



WISCONSIN DEPARTMENT
of HEALTH SERVICES



Zion Environmental Radioactivity Survey 2020

Wisconsin Department of Health Services
Division of Public Health
Bureau of Environmental and Occupational
Health – Radiation Protection Section
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Executive Summary

The Wisconsin Department of Health Services (DHS) monitors environmental radiation around nuclear power facilities that affect Wisconsin, as required by Wisconsin Stat. § 254.41.

This report covers the Zion Nuclear Generating Plant in Zion, Illinois, for the 2020 calendar year. It describes the environmental monitoring program and presents its results.

DHS conducts environmental radiation monitoring around the Zion Nuclear Generating Plant, which sits just south of the Wisconsin-Illinois border along Lake Michigan. Although the plant is in Illinois, the southeastern part of Wisconsin lies within the Emergency Planning Zone to protect Wisconsin public health. All 2020 sample results fall below state and federal standards or guidelines. This confirms no radiological concern for Wisconsin residents from the plant.

The program collects and analyzes samples from air, water, and terrestrial pathways. It includes ambient gamma radiation (measured continuously at fixed locations), surface water, soil, and vegetation. DHS interprets results to establish baseline radioactivity levels and detect any changes.

Environmental radioactivity levels continue to trend downward since the 1950s–1960s atmospheric nuclear testing and the 1986 Chernobyl incident. No events in 2020 trigger additional monitoring.

Decommissioning of Zion Nuclear Power Plant is the regulated process of retiring a nuclear power plant from service, removing radioactive contamination, and returning the site to a safe condition for other uses, which will be completed in fall 2020. This serves as the final environmental monitoring report for the facility.

Program Summary

DHS maintains ongoing baseline measurements of environmental radioactivity. These baselines help assess health risks from nuclear facilities near Wisconsin or from radiological incidents anywhere.

All 2020 results from the Zion monitoring area are below regulatory limits. This outcome aligns with long-term downward trends in background radiation. The data supports continued public confidence in environmental safety.

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Zion Environmental Radioactivity Survey, 2020

Introduction

The Wisconsin Department of Health Services (DHS) monitors environmental radiation around nuclear facilities that affect Wisconsin residents. [Wisconsin Stat. § 254.41](#) requires this monitoring.

This report covers the Zion nuclear facility in Zion, Illinois, for the 2020 calendar year. It describes the environmental monitoring program and presents its results.

Wisconsin DHS Zion Environmental Monitoring Sampling Program

The program collects samples from air, water, and terrestrial pathways. It collects 8 ambient gamma radiation samples using thermoluminescent dosimeters (TLDs), devices that store energy from radiation exposure and release it as light when heated for measurement. The program also gathers one surface water, two soil, and two vegetation samples at selected locations on a scheduled basis.

Table 1 lists current sampling sites. All samples sites are within Wisconsin and would identify radiological contamination affecting Wisconsin residence. Table 2 details samples collected, frequencies, sites, numbers collected, missing samples or deviations, and required analyses. Table 3 explains any missing samples or non-routine analyses. Figure 1 shows a map of all sampling site locations.

Program Modifications

Major demolition and decommissioning of the Zion facility started in 2010 and completed in 2020. This report serves as the final environmental report for the Zion Nuclear Plant.

Laboratory Services and Quality Assurance

The Wisconsin State Laboratory of Hygiene (WSLH) analyzes samples under contract. WSLH runs a quality assurance program. It performs routine replicate analyses to confirm methods and instrument performance. Staff use traceable sources to calibrate instruments daily and run performance checks. WSLH maintains quality control data for instrumentation and provides them upon written request.

Detection Limits

Detection limits, required by Wisconsin DHS, will be expressed as a lower limit of detection (LLD). The required DHS LLD as indicated in Table 4 under the heading "Target LLD" is an "a priori" estimate of the capability for detecting an activity concentration by a given measurement system, procedure, and type of sample. Counting statistics of the appropriate instrument background are used to compute the

LLD for each specific analysis. Using 4.66 times the standard deviation (s_b) of the instrument background, the LLD for each specific analysis is defined at the 95% Confidence Level.

The LLD for each radioisotope listed in Table 4 has been calculated from the following equation (Meinke and Essig, 1991):

$$LLD = \frac{4.66 S_b}{E * V * 2.22 * Y * S * \exp(-dt)}$$

Where:

LLD	is the "a priori" lower limit of detection as defined above, as picocuries per unit mass or volume.
s_b	is the standard deviation of the background counting rate or of the counting rate of blank sample as appropriate, as counts per minute.
E	is the counting efficiency, as counts per disintegration.
V	is the sample size in units of mass or volume.
2.22	is the number of disintegrations per minute per picocurie.
Y	is the fractional radiochemical yield, when applicable.
S	is the self-absorption correction factor.
d	is the radioactive decay constant for the particular radionuclide.
t	is the elapsed time, for environmental samples, between sample collection, or end of the sample collection period, and time of counting.

Typical values for E, V, Y and dt have been used to calculate the LLD.

Reporting Sample Analysis Results

Laboratories report results for specific radiological analyses as either a “less than” (<) value or an actual activity value.

A “less than” (<) result shows that the radionuclide activity falls below the detection limit for a specific isotope. Analysts use this format when the results do not exceed background or statistical criteria for positive detection. These "<" values often stay lower than the DHS Target Lower Limit of Detection (LLD), and below the Nuclear Regulatory Commission’s Lowest Level Detection (Meinke and Essig, 1991).

An actual activity value appears when the measurement exceeds the detection criteria. Analysts report this value together with its uncertainty. The uncertainty term uses a plus-or-minus ($\pm$) symbol to show

counting uncertainty at the 2 sigma (95% confidence interval) level. This format provides both the best estimate of activity and the range where the true value likely falls.

The “Range” in Table 4 and the values in Tables 5–7 come from a posteriori calculation. The values are based on the actual sample values for parameters such as E (likely efficiency), V (volume), Y (yield or chemical recovery), and dt (counting time or decay time). This post-measurement approach tailors the reported range or uncertainty to the specific conditions of each sample.

The table below illustrates these reporting practices. In example "< 10 pCi/L" means activity stays below 10 picocuries per liter. An actual value like in example 2 of " 15 ± 0.3 pCi/L" shows a detected activity of 15 picocuries per liter with uncertainty of ± 0.3 at 95% confidence. These formats ensure clear, defensible communication of radiological sample results.

Example	Nuclide	Activity reported
1	^{137}Cs	< 10 pCi/liter
2	^{137}Cs	15 ± 3 pCi/liter

Table 1 presents sample sites for environmental monitoring near the Zion Nuclear Power Station. These sites track potential radiological impacts through air, water, soil, vegetation, and direct radiation measurements.

Table 1. Wisconsin DHS Zion environmental monitoring sampling sites.

Sample site	Distance and direction (miles)	Location Description
ZI-1	3.8 N	Chiwaukee Prairie
ZI-4	5.9 NW	Junction of Highway 31 and County ML.
ZI-5	3.5 N	Prairie Harbor Yacht Club
ZI-T41	4.7 NW	Junction of 122th Street and 39th Avenue
ZI-T42	3.8 N	Chiwaukee Prairie

Table 2 summarizes key details about the sampling program. It lists sample type, collection frequency, site location, number of samples collected, and any deviations that prevent sample collection. The required analysis column specifies lab tests that the laboratory performs on collected samples which are presented in this annual report.

Table 2. Sample collection summary and required analyses.

Sample Type	Collection and Frequency	Site Locations	Number of Samples Collected	Number of Samples Deviations	Required Analyses
TLD	C/Q	T41 - T42	8	0	ambient gamma
Surface Water	G/A	5	1	0	GA ^{u,v} , GB ^{u,v} , GI, Sr ^z , H ^z , I ^y
Vegetation	G/A	1, 4	2	0	GA, GB, GI
Soil	G/A	1, 4	2	0	GA, GB, GI
Collection type: C/ = continuous; G/ = grab					
Frequency: /W = weekly; /M = monthly; /Q = quarterly; /A = annually; /BW = bi-weekly; /SA = semi-annually					
Required analyses: GA = gross alpha; GB = gross beta; GI = gamma isotopic; Sr = strontium; I = iodine; H = tritium					
^u = Soluble					
^v = Insoluble					
^w = A quarterly composite for each site					
^x = One monthly composite from 2 sites					
^y = The procedure is performed six (6) times per year for each sample site					
^z = The procedure is performed for each site on a quarterly composite (3-month composite)					

Table 3. Missing sample report and listing of non-routine analyses.

Sample type	Date	Site	Explanation
Soil	06/04/2020	ZI-1	Analyzed past 180 days holding time
Soil	06/04/2020	ZI-4	Analyzed past the 180 days holding time
Soil	06/04/2020	ZI-1	Gross Alpha and Beta not reported by lab
Soil	06/04/2020	ZI-4	Gross Alpha and Beta not reported by lab
Surface Water (Tritium)	06/04/2020	ZI-5	Analyzed past the 180 days holding time
Surface Water (Sr89/90)	06/04/2020	ZI-5	Sr89/90 accuracy and matrix limits were not met, all other QC criteria met, Sr89/90 analysis qualified
Surface Water	06/04/2020	ZI-5	Gross Alpha and Beta soluble
Surface Water	06/04/2020	ZI-5	Gross Alpha and Beta suspended soluble

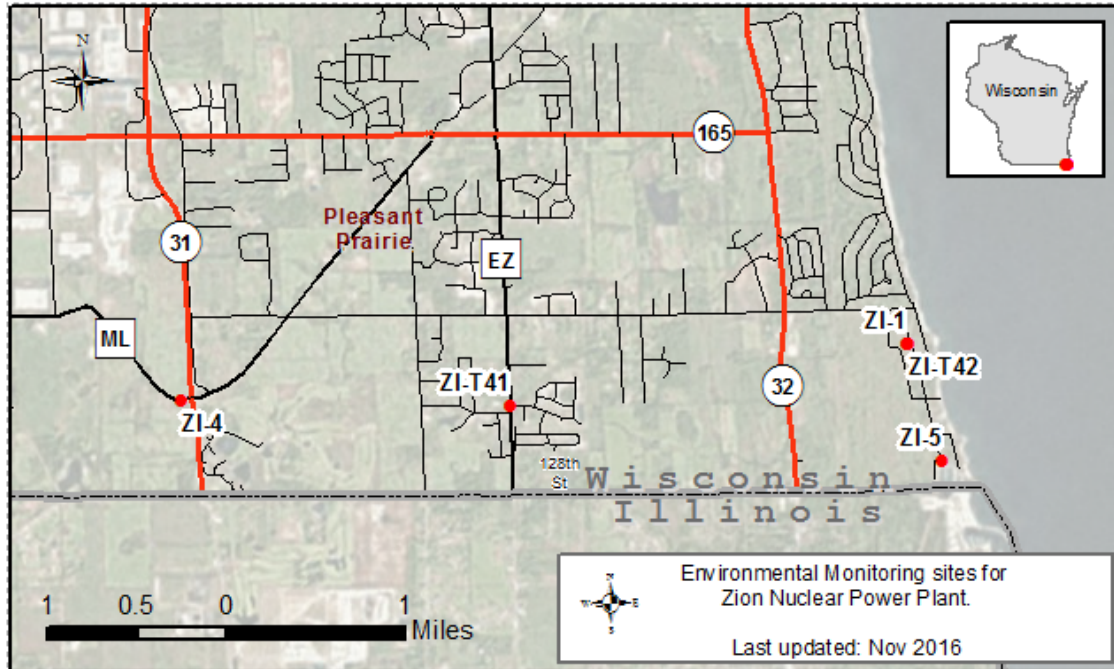


Figure 1. Wisconsin DHS environmental monitoring sites for the Zion environmental monitoring program.

Results and Discussion for the Zion Environmental Monitoring Program

Ambient Gamma Radiation – Thermoluminescent Dosimeters (TLDs)

DHS reports ambient gamma radiation activities in Table 4 and presents results from individual sample analyses in Table 5.

DHS monitors ambient gamma radiation (TLD) data from its network in 2020, and the results show comparable levels across all sites. No significant differences in exposure occur, regardless of distance from Zion. The two sites located within Wisconsin record an average exposure of 14.4 ± 2.5 milliroentgens. This average yearly exposure remains at typical background levels and matches exposures in other Wisconsin areas. The decommissioning of Zion removed all the buildings and infrastructure. Once the buildings and infrastructure were removed, a final site survey was conducted confirming radiation did not exceed federal standards.

Surface Water

DHS reports activities for surface water samples in Table 4 and presents results from individual sample analyses in Table 7.

The average yearly exposure remains at background levels and matches data from previous years. Surface water samples consistently show activities below state and federal standards. Analysis of surface water samples reveals no evident influence from the Zion facility.

Vegetation

Table 4 summarizes reported activities by DHS for vegetation samples. Table 6 presents results from individual sample analyses.

Gross beta concentration at site ZI-1 exceeds the Target LLD. Gamma isotopic analysis detects concentrations above the Target LLD for naturally occurring beryllium-7 (Be-7) at site ZI-1 and for potassium-40 (K-40) at sites ZI-1 and ZI-4. Vegetation sample analysis shows no evident influence from the Zion facility. All samples that register values above Target LLD remain below state and federal standards. All other gamma-emitting isotopes measure below detection levels.

Soil

DHS reports activities for soil samples in Table 4 and presents results from individual sample analyses in Table 6.

Gamma isotopic analysis detects naturally occurring radioisotope potassium-40 (K-40) at sites ZI-1 and ZI-4 above the target lower limit of detection (LLD). Analysts also detect cesium-137 (Cs-137) with reported activities consistent with previous years; these levels stem from fallout produced by earlier atmospheric nuclear tests. Naturally occurring radioisotopes from the uranium-238 (U-238) and thorium-232 (Th-232) decay series appear commonly, yet the program does not quantify or report them. Soil sample analysis shows no evidence of influence from the Zion facility.

Dose to an Average Individual

Federal regulations under 10 CFR 20, 10 CFR 50 Appendix I, and 40 CFR 190 restrict the annual exposure of the population from all parts of the nuclear fuel cycle, including nuclear power plants. Doses from gaseous and liquid effluent releases at the Zion facility remain well below these federal limits.

Wisconsin administrative code DHS 157.23 defines permissible levels of radiation exposure from external sources in unrestricted areas. Doses from gaseous and liquid effluent releases at the Zion facility are below the limits in Wis. Admin. Code § DHS 157.23.

References

Code of Federal Regulation. (2019). Title 40, Chapter 40, Part 190 – Environmental Radiation Protection Standards for Nuclear Power Operations.

Meinke, W. W. & Essig T. H. (1991, April). Offsite Dose Calculation Manual Guidance: Standard Radiological Effluent Controls for Pressurized Water Reactors (NUREG-1301, Generic Letter 89-01, Supplement No. 1). Division of Radiation Protection and Emergency Preparedness Office of Nuclear Regulatory Commission, Table 4.12.1, pp 47, 65.

Nuclear Regulatory Commission. (1991). Title 10, Part 20-Standards for Protection Against Radiation. § 20.1301.

Nuclear Regulatory Commission. (2019). Title 10, Appendix I to Part 50—Numerical Guides for Design Objectives and Limiting Conditions for Operation To Meet the Criterion “As Low as is Reasonably Achievable” for Radioactive Material in Light-Water-Cooled Nuclear Power Reactor Effluents.

Wisconsin Admin. Code § DHS 157.23

Sample Activity Summary

Table 4. Sample activity summary for the Wisconsin DHS Zion environmental monitoring program for 2020.

Sample type (units)	Target LLD	Number of Samples ^a	Analysis	Range
Ambient radiation (mR/Std Qtr)	1.0 ^b	8 / 8	ambient gamma (TLD)	11.6 – 17.6
Vegetation (pCi/kg wet)	5000	2 / 0	Gross Alpha	< 1670
	4000	2 / 1	Gross Beta	3470 - 6170
	350	2 / 0	Barium 140	< 118
	600	2 / 1	Beryllium 7	360 - 1730
	80	2 / 0	Cesium 134	< 18.2
	90	2 / 0	Cesium 137	< 22.2
	600	2 / 0	Cobalt 58	< 15.8
	100	2 / 0	Cobalt 60	< 21.4
	80	2 / 0	Iodine 131	< 47.4
	200	2 / 0	Iron 59	< 39.3
	100	2 / 0	Lanthanum 140	< 38.2
	90	2 / 0	Manganese 54	< 17.3
	100	2 / 0	Niobium 95	< 19
	2000	2 / 2	Potassium 40	3560 - 4620
	250	2 / 0	Zinc 65	< 38.6
	200	2 / 0	Zirconium 95	< 33.5
Surface water (pCi/liter)	3	1 / 0	Gross Alpha Sus Sol	*d
	3	1 / 0	Gross Beta Sus Sol	*d
	3	1 / 0	Gross Alpha	*d
	3	1 / 0	Gross Beta	*d
	0.5	1 / 0	Iodine 131	*d
	300	1 / 0	Tritium	< 119
	2	1 / 0	Strontium 89	0.549 ± 0.259
	1	1 / 0	Strontium 90	0.378
	350	1 / 0	Barium 140	< 21.5
	80	1 / 0	Cesium 134	< 5.12
	90	1 / 0	Cesium 137	< 5.06
	600	1 / 0	Cobalt 58	< 4.61
	100	1 / 0	Cobalt 60	< 4.48
	80	1 / 0	Iodine 131	< 6.70
	200	1 / 0	Iron 59	< 8.31
	100	1 / 0	Lanthanum 140	< 7.97
	90	1 / 0	Manganese 54	< 4.88

Table 4 (continued) Sample activity summary for the Wisconsin DHS Zion environmental monitoring program for 2020.

Sample type (units)	LLD	Number of samples ^a	Analysis	Range
Surface water (pCi/liter)	100	1 / 0	Niobium 95	< 5.51
	250	1 / 0	Zinc 65	< 9.74
	200	1 / 0	Zirconium 95	< 8.20
Soil (pCi/kg dry)	15000	2 / 0	Gross Alpha	*d
	6000	2 / 0	Gross Beta	*d
	80	2 / 0	Cesium 134	< 5.11
	80	2 / 1	Cesium 137	38.6 - 248
	90	2 / 0	Cobalt 58	< 14.7
	90	2 / 0	Cobalt 60	< 4.97
	600	2 / 0	Iron 59	< 72.7
	60	2 / 0	Manganese 54	< 9.19
	100	2 / 0	Niobium 95	< 64.7
	800	2 / 2	Potassium 40	9030 - 20400
	300	2 / 0	Zinc 65	< 15.9
	250	2 / 0	Zirconium 95	< 32.9
a - Number of analyses / number of analyses detected above the WI DHS LLD. b - 1.0 mR/TLD c - Sample was more than six months old, too old to run Gross alpha/beta d - Data not reported by lab				

Table 5. Wisconsin DHS TLD network for the Zion environmental monitoring program.



	1st quarter	2nd quarter	3rd quarter	4th quarter
Date Placed:	1/17/2020	4/10/2020	7/16/2020	10/13/2020
Date Removed:	4/10/2020	7/16/2020	10/13/2020	1/12/2021
Average Days is the Field:	84	97	89	91
Location:				
T-41	16.9 ± 1.2	15.3 ± 0.7	17.6 ± 1.0	16.3 ± 0.6
T-42	11.8 ± 0.9	11.6 ± 0.9	11.7 ± 0.5	13.8 ± 0.9

Table 6. Wisconsin DHS analysis results for vegetation and soil samples collected for the Zion environmental monitoring program.

Vegetation 			Soil 		
pCi/kilogram (wet)			pCi/kilogram (dry)		
Site:	ZI-1	ZI-4	Site:	ZI-1	ZI-4
Collection date:	6/4/2020	6/4/2020	Collection date:	6/4/2020	6/4/2020
gross alpha	< 1350	< 1670	gross alpha	*a	*a
gross beta	6170 ± 421	3470 ± 355	gross beta	*a	*a
gamma isotopic			gamma isotopic		
Barium 140	< 118	< 57.7	Cesium 134	< 4.53	< 5.11
Beryllium 7	1730 ± 176	360 ± 69	Cesium 137	248 ± 14.8	38.6 ± 3.98
Cesium 134	< 18.2	< 11.3	Cobalt 58	< 14.6	< 14.7
Cesium 137	< 22.5	< 11.1	Cobalt 60	< 4.77	< 4.97
Cobalt 58	< 15.8	< 11.1	Iron 59	< 68.9	< 72.7
Cobalt 60	< 21.4	< 15.5	Manganese 54	< 5.93	< 9.19
Iodine 131	< 47.4	< 18.5	Niobium 95	< 57.8	< 64.7
Iron 59	< 39.3	< 27.4	Potassium 40	9030 ± 1440	20400 ± 3230
Lanthanum 140	< 38.2	< 18.5	Zinc 65	< 14.9	< 15.9
Manganese 54	< 17.3	< 11.1	Zirconium 95	< 32.9	< 32.6
Niobium 95	< 19.0	< 13.9			
Potassium 40	4620 ± 799	3560 ± 636			
Zinc 65	< 38.6	< 28.9			
Zirconium 95	< 33.5	< 22.7			
Soil: Naturally occurring radioisotopes such as radium-226 (²²⁶Ra), bismuth-214 (²¹⁴Bi), lead-214 (²¹⁴Pb), actinium-228 (²²⁸Ac), bismuth-212 (²¹²Bi), lead-212 (²¹²Pb) from the naturally occurring uranium-238 (²³⁸U), and thorium-232 (²³²Th) decay series are commonly detected but have not been quantified or reported. Radioisotopes other than those reported were not detected a – Data not reported by lab					

Table 7. Wisconsin DHS analysis results for surface water samples collected for the Zion environmental monitoring program.

Surface Water 	
Measurements in units of pCi/liter	
Site ZI-5	
Collection date:	6/4/2020
Gross Alpha Sus Sol	*a
Gross Beta Sus Sol	*a
Gross Alpha	*a
Gross Beta	*a
Iodine 131	*a
Tritium	< 119
Strontium 89	0.549 ± 0.259
Strontium 90	0.378
Barium 140	< 21.5
Cesium 134	< 5.12
Cesium 137	< 5.06
Cobalt 58	< 4.61
Cobalt 60	< 4.48
Iodine 131	< 6.70
Iron 59	< 8.31
Lanthanum 140	< 7.97
Manganese 54	< 4.88
Niobium 95	< 5.51
Zinc 65	< 9.74
Zirconium 95	< 8.20
Radioisotopes other than those reported were not detected.	
a – Data not reported by lab	

Appendices

Appendix A Radionuclide Concentration Levels needing review by state radiological coordinator (SRC)

Should radioactivity concentrations exceed SRC review levels for a given radionuclide, the SRC will be consulted for review and assessment.

Medium	Radionuclide	SRC Review Level ^a
Water (pCi/l)	Gross Alpha	10
	Gross Beta	30
	H-3	10,000
	Mn-54	100
	Fe-59	40
	Co-58	100
	Co-60	30
	Zr-Nb-95	40
	Cs-134	10
	Cs-137	20
	Ba-La-140	100
	Sr-89	8
	Sr-90	8
	Zn-65	30
Vegetation (pCi/kg wet)	Gross Beta	30,000
	I-131	100
	Cs-134	200
	Cs-137	200
	Sr-89	1,000
	Sr-90	1,000
Soil, Bottom Sediment (pCi/kg)	Gross Beta	5,000
	Cs-134	5,000
	Cs-137	5,000
	Sr-89	5,000
	Sr-90	5,000
Radionuclides will be monitored by the Wisconsin Department of Health Services, Radiation Protection Section's Environmental Monitoring program and concentrations above the listed levels will be reported to the Wisconsin state radiological coordinator (SRC) for further review and assessment.		

Appendix B Sample Point Locations

Sample Point	Location Description	Longitude or X	Latitude or Y
ZI-1	Chiwaukee Prairie.	-87.80925	42.50461
ZI-4	Junction of Highway 31 and County ML.	-87.88893	42.50156
ZI-5	Prairie Island Yacht Club	-87.80569	42.49509
ZI-T41	Junction of 122th Street and 39th Avenue	-87.85287	42.5005
ZI-T42	Chiwaukee Prairie.	-87.80911	42.50469