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Created By:	Stein, S. Joshua

Environmental Review Form for Argonne National Laboratory

Creator

Badge:	**36880**	Name:	**Stein, S. Joshua**
Cost Center:	**105**	Division:	**MSD**
Job Title:	**Principal Electrical Engineer**	Employee Type:	**Regular Full-Time Exempt**
Building:	**211**	Lab Extension:	**2-4105**

General Information

Project/Activity Title: NAUTICAS
ASO NEPA Tracking No.: Type of Funding:
B & R Code: Identifying Number: TBD
SPP Proposal Number: CRADA Proposal Number:
Work Project Number: ANL Accounting Number: (Item 3a in Field Work Proposal)
Other (explain):
List appropriate NEPA Owners:
Division: MSD NEPA Owner:

Financial Plans

To select a Financial Plan, click the magnifying glass icon to open a search window.

Cost Center: Project: Phase: Task:

Description of Proposed Action

This environmental review form is an addendum to ASO-CX-299 covering operation of the NAUTICAS system outdoors for experimental purposes.The experimental apparatus would be transported to the site the day of operation, and returned to storage at the completion of the experiment or at the end of the day (whichever occurs first). The experimental equipment would be transported in a government passenger vehicle. No permanent installations or modifications of structures are required. The experiments would operate for no longer than 8 hours on a given day, for less than a total of four weeks out of the year.

Description of Affected Environment

South of bldg 320 inside bermed area (primary location) or near bldg 567 near Kearney and Westgate road (alternative location). As outlined in the attached memo, no long-term effects of soil or surrounding vegetation are expected. As required during experimental operations, a small hole may be dug approx 24x24x24 inches to facilitate different modes of operation. This fill would be replaced at the conclusion of operation. An Argonne dig permit would be obtained before any digging would commence.

Potential Environmental Effects

- Attach explanation for each "yes" response near bottom of form.
- **See Instructions for Completing Environmental Review Form.**

Section A (Complete For All Projects)		Yes	No	Explanation
1.	Project evaluated for Pollution Prevention and Waste Minimization opportunities and details provided under items 2, 4, 6, 7, 8, 16, and 20 below, as applicable	◉	○	Simulation of operation shows no appreciable contamination of soil or air during or after operation. See attached memo.

2.	Air Pollutant Emissions	◉	○	As outlined in attached memo, there would be very short lived activation products produced in the surrounding air during operation. A gasoline powered electrical generator may be required depending on local availability of line power. This unit would generate the typical pollutants common with a small (man-portable) gasoline powered 4-cycle engine.
3.	Noise	○	◉	
4.	Chemical/Oil Storage/Use	◉	○	If a gasoline powered electric generator is required, this unit would require unleaded gasoline and motor oil for operation. A spill kit would be present at the experimental location during any operations requiring a gasoline powered generator.
5.	Pesticide Use	○	◉	
6.	**Toxic Substances Control Act (TSCA) Substances**			
	6a. Polychlorinated Biphenyls (PCBs)	○	◉	
	6b. Asbestos or Asbestos Containing Materials	○	◉	
	6c. Other TSCA Regulated Substances	○	◉	
	6d. Import or Export of Chemical Substances	○	◉	
7.	Biohazards	○	◉	
8.	Effluent/Wastewater (If yes, see question #12 and contact Peter Lynch (HSE) at 2-4582 or lynch@anl.gov)	○	◉	
9.	**Waste Management**			
	9a. Construction or Demolition Waste	○	◉	
	9b. Hazardous Waste	○	◉	
	9c. Radioactive Mixed Waste	○	◉	
	9d. Radioactive Waste	○	◉	
	9e. Asbestos Waste	○	◉	
	9f. Biological Waste	○	◉	
	9g. No Path to Disposal Waste	○	◉	
	9h. Nano-material Waste	○	◉	
10.	Radiation	◉	○	The nature of the experiment emits ionizing radiation. Simulation shows little to no effect on the environment. See attached memo. Radiological hazards would be managed by ANL Health Physics group.Access control to the experimental area up to and including radiation boundaries would be maintained at all times during operation. Post experimental radiation surveys would be performed to verify no residual activation.
11.	Threatened Violation of ES&H Regulations or Permit Requirement	○	◉	
12.	New or Modified Federal or State Permits	◉	○	Illinois EPA permit required and applied for.
13.	Siting, Construction, or Major Modification of Facility to Recover, Treat, Store, or Dispose of Waste	○	◉	
14.	Public Controversy	○	◉	
15.	Historic Structures and Objects	○	◉	
16.	Disturbance of Pre-existing Contamination	○	◉	

		Yes	No	
17.	Energy Efficiency, Resource Conserving, and Sustainable Design Features	○	◉	
Section B (For Projects that Occur Outdoors)		**Yes**	**No**	
18.	Threatened or Endangered Species, Critical Habitats, and/or other Protected Species	◉	○	Endangered insect (Hine's emerald dragonfly) migration area is potentially within the boundary of the experiment. Given correspondence between ANL and USFWS, we are confident that a compromise will be reached which would allow operation of our experiment without a detrimental effect on the Hine's Emerald Dragonfly.
19.	Wetlands	○	◉	
20.	Floodplain	○	◉	
21.	Landscaping	○	◉	
22.	Navigable Air Space	○	◉	
23.	Clearing or Excavation	◉	○	Possibility of excavating holes of approx 2' square and 2' deep. At the conclusion of operations, the hole would be refilled with the original soil. Before any digging would commence, an Argonne dig permit would be obtained.
24.	Archaeological Resources	○	◉	
25.	Underground Injection	○	◉	
26.	Underground Storage Tanks	○	◉	
27.	Public Utilities or Services	○	◉	
28.	Depletion of a Non-Renewable Resource	○	◉	
Section C (For Projects Outside of ANL)		**Yes**	**No**	
29.	Prime, Unique, or Locally Important Farmland	○	○	
30.	Special Sources of Groundwater (such as sole source aquifer)	○	○	
31.	Coastal Zones	○	○	
32.	Areas with Special National Designations (such as National Forests, Parks, or Trails)	○	○	
33.	Action of a State Agency in a State with NEPA-type Law	○	○	
34.	Class I Air Quality Control Region	○	○	

Categorical Exclusion

ANL NEPA Reviewer Use Only

○ My approval is the final approval necessary

◉ This form requires additional approval from DOE

To be Completed by DOE/ASO

Section D	Yes	No
Are there any extraordinary circumstances related to the proposal that may affect the significance of the environmental effects of the proposal?	○	◉
Is the project connected to other actions with potentially significant impacts or related to other proposed action with cumulatively significant impacts?	○	◉
If yes, is a categorical exclusion determination precluded by 40 CFR 1506.1 or 10 CFR 1021.211?	○	○
Can the project or activity be categorically excluded from preparation of an Environment Assessment or Environmental Impact Statement under Subpart D of the DOE NEPA Regulations?	◉	○

If yes, indicate the class or classes of action from Appendix A or B of Subpart D under which the project may be excluded:

Categorically excluded under 10 CFR 1021, Subpart D, Appendix B: B3.6 Small-scale research and development, laboratory operations, and pilot projects; and B3.11 Outdoor tests and experiments on materials and equipment components.
If no, indicate the NEPA recommendation and class(es) of action from Appendix C or D to Subpart D to Part 1021 of 10 CFR.

Attachments

File Description: Radiation simulation results memo View Attachment

Comments

Categorically excluded by DOE and tracked as ASO-CX-360.

Add Approver

Approver Name	Approver Badge	Reason	Delete
Woodford, John B.	51790	Acting Environmental Compliance Representative	
Skubal, Laura Rachel	36447	Primary Investigator	
Peterson, Donald A.	43341	Researcher	

Notifications

The approval notification email will be copied to the people listed below.

Badge	Name	Division	Delete

ASO-CX Number

ASO-CX- 360

Comments:

Categorically excluded by DOE and tracked as ASO-CX-360.

Approval

Approver	Action	Date Routed	Action Date	Approval Reason / Comments	Approval Type
Stein, S. Joshua	APPROVED	2019-01-18	2019-01-18 12:09:33.0	Creator :	PRIMARY
Stein, S. Joshua	APPROVED	2019-01-18	2019-01-18 12:09:33.0	Project Manager :	PRIMARY
Skubal, Laura Rachel	APPROVED	2019-01-18	2019-01-18 12:43:38.0	Primary Investigator :	PRIMARY
Peterson, Donald A.	APPROVED	2019-01-18	2019-01-21 09:45:53.0	Researcher :	PRIMARY
Woodford, John B.	APPROVED	2019-01-18	2019-01-21 08:47:51.0	Acting Environmental Compliance Representative :	PRIMARY
Brocker, William A.	APPROVED	2019-01-21	2019-01-21 10:44:55.0	NEPA Owner Approval for Argonne Environmental Review :	PRIMARY
Ptak, Jill S.	APPROVED	2019-01-21	2019-01-22 15:57:22.0	ANL NEPA Reviewer :	PRIMARY
Hellman, Karen B.	APPROVED	2019-01-22	2019-02-04 15:42:00.0	ANL-985 Review and Approval :	PRIMARY
Stine, Gail Y.	APPROVED	2019-02-04	2019-02-13 10:57:53.0	ANL-985 Review and Approval :	PRIMARY
Kearns, Paul K.	APPROVED	2019-02-13	2019-02-13	ANL-985 ANL COO Review and	PRIMARY

			15:26:23.0	Approval :	
Joshi, Kaushik N.	APPROVED	2019-02-13	2019-02-28 11:11:23.0	ANL-985 DOE-ASO Review and Approval : **Tracked as ASO-CX-360.**	PRIMARY
Siebach, Peter Rudolf	APPROVED	2019-02-28	2019-03-04 13:46:02.0	ANL-985 DOE NEPA Compliance Officer Review and Approval :	PRIMARY

Intra-Laboratory Memo

04 October 2018

TO: Laura Skubal, MSD

FROM: Brad Micklich, PSC

SUBJECT: Dose rates and induced activation due to outdoor operation of a DT neutron generator

In support of our request to operate a DT neutron generator outdoors at ANL, I ran some MCNP simulations to determine dose rates near the generator as well as to get some preliminary results for air and soil activation. The neutron and photon transport were simulated using MCNP [1], and the activation calculations performed with CINDER2008 [2]. The air composition, shown in Table 1, was taken from EPA Federal Guidance Report (FGR) 15 [3]. Three soil compositions (see Table 2) were studied: the composition used in FGR 15, and two compositions from Shue [4]. These three compositions should provide a general idea of radioactivity in soil.

Table 1. Air composition used in EPA Federal Guidance Report 15 (density 1.205 kg/m^3).

Element	weight fraction
H	0.00064
C	0.00014
N	0.75086
O	0.23555
Ar	0.01281

Table 2. Elemental weight fractions and total density of three types of soil.

Element	FGR15	nominal (Shue)	wet dense soil (Shue)
H	0.021	0.023	0.03
C	0.016		
O	0.577	0.559	0.585
Na		0.023	0.021
Mg		0.017	0.015
Al	0.050	0.065	0.060
Si	0.271	0.223	0.206
K	0.013	0.021	0.019
Ca	0.041	0.029	0.027
Fe	0.011	0.040	0.037
density (g/cm^3)	1.60	1.60	2.094

The current system, denoted as the Mod2v system, was oriented as shown in Figure 1, with the neutron source point about 37 cm above the ground, the position in which it is mounted during operations. The environment in this simulation extended ±50 m horizontally, 50 m vertically upward, and 10 m vertically downward. This volume captures the majority of the activation induced in the environment. Figure 2 shows the geometry on a larger scale. The ground beneath the system was divided using a set of concentric hemispheres below the surface, with the radii at 1-meter increments. Activation was calculated in each region separately, and the activation in all regions was added together.

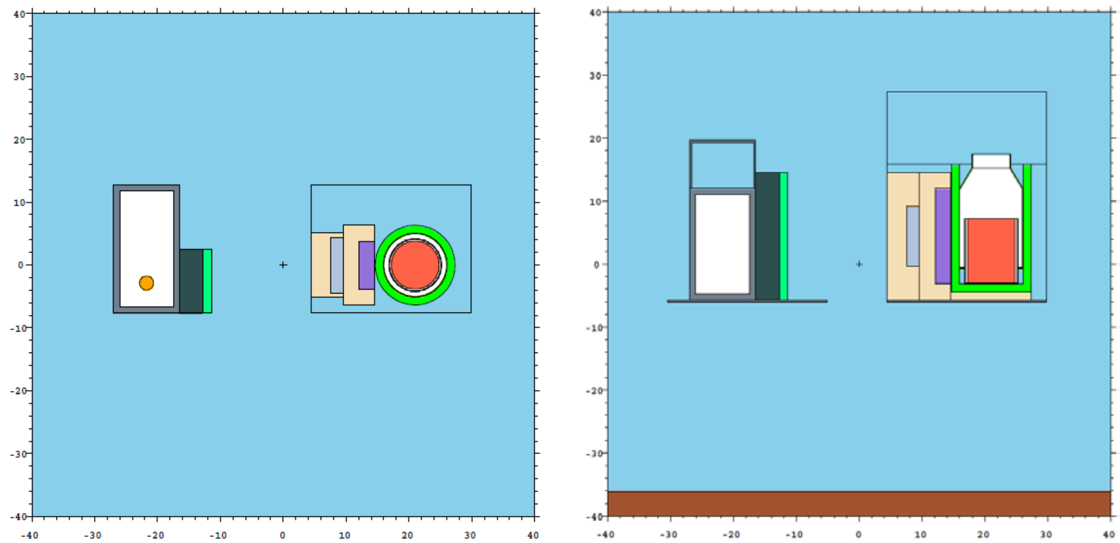

Figure 1. Top view (left) and side view (right) of the generator and detector. Dimensions are in cm.

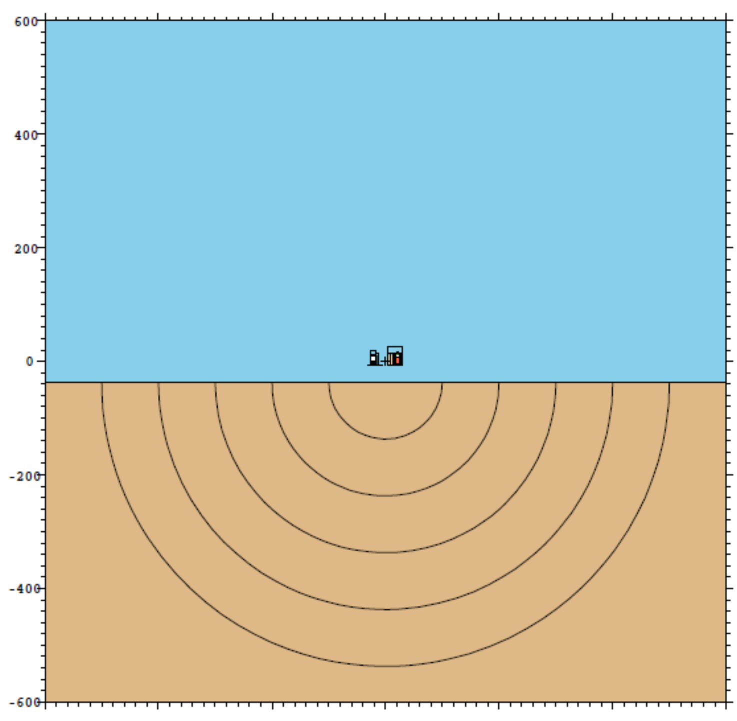

Figure 2. Generator and detector showing the hemispheres in soil. Dimensions are in cm.

Dose rates

Figure 3 shows the dose rate in air surrounding the neutron generator running at its maximum output of $3 \cdot 10^8$ n/s. The approximate boundary of the area with neutron dose rate above 1 mrem/h is marked with the red dashed line. The dose rate is somewhat smaller on the right side of the figure due to the shielding between the neutron source and the gamma detector and due to attenuation in the detector itself. Figure 4 shows the dose rate in air along a line (top to bottom in Figure 3) through the source point. The dose rate due to photons (primarily capture gamma rays) is much less than that due to neutrons. The dose rate falls to 1 mrem/h at about 20 m (65') from the source point.

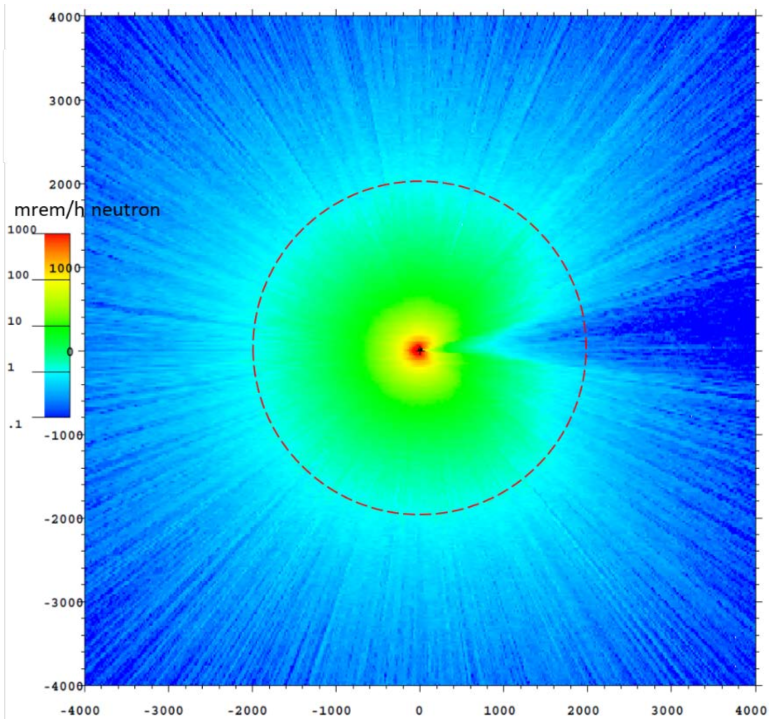

Figure 3. Neutron dose rate at the height of the DT source. Dimensions are in cm.

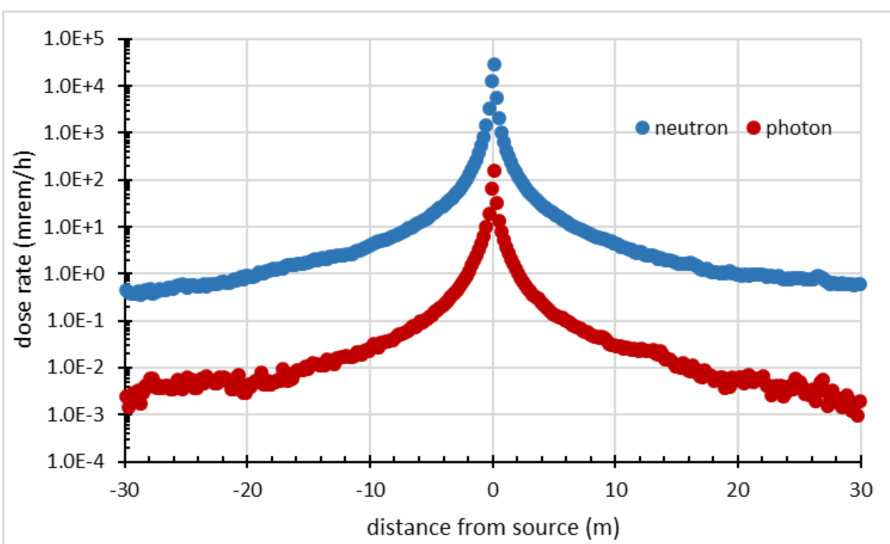

Figure 4. Neutron and photon dose rates as functions of distance from the DT source.

Air and soil activation

CINDER2008 was used to calculate the activation in air and soil using the compositions given in Table 1 and Table 2, respectively. The calculation assumed that the DT generator operates at its full output of $3 \cdot 10^8$ n/s for 1,000 hours continuously. Figure 5 shows the neutron flux in the soil as a function of distance from the source location. The flux is reduced by about a factor of ten for each meter further away from the source. Thus nearly all the activity induced in soil will be within the first few meters. The figure also shows that the shape of the energy spectrum does not change with distance. This is because the source neutrons, having a long mean free path, stream out from the source until they experience a large-energy-loss collision. The neutrons then thermalize in the immediate vicinity of that collision. As a result the neutron energy spectrum remains the same at any distance.

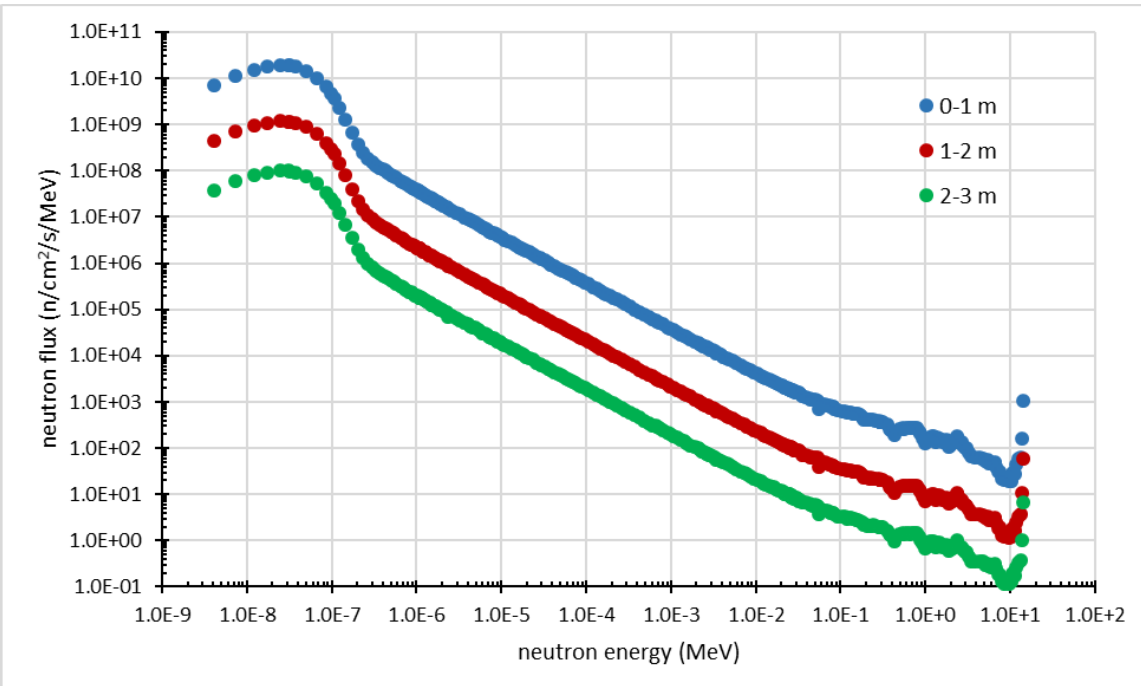

Figure 5. Neutron energy spectrum in soil at several distances from the DT source.

Table 3 gives the nuclide inventory immediately after shutdown for each of the three soil types. The table lists all nuclides present in amounts greater than 1 nCi at shutdown. For each soil type, the naturally-occurring ^{40}K in soil accounts for at least 93.7% of the activity in the soil at the end of irradiation. Most of the induced activity has short half-lives. After just one day of decay, the induced activity remaining is only 13 µCi / 31 µCi / 27 µCi in the three soil types, respectively, in a total volume of $2.62 \cdot 10^8$ cm^3.

Table 3. Activity induced in three types of soil after operation of DT generator at $3{\cdot}10^{8}$ n/s for 1,000 h.

Nuclide	half-life (s)	activity after shutdown (0-5 m) (Ci)			comment
		FGR 15	nominal (Shue)	wet dense (Shue)	
K 40	3.94E+16	4.67E-03	7.54E-03	8.93E-03	natural
Ar 37	3.03E+06	7.73E-06	5.36E-06	4.65E-06	no γ
Na 24	5.39E+04	1.19E-05	6.87E-05	5.94E-05	
Ca 45	1.41E+07	3.34E-07	1.95E-07	1.73E-07	low γ
K 42	4.45E+04	3.68E-06	4.89E-06	4.19E-06	
Fe 55	8.64E+07	1.63E-07	5.41E-07	4.71E-07	no γ
Sc 47	2.89E+05	8.40E-08	5.86E-08	5.10E-08	
Ca 47	3.92E+05	8.44E-08	5.89E-08	5.12E-08	
Fe 59	3.84E+06	3.80E-08	1.14E-07	1.01E-07	
Mn 54	2.70E+07	3.06E-08	1.10E-07	9.44E-08	
Cr 51	2.39E+06	3.10E-08	1.12E-07	9.68E-08	
Ar 39	8.49E+09	3.17E-09	4.68E-09	3.92E-09	no γ
K 43	8.03E+04	9.04E-09	6.33E-09	5.52E-09	
Si 31	9.44E+03	3.98E-06	2.81E-06	2.41E-06	low γ
Mn 56	9.28E+03	1.09E-06	3.92E-06	3.39E-06	
Ar 41	6.58E+03	8.16E-08	1.12E-07	9.47E-08	
Na 22	8.21E+07		1.52E-08	1.30E-08	
H 3	3.89E+08		1.10E-09		no γ
sum of above		4.70E-03	7.63E-03	9.00E-03	
sum – K40		2.92E-05	8.70E-05	7.51E-05	
all nuclides		4.98E-03	7.90E-03	9.25E-03	
all – K40		3.11E-04	3.57E-04	3.18E-04	

Table 4 shows the activity induced in air due to operation of the DT generator at $3{\cdot}10^{8}$ n/s for 1,000 h. This calculation assumes that the air is operated in a confined space, with the only decrease in activity due to radioactive decay. Again, most of the nuclides have very short half lives. The largest contributors to activity immediately after shutdown are ^{16}N ($t_{1/2}$ = 7.13 s) and ^{13}N ($t_{1/2}$ = 598 s). Figure 6 shows the decay of the induced activity with time. The total activity would decay to 0.1 µCi after 8 hours, and more slowly thereafter, with the primary contributors at long times being ^{3}H, ^{14}C, and ^{37}Ar. None of these emits a gamma ray upon decay, so the immersion dose would be essentially zero after about one hour (after the ^{13}N has decayed).

In summary, even if a DT neutron generator were to operate at its full output continuously for its design lifetime, only very small amounts of radioactivity would be generated in soil or air.

Table 4. Activity induced in air after operation of a DT generator at 3·10⁸ n/s for 1,000 h.

nuclide	half-life (s)	activity (Ci)
H 3	3.89E+08	6.54E-08
Be 8	8.18E-17	1.22E-09
B 12	2.02E-02	5.30E-11
C 14	1.80E+11	3.15E-09
N 13	5.98E+02	4.23E-06
N 16	7.13E+00	9.68E-06
S 35	7.56E+06	3.38E-11
S 37	3.03E+02	6.17E-08
Cl 36	9.50E+12	2.30E-15
Cl 38	2.23E+03	2.81E-10
Cl 39	3.37E+03	8.45E-09
Cl 40	8.10E+01	7.15E-08
Ar 37	3.03E+06	5.27E-09
Ar 39	8.49E+09	1.14E-09
Ar 41	6.58E+03	3.38E-07
total		1.45E-05

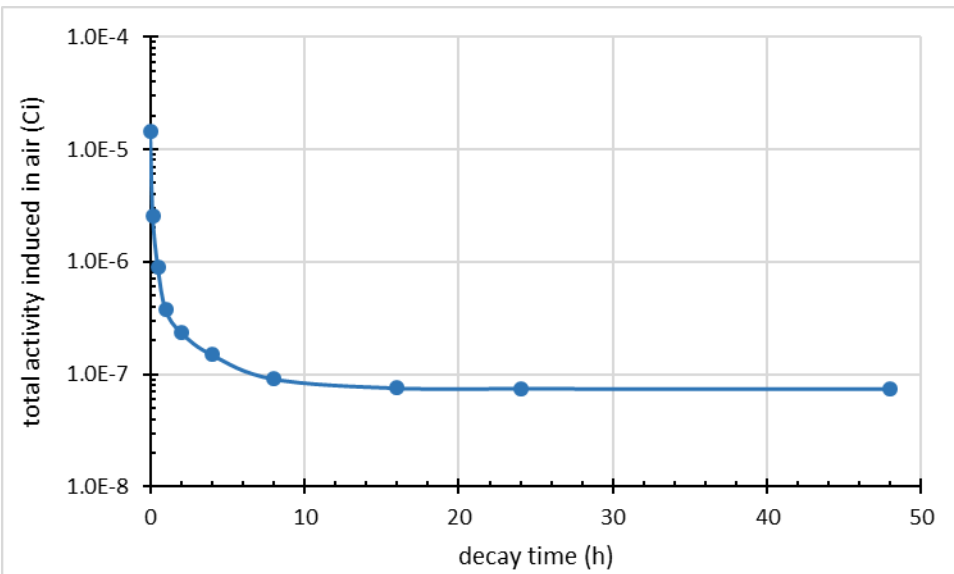

Figure 6. Activity induced in air due to operation of a DT neutron source at $3 \cdot 10^8$ n/s for 1,000 h.

Air emissions

I also calculated the activation in air assuming that all radionuclides created are immediately "exhausted". Since the activation is generated throughout the volume, there is no single emission point. I just assumed that the prevailing wind would take the generated products away from the vicinity of the neutron generator. The amount of each radionuclide created is just the source rate times the operating period of 1000 h/y.

I estimated the source rate in two different ways. First, I used MCNP to calculate the reaction rates through which each radionuclide is produced. The relevant reactions are shown in Table 5. Since some of these products are created through two-stage reaction processes, we cannot calculate all the production rates this way (in particular for the sulfur isotopes). I also calculated the production rates using the CINDER results. For the short half-life nuclides, equilibrium between generation and decay is established and the production rate of the ith nuclide is simply $S_i = A_i \cdot \lambda_i$ where A_i is the activity of the ith nuclide at the end of operation and λ_i is its half-life. For the long half-life nuclides ^{3}H, ^{14}C, ^{36}Cl, and ^{39}Ar, there is little decay and the amount produced is essentially the activity remaining at the end of operation. In general, one can account for both production and decay using the equation $S_i = (A_i \cdot \lambda_i)/(1-\exp(-\lambda_i t)$, where t is the operating time of the generator (1000 h). I omitted the nuclides ^{8}Be and ^{12}B from this calculation because of their short half-lives. Table 5 shows the results. In most cases where I used two estimates for nuclide production, the two are in relatively good agreement. For all cases, we should use the larger of the two values.

Table 5. Activity released in air during operation of a DT generator at $3{\cdot}10^8$ n/s for 1,000 h.

			activity released (Ci)	
nuclide	half-life (s)	reaction (MCNP)	MCNP	CINDER
H 3	3.89E+08	^{14}N(n,t)+^{40}Ar(n,t)	1.67E-07	6.56E-08
C 14	1.80E+11	^{14}N(n,p)	2.73E-09	3.15E-09
N 13	5.98E+02	^{14}N(n,2n)	1.92E-02	1.76E-02
N 16	7.13E+00	^{16}O(n,p)	3.31E+00	3.39E+00
S 35	7.56E+06			3.97E-11
S 37	3.03E+02			5.08E-04
Cl 36	9.50E+12			2.30E-15
Cl 38	2.23E+03	^{40}Ar(n,t)	1.59E-08	3.14E-07
Cl 39	3.37E+03	^{40}Ar(n,d)+^{40}Ar(n,np)	1.18E-06	6.25E-06
Cl 40	8.10E+01	^{40}Ar(n,p)	1.96E-03	2.20E-03
Ar 37	3.03E+06			7.74E-09
Ar 39	8.49E+09	^{40}Ar(n,2n)		1.14E-09
Ar 41	6.58E+03	^{40}Ar(n,γ)	1.15E-04	1.28E-04

References

[1] D. Pelowitz, ed., "MCNP6 User's Manual," LA-CP-13-00634, Rev. 0 (May 2013); C. J. Werner, ed., "MCNP User's Manual, Code Version 6.2," LA-UR-17-29981 (2017).
[2] S. T. Holloway et al., "A Manual for CINDER2008 Codes and Data," LA-UR-11-00006 (March 2011).
[3] M. B. Bellamy et al., Federal Guidance Report No. 15, External Exposure to Radionuclides in Air, Water, and Soil, EPA-402/R18/001 (June 2018).
[4] S. L. Shue, R. E. Faw, and J. K. Shultis, "Fast Neutron Thermalization and Capture Gamma-Ray Generation in Soils," HSRC/WERC Joint Conference on the Environment, Albuquerque, NM (May 1996).