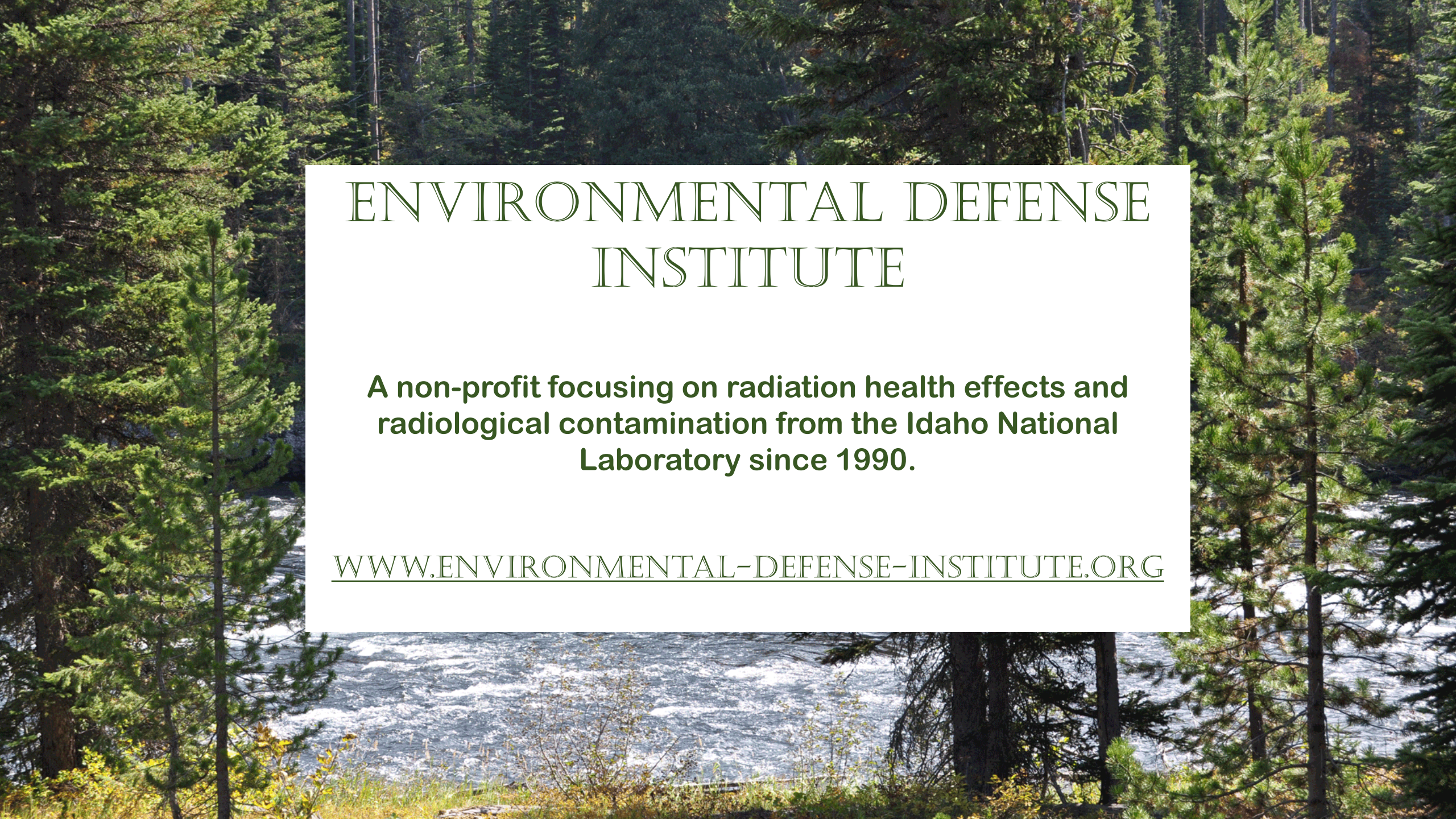

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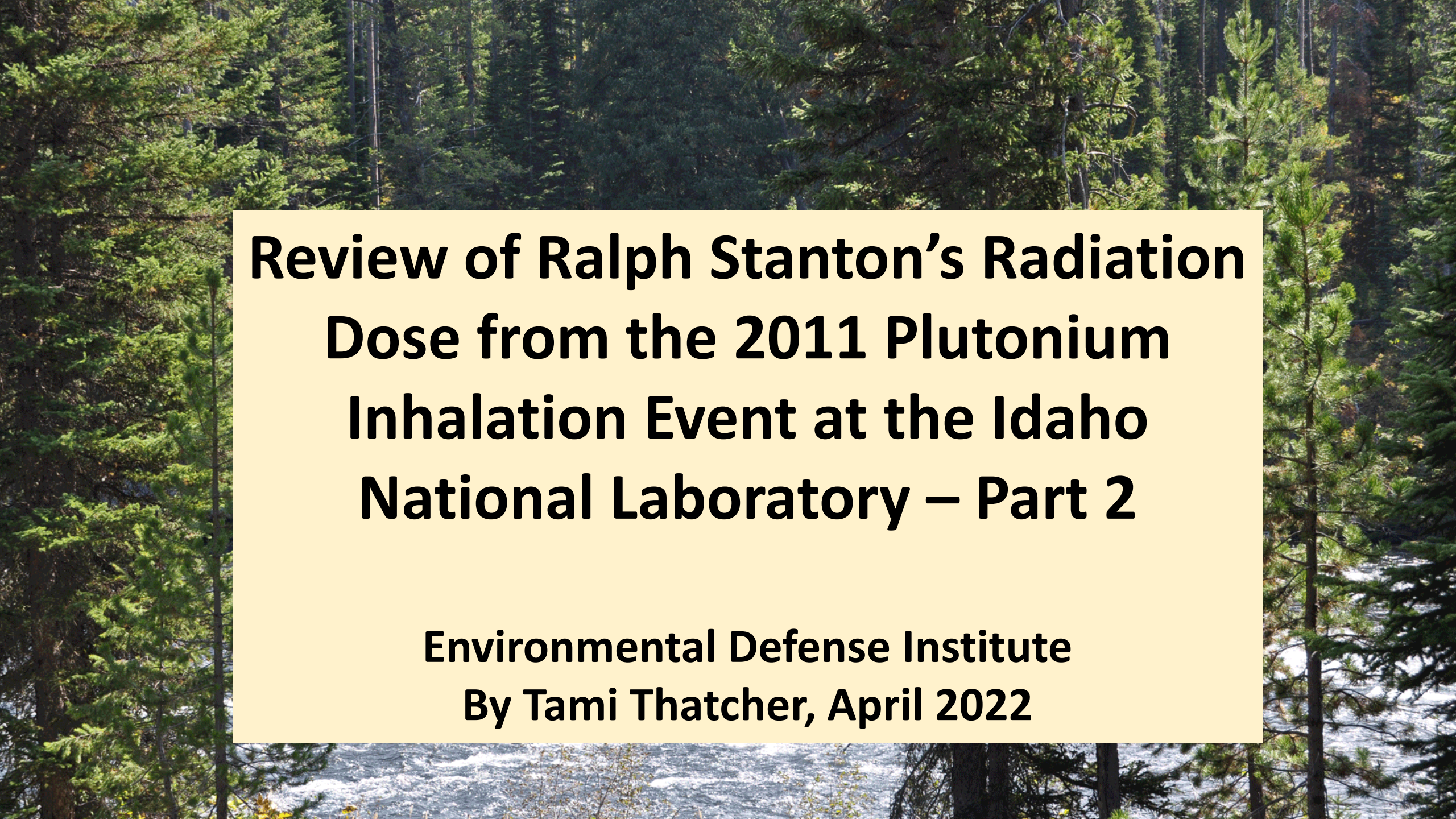

Review of Ralph Stanton's Radiation Dose from the 2011 Plutonium Inhalation Event at the Idaho National Laboratory – Part 2

Environmental Defense Institute
By Tami Thatcher, April 2022

The November 8, 2011 plutonium inhalation event at the Department of Energy's Idaho National Laboratory (INL)

- The accident occurred at the Materials and Fuels Complex (MFC) at the Zero Power Physics Reactor (ZPPR) facility.
- The Department of Energy Accident Investigation found that the accident was preventable and Battelle Energy Alliance failed to put mitigations in place, and ignored multiple warnings of risk to workers concerning plutonium plates.
- Battelle Energy Alliance faced fines if the maximum dose to a worker exceeded 5 rem/yr effective whole body or 50 rem/yr limiting organ or tissue.
- **A 0.1 rem (100 mrem) dose is the level that would indicate to DOE that the accident was of no serious consequence.** Using lung counting, urine and fecal bioassay and conducting a special solubility study, Battelle Energy Alliance estimated Ralph Stanton's dose from the accident as 102.5 millirem, effective whole body and 1166.3 millirem Bone Surface, or **0.1 rem whole-body and 1.2 rem bone.**

Leading up to the November 8, 2011 plutonium inhalation event at the Department of Energy's Idaho National Laboratory (INL)

- ***Inadequate Safety Analysis.*** The Department of Energy, although approving the safety analyses for the Materials and Fuels Complex (MFC) including the Zero Power Physics Reactor (ZPPR) facility as 10 CFR 830 compliant commences a multi-year effort to upgrade the safety analyses because the intent of 10 CFR 830 has not been met.
- ***Warnings Ignored.*** Battelle Energy Alliance's Independent Safety Review Chairman's repeated warnings of worker safety issues for using the hood to examine ZPPR plates are ignored.
- ***Workers Directed to Proceed.*** Workers question the markings on the ZPPR plate. Battelle Energy Alliance's Nuclear Facility Manager, responsible for meeting all safety analysis and for conducting work safely, directs workers at ZPPR to inspect the ZPPR plutonium fuel plates.
- ***Plutonium and Americium Inhalation Event.*** Powder is seen at 11:04 am, swipe conducted and CAM alarms.

Decision to provide Chelation Therapy and conduct lung counting the day of the plutonium inhalation event

- Area swipes detect 5.5 million disintegrations per minute.
- Constant Air Monitor located 15 ft from workers alarms at 791 DAC and later peaks exceeding 4000 DAC.
- Takes 5 minutes to evacuate.
- Worker clothing and skin surveys find high levels of contamination. Skin surveys with damp skin.
- Nasal swab results find high levels of contamination.
- Workers taken to INL Site Medical Facility at Central Facilities.

Decision to provide Chelation Therapy and conduct lung counting the day of the plutonium inhalation event

- At Site Medical Facility, some workers are vomiting.
- At Site Medical Facility, several workers are given Chelation Therapy that is hoped to reduce absorption of plutonium and americium. But chelation conducted 4 hours after the inhalation and needed within 2 hours.
- Blood is drawn for a Complete Blood Count.
- Lung counting conducted the day of the accident (November 8). Two workers had americium-241 results exceeding Decision Level. The americium-241 detections in lung counts will be used to estimate the intake of americium and of plutonium (which is harder to detect), based on plate composition.

ZPPR Plate Activity Ratio

Nuclide	Activity Ratio Relative to Am-241
Pu-238	0.135
Pu-239	1.01
Pu-240	0.490
Pu-241	4.34
Pu-242	0.000144
Am-241	1.0

From Oak Ridge Bounding Intake and Dose Estimate, December 14, 2011. They used the ratio of Pu/Am of 1.7. [Pu-238 + Pu-239 + Pu-240]/Am-241 ratio of 1.7. The ratio of [Pu-239 + Pu-240]/Am-241 is 1.5.

Oak Ridge left out the Pu-241 ingrowth contribution to Am-241, acceptable for Type M (moderate clearance time) but not for Type S (slow, years of clearance time).

Low Activity Ratios for U-234 (2.65E-5), U-235 (2.63E-7) and U-238 (1.55E-5)

Next day, additional lung counting

- Lung counting was conducted again on November 9. Ralph was the only worker who had 2 lung counts on November 9.
- The DOE Investigation report states “The rapid decreases in results following the initial counts indicates that at least part of the initial positive Am-241 count results could have been due to low-level external contamination…” DOE-ID states no external contamination affected the Day 1 lung count.
- Blood count results and nausea attributed to flu.
- No collection of vomit. Reported vomiting is not recorded in medical dictations.

Urine and Fecal Bioassay

- November 8, within hours of the accident, urine sample indicates Am-241, but is below “Decision Level.” Pu-239 also below “Decision Level” but oddly high “Decision Level.”
- Urine and Fecal samples collected during the first 24 hours and for 7 days thereafter.
- BEA states information concerning sample collection is doubtful or unrecorded for dates and times of sample collection. To Day 7, there are days with no sample result.
- The Day 1 Am-241 urine sample is destroyed.

Fecal Bioassay

- Very high fecal result detected for first elapsed day for plutonium-239, americium-241 and plutonium-239, all above “Decision Level.”
- The fecal sample collected in the first 24 hours will include radioactivity from posterior nasal passage and pharynx and would be expected to be the highest sample result.
- BEA says “the first [fecal] sample contained more activity than expected.” Many errant modeling choices based on this.
- Fecal results are still above “Decision Level” 224 days after the accident.

Urine Bioassay

- Americium and plutonium are normally difficult to detect in urine but do reflect levels in the blood.
- Day 1 and Day 5 urine Pu-239 above “Decision Level”.
- Day 5 Am-241 above “Decision Level” but Day 1 Am-241 sample destroyed.
- Urine excretion predictions would result in high “intake” estimates.
- BEA constrains urine “intake” estimates based on low-balled fecal modeling that discounts the timing of the first fecal sample.
- BEA makes additional modeling assumptions that greatly lower the intake estimate normally associated with such high fecal and urine excretion.

BEA Assumptions to lower dose

- Well known that first 24-hour fecal excretion would be expected to include radioactivity from posterior nasal passage and pharynx, BEA declares the high radioactivity in the first fecal sample as “unexpected.”
- BEA constrains urine intake estimates to values indicated by BEA’s wrong modeling of fecal excretion.
- Urine and fecal excretion trends not as expected. Yet, small particle size and inhaled chemical form not investigated.

BEA Assumptions to lower dose

- BEA states workers may have had high ingestion intake due to “face touching and drinking” immediately following evacuation.
- This is to lower the dose because ingestion dose is lower than inhalation dose.
- Video surveillance obtained only with legal action to obtain it proves that no face touching or drinking occurred following evacuation.
- BEA uses ingestion intake to reduce the inhalation intake and makes various assumptions to greatly reduce predicted intakes from fecal and urine excretion.

BEA Assumptions

- Chelation therapy IV needed within 2 hours but given after 4 hours. Chelation effectiveness in increasing Am and Pu excretion in urine highly uncertain. (No effect on fecal excretion expected.)
- Chelation assumptions reduce urine bioassay intake estimates.
- Area contamination levels on swipes 5.5 million dpm ignored.
- Nasal swab result only 284 dpm for one nostril, only the Pu-239/240, actually above what BEA stated as 150 dpm

BEA Assumptions

- Lung count results greater than “Decision Level” are ignored. Numerous lung count report irregularities not discussed.
- By the second day, BEA medical personnel seem to believe that the lung count results mean no inhalation of plutonium or americium had occurred.
- BEA medical personnel ignore sharp decline in blood lymphocytes within 4 hours of the accident.
- Vomiting reported by workers but not included by BEA medical dictation. Vomit should have been collected as bioassay. Vomiting is a sign of acute radiation exposure.

BEA Assumptions

- BEA dose assessment, having ignored lung count results, destroyed actual nasal swab results, and ignored sharp drop in blood lymphocytes relies on urine and fecal bioassay for dose assessment.
- Urine bioassay results for Day 1 and Day 5 for Pu-239 and Day 5 Am-241 can indicate the “intake.” But numerous BEA assumptions reduce the estimated “intake”: Low-balled fecal modeling used to constrain urine-based intakes, assumed chelation enhancement, assumed 30 percent of intake is ingestion rather than inhalation, and various assumptions for “fitting” of data.

Fecal Bioassay

Pu-239				Maximum Intake	Initial BEA Intake
Elapsed Time	Sample mass	Result, dpm	Inhalation Excretion Fraction	Intake Estimate, dpm using NUREG/CR-4884	Intake Pu-239 Estimate, dpm using accumulated activity approach
1 Day	100.47 g	2380 dpm	5.21E-2 (1984 NUREG/CR-4884)	45,681 dpm	4,950 dpm (Factor of 9.2 Low)
Positive for Days 1 through 7					

Note: Low fecal mass of about 100 grams when an average adult male excretion of 350 grams would be expected. Vomit has not been collected by BEA.
I use NUREG/CR-4884 only because of difficulty obtaining more recent excretion rates as not all ICRP information is readily available online.

Urine Bioassay

Pu-239					
Elapsed Time	Sample volume	Result, dpm	Volumized Result, dpm	Inhalation Excretion Fraction	Initial Pu-239 Intake Estimate, dpm
1 Day	60 mL	0.089	0.2321	2.35E-6	Based only on first day, volumized: 98,766 dpm
5 Day	1640 mL	0.022	0.0191	4.55E-7	For both days: 89,700 dpm (Table 39, but not the value used by BEA)
Am-241					
Elapsed Time	Sample volume	Result, dpm	Volumized Result, dpm	Inhalation Excretion Fraction	Initial Am-241 Intake Estimate, dpm
5 Day	1640 mL	0.044	0.0375	1.399E-6 (Table 40, 100% inhalation)	26,800 dpm (Table 40, but not the value used by BEA)

Inhalation Estimates from Urine/Fecal

Plutonium-239

Standard Intake Estimate	BEA Intake Estimate
98,766 dpm	89,700 dpm
	Reduced to 6040 dpm by BEA modeling assumptions
98,766 dpm (44.5 nCi)	Further reduced to 4230 dpm inhalation (1.9 nCi)
	Factor of 23.3 Low

Americium-241

Standard Intake Estimate	BEA Intake Estimate
98,766/1.5 = 65,844 dpm	26,800 dpm
	Reduced to 3451 dpm by BEA modeling assumptions
65,844 dpm (29.7 nCi)	Further reduced to 2416 dpm inhalation (1.088 nCi)
	Factor of 27.3 Low

Note: Very limited urine data and it may underestimate dose. Fecal data less representative of intake than urine. Integrity of bioassay questionable.

Dose Conversion Factors

- Intake multiplied by Dose Conversion Factor equals Dose
  - Intake (Ci) x DCF (Rem/Ci) = Dose (Rem)
  - Or Intake (Bq) x DCF (Sv/Bq) = Dose (Sv)
- Type S (insoluble material) gives lower dose than Type M.
  - Type S (insoluble) stays in lungs longer.
  - Type M spreads to bone and liver faster than Type S.
  - Even Type S material has some fraction of Type M material.
- BEA uses Type S for both the Pu and the Americium
- BEA ignores Am-241 ingrowth from inhaled Pu-241
- *2019 Dose Conversion Factors have increased for Pu, Am*

ZPPR Plate Dose Conversion Factors, Type M

Nuclide	Half-Life	Percent Mass	Activity Ratio to Am-241	DCF Effective Whole Body (Sv/Bq)	DCF Bone Surface (Sv/Bq)
Pu-238	87.7 year	0.0 %	0.135	3.0E-5	9.1E-4
Pu-239	24,100 year	25.0 %	1.01	3.2E-5	1.0E-3
Pu-240	6540 year	3.3 %	0.490	3.2E-5	1.0E-3
Pu-241	14.4 year	0.1 %	4.34	5.8E-7	2.0E-5
Pu-242	380,000 year	0.0 %	1.44E-4	3.1E-5	9.6E-4
Am-241	433 year	0.4 %	1.0	2.7E-5	1.1E-3
U-238	4.47 billion year	70.9 %	1.55E-5	1.6E-6	(low contribution)

These DCFs are for 5 micrometer particles.

Dose Conversion Factors, Inhalation, Effective Whole-body from ICRP 68, 5 um

	Pu-239	Am-241	
Type M, rem/Ci	1.20E+8	1.00E+8	Type M gives higher dose
Type S, rem/Ci	3.10E+7	3.182E+7	than Type S

Alternate units of sievert per becquerel (Sv/Bq):

	Pu-239	Am-241
Type M, Sv/Bq	3.20E-5	2.70E-5
Type S, Sv/Bq	8.37E-6	8.60E-6

- Type M (moderate absorption in the body) predicts a higher dose than Type S (slow absorption in the body and slow clearance). BEA declared the dose to be from Type S but left out Pu-241 ingrowth of Am-241, incorrectly lowering their predicted dose about 10 percent.

Dose Conversion Factors

- Pu-239 DCF for Type M/Type S = (1.2E8/3.1E7) = 3.87
- Am-241 DCF for Type M/Type S = 1.0E8/3.1E7 = 3.14
- Whole-body dose reduced by choosing all Type S.
  - Higher ratio of Am-241 to Pu-239 in urine would indicate Type M.
  - BEA solubility study not conducted long enough
  - BEA solubility study may not represent chemistry in the body
  - The oxidation occurring after the release may not reflect the hydride and other chemical forms inhaled, especially for the americium-241 released when the plate was unwrapped.
- BEA ignores Am-241 ingrowth from inhaled Pu-241, which would be Type M

Actinide Radioactive Decay Series

Plutonium-241 (half-life of 14.35 years) decays to americium-241 which decays to neptunium-237 and through the “neptunium” series. Americium-241 ingrowth from Pu-241 increases significantly in just a few years.

	beta		alpha		alpha	
Pu-241	→	Am-241	→	Np-237	→	Pa-233 → more
(14 year)		(433 year)		(2,200,000 year)		

The decay of Pu-241 to Am-241 causes Am-241 to buildup in a few years time. Pu-241’s beta emission has a low dose, but Am-241 gives a large dose. Inhaled Pu-241 also decays to Am-241 in the body but BEA ignores this.

Dose Estimates from Urine/Fecal

Plutonium-239

Standard Intake Estimate	Final BEA Intake Estimate
98,766 dpm	4239 dpm
Type S DCF 8.37E-6 Sv/Bq	
1.37 Rem	0.059 Rem (Factor of 23 Low)
Type M DCF 3.2E-5 Sv/Bq	
5.27 Rem	0.225 Rem (Factor of 23 Low)

Americium-241

Standard Intake Estimate	Final BEA Intake Estimate
98,766/1.5 = 65,844 dpm	2416 dpm
Type S 8.60E-6 Sv/Bq	
0.943 Rem	0.0345 Rem (Factor of 27 Low)
Type M 2.7E-5 Sv/Bq	
2.96 Rem	0.1087 Rem (Factor 27 Low)

Intake in dpm is divided by 60 to obtain Becquerel, or disintegrations per second.
Intake (Bq) multiplied by DCF (Sv/Bq) equals Sv. And 1 Sv equals 100 rem.
Total dose is Pu-239 plus Am-241 dose and contributions from Pu-238 and other plate material not included here and Am-241 ingrowth from Pu-241 decay of inhaled Pu-241. Integrity of bioassay data questionable.

BEA Underestimated Ralph's Radiation Intake and Dose

- BEA's estimated intake based on urine and fecal bioassay for Pu-239 and Am-241 are a factor of 23 and 27 low, relative to a more conventional approach.
- BEA's dose was **0.102 rem whole-body** and an inhalation intake of 2.99 nCi (Pu + Am) with some ingestion and used Type S dose conversion factors. This low dose is incongruent with the evidence.
- Of the three urine samples used for this dose, if Type M, 5um were used, the dose would be over **8.23 rem whole-body** for an inhalation intake.
- **The symptoms and long-lasting blood changes mean the dose was likely higher than the 8.23 rem indicated by available urine and fecal data.**

Overview of various intake and dose estimates

Approach	Intake, (dpm)	Whole-body dose, (rem) using Type M DCFs, 5um	Comments
Area contamination swipes	5 million dpm	265 rem	An upper bound
Conventional urine bioassay analysis	164,610 dpm	8.23 rem	Only 2 samples for Pu-239, first day returning the highest result. Americium-241 sample for the first day destroyed.
First Day Lung Count, Am-241 result	122,277 dpm	6 rem	Intake and dose too low, lung count irregular; indicates peak deletion.
Nasal swabs documented in missing logbook, 4625 dpm one nostril, only Pu-239/240	308,333 dpm	15.6 rem (5 um) 60 rem (1 um)	Missing logbook. Particle size matters!

Overview (continued)

Approach	Disintegrations per minute (dpm)	Whole-body dose, (rem) using Type M DCFs, 5um	Comments
Lung Counting results BEA sent to Oak Ridge, excludes First Day lung count result	28,860 dpm	1.45 rem	Intake and dose far too low, not representative of intake
Nasal swab data documented by Oak Ridge, 639 dpm Pu+Am	12,780 dpm	0.62 rem	Intake and dose far too low, actual nasal swab far higher
BEA fecal-constrained, chelation-credited urine, ingestion reduced bioassay result	6646 dpm (inhalation portion)	0.33 rem	Intake and dose far too low, BEA's dose using Type S was 0.1 rem

BEA's low dose estimate of 102 millirem is not credible. And 5 rem whole-body was substantially exceeded.

A Closer Look at the Nasal Swab Debacle

- DOE's Accident Investigation report states that on the day of the accident, REAC/TS recorded: "highest nasal smear was 150 dpm" (page 57) (obviously not the highest nasal smear)
- DOE's Accident Investigation report states that "six individuals with the highest nasal smears (overall results ranged from 3 to 289 dpm" (page 58) (implies total alpha but appears to be only the Pu-239, one nostril)
- Oak Ridge December report has nasal smear analysis of Pu-239, Pu-238 and Am-241. Highest total alpha (one nostril) is 469 dpm. Ralph has the highest smear and **both nostrils added equal 660 dpm.**
- (Note: I used 639 dpm, just the Pu-239 and Am-241, when using those dose conversion factors – leaving out the Pu-238)
- Ralph's medical dictation states 150 dpm which does not correspond to Ralph's nasal smear data given to Oak Ridge or destroyed logbook (4000 dpm). By Day 2, medical personnel told no intake occurred, yet fecal samples are above "Decision Level" for plutonium and americium radioactivity 224 days after event.

Very High Nasal Swab Data

- DOE's Accident Investigation report states that on the day of the accident, REAC/TS recorded: "highest nasal smear was 150 dpm" (page 57) (obviously not the highest nasal smear)
- Initial call to CFA Medical produces call for 17 patient beds for chelation. This makes no sense for "150 dpm" maximum swab.
- Ralph told by non-BEA personnel prior to lung counts that his dose is estimated at about 10 rem. But only nasal swab for Pu-239/240 available. Unusually high americium-241 not recognized yet. A 10 rem whole-body dose based on Type M, 5 um, Pu-239/240 would require **each nasal swab to be 4625 dpm.**
- [2 x 4625 dpm]/0.05 = 185,000 dpm intake of Pu-239/240] and Pu-239/240 to Am-241 ratio of 1.5.

Criteria for chelation

- DOE's Accident Investigation report states that on the day of the accident, REAC/TS recorded: "highest nasal smear was 150 dpm" (page 57) (obviously not the highest nasal smear)
- Oak Ridge REAC/TS criteria for a serious inhalation is 325 dpm per nasal swab (13,000 dpm intake of Am-241 or Pu)
- CDC ORAUT-TKBS-0010-5 for Los Alamos National Laboratory chelation would be indicated for single nasal swab above 2000 to 4000 dpm.
- BEA initially prepares to give 17 chelation treatments. Ultimately, 6 treatments are offered and 4 workers are chelated but only 4 hours after event.

Information needed for accident response and dose estimate

- Isotopic composition of radionuclides inhaled – the proportion of plutonium-239, americium-241, plutonium-238, etc. Not known at time of accident.
- Decay or ingrowth of radionuclides at time of accident. Not known at time of accident. The actual high ingrowth of Am-241 not known on day of accident.
- Solubility of the radionuclides inhaled. Oxidation prior to inadequate study of material inhaled.
- Particle sizes of radionuclides inhaled. Never investigated.
- Surface area of the particles. Never investigated.
- Chemical form of the particles. Never investigated.

Nasal smear results

Pu-239 Activity, nCi	Am-241, nCi	Both nostrils, Pu+Am dpm	Intake, Pu+Am dpm	Basis
0.181 nCi	0.107 nCi	401 + 238 dpm	12,780 dpm	BEA's stated nasal results, max. 284 dpm one nasal swab, Pu-239/240. Total 639 dpm for left and right nostril Pu-239/240 and Am-241
4.17 nCi	2.78 nCi	9250 dpm + 6167 dpm	185,000 + 123,333 dpm	For 4625 dpm one nasal swab, Pu-239/240 (missing logbook). Total 15,417 for left and right nostril Pu-239/240 and Am-241. The Pu-239 alone yields 10 rem (Type M, 5 um) For both Pu and Am, 60 rem (Type M, 1 um)

- Left and right nostrils added together are divided by 0.05 to estimate intake.
- 4625 dpm x 2 = 9250 dpm for left and right nostrils, only Pu-239/240.

Battelle Energy Alliance's Dose Estimate

- Battelle Energy Alliance requested a worker to sign that he had seen his written dose assessment without actually being allowed to see it.
- Battelle Energy Alliance claimed that obtaining his written dose assessment would be simple, but it was not.
- Battelle Energy Alliance endeavored to prevent a worker from seeing his dose assessment and bioassay results.
- Battelle Energy Alliance states an unrealistically low dose of 0.1 rem (whole body dose) from a large plutonium and americium inhalation, but the evidence indicates a far higher dose, over 5 rem.
- The inhalation event caused a serious drop in blood lymphocytes within 4 hours. This inhalation event yielded above "Decision Level" fecal sample radioactivity 224 days after the inhalation event.

Whole-Body Dose Conversion Factors

Particle Size and Solubility Type	Effective Whole-Body DCF, rem/Ci (Bone Surface DCF, rem/Ci)	
	Am-241	Pu-239/240
5 um, Type M	1.0E8 rem/Ci WB (40.7E8 rem/Ci Bone)	1.2E8 rem/Ci WB (37.0E8 rem/Ci Bone)
1 um, Type M	4.44E8 rem/Ci WB (80.3E8 rem/Ci Bone)	4.29E8 rem/Ci WB (78.07E8 rem/Ci Bone)

- FGR 11, 1 micrometer diameter (1 um), Type M. Smaller particle size delivers higher dose.
- ICRP 68, (1994) 5 um, Type M.
- Intake multiplied by DCF equals radiation dose.

Effective Whole-Body and Bone Dose Estimates

Am-241 Activity, nCi	Pu-239, Activity, nCi	Pu+Am dpm	Effective Whole-Body Dose, rem	Bone Surface, Committed Equivalent Dose, Rem	Basis
55.55 nCi	83.33 nCi	308,333 dpm	60 rem (1 um)	1096 rem bone (1 um)	Based on nasal swab result of 4625 dpm per nostril Pu-239/240
1.09 nCi	1.9 nCi	6646 dpm	0.1 rem	1.2 rem bone	BEA's Final Dose Estimate, Type S, 5 um particle size. Dose estimate not credible.

BEA's low dose estimate of 102.5 millirem is not credible. And 5 rem whole-body was substantially exceeded.

Key References

- U.S. Department of Energy Office of Health, Safety and Security Accident Investigation Report, *Plutonium Contamination in the Zero Power Physics Reactor Facility at the Idaho National Laboratory, November 8, 2011*, January 2012.
- Oak Ridge National Laboratory, UT-Battelle, *Independent Review, Bounding Intake and Dose Estimates Associated with the November 8, 2011 Airborne Release at the INL Zero Power Physics Reactor*, December 14, 2011.
- Battelle Energy Alliance, Dose Assessments for November 8, 2011 ZPPR Event, INL/INT-12-12-27269, September 2012. Partial report, Redacted.
- Lung count reports issued by Battelle Energy Alliance for Ralph Stanton for November 8, 9 (12:44), 9 (15:41) and November 15.

Thank you

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Helpful conversions

- 1000 nanocurie (nCi) is equal to 1 microcurie (uCi)
- 1 disintegration per minute (dpm) is divided by 60 to obtain 0.0167 disintegrations per second (dps)
- 1 disintegration per second equals 1 becquerel (Bq)
- 1 curie equals 37 E+9 Bq
- 1 dpm/2220 equals the result in nCi
- Derived Air Concentration (DAC) requires the radionuclide's 10 CFR 835 radioisotope's Appendix A concentration

- Added Nasal Swab Debacle, March 22, 2022.
- April 22, 2022 revised nasal swab for 4625 dpm Pu-239/240 each nostril and added Am-241 based on ratio of Pu-239/240 to Am-241 of 1.5. Dose using 1 micrometer diameter FGR 11 rather than 5 um dose conversion factors.