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EXECUTIVE SUMMARY

The Ohio Department of Natural Resources (ODNR) requested RESRAD software code modeling of the application of a commercially available de-icing product made from oil and gas brine, using concentration limits of 20,000 picocuries per liter for Radium-226 and 2,500 picocuries per liter of Radium-228, the two radionuclides of concern.

The modeling was performed using application of Radium-226 and Radium-228 as the radionuclides under evaluation. The modeling was conducted assuming a consumer performed 12 applications each winter in a residential setting. This value is an estimate for the average number of snowfalls across Ohio. More applications increase the dose. If, for example, there were 24 applications of snow, the dose would double.

Each application used the entire container (2.11 gallons) and was spread over the listed coverage area of 1,000 square feet.

There are several limitations of this model, which include:

1.) This model does not apply to repetitive spreading of larger volumes of de-icing materials on streets or roadways.
2.) This model does not consider tracking the product from the application site into buildings by people or pets.
3.) The model does not consider a hard surface as a pathway, but it does consider migration of radionuclides into the surrounding soil.
4.) While the model does consider ingestion of the product, it does not consider ingestion from eating snow by either adults or children.
5.) The RESRAD model does not include exposure to unused product stored inside a building. Modeling using the software program Microshield for one consumer container calculated an exposure rate of 3.233E-7 mR/hr, which is not measurable by standard radiation survey equipment.
6.) The model does not consider using the grass grown on the area as composting material.

The RESRAD model calculated the radiation dose over a 20-year period for a person who spends two hours per day, every day in the area being modeled and is exposed to the following exposure pathways:

- Direct radiation exposure to the product.
- Inhalation through resuspension of the product.
- Ingestion of contaminated soil.
- Ingestion of contaminated groundwater.
- Ingestion of food grown in a garden over the application area.
- Ingestion of contaminated fish residing in a pond that received runoff from the contaminated area.
- Ingestion and inhalation of contaminated water due to swimming in a contaminated pond.

The number of product applications is 12 applications each year for periods of one year, two years, three years, and up to 20 years. The total radiation dose is the sum of the radiation doses received each year by an individual as specified above, over a 20-year period. (See table on page 8.)

These time periods were included in the analysis because radium accumulates over time in the area modeled making the radiation dose cumulative over time. Radiation dose is still received by humans after the application stops.

The total radiation dose to an adult who spends two hours per day, every day, on the area of application or driveway over a 20-year period from exposure to concentration limits of 20,000 picocuries per liter for Radium-226 and 2,500 picocuries per liter of Radium-228 would range from:

- 615 millirem if applied for one year, then stopped.
- 8,519 millirem, if applied for 20 years.

The total radiation dose to a child who spends two hours per day, every day, on the area of application or driveway over a 20-year period from exposure to concentration limits of 20,000 picocuries per liter for Radium-226 and 2,500 picocuries per liter of Radium-228 would range from:

- 671.71 millirem if applied for one year, then stopped.
- 9,313.77 millirem, if applied for 20 years.

For comparison, the average radiation dose received by the public from all background sources of radiation (naturally occurring and manmade) is approximately 620 millirem per year (NCRP 2015). Any dose received using the de-icing product would be in addition to the 620 millirem per year average background radiation dose.

If an individual spends more time each day in the contamination area, or if more applications of the product are used, the total dose will increase. If an individual spends less time outside, then the total radiation dose will decrease.

“As Low As Reasonably Achievable” (ALARA) is a fundamental principle in radiation protection.

ALARA is defined in Rule 3701:1-38-01(A)(15) of the Ohio Administrative Code:

> "ALARA" or "as low as is reasonably achievable" means every reasonable effort to maintain exposures to radiation as far below the dose limits as is practical consistent with the purpose for which the licensed or registered activity is undertaken, taking into account the state of technology, the economics of improvements in relation to benefits to the public health and safety, and other societal and socioeconomic considerations, and in relation to utilization of nuclear energy and licensed materials and registered activities in the public interest.”

From an ALARA standpoint, routine applications of this product at the radionuclide proposed concentrations for a single year or over a multi-year period provides a radiation dose that is unnecessary and avoidable.

Due to the increased levels of human exposure to radiation, use of products derived from oil and gas production brine is not recommended.

1. BACKGROUND

The Bureau of Environmental Health and Radiation Protection (BEHRP) was asked by ODNR to conduct RESRAD modeling of the application of a commercially available de-icing product, known as Aqua-Salina, which is made from oil and gas brine. The RESRAD model evaluates proposed concentration limits of 20,000 picocuries per liter for Radium-226 and 2,500 picocuries per liter of Radium-228.

The modeling was performed using application of Radium-226 and Radium-228 as the radionuclides under evaluation. The modeling was conducted assuming a consumer performed 12 applications per year in a residential setting to a driveway or sidewalk and that all the product ran off into a soil area equal to the coverage area of 1,000 square feet. If most of the product runs off and does not infiltrate into the subsurface, the model will not have much, if any, exposure pathway for drinking water or ingestion from a garden inside the contaminated area because very little radium will travel through the soil to be taken up by plant roots, or travel to the water table. It should be noted that runoff of the product will transfer the Radium-226 and Radium-228 to other media such as surface water streams potentially causing radioactive contamination of these water sources. The purpose of these assumptions is to be conservative.

Each application used one 2.11-gallon container and was spread over the listed coverage area.

RESRAD-Onsite is a computer modeling software that was developed to calculate radiation dose and health risks to an average member of the critical group from residual radioactive materials. RESRAD-Onsite is commonly accepted and used to calculate radiation dose and health risk from residual radioactive materials.

The critical group is defined in Rule 3701:1-38-01(A)(38) of the Ohio Administrative Code:

> *"Critical group" means the group of individuals reasonably expected to receive the greatest exposure to residual radioactivity for any applicable set of circumstances.*

The radiological concentrations entered into the model were:

- 20,000 **picoCuries per liter** (16 **picoCuries per gram**) Radium-226; and
- 2,500 **picoCuries per liter** (2 **picoCuries per gram**) of Radium-228.

AquaSalina's safety data sheets (SDS) list the density of the product as 1.2 grams per milliliter – 1.3 grams per milliliter. The density that was used to calculate the concentration was 1.25 grams per milliliter.

2. MODEL SCENARIO

The product is applied over a 1,000 square-foot area simulating a driveway and assumes that all the product ran off into an area equal to the coverage area, rather than a hard surface.

The modeling was conducted assuming a consumer performed 12 product applications per year in a residential setting to a driveway or sidewalk and that all the product ran off into a soil area equal to the coverage area of 1,000 square feet.

The model assumes a person resides in the contaminated area two hours per day, seven days a week, 365 days per year. The time is spent entirely outside. If the person increases their time to four hours a day in the contaminated area, then their dose would double.

The purpose of the model is to simulate a residential application of the product on driveways or sidewalks and determine the dose of radiation received to an adult or child over the modeled time period.

3. ADDITIONAL ASSUMPTIONS USED FOR THE RESRAD RUN

The following assumptions were also made when using the computer model:

- The limits for Radium-226 and Radium-228 were converted to picoCuries/gram.
- There is no irrigation applied during the time period of simulation. If irrigation is considered, then there is potential for more material runoff into a nearby stream or pond.
- Each application was applied one time over a 1,000 square-foot area.
- The product saturates the soil in the modeled area two inches deep.
- All the product ran off from the driveway into a soil area equal to the coverage area immediately after application. It did not run off into a nearby water body immediately after application.

  This assumption was used because the model includes the well and garden inside the contaminated area. If the majority of the product runs off to a nearby stream or pond immediately after application, there will be a very limited, if any, exposure from either ingestion of groundwater or produce grown on contaminated soil because very little radium will travel through the soil to be taken up by plant roots, or travel to the water table.

  If the product runs off to a stream or pond immediately after application, then there would be more of an impact to streams and waterways than modeled.
- Runoff to a pond after deposition in the soil is included in the model.
- The following exposure pathways are considered:
    - Direct radiation exposure to the product.
    - Inhalation through resuspension of the product.
    - Ingestion of contaminated soil.
    - Ingestion of contaminated groundwater.
    - Ingestion of food grown in a garden over the application area.
    - Ingestion of contaminated fish residing in a pond that received runoff from the contaminated area.
    - Ingestion and inhalation due to swimming in a contaminated pond.

- RESRAD defaults were used for all parameters except precipitation, contaminated zone hydraulic conductivity, total and effective porosity, and irrigation coefficient. The irrigation coefficient was equal to zero in the model.

- US Environmental Protection Agency (USEPA) child soil ingestion rates, inhalation rates, and ingestion rates were used (USEPA 2011). The values used are shown in the table below:

Parameter	Handbook value	Converted to RESRAD-Onsite units
Soil + dust ingestion	100 mg/day	36.5 g/year (Same as RESRAD-Onsite default value)
Inhalation (high intensity, mean value)	4.9E-2 m^3/minute = 25,754.4 m^3/year (calculated value)	20,000 m^3/year (maximum RESRAD-onsite value) As a result, depending on the activity level, the calculated doses may be higher.
Drinking water intake 11 – 16 years	520 mL/day = 189.9 L/year	510 L/year (RESRAD-Onsite default value)
Body weight 2-3 years 11-16 years	18.6 kg 56.8 kg	N/A
Fruit intake 2 – 3 years	7.8 g/kg day = 145 g/day = 0.145 kg/day	52.2 kg/year
Vegetable Intake 11 – 16 years	2.3 g/kg day = 130.64 g/day = 0.131 kg/day	47.8 kg/year
Grain intake 11 – 16 years	2.4 g/kg day = 136.32 g/day = 0.136 kg/day	49.64 kg/year
Total fruit, vegetable, and grain consumption (leafy vegetable consumption RESRAD default used)	Sum = 149.64 kg/year	160 kg/year (RESRAD-Onsite default value)

Parameter	Handbook value	Converted to RESRAD-Onsite units
Fish intake 11 – 16 years	0.13 g/kg day = 7.384 g/day = 0.0074 kg/day = 2.701 kg/year	5.4 kg/year (RESRAD-Onsite default value)
Meat intake 11 – 16 years	2 g/kg day = 113.6 g/day = 0.113 kg/day = 41.25 kg/year	63 kg/year (RESRAD-Onsite default value)
Dairy intake 2 – 3 years	43.2 g/kg day = 803.52 g/day = 0.804 kg/day = 0.777 liters/day	283.6 liters/year
Fraction of Time outdoors 6 – 11 years	132 minutes/day = fraction of time = 0.092	0.092

Geological values assume clay soil that occurs commonly in Ohio (Argonne National Laboratory 2015) with an underlying sandstone aquifer. An aquifer is a geologic formation capable of storing and transmitting groundwater. The aquifer is assumed to be sandstone to reflect one of the more productive aquifers in Ohio.

Parameter	Value
Dry Bulk Density	1.64 g/cm^3
Total Porosity (contaminated zone unsaturated zone)	0.42
Effective Porosity (contaminated zone unsaturated zone)	0.06
Total Porosity (saturated zone)	0.37
Effective Porosity (saturated zone)	0.27
Soil Specific Exponential b parameter	11.4

Parameter	Value
Field Capacity	0.42
Precipitation	40 inches/year (1.016 m/year)
Hydraulic Conductivity, maximum value (contaminated and unsaturated zone)	0.01 m/year
Saturated zone hydraulic zone conductivity	10 m/year

- One normal year was considered to be 12 applications.
- To determine the annual radiation dose, the radiation dose from one application was multiplied by 12.
- To better illustrate that radiation dose is cumulative over time and that radiation dose continues after the applications stop, the radiation dose for each year of application and subsequent annual radiation dose after the applications stopped were summed to calculate the 20-year radiation dose.
- The model also included radioactive decay of Radium-228 (which has a 5.75-year radioactive half-life) and weathering of the material for each year after the application stopped. Radioactive decay of Radium-226 is not a factor because it has a half-life of 1,600 years, which means that there will be negligible decay of Radium-226 over a 20-year period.
- The model was run for the following cases:

Year	Cumulative Number of Applications
1	12 Applications
2	24 Applications
3	36 Applications
4	48 Applications
5	60 Applications
6	72 Applications
7	84 Applications
8	96 Applications

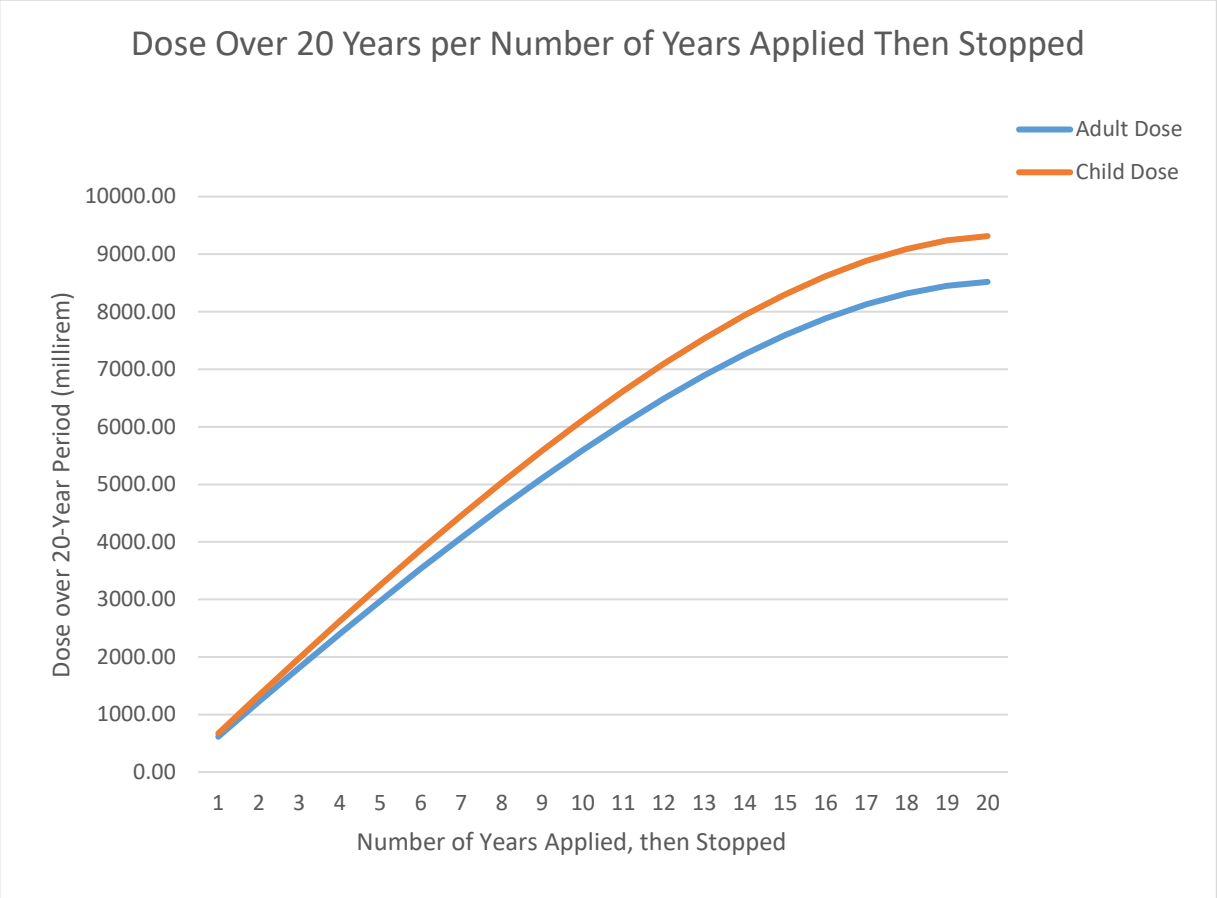
Year	Cumulative Number of Applications
9	108 Applications
10	120 Applications
11	132 Applications
12	144 Applications
13	156 Applications
14	168 Applications
15	180 Applications
16	192 Applications
17	204 Applications
18	216 Applications
19	228 Applications
20	240 Applications

The RESRAD output file is available upon request at BRadiation@odh.ohio.gov.

4. RESULTS

The total radiation doses over a 20-year period, using the assumptions given in Section 3, are shown in the following graph.

If an individual spends more time each day in the contamination area, or if more applications of the product are used, the total dose will increase.


Dose Over 20 Years per Number of Years Applied Then Stopped
Adult Dose
Child Dose
Dose over 20-Year Period (millirem)
10000.00
9000.00
8000.00
7000.00
6000.00
5000.00
4000.00
3000.00
2000.00
1000.00
0.00
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
Number of Years Applied, then Stopped

Adult Doses - Lifetime Doses in Millirem for 12, 24, 36, 48 and 60 Cumulative Applications

Year	12 Applications (Cumulative)	24 Applications (Cumulative)	36 Applications (Cumulative)	48 Applications (Cumulative)	60 Applications (Cumulative)
1	69.47	69.47	69.47	69.47	69.47
2	63.59	133.06	133.06	133.06	133.06
3	57.71	121.30	190.76	190.76	190.76
4	52.12	109.82	173.41	242.88	242.88
5	46.91	99.02	156.73	220.32	289.79
6	42.12	89.03	141.14	198.85	262.44
7	37.75	79.87	126.78	178.90	236.60
8	33.82	71.57	113.69	160.60	212.71
9	30.26	64.08	101.83	143.95	190.86
10	27.07	57.34	91.15	128.90	171.02
11	24.20	51.28	81.54	115.36	153.11
12	21.65	45.85	72.92	103.19	137.00
13	19.36	41.00	65.21	92.28	122.54
14	17.29	36.65	58.30	82.50	109.57
15	15.46	32.75	52.10	73.75	97.96
16	13.81	29.27	46.56	65.92	87.56
17	12.34	26.15	41.60	58.90	78.25
18	11.02	23.36	37.17	52.63	69.92
19	9.84	20.86	33.20	47.01	62.47
20	8.78	18.63	29.65	41.98	55.80
Lifetime Dose	**614.56**	**1,220.34**	**1,816.28**	**2,401.20**	**2,973.78**

Adult Doses - Lifetime Doses in Millirem for 72, 84, 96, 108 and 120 Cumulative Applications

Year	72 Applications (Cumulative)	84 Applications (Cumulative)	96 Applications (Cumulative)	108 Applications (Cumulative)	120 Applications (Cumulative)
1	69.47	69.47	69.47	69.47	69.47
2	133.06	133.06	133.06	133.06	133.06
3	190.76	190.76	190.76	190.76	190.76
4	242.88	242.88	242.88	242.88	242.88
5	289.79	289.79	289.79	289.79	289.79
6	331.91	331.91	331.91	331.91	331.91
7	300.19	369.66	369.66	369.66	369.66
8	270.42	334.01	403.48	403.48	403.48
9	242.98	300.68	364.27	433.74	433.74
10	217.93	270.05	327.76	391.34	460.81
11	195.23	242.14	294.25	351.96	415.55
12	174.76	216.88	263.78	315.90	373.61
13	156.36	194.11	236.23	283.14	335.26
14	139.84	173.65	211.40	253.52	300.43
15	125.03	155.29	189.11	226.86	268.98
16	111.77	138.84	169.10	202.92	240.67
17	99.90	124.10	151.18	181.44	215.26
18	89.27	110.92	135.13	162.20	192.46
19	79.76	99.12	120.76	144.97	172.04
20	71.25	88.54	107.90	129.55	153.75
Lifetime Dose	**3,532.54**	**4,075.86**	**4,601.88**	**5,108.54**	**5,593.56**

Adult Doses - Lifetime Doses in Millirem for 132, 144, 156, 168 and 180 Cumulative Applications

Year	132 Applications (Cumulative)	144 Applications (Cumulative)	156 Applications (Cumulative)	168 Applications (Cumulative)	180 Applications (Cumulative)
1	69.47	69.47	69.47	69.47	69.47
2	133.06	133.06	133.06	133.06	133.06
3	190.76	190.76	190.76	190.76	190.76
4	242.88	242.88	242.88	242.88	242.88
5	289.79	289.79	289.79	289.79	289.79
6	331.91	331.91	331.91	331.91	331.91
7	369.66	369.66	369.66	369.66	369.66
8	403.48	403.48	403.48	403.48	403.48
9	433.74	433.74	433.74	433.74	433.74
10	460.81	460.81	460.81	460.81	460.81
11	485.02	485.02	485.02	485.02	485.02
12	437.20	506.66	506.66	506.66	506.66
13	392.96	456.55	526.02	526.02	526.02
14	352.55	410.26	473.84	543.31	543.31
15	315.89	368.00	425.71	489.30	558.77
16	282.79	329.70	381.82	439.52	503.11
17	253.01	295.13	342.04	394.15	451.86
18	226.28	264.03	306.15	353.06	405.17
19	202.30	236.12	273.87	315.99	362.90
20	180.82	211.09	244.90	282.66	324.78
Lifetime Dose	**6,054.37**	**6,488.11**	**6,891.58**	**7,261.24**	**7,593.15**

Adult Doses - Lifetime Doses in Millirem for 192, 204, 216, 228 and 240 Cumulative Applications

Year	192 Applications (Cumulative)	204 Applications (Cumulative)	216 Applications (Cumulative)	228 Applications (Cumulative)	240 Applications (Cumulative)
1	69.47	69.47	69.47	69.47	69.47
2	133.06	133.06	133.06	133.06	133.06
3	190.76	190.76	190.76	190.76	190.76
4	242.88	242.88	242.88	242.88	242.88
5	289.79	289.79	289.79	289.79	289.79
6	331.91	331.91	331.91	331.91	331.91
7	369.66	369.66	369.66	369.66	369.66
8	403.48	403.48	403.48	403.48	403.48
9	433.74	433.74	433.74	433.74	433.74
10	460.81	460.81	460.81	460.81	460.81
11	485.02	485.02	485.02	485.02	485.02
12	506.66	506.66	506.66	506.66	506.66
13	526.02	526.02	526.02	526.02	526.02
14	543.31	543.31	543.31	543.31	543.31
15	558.77	558.77	558.77	558.77	558.77
16	572.58	572.58	572.58	572.58	572.58
17	515.45	584.92	584.92	584.92	584.92
18	462.88	526.47	595.94	595.94	595.94
19	415.02	472.72	536.31	605.78	605.78
20	371.68	423.80	481.51	545.10	614.56
Lifetime Dose	**7,882.94**	**8,125.82**	**8,316.58**	**8,449.64**	**8,519.11**

Child Doses - Lifetime Doses in Millirem for 12, 24, 36, 48 and 60 Cumulative Applications

Year	12 Applications (Cumulative)	24 Applications (Cumulative)	36 Applications (Cumulative)	48 Applications (Cumulative)	60 Applications (Cumulative)
1	75.96	75.96	75.96	75.96	75.96
2	69.54	145.50	145.50	145.50	145.50
3	63.11	132.65	208.61	208.61	208.61
4	57.00	120.11	189.65	265.61	265.61
5	51.30	108.30	171.41	240.95	316.91
6	46.06	97.36	154.36	217.46	287.00
7	41.28	87.34	138.64	195.64	258.74
8	36.96	78.24	124.30	175.60	232.60
9	33.07	70.03	111.31	157.37	208.67
10	29.58	62.65	99.61	140.89	186.95
11	26.45	56.03	89.10	126.06	167.34
12	23.64	50.09	79.67	112.74	149.70
13	21.13	44.77	71.22	100.80	133.87
14	18.89	40.02	63.66	90.11	119.69
15	16.87	35.76	56.89	80.53	106.98
16	15.07	31.94	50.83	71.96	95.60
17	13.46	28.54	45.41	64.30	85.43
18	12.02	25.49	40.56	57.43	76.32
19	10.73	22.76	36.22	51.29	68.17
20	9.58	20.31	32.34	45.80	60.87
Lifetime Dose	**671.71**	**1,333.84**	**1,985.23**	**2,624.61**	**3,250.51**

Child Doses - Lifetime Doses in Millirem for 72, 84, 96, 108 and 120 Cumulative Applications

Year	72 Applications (Cumulative)	84 Applications (Cumulative)	96 Applications (Cumulative)	108 Applications (Cumulative)	120 Applications (Cumulative)
1	75.96	75.96	75.96	75.96	75.96
2	145.50	145.50	145.50	145.50	145.50
3	208.61	208.61	208.61	208.61	208.61
4	265.61	265.61	265.61	265.61	265.61
5	316.91	316.91	316.91	316.91	316.91
6	362.96	362.96	362.96	362.96	362.96
7	328.28	404.24	404.24	404.24	404.24
8	295.70	365.24	441.20	441.20	441.20
9	265.67	328.78	398.32	474.28	474.28
10	238.25	295.25	358.36	427.90	503.86
11	213.40	264.70	321.70	384.80	454.34
12	190.98	237.04	288.34	345.34	408.44
13	170.83	212.11	258.17	309.47	366.47
14	152.76	189.72	231.00	277.06	328.36
15	136.56	169.63	206.59	247.87	293.93
16	122.05	151.63	184.70	221.66	262.94
17	109.07	135.52	165.10	198.17	235.13
18	97.45	121.09	147.54	177.12	210.19
19	87.05	108.19	131.83	158.27	187.85
20	77.74	96.63	117.76	141.40	167.85
Lifetime Dose	**3,861.35**	**4,455.31**	**5,030.39**	**5,584.33**	**6,114.64**

Child Doses - Lifetime Doses in Millirem for 132, 144, 156, 168 and 180 Cumulative Applications

Year	132 Applications (Cumulative)	144 Applications (Cumulative)	156 Applications (Cumulative)	168 Applications (Cumulative)	180 Applications (Cumulative)
1	75.96	75.96	75.96	75.96	75.96
2	145.50	145.50	145.50	145.50	145.50
3	208.61	208.61	208.61	208.61	208.61
4	265.61	265.61	265.61	265.61	265.61
5	316.91	316.91	316.91	316.91	316.91
6	362.96	362.96	362.96	362.96	362.96
7	404.24	404.24	404.24	404.24	404.24
8	441.20	441.20	441.20	441.20	441.20
9	474.28	474.28	474.28	474.28	474.28
10	503.86	503.86	503.86	503.86	503.86
11	530.30	530.30	530.30	530.30	530.30
12	477.98	553.94	553.94	553.94	553.94
13	429.58	499.12	575.08	575.08	575.08
14	385.36	448.46	518.00	593.96	593.96
15	345.23	402.23	465.34	534.88	610.84
16	309.00	360.30	417.30	480.41	549.95
17	276.41	322.46	373.76	430.76	493.87
18	247.15	288.43	334.49	385.79	442.79
19	220.93	257.89	299.17	345.22	396.52
20	197.43	230.50	267.46	308.74	354.80
Lifetime Dose	**6,618.49**	**7,092.77**	**7,533.97**	**7,938.22**	**8,301.18**

Child Doses - Lifetime Doses in Millirem for 192, 204, 216, 228 and 240 Cumulative Applications

Year	192 Applications (Cumulative)	204 Applications (Cumulative)	216 Applications (Cumulative)	228 Applications (Cumulative)	240 Applications (Cumulative)
1	75.96	75.96	75.96	75.96	75.96
2	145.50	145.50	145.50	145.50	145.50
3	208.61	208.61	208.61	208.61	208.61
4	265.61	265.61	265.61	265.61	265.61
5	316.91	316.91	316.91	316.91	316.91
6	362.96	362.96	362.96	362.96	362.96
7	404.24	404.24	404.24	404.24	404.24
8	441.20	441.20	441.20	441.20	441.20
9	474.28	474.28	474.28	474.28	474.28
10	503.86	503.86	503.86	503.86	503.86
11	530.30	530.30	530.30	530.30	530.30
12	553.94	553.94	553.94	553.94	553.94
13	575.08	575.08	575.08	575.08	575.08
14	593.96	593.96	593.96	593.96	593.96
15	610.84	610.84	610.84	610.84	610.84
16	625.91	625.91	625.91	625.91	625.91
17	563.41	639.37	639.37	639.37	639.37
18	505.90	575.44	651.40	651.40	651.40
19	453.52	516.63	586.17	662.13	662.13
20	406.10	463.10	526.21	595.75	671.71
Lifetime Dose	**8,618.09**	**8,883.70**	**9,092.31**	**9,237.81**	**9,313.77**

5. CONCLUSIONS

The total radiation dose over a 20-year period, using the proposed concentrations, ranges from 615 millirem (if applied for one year, then stopped) to 8,519 millirem (if applied for 20 years) for an adult and from 672 millirem to 9314 millirem for a child. If an individual spends more time each day in the contamination area, or if more applications of the product are used, the total radiation dose will increase. If an individual spends less time outside, then the total radiation dose will decrease.

From an ALARA standpoint, routine applications of this product at the proposed radionuclide concentrations for a single year or for a multi-year period provides a radiation dose that is unnecessary and avoidable.

Due to the increased levels of human exposure to radiation, use of products derived from oil and gas production brine is not recommended.

6. REFERENCES

Argonne National Laboratory, Environmental Science Division. “Data Collection Handbook to Support Modeling Impacts of Radioactive Material in Soil and Building Structures” ANL/EVS/TM-14/4, September 2015.

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