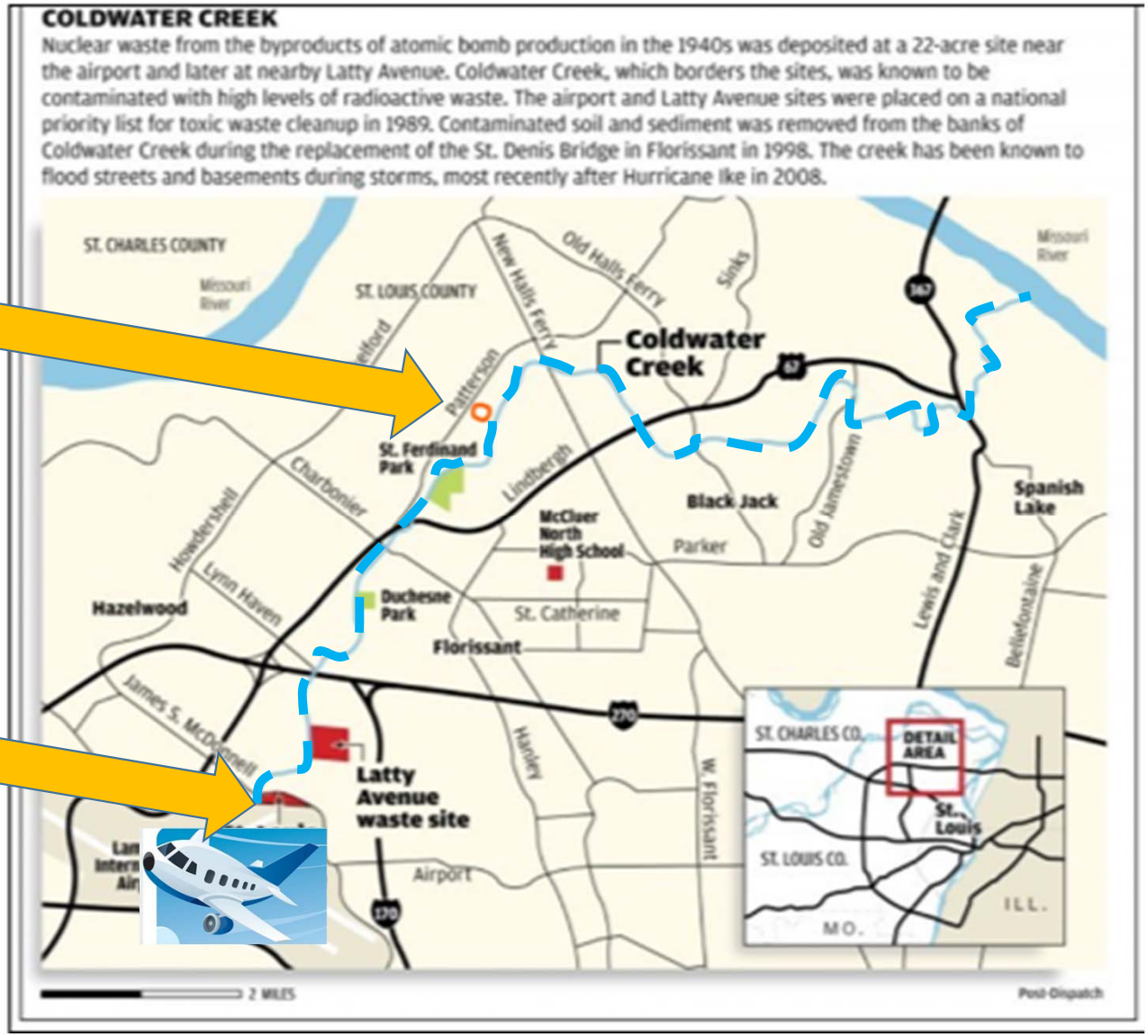
1979: adjoining quarry licensed for municipal waste

Current: subsurface smoldering in waste area.

Jana
Example # 1

SLAPS
Example # 2

Other examples as time permits



2. First some units and distinctions

Decay rate

Curie Ci ≡ 3.7 x 10^{10} decays/s

pCi = 3.7 x 10^{-2} = 0.037 d/s

SI unit

Becquerel Bq ≡ 1 d/s

= 27.0 pCi ←

remember this conversion

Absorbed dose

rad = 100 ergs/g

= 0.01 J/kg = 0.01 Gy

SI unit

Gray Gy = 1 J/kg = 100 rad

Corrected for bio damage

rem = roentgen equivalent man

≡ QF * rad

= 0.01 Sv

SI unit

Sievert = QF * Gy = 100 rem

1 mSv = 100 mrem

The Quality Factor (Q) is a correction for the spatial-temporal correlated energy deposition.

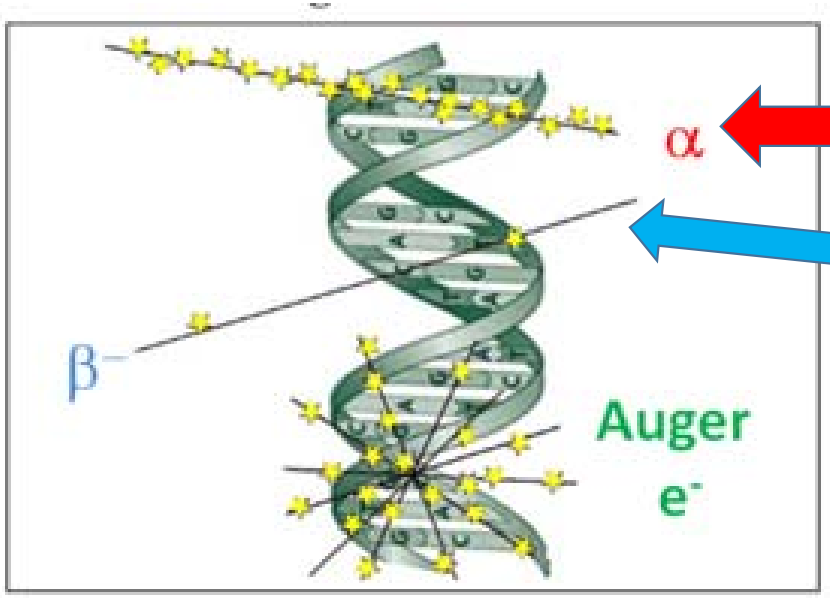
A large Q ➔ more effective the radiation is at inducing bio damage.

With one caveat:
One should care about the number of mrem (mSv) not the origin of the radiation.

For alpha rad, the issue is internal, inhale or ingest.
The damage is local and can overwhelm natural repair mechanisms.
Some history: Ra and Rn.

Why large Q(F) for alphas? ANS large dE/dx or LET

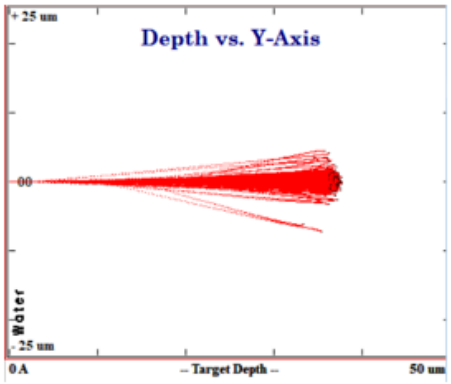
Decay Mode	Energy Range	Range in Tissue	LET
Auger	eV-keV	nm	~4-26 keV/μm
α	5-9 MeV	μm	~80 keV/μm
β^-	0.05-2.3 MeV	mm	~0.2 keV/μm



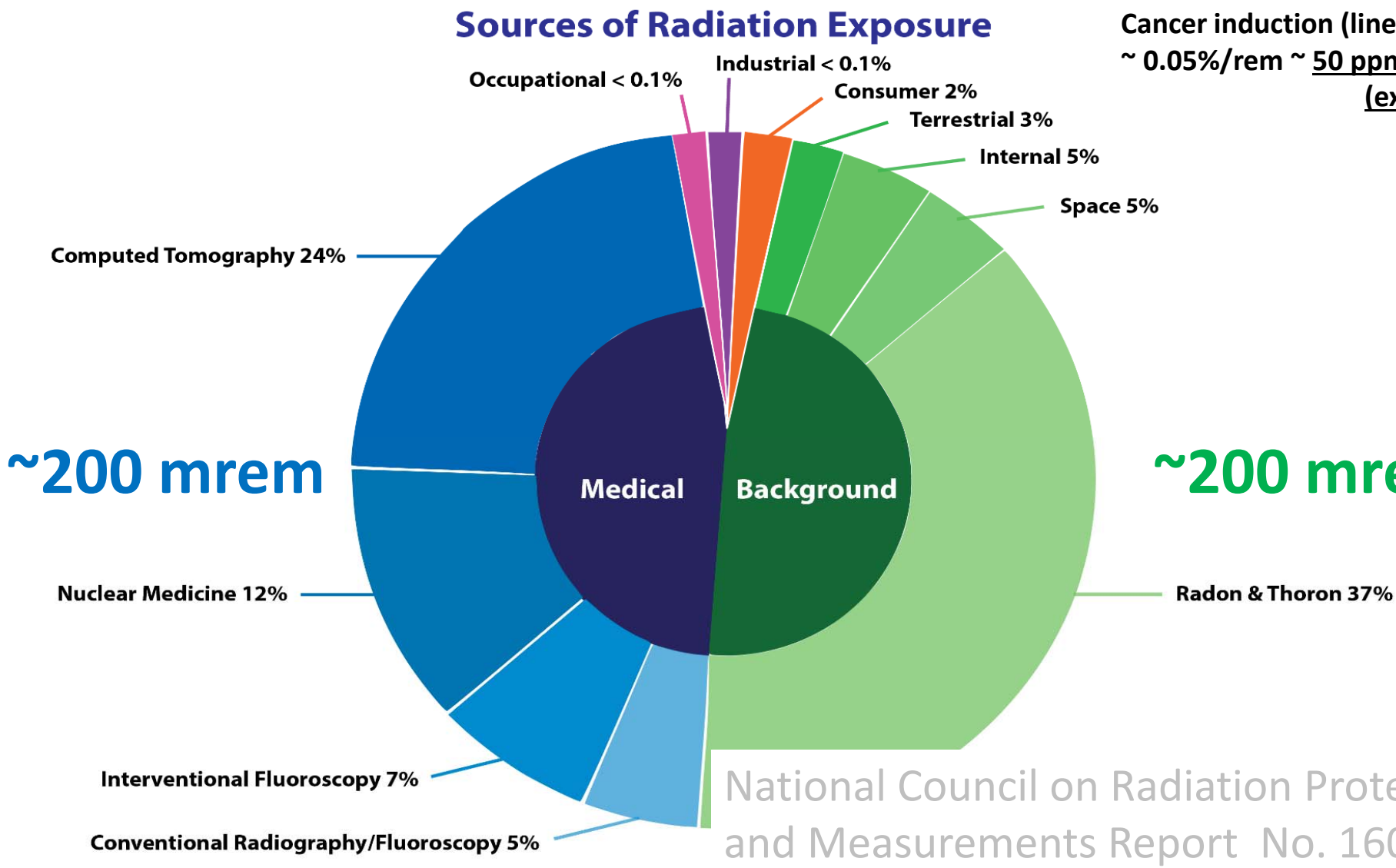
α – large QF

β – small QF

The unit "rem" takes this into account.

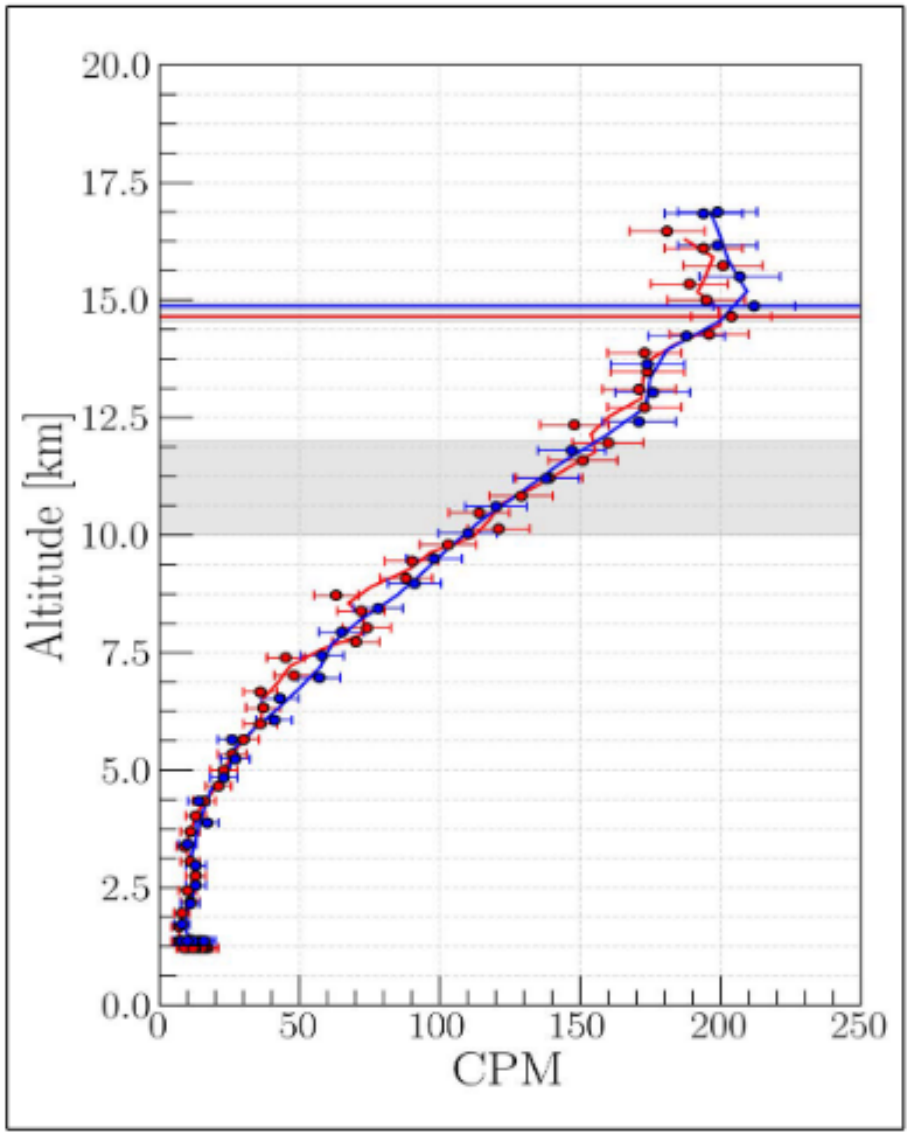


Alpha particle through water (tissue)
Avg: 36.7 um



Cancer induction (linear response)
~ 0.05%/rem ~ 50 ppm/100 mrem (extrapolation)

National Council on Radiation Protection and Measurements Report No. 160 (2006)



Cosmic rays

Translates to 3 mrem/1000’ at low alts.

City	height above sea level
STL	466’
Chicago	600’
KC	909’
Boulder	5430’

If you are worried about an extra 1 mrem
– do not –
move to KC, fly, or go to the dentist.
➔ Remember the 1 mrem extra risk.

Common Doses

- **Medical Scans**
  - **Chest X-ray:** **10-60 mrem**
  - **Dental X-ray:** **0.5 mrem**
- **Flight from Boston to California:** **3.5 mrem**
  - **Air crew yearly dose limit:** **300 mrem**
- **TSA screening machine:** **0.003 mrem**
- **Living within 50 miles of a nuclear plant:** **0.009 mrem**
- **Living within 50 miles of a coal-fire plant:** **0.030 mrem**
- **Eating a banana:** **0.010 mrem**
- **Yearly occupational limit for rad worker:** **5000 mrem**

500 mrem "additional" dose limit at WU

https://www.nrc.gov/about-nrc/radiation/around-us/doses-daily-lives.html#3

Questions from marginal to good

A poor question: **Is any particular sampling near background?**
I will explain why this is question can be misleading.

A better question: **Is a set of samples near background?**

An interesting question: **Is an activity above nominal background due to**
(a) Mallinckrodt raffinate infiltration or
(b) concentrated natural, or anthropomorphic generated, activities/fallout?
➔ There are signatures that differentiate.

A good question: **Does a dose – regardless of origin – pose a "risk"?**
"Risk" must be put in perspective.

3. Human redistribution of natural radioactivity

Natural (U/Th) can vary over many orders of magnitude

~~ 1 pCi/g (per isotope) to 1,600,000 pCi/g

in VERY unusual – but natural - places

Note:

1. **Natural <u>does not mean</u> low background.**

2. **Natural <u>does not necessarily mean</u> safe.**

Shinkolobwe mine some deposits as rich as 65% U_3O_8 .
This ore has a specific activity of as much as
200 nCi/g = 200,000 pCi/g from U alone or
The total specific alpha activity would be ~1.6 uCi/g

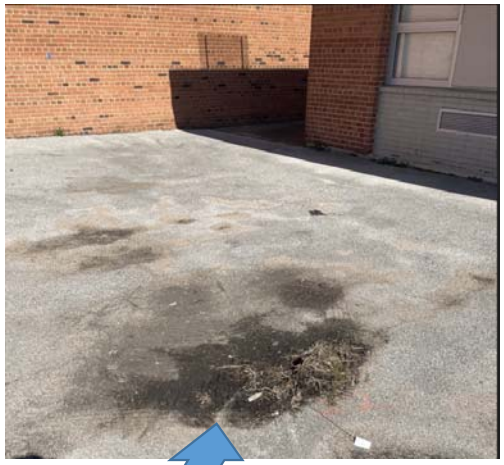
Ramsar Iran
Guarapari Brazil
Orissa/Kerala India
Yan Jiang China

background from U/Th
several 100 mrem/year

Human redistribution of natural material

Intentional Relocation of Natural – but Unusual – Material

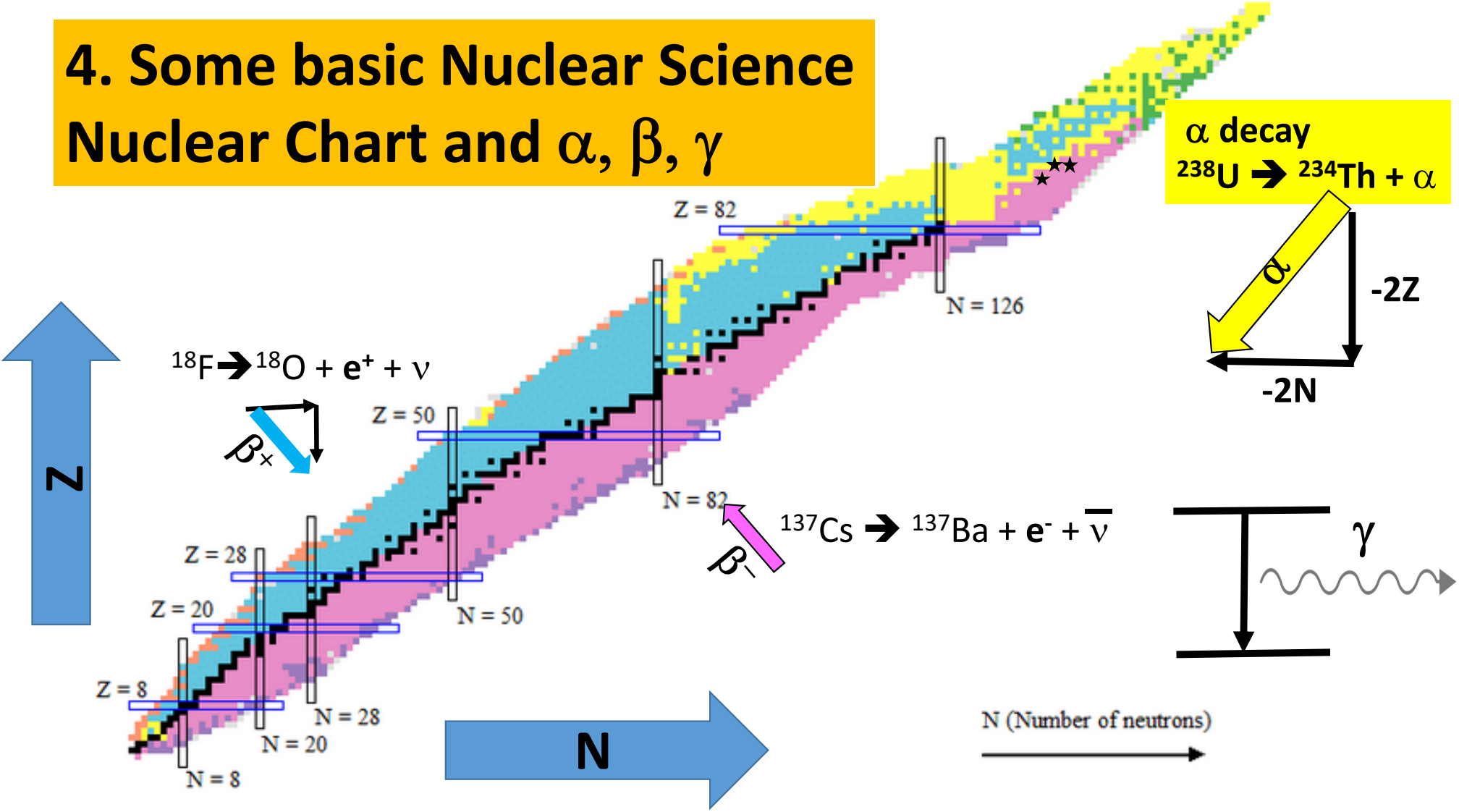
Unintentional concentration of natural **or** fallout material

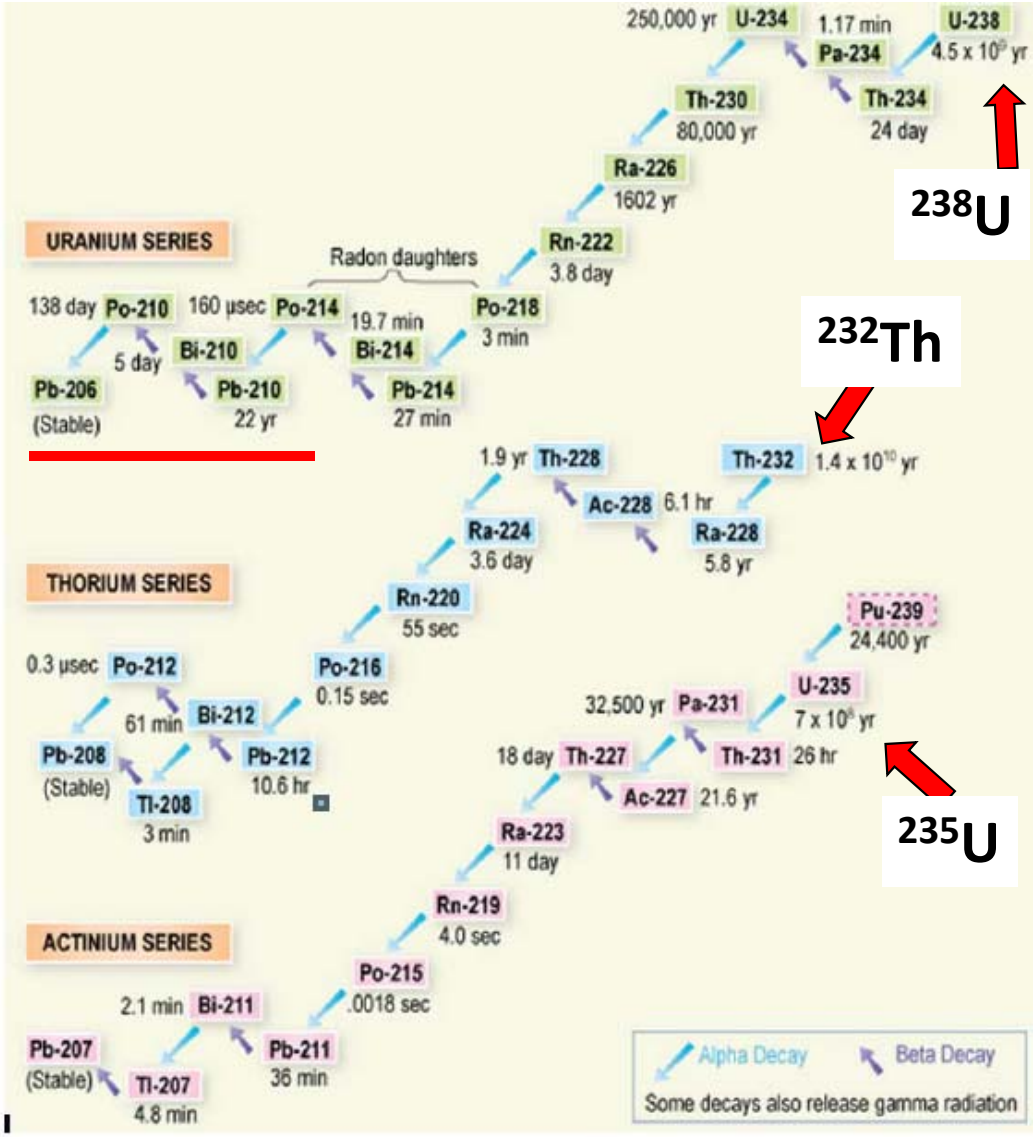


SCI location S8

Site of elevated ^{210}Pb

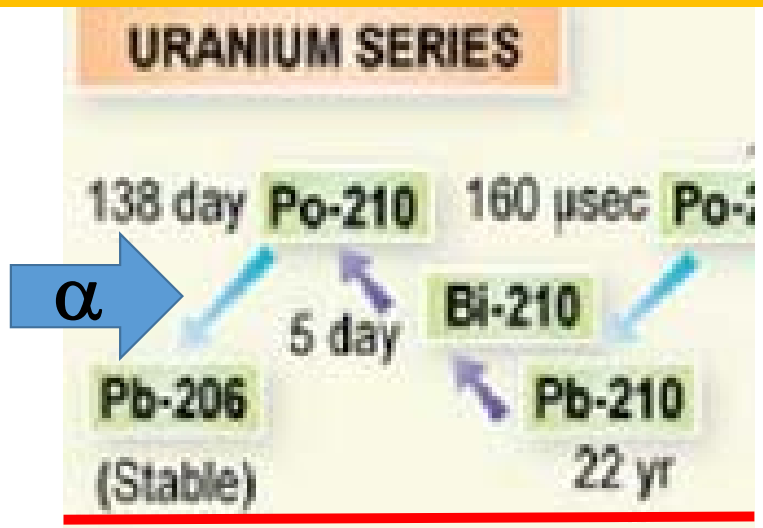
4. Some basic Nuclear Science
Nuclear Chart and α, β, γ





Natural decay chains

"Parented" by nuclides with half-lives commensurate with the age of the Earth ~ 4.5 x 10^9 years



^{210}Pb: a) does NOT α decay,
it's the granddaughter ^{210}Po does.
b) is the only long lived isotope below Rn
c) **The dose (rem) should not be x by 2.**

First-order decay and "Secular equilibrium"

Activity A ≡ - dN/dt = $N\lambda$

N is the number of any species & the decay rate $\lambda = 0.693/t_{1/2}$

IF a) the parent has a decay rate << the decay rate of the daughter
and
b) Enough time has elapsed

➔ the decay from the daughters decay with a rate equal to that of the long-lived parent. This is the expectation for "natural" undisturbed chains.

$$A(each) = (N\lambda)_P = (N\lambda)_{D1} = (N\lambda)_{D2} = ... = (N\lambda)_{Dn}$$

Condition b) is broken with chemical processing.
It will only be reestablished on a time scale commensurate with the half-life of the long-lived component of the chemically fractionated component.

"Secular Equilibrium" summary

1. **The undisturbed natural expectation is that activities in the decay chain decay at the rate of the long-lived parent.**

2. **An indication of the infiltration of chemically processed materials is the unequal decay rates of mother/daughter, e.g. $A(^{230}Th)/A(^{226}Ra) \neq 1$.**

3. **If, for example, $A(^{230}Th)/A(^{226}Ra) >> 1$, the daughter activity (^{226}Ra in this case) will grow in with time. The time scale might/is incomparable with times humans can appreciate.**

4. **This requires estimating the risk at present day + 1000 y.**

5. **Secular equilibrium IS broken at sites requiring remediation. There is no evidence that secular equilibrium is broken at Jana.**

5. Mallinckrodt war-time effort

Because the uranium effort in the St. Louis area was primarily technical in nature, the history of the operation is, in large part, a technical history.

It began in April, 1942, when Dr. Arthur Holly Compton, Dr. Norman Hilberry, and Dr. Frank H. Spedding approached Edward Mallinckrodt, Jr., to seek his Company's assistance in preparing the extremely pure uranium compounds which were needed as fuel for an experimental atomic reactor at the University of Chicago. The reactor, if successful, would achieve a self-sustaining nuclear chain reaction.

The whole project was of extreme importance to the national security. At the time, the United States had been engaged in World War II for nearly a year, and the nuclear reactor experiment had the potential for making a major contribution to the war effort. A successful nuclear fission reaction, on a proper scale, would release an incredibly enormous amount of energy, and could produce an explosion of immense proportions. The possibility that scientists of the Axis powers might develop a device to achieve such a frightening explosion made imperative a vast effort -- the Manhattan Project -- within the United States to develop such a device first.

It was in this tense, wartime environment that Mallinckrodt was asked to produce the key uranium compounds which were needed before further progress could be made. Dr. Compton and his associates at the University of Chicago already had approached several other major chemical producers to ask their assistance, but they all declined -- partly because of other wartime commitments, and partly because of the difficulty and risk involved in the uranium-purification assignment.

To produce the needed uranium fuel, impure uranium concentrates would have to be purified by extraction with ether. Never before had the extraction been achieved on anything but a laboratory scale, and even on that small scale, the explosive and erratic nature of the ether made the operation extremely hazardous.

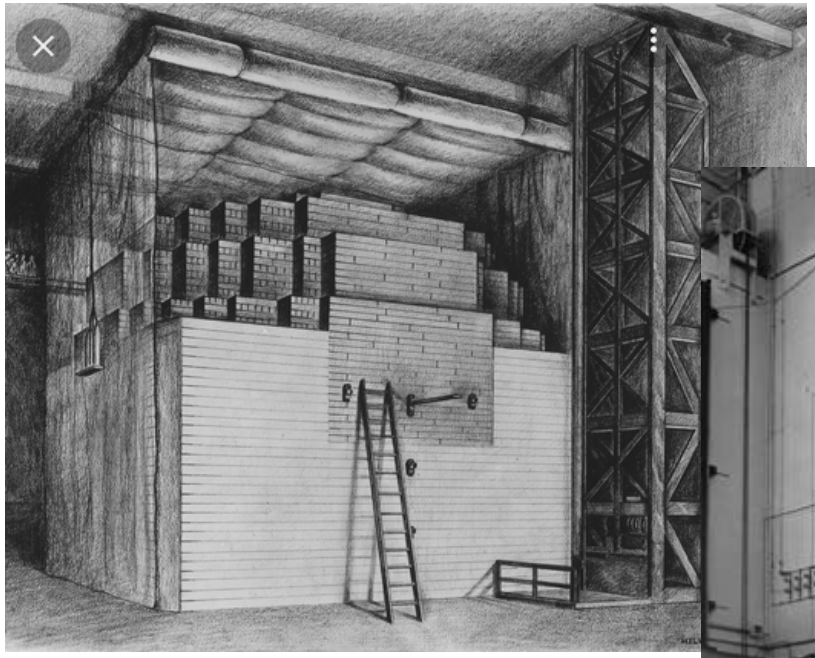
Dr. Compton turned to Mallinckrodt because he was familiar with the Company's outstanding reputation for safely producing high-quality, high-purity products, and because he knew that the Company was expert in handling ether.

Mallinckrodt accepted the challenging assignment, and within 50 days, the Company accomplished the "remarkable achievement" of producing highly purified uranium oxide on a tonnage scale.

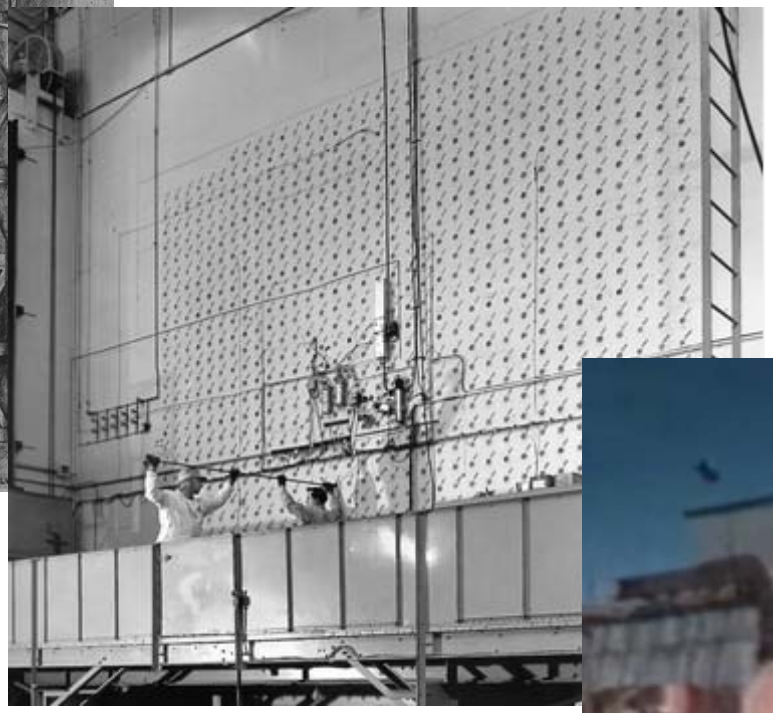
MAJOR CONTRIBUTIONS BY MALLINCKRODT CHEMICAL WORKS

* First Commercial Process for Ether Extraction of Uranyl Nitrate
* First Factory Production of Orange Oxide from Uranyl Nitrate
* First Factory Process for Producing Brown Oxide
* Early Production of Green Salt
* Early Commercial Reduction and Casting of Uranium Metal
* First Stirred-Bed Reactor for Continuous-Process Production of Green Salt and Brown Oxide
* First Commercial Continuous Ether-Extraction Process
* First TBP-Kerosene and TBP-Hexane Processes for Uranium-Ore Refining
* Numerous Advances in Uranium Metal Production, Including Slag Liner, Dingot-Extrusion, and Electrolytic Reduction
* First Successful, Commercial Fluid-Bed Denitration System
* First Integrated, Continuous-Process Fluid-Bed Uranium Production
* Adaption of Uranium Processing Equipment to Commercial Production of Purified Dense Thoria
* Continuous Cost Reduction Through Advances in Manufacturing Practices and Scrap Recovery
* Consistent Fulfillment of AEC Production Objectives

Fermi's "Chicago pile-1" CP-1 reactor (mixed $^{nat}UO_2$ and metal)



ORNL X-10 (^{nat}U metal)



~ 100,000 kg ~ 100 tonnes
Of U purified by **Mallinckrodt**
At 19 g/cm^3 or 19 t/m^3
➔ ~ 5m^3 ~ (1.7m)^3

Hanford B (^{nat}U metal)

The first reactors used
a) natural U purified from the ore by Mallinckrodt in StL.
b) Ultra pure graphite (C with B removed).

Summary of MCW work: batch ➔ continuous systems

Pitchblend mixed oxides

Ether or diluted TBP

*"Raffinate" : a liquid into which impurities have been removed by solvent extraction.

Uranyl nitrate (UNH)

$UO_2(NO_3)_2*6H_2O$

UNH

↓ Δ In SS ovens

UO_3

↓ Reduction using "cracked" NH_3 Δ + Ni NH_3 ➔ $N_2 + 3H_2$

UO_2

↓ HF & Δ

UF_4

↓ Reduction
Mg thermite reduction
Later Electrolytic

U (metal)

> 100 tons U, later ~ 500 tons ThO_2 (@ Weldon Springs)

6. Cleanup agenda: Assessing what to remediate and to what criteria
➔ assessing the "additional" risk & USACE procedure

1. **10 CFR 300.430**: Protectiveness is achieved when additional lifetime risk is

   less than < 1.0 x 10^{-4} (1 in 10,000). "Additional" means more than naturally occurring background.

2. **For reference: lifetime CA risk**

   From natural background: Resident 1.8 x 10^{-4} (1.8 in 10,000) Farmer 2.8 x 10^{-4} (2.8 in 10,000)

   All CA - Unascribed : Female 39.6% (13% breast), Male 41.6% (13% prostate)

3. **Procedure (Outline/Sketch)**

   a) Risk assessed for properties listed in the ROD

   b) Soil sampling/structure survey data is used to determine additional risk to a resident/occupants.

   c) **S**um **O**f **R**atios for both surface ($\mathrm{SOR} \equiv \frac{^{226}Ra}{5} + \frac{^{230}Th}{14} + \frac{^{238}U}{50}$) and subsurface (15/15/50) constructed.

   d) If SOR > 1 ➔ clean up.

   e) If SOR for any single measurement > 1, collected more sample in region and generate (biased) SOR.

   Only if biased SOR < 1 is the parcel considered remediated.

4. What does remediated mean? The risk is assessed at PD + 1000 years and this risk must be < **1.0 x** 10^{-4} .

   Almost always a factor of several – 10 lower. (Examples to follow.) This is before topsoil is added.

SCI ENGINEERING, INC.

Soil Results (pCi/g)

Example # 1 Jana

	U-238	Th-230	Ra-226	Pb-210		U-238	Th-230	Ra-226	Pb-210
S-1	0.84	1.24	1.41	2.35	S-16	1.44	0.737	0.682	1.35
S-2	0.812	1.18	1.47	1.75	S-17	0.917	0.894	1.59	1.56
S-3	0.769	0.848	1.16	3.76	S-18	0.871	1.18	1.23	2.11
S-4	0.813	1.00	1.29	4.45	S-19	0.969	1.36	1.14	-1.93
S-5	0.871	0.937	1.29	4.09	S-20	1.37	0.841	0.669	2.63
S-6	0.679	1.05	1.03	3.46	S-21	0.721	1.07	1.32	2.65
S-7	0.682	0.704	1.33	1.99	S-22	0.94	0.99	1.44	1.49
S-8	0.594	0.663	0.721	42.3	S-23	0.899	0.768	0.193	0.881
S-9	0.902	1.07	0.814	0.604	S-24	0.651	0.852	2.03	3.18
S-10	0.747	0.767	1.37	-0.98	S-25	0.86	1.36	1.5	2.27
S-11	1.17	0.812	1.31	2.09	S-26	0.664	0.8	0.49	3.36
S-15	0.71	0.659	0.843	0.279	S-27	0.651	0.738	0.959	5.18
S-13	0.63	1.17	1.55	0.988	S-28	0.742	0.861	1.5	1.91
S-14	0.937	0.88	1.48	2.29	S-29	0.794	0.859	1.39	2.33
S-15	0.835	0.773	1.26	-3.03	S-30	0.884	0.822	1.36	-0.868

Three conclusions

1. $\langle^{238}U\rangle = 0.84$ pCi/g
   $\langle^{230}Th\rangle = 0.93$
   $\langle^{226}Ra\rangle = 1.19$

➔ All consistent with local bkgd

2. R ≡ Th/Ra ratio
   $\langle R\rangle = 0.92$, $\sigma = 0.64$
   $R_{max} \sim 4$, $R_{min} \sim 0.4$
   ➔ NOT elevated

3. One sample (S8) - of 30 - and the sampling of the same spot by BCDC deserves closer study.
   SCI / BCDC
   S8 / STL 2022-015S

Have "^{210}Pb" = 42 pCi/g
WHY?

Second site of somewhat elevated ^{210}Pb.

Dust Wipes(pCi/w)

	U-238	Th-230	Pb-210		U-238	Th-230	Pb-210
DW-1	0.08	0.002	14.4	DW-16	0.154	0.12	-2.19
DW-2	0.098	0.437	3.23	DW-17	0.022	0.343	-2.61
DW-3	0.032	0.241	0.45	DW-18	0.08	0.155	-1.28
DW-4	0.023	0.036	0.355	DW-19	0.015	0.407	-2.6
DW-5	0.108	0.336	-0.481	DW-20	-0.041	0.26	-2.41
DW-6	0.006	0.334	0.051	DW-21	0.003	0.432	-3.35
DW-7	0.003	0.297	7.59	DW-22	0.096	0.224	-1.51
DW-8	0.138	0.558	-1.19	DW-23	0.088	0.016	-2.98
DW-9	0.076	0.134	-0.102	DW-24	0.082	0.333	-2.45
DW-10	0.067	0.03	-0.933	DW-25	0.044	0.21	-2.84
DW-11	0.022	0.135	-0.271	DW-26	0.051	0.441	-1.64
DW-12	0.105	0.11	-0.555	DW-27	0.134	0.22	1.07
DW-13	0.412	0.228	12.7	DW-28	0.074	0.268	2.84
DW-14	0.085	-0.009	-2.2	DW-29	0.065	0.211	-2.43
DW-15	0.053	0.18	-1.59	DW-30	0.512	0.655	-2.08

Results (pCi/w)

	SCI Average	SCI Background
Uranium 238	0.075	0.512
Thorium 230	0.231	0.665
Lead 210	0.244	-2.08

Radon Testing

Sampling Plan

- 17 Locations throughout building
- 2 Duplicates
- 1 Blank

Result

- Average Radon 1.89 pCi/L

EPA Action Level

- 4.0 pCi/L

Radon Zone 2 (includes St. Louis County)

- 2-4 pCi/L

“Wipes” and radon testing show NO elevation

Negative numbers are occasionally expected and in this case the result of only one background measurement.

Returning to the elevated "^{210}Pb".

This is a real result, all three investigations: USACE, BCDC, & SCI found elevated ^{210}Pb in ~ this location (shown on slide 15)

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journal homepage: www.elsevier.com/locate/jhydrol

Research papers

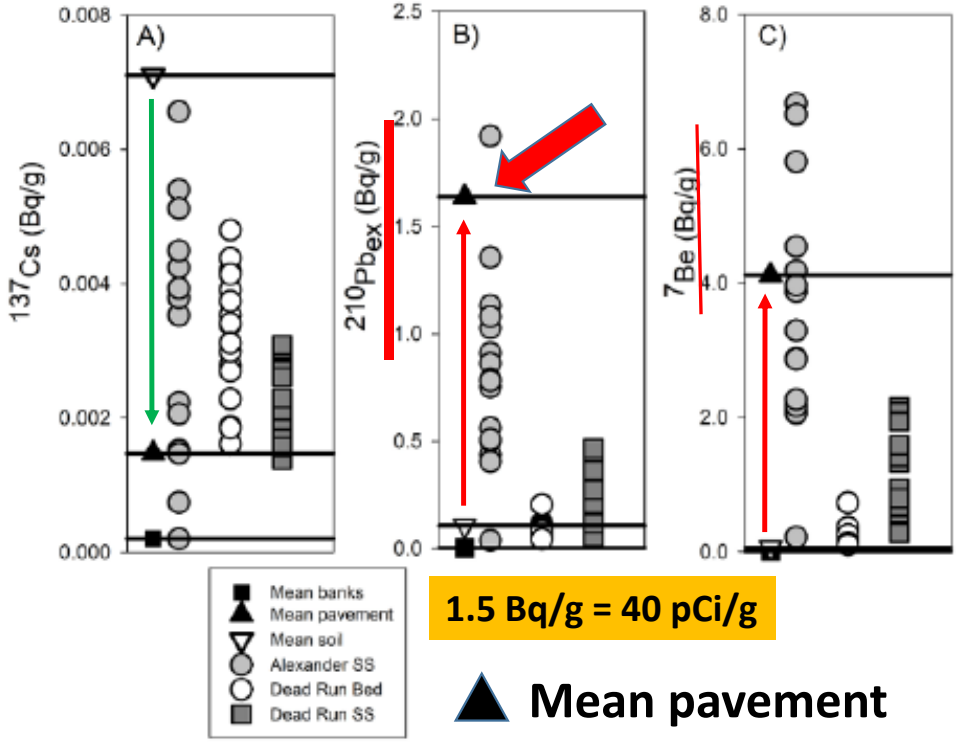
Pavement alters delivery of sediment and fallout radionuclides to urban streams

Allen C. Gellis[a,*], Christopher C. Fuller[b], Peter C. Van Metre[c], Barbara J. Mahler[c], Claire Welty[d,e], Andrew J. Miller[d,f], Lucas A. Nibert[g], Zach J. Clifton[a], Jeremy J. Malen[a], John T. Kemper[h]

Study from Baltimore

➔ Concentration of "fallout" ←

From Summary and Conclusions….

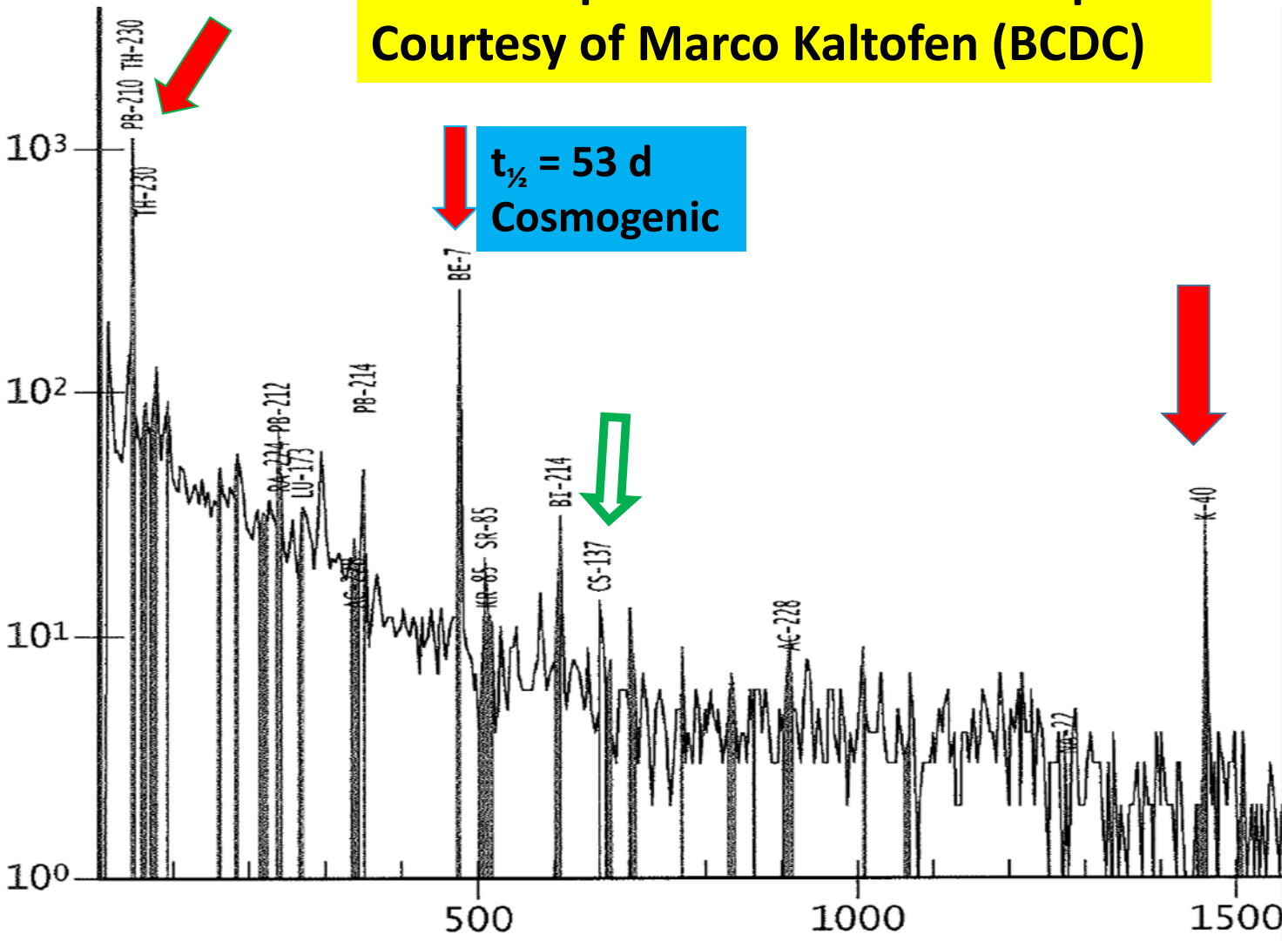


1.5 Bq/g = 40 pCi/g

▲ **Mean pavement**

streambanks. These findings support the hypothesis that sediment from urban impervious surfaces is substantially enriched in $^{210}Pb_{ex}$ and ^{7}Be from rainfall but not in ^{137}Cs, resulting in a unique radionuclide signature compared to other sediment-source settings. This difference in

Gamma spectrum of ^{210}Pb hot spot. Courtesy of Marco Kaltofen (BCDC)



STL 2022-015S

(Highest BDCD value 46.9 pCi/g)

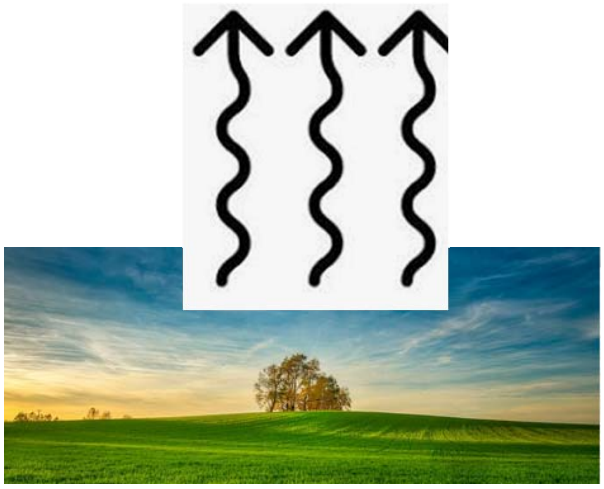
K - 40
Ac-228
Cs-137
Bi-214
Kr-85/Sr-85
Be-7
Pb-214
Lu-173
Pb-212/Ra-224
Th-230
Pb-210

X

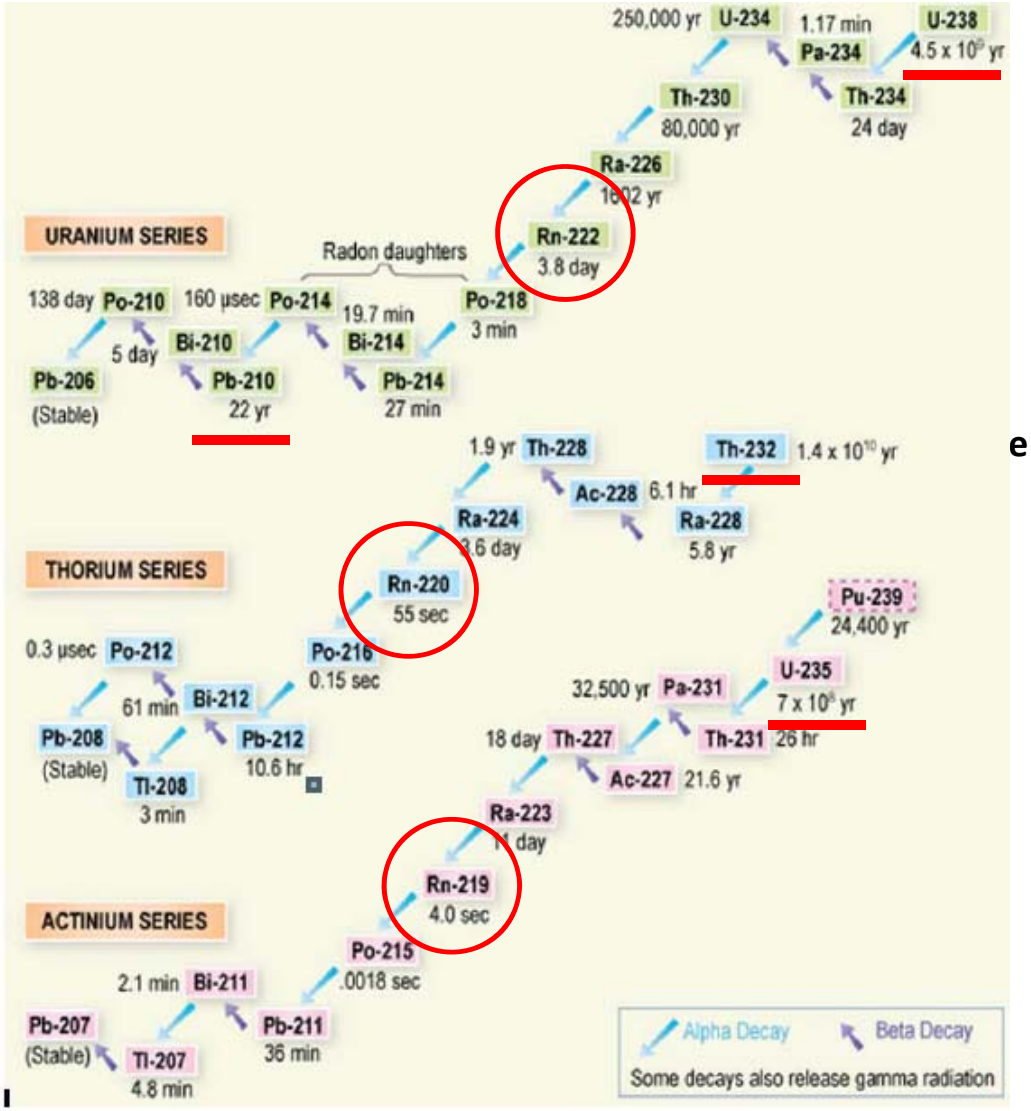
Gamma Energy (keV)

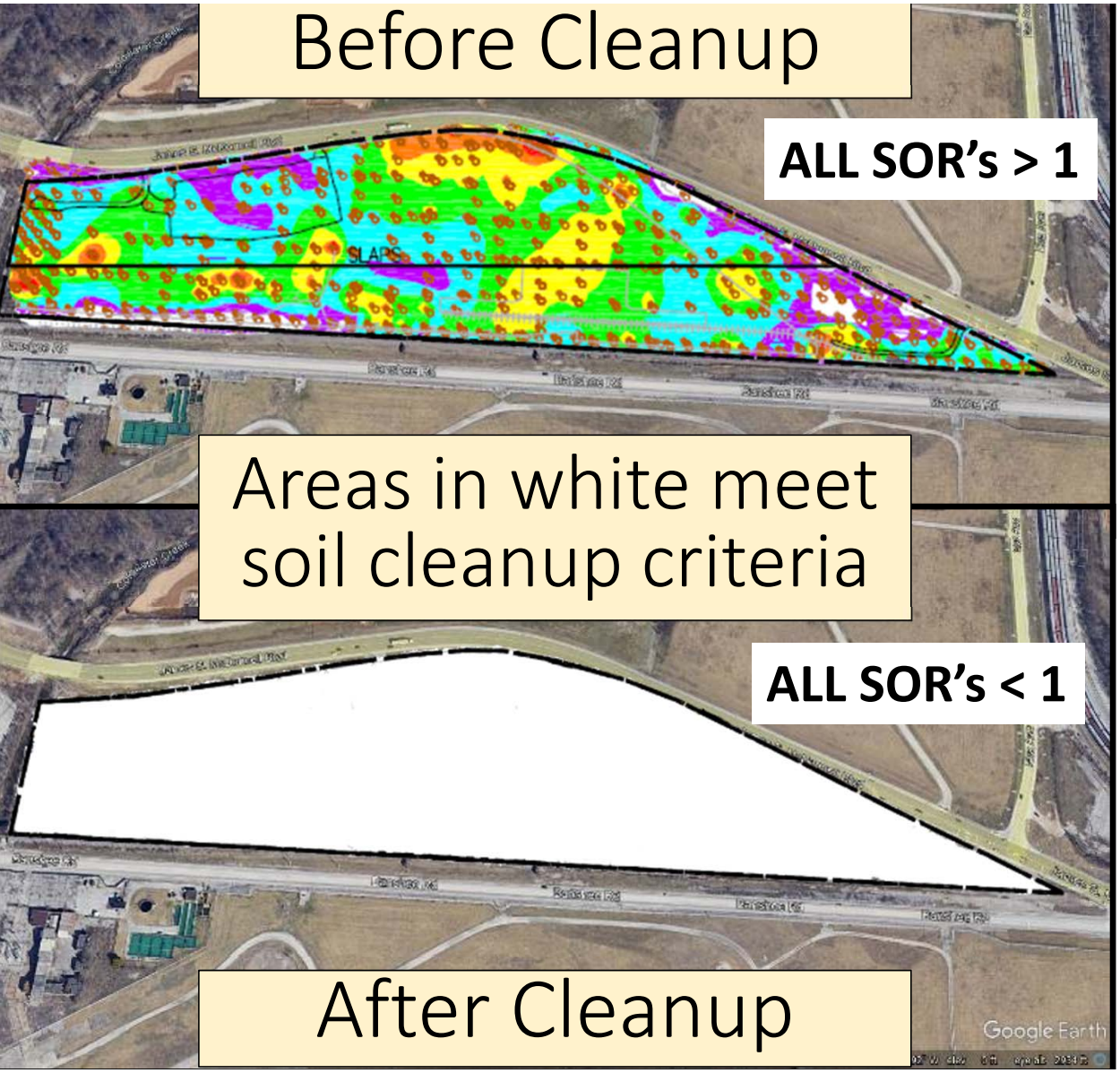
SUMMARY: Unintentional human redistribution of natural radioactivity. Modern society is rife with these marginal increases in activity.

Rn gas



^{235,238}U, ^{232}Th and all daughters





Example # 2 SLAPS

Pre-remediation

Almost all of the initial SLAPS soils exceeded dose/risk cleanup criteria, i.e. required cleanup by ROD standards.

Post-remediation

All of SLAPS soils below dose/risk cleanup criteria

* SLIDE FROM USACE

EXAMPLE # 3 CWC property cleanup

PRE-DESIGN INVESTIGATION SUMMARY REPORT AND FINAL STATUS SURVEY EVALUATION FOR COLDWATER CREEK (CWC)-FLOODPLAIN PROPERTIES CWC-263 THROUGH CWC-285, PADDOCK CREEK, AND EAST HUMES LANE

ST. LOUIS, MISSOURI

MARCH 9, 2022

Calculated

Additional lifetime generally a factor of 10 lower then 10^{-4}

Additional DOSE ~< 1 mrem/year

UUUE (unlimited use – residential gardener)

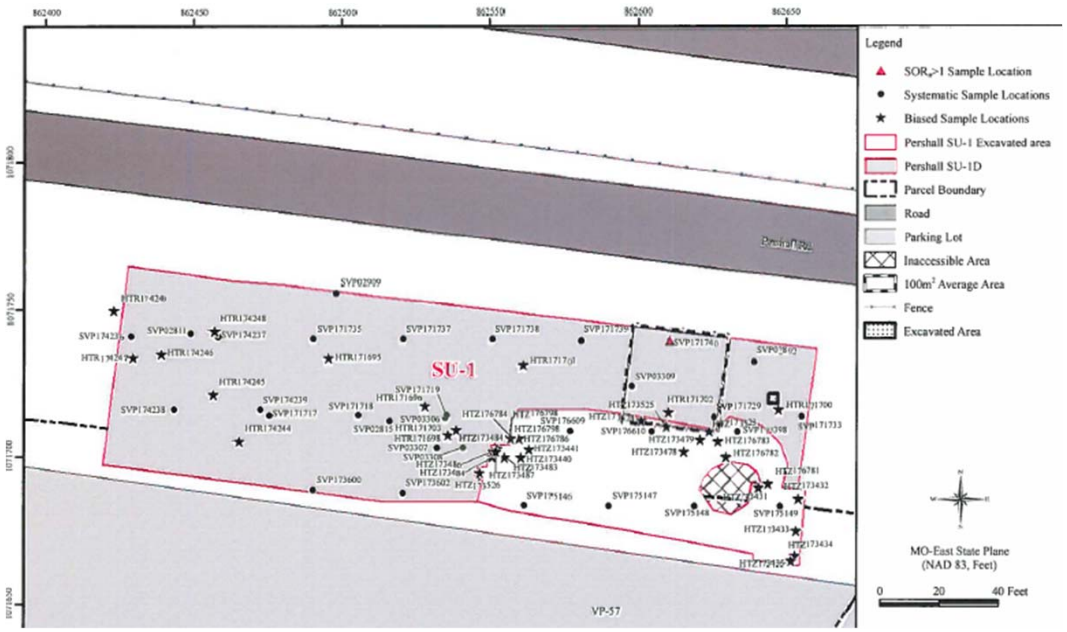
Informational (recreational)

Table 6. Comparison of Results to Remediation Goals

RG Type	Specification	Results
Soil Radionuclide SOR_N Note: Area-weighted average in a 0.5-ft-thick layer of soil over a 100-m^2 area.[a]	$SOR_N \leq 1.0$ when averaged over 100 m^2. $SOR_N \leq 1.0$ when systematic or random soil sample analytical results are averaged over an SU.	No Class 1 SUs identified. Average Systematic SOR_N Values: SU-1: 0.03 SU-2: 0.07 SU-3: 0.05
Soil Radionuclide WRS Test	Pass the MARSSIM WRS Test.	Passes the WRS Test.
Structure Surfaces DCGL	Calculate the DCGL. Fixed-point measurements do not exceed the DCGL for structure surfaces when averaged[b] over 1 m^2.	The DCGL is determined to be 2,800 dpm/100 cm^2 of gross alpha radioactivity.
Structure Surface Sign Test	Pass the MARSSIM Sign Test.	Structure surfaces are evaluated as non-impacted; the greatest PDI result is 8 percent of the DCGL (Section 3.4). No FSS is required.
Health Risk[c,d]	Less than the upper bound of the CERCLA target risk range of 10^{-6} to 10^{-4}.	1.9×10^{-5} (UUUE) 2.2×10^{-7} (Informational) 2.0×10^{-5} (Informational)
Dose[d]	Total effective dose equivalent (TEDE) <19 mrem/year.	1 mrem/year (UUUE) 0.3 mrem/year (Informational) 1 mrem/year (Informational)
Groundwater	No RG. Environmental monitoring results are documented in annual Environmental Monitoring Data and Analysis Reports.	Because no soil areas are in excess of the ROD RGs, long-term groundwater monitoring is not required.
Surface Water	No RG. Environmental monitoring results are documented in annual Environmental Monitoring Data and Analysis Reports.	Because the CWC corridor is not included in the scope of this PDIR-FSSE, surface water and sediment are not applicable to these CWC-floodplain properties.
Contaminated Soil under Structures	If soil under structures is contaminated, the average of net radiation measurements does not exceed the background level by more than 20 µR/hour.	Soil under structures meets the criteria for UUUE.

DRAFT

Example # 4
Pershall South ditch Survey Unit 1



"Biased" study (non-random) In region of Max SOR

Sample HTZ75358			
Sample ID	Area (m²)	SOR$_N$	Weighted SOR
SVP171740	47.5	1.50	0.71
SVP03309	1.0	0.84	0.01
SVP171729	47.5	0.34	0.16
HTR171702	1.0	0.25	0.00
HTZ173523	1.0	0.30	0.00
HTZ173525	1.0	0.36	0.00
HTZ173524	1.0	0.15	0.00
TOTALS	100.0		0.89

SOR

Final Status Survey MARSSIM Evaluation Report
North St. Louis County Site Property Pershall South Ditch Survey Unit 1

DATA SUMMARY TABLE

Survey Unit Descriptive Information			
Site:	North County	Property:	Pershall South Ditch
Survey Unit:	SU-1	Evaluation Result:	Passed
Area (m²):	1476	Excluded Area (m²):	0
Soil Sample Planning Information			
MARSSIM Class:	1	MARSSIM DCGL:	1
MARSSIM LBGR:	0.4	Effective St. Dev.:	0.24
MARSSIM Relative Shift:	2.55	Estimate of minimum number of systematic samples required:	6
Soil Sample Summary Information			
No. Sys. Samples Collected:	22	Mean/Median Sys. SOR$_N$:	0.30/0.17
No. GWS-Based Samples:	38	St. Dev. Systematic SOR$_N$:	0.34
No. Other Biased Samples:	9	Max. Sample SOR$_N$:	1.50
No. Samples Below Excav. Surf.:	42	Max. 100 m² SOR$_N$:	0.89
No. Samples SOR$_N$>1:	1	No. QC Split/Dup. Samples	3
Ra-226 Contribution to SOR$_G$ (%)	8%	Th-230 Contribution to SOR$_G$ (%)	90%
No. Non-rad. Samples	0	Non-rad. Results Greater than RG: (element/RG/Results in mg/kg)	NA
Preliminary Risk and Dose Information			
Preliminary Risk Est.:	1 x10^{-5}	Max. Hotspot Risk Est.:	4 x10^{-5}
Prelim. Dose Est. (mrem/yr):	1	Max. Hotspot Dose Est. (mrem/yr):	2
Prelim. Risk/Dose at Year:	1000	Max. Hotspot Risk/Dose at Year:	1000
Structure Survey Summary Information			
Class 1 Structure Area (m²):	None	Alpha Limit (dpm/100 cm²):	N/A
Min. No. Sys. F-P Surveys Req.:	N/A	Max. Alpha Result > RG (dpm/100 cm²):	N/A
No. Sys. Fixed-Point Surveys:	N/A	Beta Limit (dpm/100 cm²):	N/A
		Max. Beta Result > RG (dpm/100 cm²):	N/A
		Max. 1 m² Avg. Alpha (dpm/100 cm²):	N/A

SIGNATURES

Sample		Ac-227$_G$ (pCi/g)	Pa-231$_G$ (pCi/g)	Ra-226$_G$ (pCi/g)	Ra-228$_G$ (pCi/g)	Th-230$_G$ (pCi/g)	Th-232$_G$ (pCi/g)	U-238$_G$ (pCi/g)	SOR$_N$	Evaluation Depth
SVP171718		0.09	-0.03	1.20	0.78	2.42	1.05	0.86	0.12	Surface
SVP171719		0.05	0.00	1.15	0.78	2.75	0.84	0.84	0.13	Surface
SVP171729		0.18	-0.05	1.15	0.95	5.62	0.92	1.12	0.34	Surface
SVP171733		0.09	0.15	1.18	0.99	6.18	0.88	1.53	0.39	Surface
SVP171735		0.05	0.26	1.19	0.96	4.50	0.97	1.04	0.26	Surface
SVP171737		-0.02	0.05	1.17	0.94	3.37	1.59	0.93	0.18	Surface
SVP171738		0.33	-0.09	1.23	0.87	13.20	0.64	1.63	0.90	Surface
SVP171739		0.12	0.00	1.10	0.80	8.66	0.82	0.92	0.54	Surface
SVP171740		0.33	0.39	1.26	0.85	21.50	1.23	1.74	1.50	Surface
SVP173600		-0.02	-0.46	1.18	0.41	1.36	0.46	0.91	0.05	Surface
SVP173602		0.01	0.02	1.16	0.71	5.83	1.14	0.59	0.35	Surface
SVP174236		-0.05	0.33	1.11	1.02	1.52	0.77	1.41	0.04	Surface
SVP174237		-0.03	0.00	1.05	0.85	2.95	0.77	0.79	0.12	Surface
SVP174238		0.02	-0.15	1.09	0.89	2.76	0.99	1.04	0.12	Surface
SVP174239		-0.21	0.41	1.35	0.95	2.48	1.15	1.49	0.16	Surface
SVP175146		-0.09	0.03	1.09	0.85	2.11	1.19	1.42	0.08	Surface
SVP175147		0.06	0.15	1.18	1.05	1.29	1.14	1.26	0.05	Surface
SVP175148		-0.12	0.48	1.23	1.19	3.07	1.16	2.52	0.20	Surface
SVP175149		0.12	-0.14	1.26	0.94	6.08	0.77	1.37	0.40	Surface
SVP176609		-0.17	0.38	1.20	0.91	1.44	0.93	2.11	0.07	Surface
SVP176610		0.02	0.01	1.30	0.97	6.29	0.73	1.30	0.42	Surface
SVP177398		-0.01	0.22	1.16	1.08	2.28	1.36	1.69	0.11	Surface
Mean	*(x)*	0.03	0.09	1.18	0.90	4.89	0.98	1.29	**0.30**	Mean
Median		0.02	0.02	1.18	0.92	3.01	0.95	1.28	0.17	Median
St. Dev.	*(s)*	0.14	0.23	0.07	0.15	4.68	0.26	0.46	**0.34**	St. Dev.
Minimum		-0.21	-0.46	1.05	0.41	1.29	0.46	0.59		Minimum
No. Samples	*(n)*								**22**	No. Samples

Conclusions

1. The ratio R ≡ $^{230}Th/^{226}Ra$ >> 1 indicates Mallinckrodt infiltration and the need for remediation.
   This was the case at SLAPS, portions of CWC, …. but NOT Jana.

2. The lesson from Jana,
   a) the samples, wipes, and air monitors are NOT cause for concern and
   b) the high "^{210}Pb" is localized and consistent with concentration of natural material by human-made impervious surfaces i.e. not from infiltration of MCW U-ore processing.

3. To address above issue: If one finds elevated ^{210}Pb ↑, look for ^{7}Be ↑ and suppressed ↓ ^{137}Cs.
   If this finger print is found, rework drainage and let USACE move on to focus on the areas that do require remediation. ➔ There are many.

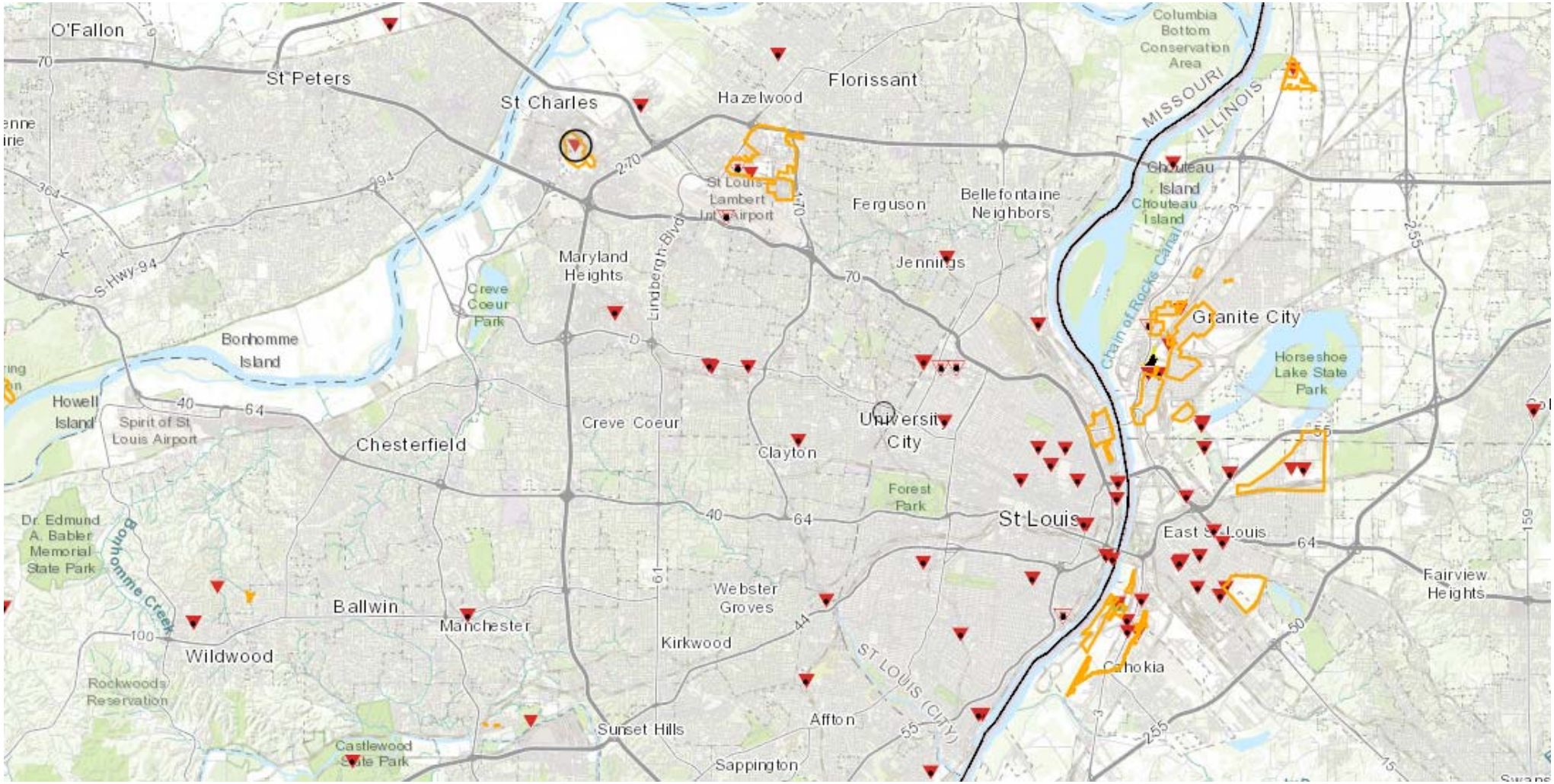
4. To date > 1.45M cy (almost 18,000 rail cars) of soil have been shipped out.
   100 k cy ~ 1000 train car loads before 2000.
   Job completion (additional risk < 10^{-4} @PD+1000 y for unrestricted use) will require > a decade.

5. If this job is completed, the elevated risk that certainly existed in the past, will be reduced to a level well below that caused by natural background. The "additional" dose/rick is cannot be 0.

6. Additional considerations: signage and ultimate land use.

"The single biggest problem with communication is the illusion that it has taken place" G. B. Shaw.

EXTRA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St Peters
St Charles
Hazelwood
Florissant
Columbia Bottom Conservation Area
MISSOURI
ILLINOIS
Chouteau Island
Chouteau Island
Bellefontaine Neighbors
Ferguson
St Louis Lambert Intl Airport
Maryland Heights
Jennings
Lindbergh Blvd
Creve Coeur Park
Granite City
Chain of Rocks Canal
Horseshoe Lake State Park
Bonhomme Island
Howell Island
Spirit of St Louis Airport
Chesterfield
Creve Coeur
University City
Clayton
Forest Park
St Louis
East St Louis
Fairview Heights
Dr. Edmund A. Babler Memorial State Park
Bonhomme Creek
Ballwin
Manchester
Webster Groves
Kirkwood
Wildwood
Rockwoods Reservation
Cahokia
ST LOUIS (CITY)
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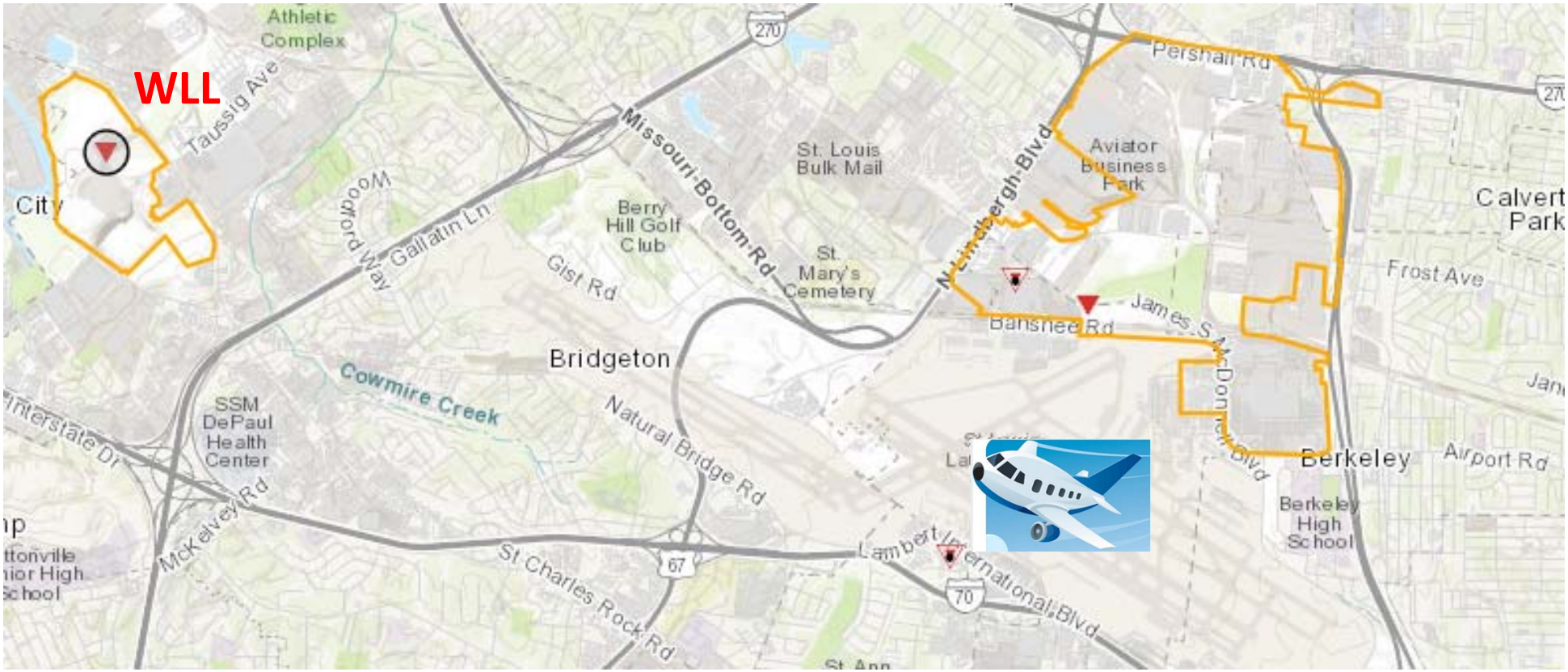
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City
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Gallatin Ln
Missouri Bottom Rd
St. Louis Bulk Mail
Berry Hill Golf Club
St. Mary's Cemetery
Gist Rd
Bridgeton
Cowmire Creek
Natural Bridge Rd
SSM DePaul Health Center
McKelvey Rd
St Charles Rock Rd
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70
Lambert International Blvd
Pershall Rd
Aviator Business Park
N Lindbergh Blvd
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Calvert Park
Berkeley
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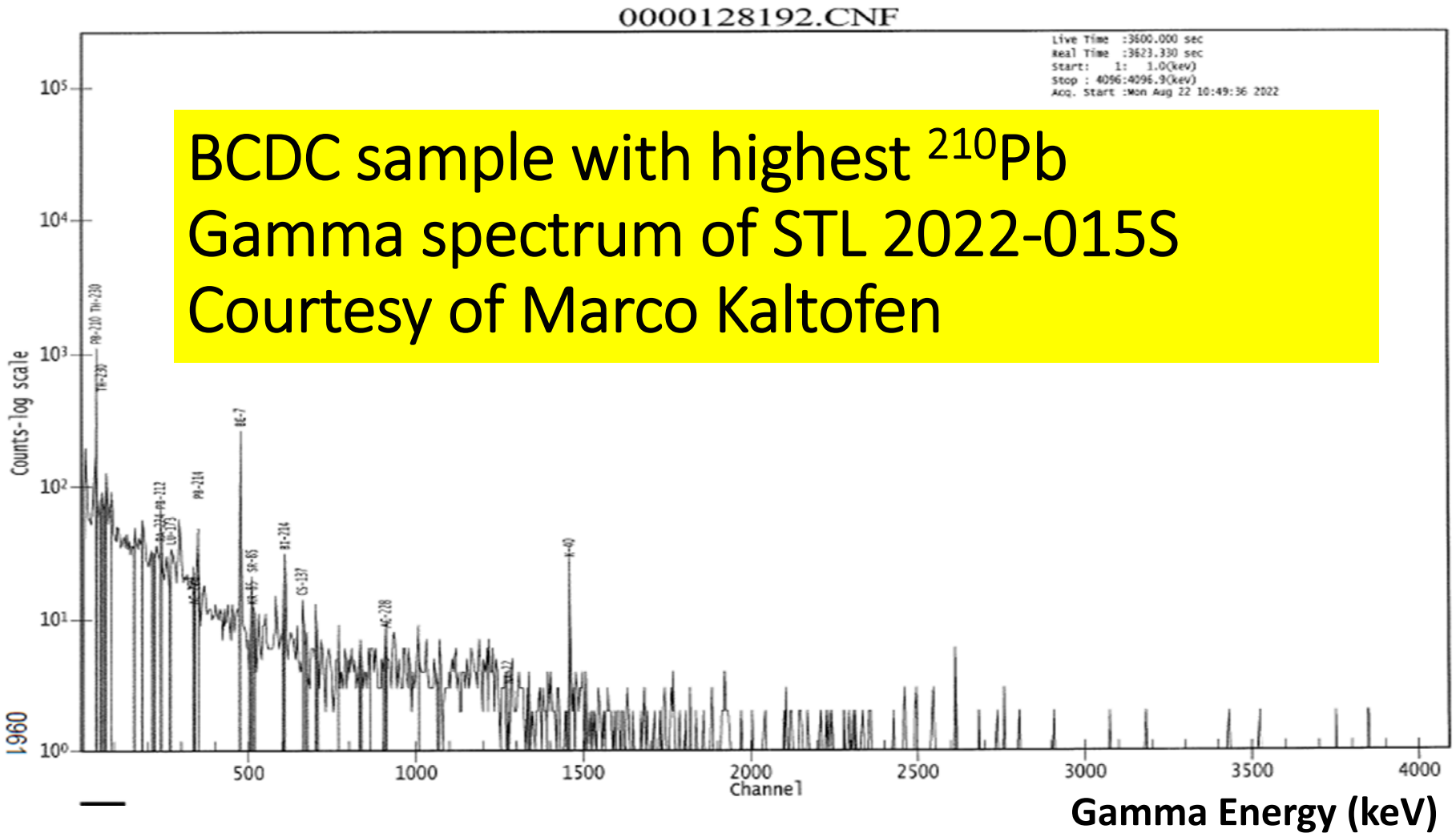
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Real Time :3623.330 sec
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Stop : 4096:4096.9(kev)
Acq. Start :Mon Aug 22 10:49:36 2022
BCDC sample with highest 210Pb
Gamma spectrum of STL 2022-015S
Courtesy of Marco Kaltofen
Counts-log scale
Channel
Gamma Energy (keV)
PB-210 TH-230
BI-214
PB-214
K-40
1960

BCDC

One nearby home on Moule Drive was tested and found to be contaminated by these same radioactive wastes. Worse, this same home also had metallic thorium (used in the making of atomic bombs) and cesium-137 (a radioactive isotope associated with nuclear wastes). Indoor dust samples collected from this home were found to

In addition, lead-210 was found in soils immediately adjacent to the school's basketball courts at 25.8 ± 0.93 pCi/g. This activity level is

ppm) and cadmium (14.3 ppm). These concentrations for mercury and cadmium are more than ten times the expected level. Radioactive cesium-137 was found at 2.20 ± 1.09 and at 4.71 ± 2.80 pCi/g; more than twenty times the highest background levels found in the area

13 - Boston Chemical Data Corp., Review of Jana Elementary School Data

137Cs has nothing to do with MCW
Uncertainties make measurement of little value and unconfirmed by others. …. "Red Herring"

(Kaltofen 2018 citing Wallo 1994). Indoor dust at the home also had 6.23 ± 0.52 pCi/g of Pb210, compared to the background activity of 2.08 pCi/g (EPA Region 7 Site Background & Current Conditions, https://semspub.epa.gov/work/07/30337840.pdf).

The presence of lead-210 in soils and dusts at the Jana School is important beyond the excess radioactivity detected. Alpha radiation is especially biologically damaging compared to other forms of radiation such as beta and gamma radiation. Lead-210 is an alpha

17 - Boston Chemical Data Corp., Review of Jana Elementary School Data

emitter (Kaltofen 2021). Lead-210 also produces polonium-210 when it decays. Every time an atom of lead-210 decays, it decays into polonium-210 within a few days or weeks. Polonium-210 is itself an alpha emitter, and it decays with a half-life of much less than a year (138 days). This means that each decay of lead-210 will shortly be followed by an equally damaging decay of polonium-210. This is called secular equilibrium.

WRONG

Because of the impact of secular equilibrium in lead-210 decay, the true activity resulting from the 46.8 pCi/g of lead-210 found at the school is effectively doubled when polonium-210 is accounted for, resulting in 93.6 pCi/g of alpha activity, vs. the background (4.16 pCi/g for combined lead-210 and polonium-210) or the maximum net amount of alpha activity allowed in surface soils by CERCLA, which is 5.0 pCi/g. Likewise, lead-210 and polonium-210 were found in indoor dust from the Jana School kitchen at a combined total activity of 27.8 ± 3.0 pCi/g.

Source	Annual Effective Dose Equivalent (mSv/yr)(1)	Annual Risk per million people (2) (cancer deaths attributable to these sources)	Lifetime Risk per million people (3) (cancer deaths attributable to these sources)
Natural			
Radon	10.4	310	22,000
Cosmic	0.50	40	2800
Terrestrial	0.46	37	2600
Internal	0.39	31	2200
sub-total	11.8	**420** deaths per million	**30,000** deaths per million
Artificial			
Medical			
a) x-ray diagnosis	0.39	31	2200
b) Nuclear medicine	0.14	11	770
Consumer products	0.1	8	560
sub-total	0.6	**50** deaths per million	**3500** deaths per million
TOTAL	12.4	**470** deaths per million	**33,000** deaths per million

Huge variability

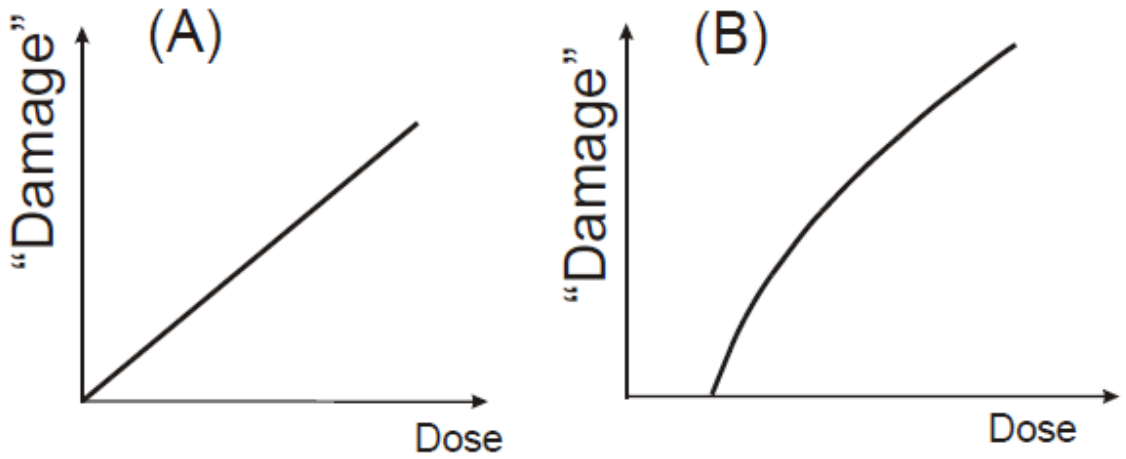
Lifetime Risk
~ 30/1000 ~ 3 %

This is LIFETIME risk !
A short-term exposure to even 100 x background is not consequential.

This is what happens when you have a medical test.

Old & unresolved controversy:

Linear response or threshold followed by linear response.



Cancer induction (linear response) ~ 0.05%/rem ~ 5%/Sv ~ <u>0.5 ppm/mrem (extrapolation)</u>

There is an extremely efficient repair of Single-Strand DNA breaks SSB.

NOT SO WITH Double-Strand Breaks DSB. These often lead to apoptosis (cell death).

➔ The greater the ionization density the greater the probability of DSB. The "Quality factor" is meant to capture this.

3. Some basic Nuc. Sci.

1. Alpha decay occurs when the Binding Energy/nucleon drops below that of the α
   Mass = [mass of constituent p's, n's, and e-'s] – BE_N - BE_e
2. Natural decay chains are a mix of α & β^- because of the curvature of the line of stability