Surveillance2020

Vermont Yankee Nuclear Power Station

Report on Public Health Monitoring

VERMONT
DEPARTMENT OF HEALTH
Agency of Human Services

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healthvermont.gov

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Executive Summary

The Vermont Department of Health has been monitoring and reporting on radiation emissions and radiological effluents (discharges) from the Vermont Yankee Nuclear Power Station since 1971. The purpose of this environmental surveillance is to protect the public's health from excess amounts of radiation.

This *Surveillance 2020* report details nearly 800 separate measurements of over 400 samples of air, water, milk, sediment and fish taken during the year at the Vermont Yankee site boundary (property line), from the Connecticut River, and from the towns surrounding the station.

The Health Department enforces the state's Radiological Health Rule, which limits the amount of ionizing radiation to which any member of the public could be exposed if standing at the site boundary of the station. The Rule also limits the amount of gaseous, liquid, radioiodine and radioactive particulate effluents to which any member of the public could possibly be exposed because of activities at Vermont Yankee.

The Rule limits the annual direct gamma radiation from Vermont Yankee to a measured exposure value of 20 milliroentgen above background radiation at the site boundary on land. The Rule also limits specific emissions or discharges from Vermont Yankee to an effective dose of no more than 5 millirem from each pathway to any member of the public.

The Connecticut River site boundary around Vermont Yankee is regulated by the U.S. Nuclear Regulatory Commission, which limits the annual direct gamma radiation to any member of the public at this boundary to 100 millirem.

2020 Surveillance Results:

- Measurements in this report confirm no dose in excess of any limit established by the Vermont Department of Health's Radiological Health Rule.

- The numerous samples and measurements of the environment around Vermont Yankee in 2020 show no instances of non-compliance with the Radiological Health Rule from activities at Vermont Yankee.

- This report is the fifth since 2010 to not include Health Department analytical results from on-site groundwater monitoring wells. Entergy stopped splitting samples from the on-site wells with the Health Department at the end of 2015. The Health Department is thus no longer able to independently assess on-site

impacts of the tritium-contaminated plume of groundwater first detected in January 2010.

- Entergy provides annual effluent and environmental reports to the Nuclear Regulatory Commission. Those reports for the years 2005 through 2015 are available at VY Reports from Health . The 2016 through 2019 Radioactive Effluent reports may be found at VY Reports in NRC ADAMS .

- The Health Department's continuing analysis of cancer statistics for people who live in the communities surrounding Vermont Yankee shows that cancer incidence and mortality do not differ significantly from people in the rest of Windham County, elsewhere in Vermont, or in the United States.

For questions or more information – The information presented in this report is sometimes complex. We invite interested readers to contact the Health Department's Radiological Sciences program at 802-865-7730 with any questions.

Introduction

This *Surveillance 2020* report describes the amount and types of radiation found near the Vermont Yankee Nuclear Power Station located in Vernon, Vermont. Until the reactor was shut down on December 29, 2014, Vermont Yankee was generating and emitting ionizing radiation in the form of direct gamma radiation, and discharging radioactive materials that emit alpha-, beta- and gamma-radiations. A person could be exposed to radiation released from Vermont Yankee in air or liquid discharges from the station, or from unmonitored releases or leaks. After reactor shutdown, there remain sources of radiation exposure and radioactive material release pathways that may contribute to public dose. The Health Department intends to continue this surveillance until Vermont Yankee is decontaminated and dismantled, and the site is released for unrestricted use.

The Vermont Department of Health enforces the state's Radiological Health Rule, which limits the amount of ionizing radiation to which a member of the public could be exposed if standing at the site boundary (property line) of the station. Specifically, the Rule limits the annual direct gamma radiation from Vermont Yankee to a measured exposure value of 20 milliroentgen above background radiation at the site boundary on land. The Rule also limits the amount of gaseous, liquid, radioiodine and radioactive particulate effluents to which a member of the public could possibly be exposed because of activities at Vermont Yankee. The Rule limits specific emissions or discharges from Vermont Yankee to an effective dose of no more than 5 millirem from each pathway to any member of the public.

The Health Department monitors radiation levels at and near Vermont Yankee. Because both naturally-occurring and human-made radiation is all around us in the environment, the Health Department also tests other areas of the state to provide background data on types and amounts of environmental radiation. Background measurements are compared to measurements of radiation found in areas near Vermont Yankee. The two sets of values are compared to determine if Vermont Yankee's activities are resulting in an increased radiation risk to the public.

This report presents nearly 80 measurements taken from over 400 samples that were obtained near Vermont Yankee and from background locations during 2020. Air, water, milk, fish and sediment samples were collected and tested. Maps of locations where

many samples or measurements were taken, as well as the testing procedures, are provided.

Most samples are tested by the Health Department Laboratory located in Colchester, Vermont. Measurements of direct gamma radiation exposures using thermoluminescent dosimeters (TLDs) are tested by a National Voluntary Laboratory Accreditation Program (NVLAP) vendor of dosimetry.

The primary human health concern with chronic low-level exposure to ionizing radiation is the potential to develop cancer. For this reason, the Health Department also presents cancer incidence and cancer mortality data for the area near Vermont Yankee and compares it to the same type of data for the state of Vermont as well as for the U.S. population.

Tritium Contamination

Testing and evaluation of the tritium contamination described in the 2010 Surveillance Report continued in 2020. No tritium was found in any river water downstream from the station, or in samples collected from off-site wells near Vermont Yankee.

Results Presented in this Report:

- Direct gamma radiation measured continuously from 68 sites
- Air samples collected by continuous air samplers and tested for radioactive particulates, gases, vapors and radioactive iodine
- Drinking water wells, on-site monitoring wells and Connecticut River water near Vermont Yankee tested for tritium, gamma-emitting materials, total alpha radioactivity and total beta radioactivity
- Milk, river sediments and fish tested for natural and human-made radioactive materials

These data show no radiation dose in excess of the Health Department's limits as a result of Vermont Yankee activities in 2020.

The *Surveillance 2020* report is published at the Vermont Department of Health web site: www.healthvermont.gov. For questions about the content, call the Health Department's Radiological Sciences program at 802-865-7730.

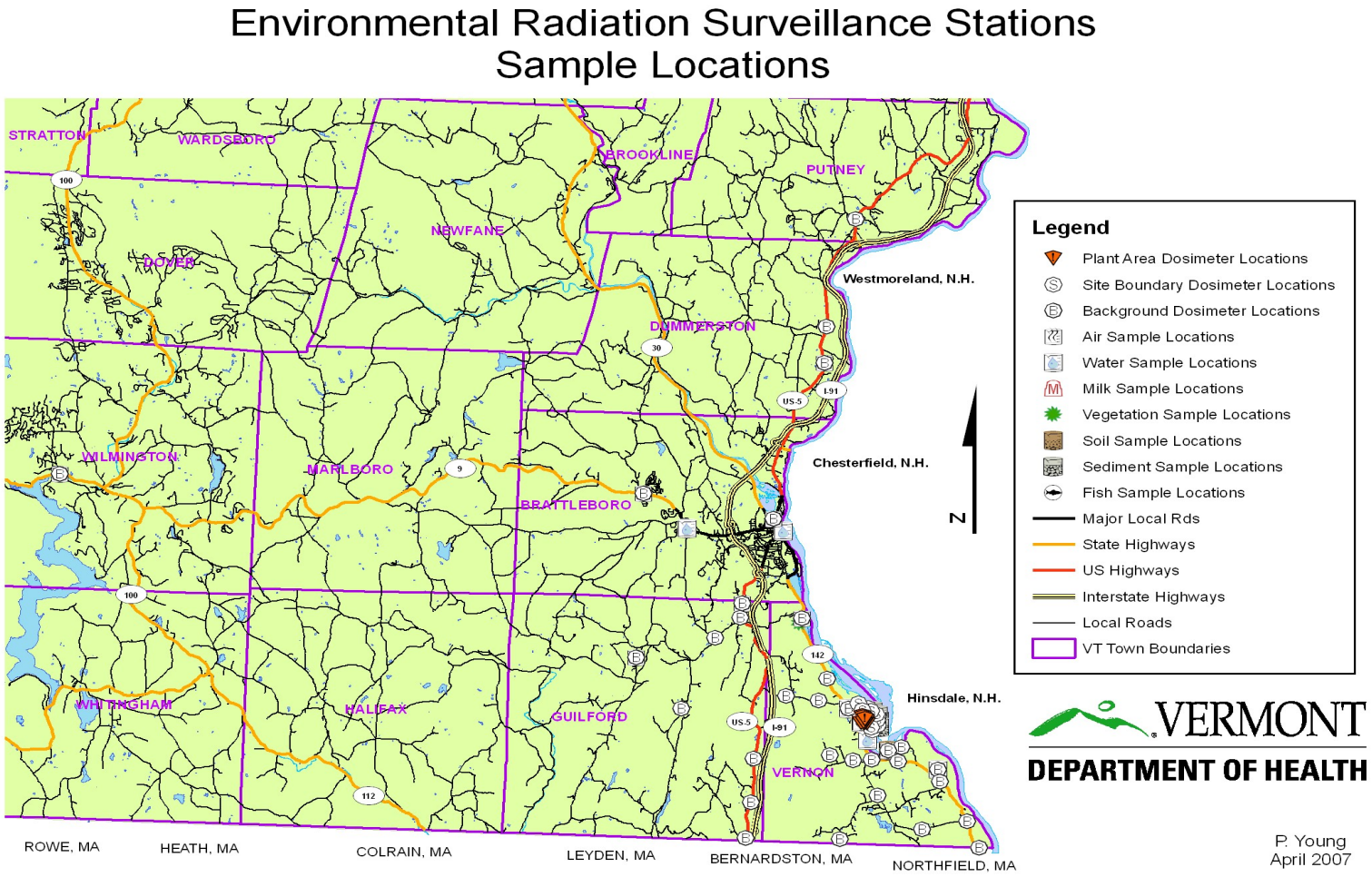
Program Results Summary

An overview of the 2020 sample data is presented in this summary. Detailed descriptions of sample measurement techniques and analyses are presented in further sections of this report. The total numbers, types of sample collected, types of analysis performed, and summary results are reported in Table 1. Routine environmental sampling sites are shown in Maps 1 and 2. Map 1 shows the locations where routine samples were taken. Map 2 shows the sample locations in Vernon.

Table 1. 2020 Summary of Samples, Tests and Results

Sample Type	Sites	Number of Tests	Test Type	Results
Direct Gamma Radiation	68	199	Thermoluminescent dosimeters	Less than 20 milliroentgen per year at the land site boundary; no single quarter exceeded 10 milliroentgen.
Air: Particulates, Gases and Vapors	9	44	Total Alpha Radioactivity	Alpha radioactivity within the historical range. No increase observed as a result of operations at Vermont Yankee.
		44	Total Beta Radioactivity	Beta radioactivity within the historical range. No increase observed as a result of operations at Vermont Yankee.
		44	Iodine-131	No iodine-131 was detected in air samples.
		44	Gamma (gas/vapors) Radioactivity	Gamma radioactivity detected was of natural origin.
		2 (*quarterly composites)*	Gamma (particulates) Radioactivity	Gamma radioactivity detected was of natural origin.
Water	15	67	Total Alpha Radioactivity	Alpha radioactivity within the historical range. No increase observed as a result of operations at Vermont Yankee.
		67	Total Beta Radioactivity	Beta radioactivity within the historical range. No increase observed as a result of operations at Vermont Yankee.
	21	110	Tritium	All samples less than the lower limit of detection except one on-site groundwater monitoring well.
		110	Gamma Radioactivity	All detected gamma radioactivity of natural origin.
Milk	2	10	Iodine-131	All samples less than the lower limit of detection.
		10	Gamma Radioactivity	All gamma radioactivity detected was of natural origin.
Sediments	18	36	Gamma Radioactivity	Gamma radioactivity detected attributable to natural, Chernobyl, Fukushima, or above-ground nuclear weapons testing origin.
Fish	2	4	Gamma Radioactivity	Gamma radioactivity detected attributable to natural, Chernobyl, Fukushima, or above-ground nuclear weapons testing origin.
Total number of tests		**791**		

Map 1


Environmental Radiation Surveillance Stations
Sample Locations
STRATTON
WARDSBORO
BROOKLINE
PUTNEY
NEWFANE
DOVER
Westmoreland, N.H.
DUMMERSTON
WILMINGTON
MARLBORO
Chesterfield, N.H.
BRATTLEBORO
N
WHITINGHAM
HALIFAX
GUILFORD
Hinsdale, N.H.
VERNON
ROWE, MA
HEATH, MA
COLRAIN, MA
LEYDEN, MA
BERNARDSTON, MA
NORTHFIELD, MA
Legend
Plant Area Dosimeter Locations
Site Boundary Dosimeter Locations
Background Dosimeter Locations
Air Sample Locations
Water Sample Locations
Milk Sample Locations
Vegetation Sample Locations
Soil Sample Locations
Sediment Sample Locations
Fish Sample Locations
Major Local Rds
State Highways
US Highways
Interstate Highways
Local Roads
VT Town Boundaries
VERMONT
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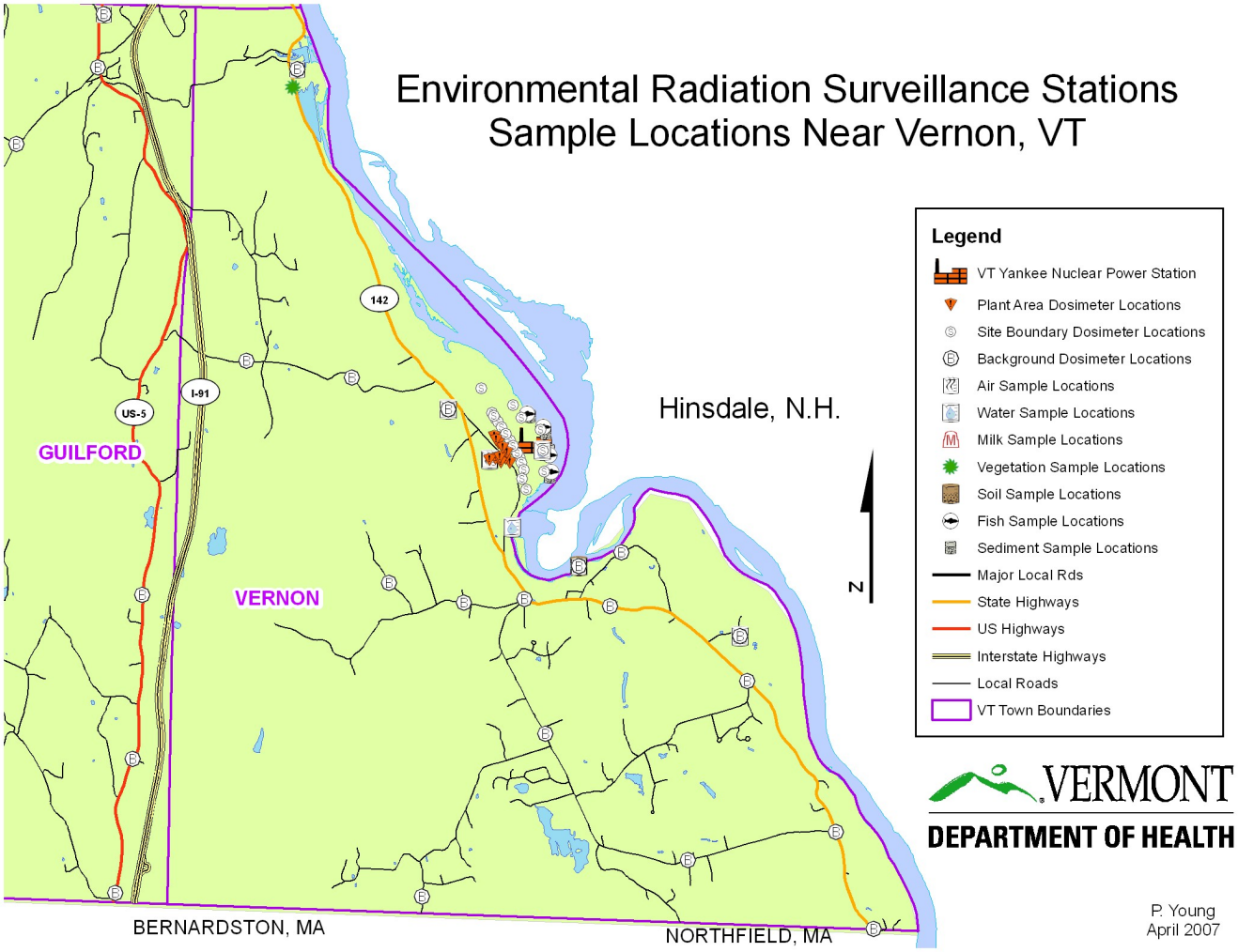
Map 2


Environmental Radiation Surveillance Stations
Sample Locations Near Vernon, VT
Hinsdale, N.H.
GUILFORD
VERNON
BERNARDSTON, MA
NORTHFIELD, MA
142
I-91
US-5
N
Legend
VT Yankee Nuclear Power Station
Plant Area Dosimeter Locations
Site Boundary Dosimeter Locations
Background Dosimeter Locations
Air Sample Locations
Water Sample Locations
Milk Sample Locations
Vegetation Sample Locations
Soil Sample Locations
Fish Sample Locations
Sediment Sample Locations
Major Local Rds
State Highways
US Highways
Interstate Highways
Local Roads
VT Town Boundaries
VERMONT
DEPARTMENT OF HEALTH
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Types of Ionizing Radiation

There are three main types of ionizing radiation that could be released from Vermont Yankee: alpha particles, beta particles and gamma rays. The risk of adverse health effects from ionizing radiation is linked to the type and energy of radiation, the length and method of exposure to the radiation, and the organ or organs of the body that are impacted. The Health Department tests for these forms of radiation in many sample types.

Alpha and Beta (particle) Radiation

Alpha and beta radiation are particle forms of radiation energy. Alpha- and beta-charged particles can only travel a short distance and are completely blocked by simple materials.

Alpha radiation is the most biologically hazardous form of ionizing radiation, causing about 20 times more tissue damage than the same amount of beta or gamma radiation energy. It is also the type of radiation that people can most easily shield against. A sheet of paper can stop an alpha particle, and so can the dead layer of skin that covers the outer surface of our bodies. Alpha particles can only cause harm if alpha-emitting materials are inhaled, ingested or otherwise taken into the body. The most common alpha radiation exposure for people is from naturally-occurring radon gas in their homes.

Table 2. Examples of Radioactive Elements that Produce Alpha-Radiations

Naturally-occurring alpha emitters	
Uranium-238	Radon-222
Thorium-232	Polonium-210
Radium-226	Bismuth-212
Human-made alpha emitters	
Americium-241	Plutonium-239
Neptunium-237	Curium-244

Beta radiation is easily stopped by simple materials like plastics, aluminum and wood, but may be able to go through the first few millimeters of human skin. Beta radiation

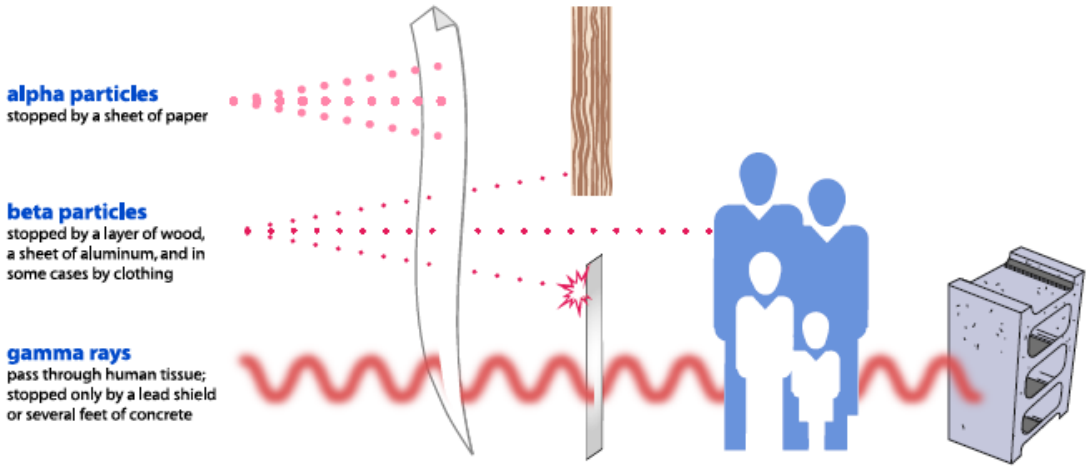
can cause damage to internal tissues and organs if a beta-emitting material is inhaled, ingested or otherwise taken into the body.

Alpha and beta-emitting materials are released from the station's air stack at Vermont Yankee. They may also be emitted in liquid discharges from contaminated reactor systems.

Table 3. Examples of Radioactive Elements that Produce Beta-Radiations

Naturally-occurring beta emitters	
Carbon-14	Potassium-40
Radium-228	Hydrogen-3, "tritium" (also human-made)
Human-made beta emitters	
Iodine-131	Technetium-99
Strontium-90	Hydrogen-3, "tritium" (also naturally-occurring)
Nickel-63	Iron-59

Figure 1. Relative Ability of Ionizing Radiations to go through Materials



Gamma Radiation

Direct gamma radiation is an electromagnetic wave of energy similar to light, except that it passes through most materials. Like all radiation, gamma radiation can also scatter off materials. Direct gamma radiation loses strength as it travels away from the source. It is also reduced after large numbers of collisions with electrons in the atom.

Gamma radiation passes through the skin and may pass through the whole body. If gamma radiation passes through the body, it may damage tissues. People can be affected by gamma radiation if they are in an area where direct gamma radiation exists, or if they ingest a gamma-emitting material.

Direct gamma radiation is emitted from the reactor and turbine systems such as those at Vermont Yankee. Gamma-emitting materials may also be released as gases or particles from the station's air stack.

Decommissioning Perspectives

While in SAFSTOR, the reactor systems are contaminated but drained of water. The water, about one million gallons, is stored in a very large doughnut-shaped tank-like structure under the reactor vessel. When the station is decontaminated and dismantled during DECON, the water will be disposed of as low-level radioactive waste along with the decontaminated and dismantled system components.

During DECON, the decontamination and dismantling of the structures, systems and components at Vermont Yankee will be monitored for human and environmental impacts. The Health Department intends to continue its monitoring of public radiation exposures and radioactive material release pathways at least until the NRC license is terminated and the site may be released for unrestricted use.

Table 4. Examples of Radioactive Elements that Produce Gamma-Radiations

Naturally-occurring gamma emitters		
Beryllium-7	Potassium-40	Thallium-208
Bismuth-212	Bismuth-214	Lead-210
Lead-212	Lead-214	Polonium-210
Actinium-228	Radium-224	Radium-226
Radium-228	Thorium-228	Thorium-229
Thorium-230	Thorium-231	Thorium-232
Thorium-234	Uranium-233	Uranium-234
Uranium-235	Uranium-238	
Human-made gamma emitters		
Antimony-124	Antimony-126	Barium-140/ Lanthanum-140
Cerium-144/ Promethium-144	Cesium-134	Cesium-136
Chromium-51	Cobalt-56	Cobalt-58
Cobalt-60	Iodine-131	Iodine-132
Iodine-133	Iodine-135	Krypton-85
Krypton-88	Manganese-54	Neptunium-239
Plutonium-239	Plutonium-240	Ruthenium-103
Tellurium-132	Strontium-85	Strontium-89
Zinc-65	Xenon-133	Xenon-133m
Xenon-135	Zirconium-95/Niobium-95	

Ionizing Radiation Risks

The radiations to which people may be exposed as a result of Vermont Yankee activities are ionizing radiations. According to the International Agency for Research on Cancer (IARC), ionizing radiation can cause cancer in humans. The energy released by ionizing radiation may directly or indirectly damage the DNA of human cells and over time cause cancer. It has been shown that people who are exposed to high doses of ionizing radiation, generally greater than 10,000 millirem, have a statistically higher risk of cancer. As with other cancer-causing agents, it is not possible to prove that low doses of ionizing radiation are without risk. The risk of developing cancer from chronic exposure to very low doses of radiation, such as the doses detailed in this report, is considered very low.

The risk management approach used for public health protection with ionizing radiation is called the ALARA Principle. The ALARA Principle states that every reasonable effort must be made to maintain radiation exposures ***A****s* ***L****ow* ***A****s* ***R****easonably* ***A****chievable*. The Health Department's Radiological Health Rule not only requires that exposures to ionizing radiation be less than specific limits, but also that Vermont Yankee and all other radiation users in industry, medicine and education use the ALARA Principle.

For more information about ionizing radiation risk:

- The National Academies of Science

  National Research Council. *Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII Phase 2*. Washington, DC: The National Academies Press, 2006.

- The Health Physics Society

  Health Physics Society, *Radiation Risk in Perspective*: *Position Statement of the Health Physics Society*. McLean, VA: The Health Physics Society, 2019

- The International Agency for Research on Cancer

  The International Agency for Research on Cancer, *Radiation, Volume 100D*. France: The World Health Organization, 2012

Cancer Prevalence, Incidence & Mortality

The primary health concern with chronic low-level exposure to ionizing radiation is the potential to develop cancer. Starting in 2007, the Health Department began presenting cancer-related health outcome data for the population in the area of Vermont Yankee. The Health Department tabulates, analyzes and provides data for cancer incidence (new cancer cases diagnosed) and cancer mortality (people dying from cancer) for Windham County and for the six towns nearest Vermont Yankee that make up the Emergency Planning Zone. The Health Department evaluates trends in all cancer types (all ages, all sites) and evaluates thyroid cancers, leukemia and pediatric (childhood) cancers separately because these types of cancers can be associated with excess radiation exposure or radiation exposure during fetal development.

Cancer Prevalence

Cancer is not one disease, but a group of more than 100 different diseases. Cancer is very common. Roughly four out of ten men and women in the U.S. will develop cancer in their lifetime. A cancer usually develops gradually as a result of a complex mix of factors related to personal behaviors, environment and genetics. Each type of cancer is caused by a different set of factors, some well-established, some uncertain, and some unknown.

Cancer *prevalence* means the number of people alive today who have ever been diagnosed with cancer. According to 2020 Behavioral Risk Factor Surveillance System (BRFSS) data, approximately 35,600 or seven percent of Vermonters age 18 and older have ever been told by a doctor they had cancer. This includes people who are newly diagnosed, in active treatment, or have completed active treatment, and people living with progressive symptoms of their disease.

As a population ages, the occurrence of new cancer cases can be expected to increase. With treatment advances, people are living longer with a cancer diagnosis. Between 2009 and 2018 the number of cancer survivors has increased by approximately a third (SEER Cancer Statistics Review 1975-2008 and 1975-2018).

Cancer Incidence

Cancer *incidence* is the number of newly diagnosed cases during a specific time period. Incidence data in Table 5 were compiled from Vermont Cancer Registry data. Incidence rates are shown for all cancers, thyroid cancers, leukemia, and childhood (pediatric) cancers for the 10-year period 2009 to 2018.

The data in Table 5 indicate that:

- Incidence rates for all cancer types combined are not different in Vermont compared to the U.S.
- Incidence rates for leukemia in the Emergency Planning Zone are not different from Windham County, Vermont, or the U.S. population.
- Incidence rates for thyroid cancer in the Emergency Planning Zone are not different from Windham County and Vermont but is lower than the U.S. population.
- Incidence rates for pediatric cancers in the Emergency Planning Zone could not be calculated.
- The incidence of thyroid cancer in Windham County is significantly lower than Vermont and the U.S. rate.
- For all cancer types combined, the rate of cancer incidence in the six towns near Vermont Yankee (Brattleboro, Dummerston, Guilford, Halifax, Marlboro and Vernon) is not different from Vermont, Windham County, or the U.S. population.

The U.S. incidence rates and mortality rates are all races population rates. Analysis prior to the 2011 report compared only U.S. white population incidence and mortality rates to Vermont rates. This change is consistent with current Health Department publications that compare Vermont (all races) to U.S. (all races) rates.

Table 5. Cancer Incidence Rates Near Vermont Yankee, in Vermont & U.S.

Age Adjusted Vermont and U.S. Cancer Incidence, All Sites, Males and Females per 100,000 population, 2009-2018.

	Rate	Lower CL	Upper CL	Avg. cases per year
U.S.	459.0	458.7	459.2	1,659,449
Vermont	460.5	455.6	465.3	3,728
Windham County	453.9	436.5	472.0	281
Emergency Zone	434.0	408.5	460.8	121

Age Adjusted Vermont and U.S. Cancer Incidence, Thyroid, Males and Females per 100,000 population, 2009-2018.

	Rate	Lower CL	Upper CL	Avg. cases per year
U.S.	14.2	14.1	14.2	46,925
Vermont	14.0	13.1	15.0	95
Windham County	9.2	6.6	12.5	5
Emergency Zone	8.6	5.1	13.6	2

Age Adjusted Vermont and U.S. Cancer Incidence, Leukemia, Males and Females per 100,000 population, 2009-2018.

	Rate	Lower CL	Upper CL	Avg. cases per year
U.S.	14.5	14.5	14.5	50,794
Vermont	13.2	12.3	14.0	102
Windham County	14.6	11.5	18.4	9
Emergency Zone	12.3	8.4	17.5	4

Age Adjusted Vermont and U.S. Cancer Incidence, Pediatric Cancers (Ages 0-19), Males and Females per 100,000 population, 2009-2018.

	Rate	Lower CL	Upper CL	Avg. cases per year
U.S.	18.8	18.7	18.9	15,546
Vermont	16.8	14.7	19.1	25
Windham County	14.9	8.1	25.1	1
Emergency Zone	--	--	--	--

-- Rates and incidence counts are only presented when the total number of cases is greater than 5.
Data Sources: Vermont Cancer Registry (VCR), Vermont Department of Health (1994-2019). NPCR and SEER Incidence - U.S. Cancer Statistics Public Use Database, 2021 Submission (2001-2019).
Technical Notes: Emergency Zone towns include: Brattleboro, Dummerston, Guilford, Halifax, Marlboro, and Vernon. All rates are age adjusted to the 2000 U.S. standard population and rates are per 100,000 population. Incidence rates are for invasive cancers and in situ urinary bladder cancers. Cancer diagnoses exclude basal cell and squamous cell skin cancers. A reporting delay by Department of Veterans Affairs (VA) has resulted in incomplete reporting of VA hospital cases in 2011-2014 and 2016-2019.

Cancer Mortality

In Table 6, mortality rates from the U.S., Vermont, Windham County, and the Emergency Planning Zone towns are presented for the 10 years 2009 to 2018. The Vermont data are from the Vermont Department of Health's Vital Statistics System. Data for U.S. cancer mortality rates are from the Vital Statistics System of the United States. Cancer mortality data are presented for all cancers, thyroid cancers, leukemia and pediatric cancers.

The data in Table 6 indicate:

- Mortality rates for all cancers combined is higher in Vermont compared to the U.S.

- For the years 2009 to 2018, cancer mortality rates for all cancers combined and the leukemia mortality rates in the six towns of the Emergency Planning Zone around Vermont Yankee do not differ from those for Windham County, Vermont or the U.S.

- Similar results were seen in mortality rates in the prior report.

- Mortality rates for thyroid and pediatric cancers in Windham County and the six towns could not be calculated as there were too few deaths (fewer than six) over the time period studied (10 years).

Table 6. Cancer Mortality Rates Near Vermont Yankee, in Vermont & U.S.

Age Adjusted Vermont and U.S. Cancer Mortality, All Sites, Males and Females per 100,000 population, 2009-2018.

	Rate	Lower CL	Upper CL	Avg. deaths per year
U.S.	161.7	161.6	161.9	587,052
Vermont	167.1	164.2	170.0	1,364
Windham County	170.0	159.7	180.9	108
Emergency Zone	167.3	152.2	183.9	49

Age Adjusted Vermont and U.S. Cancer Mortality, Thyroid, Males and Females per 100,000 population, 2009-2018.

	Rate	Lower CL	Upper CL	Avg. deaths per year
U.S.	0.5	0.5	0.5	1,837
Vermont	0.5	0.4	0.7	5
Windham County	--	--	--	<1
Emergency Zone	--	--	--	<1

Age Adjusted Vermont and U.S. Cancer Mortality, Leukemia, Males and Females per 100,000 population, 2009-2018.

	Rate	Lower CL	Upper CL	Avg. deaths per year
U.S.	6.6	6.5	6.6	23,214
Vermont	6.5	5.9	7.1	51
Windham County	8.4	6.3	11.2	5
Emergency Zone	6.6	3.9	10.7	2

Age Adjusted Vermont and U.S. Cancer Mortality, Pediatric Cancers (Ages 0-19), Males and Females per 100,000 population, 2009-2018.

	Rate	Lower CL	Upper CL	Avg. deaths per year
U.S.	2.3	2.3	2.3	1,897
Vermont	2.5	1.7	3.4	4
Windham County	--	--	--	<1
Emergency Zone	--	--	--	<1

-- Rates are only presented when the total number of deaths is greater than 5.
Data Sources: Vermont Vital Statistics System, Vermont Department of Health (1994-2019). SEER Program Mortality - Aggregated With State, Total U.S. (1990-2019).
Technical Notes: Emergency Zone towns include: Brattleboro, Dummerston, Guilford, Halifax, Marlboro, and Vernon. All rates are age adjusted to the 2000 U.S. standard population and rates are per 100,000 population.

Cancer Surveillance Methodology

The rates in this report are calculated at a 95 percent confidence level. This means, for example, given a reported thyroid cancer incidence rate of 14.0 per 100,000 for Vermont in 2009-2018, that we are 95 percent confident (not due to chance alone) that the true 2009 to 2018 Vermont thyroid cancer rate is in the range of 13.1 to 15.0 per 100,000. In Windham County, the thyroid cancer incidence rate is 9.2 cases per 100,000 people. Statistically speaking, this means we are 95 percent confident that the actual rate is between 6.6 cases and 12.5 cases per 100,000 people. Because the *ranges* for these rates do not overlap, we conclude that there is a meaningful statistical difference between the two rates.

In Table 6, it may appear that the leukemia mortality rates are different for Windham County compared to the towns included in the Emergency Planning Zone around Vermont Yankee, Vermont, or the U.S. However, the confidence intervals (ranges) for these rates overlap, and the cancer mortality rates are *not* statistically different. In Windham County, the death rate from leukemia, males and females, was 8.4 deaths per 100,000 people, while the death rate in the six towns near Vermont Yankee was 6.6 deaths per 100,000 people. The same conclusion is drawn for Vermont and the U.S. where the leukemia mortality rates are not significantly different.

Data Limitations

One limitation of these data is that the numbers of cancer cases and the number of cancer deaths in the six towns near Vermont Yankee are small. There are challenges associated with computing rates for small geographical areas, such as the Vermont Yankee Emergency Planning Zone, with an estimated population that is less than 20,000 people in 2018. When the rates are based on a small number of cases, it is almost impossible to distinguish random fluctuation from true changes in the underlying risk of disease. This is an issue in a state like Vermont, which has many communities with small populations. To improve rate stability, the cases have been combined for the 10-year period from 2009 through 2018. For more information about cancer and for resources to assist those living with cancer in Vermont: https://www.healthvermont.gov/wellness/cancer.

Environmental Surveillance Methods

The types of surveys and analyses performed by the Vermont Department of Health are described here in relationship to their role in protecting the public from ionizing radiation resulting from activities at Vermont Yankee.

Direct Gamma Radiation Monitoring

Direct gamma radiation in air is measured by the Health Department with thermoluminescent dosimeters (TLDs). Gamma radiation energy interacts with and changes the materials inside the TLDs. The more gamma energy, the more change occurs in the materials. The TLDs are then heated in a laboratory to reverse the physical changes. When this occurs, light is emitted, and the amount of light measured in the process is directly related to the amount of gamma radiation energy the TLD received in the environment. These instruments are calibrated to provide a measure of radiation exposure, reported in milliroentgen.

TLDs are placed in the environment to measure how much direct gamma radiation is being given off from Vermont Yankee and how much exists from natural or other human-made sources in background areas of Vermont. The Health Department's dosimeters are located on the site boundary (property line), in the area around the station and at background locations in Windham County. A total of 70 locations are monitored. Samples are tested quarterly by a National Voluntary Laboratory Accreditation Program vendor of dosimetry.

Vermont Yankee emits direct gamma radiation from components and nuclear reactor systems. Direct gamma radiation may also result when gases and particulates are released from the station's air stack, or from industrial activities, including spent fuel movement and building demolition. Measuring the amount emitted ensures that no member of the public is exposed to excessive increased levels of gamma radiation because of activities at Vermont Yankee.

Continuous Flow Air Sampling

Continuous air samplers are located in Vernon, Guilford, Dummerston, Wilmington and Brattleboro. An additional air sampler exists in Burlington. These air samplers have a mechanical pump that pulls air through two types of sample media, and an in-line flow

meter that tracks the volume of air pulled through the sample. The air samplers run continuously.

The samplers collect alpha-, beta- and gamma-emitting materials in air. Each sampler has two collection media to capture these radioactive materials. The first medium is a glass fiber filter. As outdoor air is pulled through the sampler, particulates containing alpha-, beta- and gamma-emitting materials are collected on the glass fiber filter.

Located behind the glass fiber filter is the second medium, a charcoal cartridge. The cartridge is treated with triethylenediamine (TEDA), a compound that attracts radioactive iodine vapors. As air passes through, radioactive iodine as well as other gamma-emitting gases and vapors are collected.

The filter is sent to the Health Department Laboratory where the alpha- and beta-emitting materials are counted on a gas flow proportional counter. The charcoal cartridge is tested by the Health Department Laboratory on a gamma spectrometer. Samples are collected and tested monthly. In addition, every three months the filters are grouped together and tested by gamma spectroscopy. These grouped samples are called quarterly composites.

Measurements of total alpha and beta radiation, gamma radiation and specifically iodine-131 ensure that activities at—and discharges from—Vermont Yankee are within limits and do not result in an increased radiation exposure to the public.

Water Monitoring

Water samples are collected at locations near Vermont Yankee. Off-site water samples include drinking water wells, a municipal water supply, and samples from the Connecticut River. These locations allow the Health Department to determine if radioactive materials have left the Vermont Yankee site and entered these waters. Water samples are also collected from four on-site locations.

Water samples can be tested for total alpha and beta radioactivity, and gamma-emitting materials. Alpha and beta radioactivity are tested with a gas proportional counter. Gamma-emitting materials are measured with a gamma spectrometer.

Water samples are also tested for tritium. Tritium is a radioactive form of hydrogen and is a weak beta-emitter. Tritium is created when water passes through the reactor core

and the hydrogen atoms in the water molecules and trace elements like boron absorb neutrons from the fission of the reactor fuel. Tritiated water can leave the power station in the same ways that non-radioactive water leaves the station: in the air, in groundwater, and through discharges into surface water. Tritium is also created by cosmic radiation in the atmosphere. The Health Department Laboratory measures tritium with a liquid scintillation counter.

Monitoring Food Chain Inputs

The Health Department also routinely tests milk, sediment and fish in the Vernon and Brattleboro area.

Milk Sampling

Milk samples are collected from two farms located near Vermont Yankee. Raw cows' milk samples are taken monthly and tested for gamma-emitting materials and specifically for iodine-131 (I-131).

Sediment Sampling

Sediments from the bottom of the Connecticut River are collected twice a year. They are tested for gamma-emitting materials.

Fish Sampling

Fish are collected at two sites in the Connecticut River by an environmental contractor and tested for gamma-emitting materials. One site is outside the Vermont Yankee discharge and the other site is about nine miles upstream from Vermont Yankee, where the Route 9 bridge crosses the Connecticut River. Fish are caught by a method known as electro-fishing. This involves putting a weak electric current in the water. Fish exposed to the current are temporarily stunned and float to the surface where they are collected. Sport and pan fish species are caught and tested, including large and small mouth bass, yellow perch and pumpkinseed.

Laboratory Testing and Measurements

Laboratory instruments at the Health Department that are used to test samples can measure very small amounts of radioactivity. Each instrument has a limit as to how low it can measure or identify radioactivity. This limit is determined by the Health Department radiochemists and reported as the *Lower Limit of Detection* (LLD). Lower Limits of Detection are calculated for each sample, based on the specific instrument and sample characteristics such as type (e.g. water, soil, milk, air), length of time the sample is tested, and the amount of the sample tested. The Health Department's Lower Limits of Detection for routine gamma spectroscopy tests are presented in Table 8.

All of the Health Department's instruments meet strict quality control checks. Data reported by the Health Department is thoroughly reviewed by both the radiochemists and data review personnel.

Units of Measurement

For most results in this report, radioactivity is reported in units of *picocuries per mass or volume* of sample. One picocurie is one trillionth of a curie. Curies and picocuries are units that measure the amount of radiation "activity" in the sample, or the rate at which a radioactive isotope decays.

Direct gamma exposure is measured and reported in milliroentgen. Milliroentgen is a unit of exposure to ionizing radiation. One milliroentgen is equal to one thousandth of a roentgen. An average dental x-ray provides a dose of around 100 milliroentgen.

Table 7. Units of Measurement

Type	Unit	Abbreviation	Measures (amount of)	Equivalent to
Radiation units	curie	Ci	activity of a radioactive material	1,000,000,000,000 picocuries (pCi)
	picocurie	pCi	activity of a radioactive material	0.000000000001 curie (Ci)
	roentgen	R	*exposure* to ionizing radiation	1000 milliroentgens (mR)
	milliroentgen	mR	*exposure* to ionizing radiation	0.001 roentgen (R)
	roentgen **e**quivalent **m**an	rem	*dose* equivalent of ionizing radiation	1000 millirem (mrem)
	milli**rem**	mrem	*dose* equivalent of ionizing radiation	0.001 roentgen equivalent man (rem)
Mass & Volume units	gram	g	mass	0.001 kilogram (kg)
	kilogram	kg	mass	1000 grams (g)
	liter	L	volume of liquid	1000 milliliters (mL)
	milliliter	mL	volume of liquid	0.001 liter (L)
	cubic meter	m^3	volume of air	1,000,000 centimeters^3 (cm^3)

Roentgens are units of radiation exposure in air. To determine the effect that the exposure would have on a person, roentgens are converted to **rem** ("**r**oentgen **e**quivalent **m**an"). A rem accounts for both the amount of radiation energy absorbed by a person and the potential biological effects of that energy in the human body. The Health Department's Radiological Health Rule provides limits for gamma radiation emitted from Vermont Yankee in units of measured exposure and relates it to a *biological dose*. As the Vermont Yankee site boundary TLDs measure exposure in milliroentgen, the corresponding limit in milliroentgen applies. Personal TLDs, like those worn by workers in nuclear power, medical or research facilities, are calibrated to provide a measure of *biological dose* for the wearer and are reported in millirem.

Uncertainty of Radiation Measurements

Measurements reported by a laboratory have an amount of *uncertainty* associated with them. Uncertainty, sometimes called error, results from variability in sampling and testing. The smaller the uncertainty associated with a measurement, the more accurate the number reported is likely to be. The uncertainty associated with a measurement is calculated by radiochemists and reported as a plus/minus (+/-) value. All of the measurements in this report are presented at the 95 percent confidence level. This means it is 95 percent certain (not due to chance alone) that the results are within the value and error range reported. Uncertainty can be minimized by increasing instrument efficiency, sample size and counting time.

Uncertainty of Thermoluminescent Dosimeter (TLD) Measurements
Dosimeter measurements over time are estimates and are also subject to uncertainty. The error for the sum of the quarterly results is the total propagated error at the 95 percent confidence level. The formula for the propagation of error is a root-mean-square formula:

$$[(\sigma_1^2) + (\sigma_2^2) + (\sigma_3^2) + (\sigma_4^2)]^{1/2}$$

Where (σ_1^2) is the uncertainty for quarter 1, (σ_2^2) is the uncertainty for quarter 2, (σ_3^2) is the uncertainty for quarter 3 and (σ_4^2) is the uncertainty for quarter 4. The Health Department regulates the direct gamma radiation exposure on the reported measurement.

Table 8. Health Department Gamma Spectroscopy Calculated Lower Limits of Detection

Radioactive element	Calculated Lower Limit of Detection: fish, water, vegetation & milk (pCi/L or pCi/kg)	Calculated Lower Limit of Detection: soil, sediment (pCi/kg)
Antimony-124	3	24
Antimony-126	3	23
Barium-133	4	30
Beryllium-7	24	183
Cadmium-109	48	349
Cerium-139	3	18
Cerium-141	4	29
Cerium-144	16	115
Cesium-134	4	25
Cesium-136	3	23
Cesium-137	4	24
Chromium-51	24	182
Cobalt-57	2	14
Cobalt-58	3	23
Cobalt-60	3	23
Iodine-131	3	23
Manganese-54	4	24
Mercury-203	3	22
Potassium-40	48	367
Ruthenium-103	3	22
Ruthenium-106	29	220
Silver-110m	3	23
Strontium-85	4	26
Tin-113	4	31
Yttrium-88	4	26
Zinc-65	6	46

Direct Gamma Radiation Results

Thermoluminescent dosimeters (TLDs) are located along the Vermont Yankee site boundary (property line) and in public areas in Vernon and other Windham County towns. Thirteen TLDs placed at the Vermont Yankee site boundary are evaluated for compliance with the regulations detailed in the Health Department's Radiological Health Rule. The Health Department limits the measured exposure at the site boundary to no more than 20 milliroentgen per year above background radiation, and no more than 10 milliroentgen per calendar quarter above background radiation.

Site boundary TLDs:

- VY North Fence
- VY North Fence #2
- VY SW Fence
- VY SW Fence #2
- VY Parking Lot A
- VDH T07A
- Governor Hunt Road # 39
- VDH T07B
- VDH DR42
- VDH DR48
- VDH DR51A
- VDH DR52A
- VDH DR53A

Five additional TLDs—VDH DR43, DR44, DR45, DR46 and DR47—are located on the Connecticut River site boundary and are subject to the U.S. Nuclear Regulatory Commission limit of 100 millirem per year.

Additional Health Department TLDs are located in other areas of Vernon, and in Guilford, Brattleboro, Dummerston, and Putney. These provide the background measurements of direct gamma radiation from both natural and human-made sources unrelated to the operation of Vermont Yankee. All TLDs are collected and tested every three months (quarterly).

Comparison to Background Levels

To determine the amount of direct gamma radiation exposure attributed to emissions from Vermont Yankee, the background gamma radiation is subtracted from the site boundary (property line) measurements. Background gamma radiation unrelated to

Vermont Yankee may be from naturally-occurring sources, other industrial applications, and global contaminants remaining from above-ground weapons testing during the 1940s, 50s and 60s and global nuclear incidents like Chernobyl and Fukushima.

To measure background gamma radiation an additional 32 TLDs are placed in locations beyond the immediate area of Vermont Yankee's activities. These locations are as far west as West Brattleboro, as far north as Putney, and as far south as the Massachusetts state line in Guilford and Vernon. Each quarter's average exposure to these 32 TLDs is calculated and used to estimate environmental background radiation. Background gamma radiation levels for the four quarters of 2019 are presented in Table 9.

The exposures reported in Tables 10 and 11 show the total (gross) dosimeter measurement and the net value. The net value is calculated by subtracting the background radiation measurement from the total radiation measurement. For regulatory purposes, the net values are compared to the quarterly and annual limits.

Table 9. 2020 Average Direct Gamma Background Radiation Results

Calendar Quarter	Average Background Exposure Measurements (milliroentgen)
January 1 to June 30	13.3 ± 2.3
July 1 to September 30	14.3 ± 2.6
October 1 to December 31	14.3 ± 2.1
Total for Calendar Year 2020	**41.9 ± 4.0**
Calendar Year 2019	54.3 ± 4.9
Calendar Year 2018	53.3 ± 4.6
Calendar Year 2017	58.2 ± 4.9
Calendar Year 2016	57.3 ± 7.4
Calendar Year 2015	55.7 ± 8.4
Calendar Year 2014	57.7 ± 4.9
Calendar Year 2013	56.8 ± 4.5
Calendar Year 2012	57.0 ± 4.4
Calendar Year 2011	56.1 ± 7.3
Calendar Year 2010	59.2 ± 7.1
Calendar Year 2009	57.9 ± 4.8
Calendar Year 2008	56.4 ± 4.6
Calendar Year 2007	56.2 ± 5.2

2020 Direct Gamma Radiation Exposure Results

The following tables show the results of the Health Department's TLD measurements of direct gamma radiation. Table 10 contains the results for the Vermont Yankee site boundary, and the dosimeters in the immediate area around the power station. Table 11 contains the results for the dosimeters placed in 30 locations beyond the immediate area of Vermont Yankee.

In 2020:

- 199 TLDs were tested for direct gamma radiation.
    - 114 of those provided background exposure measurements
    - 85 of those provided exposure measurements at the site boundary and in the immediate area of Vermont Yankee

Dosimeter locations on the site boundary bordered by land and used for direct gamma radiation compliance measurements reflect Vermont Yankee property purchases on or before August 1, 2008. The site boundary dosimeter location data are bolded in Table 10.

For 2020, the net site boundary results used for verifying compliance ranged from 0.0 to 6.4 milliroentgen.

Map 3 shows the locations of the site boundary and station area dosimeters. Maps 4 and 5 show the locations of the background dosimeters. The ID numbers on the maps can be matched to the locations in Tables 10 and 11.

_____

For 2020, the quarterly limit of 10 milliroentgen and the annual limit of 20 milliroentgen were not exceeded.

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Map 3

VT Yankee Nuclear Power Station
Site Boundary and Plant Area Dosimeter Locations

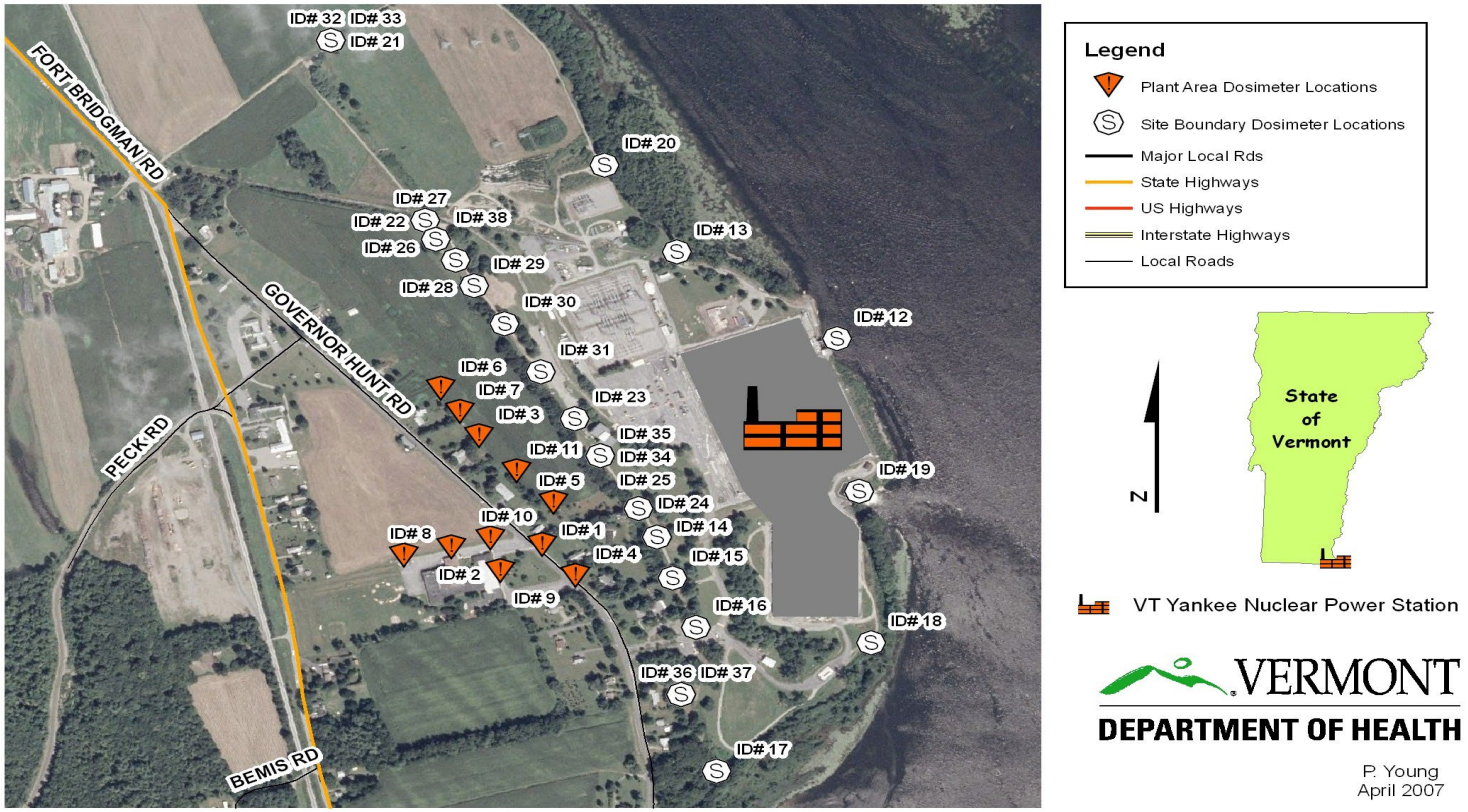


Table 10. 2020 Thermoluminescent Dosimeter Exposure Measurements and Net Gamma Radiation: Station Area & Site Boundary Locations

2020 **Site Boundary and Station Area** Dosimeter Exposure (milliroentgen)

Location	Map ID #	Half1 Gross	1SD Error	Avg Bkgrd	Half1 Net	Net H1 >=0	2SD Error	Qtr3 Gross	1SD Error	Avg Bkgrd	Qtr3 Net	Net Q3 >=0	2SD Error	Qtr4 Gross	1SD Error	Avg Bkgrd	Qtr4 Net	Net Q4 >=0	2SD Error	Annual Net	2SD Error
Gov Hunt Road #39	**1**	**13.87**	**0.59**	**13.3**	**0.6**	**0.6**	**1.2**	**14.97**	**0.67**	**14.3**	**0.6**	**0.6**	**1.3**	**14.45**	**0.84**	**14.3**	**0.2**	**0.2**	**1.6**	**1.4**	**2.4**
VDH DR06	2	13.63	0.75	**13.3**	0.4	0.4	1.5	14.75	1.09	**14.3**	0.4	0.4	2.1	14.11	0.75	**14.3**	-0.2	0.0	1.5	0.8	3.0
VDH DR51A	**3**	**13.88**	**0.68**	**13.3**	**0.6**	**0.6**	**1.3**	**15.17**	**0.91**	**14.3**	**0.8**	**0.8**	**1.8**	**14.93**	**1.11**	**14.3**	**0.7**	**0.7**	**2.2**	**2.1**	**3.1**
VDH DR52A	**4**	**14.37**	**0.49**	**13.3**	**1.1**	**1.1**	**1.0**	**15.12**	**0.78**	**14.3**	**0.8**	**0.8**	**1.5**	**15.68**	**0.83**	**14.3**	**1.4**	**1.4**	**1.6**	**3.3**	**2.4**
VDH DR53A	**5**	**14.27**	**0.53**	**13.3**	**1.0**	**1.0**	**1.0**	**15.72**	**1.06**	**14.3**	**1.4**	**1.4**	**2.1**	**15.55**	**0.65**	**14.3**	**1.3**	**1.3**	**1.3**	**3.7**	**2.6**
VDH T07A	**6**	**13.50**	**0.68**	**13.3**	**0.2**	**0.2**	**1.3**	**15.58**	**0.70**	**14.3**	**1.2**	**1.2**	**1.4**	**14.80**	**0.96**	**14.3**	**0.5**	**0.5**	**1.9**	**2.0**	**2.7**
VDH T07B	**7**	**13.34**	**0.44**	**13.3**	**0.1**	**0.1**	**0.9**	**15.82**	**0.87**	**14.3**	**1.5**	**1.5**	**1.7**	**14.81**	**0.82**	**14.3**	**0.5**	**0.5**	**1.6**	**2.1**	**2.5**
Vernon School (air sampler)	8	13.55	0.53	**13.3**	0.3	0.3	1.0	14.89	1.12	**14.3**	0.5	0.5	2.2	14.72	1.23	**14.3**	0.4	0.4	2.4	1.3	3.4
Vernon School Nurse	9	15.84	0.59	**13.3**	2.6	2.6	1.2	16.42	0.75	**14.3**	2.1	2.1	1.5	16.33	1.00	**14.3**	2.1	2.1	2.0	6.7	2.7
Vernon School Pole	10	13.78	0.68	**13.3**	0.5	0.5	1.3	14.51	0.83	**14.3**	0.2	0.2	1.6	13.99	0.86	**14.3**	-0.3	0.0	1.7	0.7	2.7
VY Parking Lot A	**11**	**15.83**	**0.61**	**13.3**	**2.6**	**2.6**	**1.2**	**16.77**	**0.86**	**14.3**	**2.4**	**2.4**	**1.7**	**15.71**	**0.71**	**14.3**	**1.4**	**1.4**	**1.4**	**6.4**	**2.5**
VDH DR45	12	24.16	1.08	**13.3**	10.9	10.9	2.1	21.24	1.01	**14.3**	6.9	6.9	2.0	20.96	1.15	**14.3**	6.7	6.7	2.3	24.5	3.7
VDH DR46	13	13.79	0.75	**13.3**	0.5	0.5	1.5	14.80	0.81	**14.3**	0.5	0.5	1.6	14.33	0.58	**14.3**	0.1	0.1	1.1	1.0	2.4
VDH DR08	15	14.10	0.48	**13.3**	0.8	0.8	0.9	14.83	0.72	**14.3**	0.5	0.5	1.4	14.24	0.63	**14.3**	0.0	0.0	1.2	1.3	2.1
VDH DR41	16	13.77	0.51	**13.3**	0.5	0.5	1.0	14.97	0.67	**14.3**	0.6	0.6	1.3	14.20	0.71	**14.3**	-0.1	0.0	1.4	1.1	2.2
VDH DR42	**17**	**13.65**	**0.57**	**13.3**	**0.4**	**0.4**	**1.1**	**15.55**	**0.80**	**14.3**	**1.2**	**1.2**	**1.6**	**14.61**	**0.76**	**14.3**	**0.3**	**0.3**	**1.5**	**1.9**	**2.4**
VDH DR43	18	15.70	0.66	**13.3**	2.4	2.4	1.3	17.20	1.00	**14.3**	2.9	2.9	2.0	16.65	0.83	**14.3**	2.4	2.4	1.6	7.7	2.9
VDH DR44	19	15.37	0.71	**13.3**	2.1	2.1	1.4	13.68	0.77	**14.3**	-0.7	0.0	1.5	13.81	0.93	**14.3**	-0.5	0.0	1.8	2.1	2.7
VDH DR47	20	13.95	0.70	**13.3**	0.7	0.7	1.4	15.06	0.73	**14.3**	0.7	0.7	1.4	14.93	1.19	**14.3**	0.7	0.7	2.3	2.1	3.1
VDH DR48	**21**	**11.15**	**0.54**	**13.3**	**-2.1**	**0.0**	**1.1**	**12.28**	**0.81**	**14.3**	**-2.1**	**0.0**	**1.6**	**12.67**	**0.57**	**14.3**	**-1.6**	**0.0**	**1.1**	**0.0**	**2.2**
VDH T01	22	13.54	0.74	**13.3**	0.3	0.3	1.5	14.69	0.84	**14.3**	0.3	0.3	1.6	14.47	0.84	**14.3**	0.2	0.2	1.6	0.8	2.7
VDH DR49	22	12.75	0.62	**13.3**	-0.5	0.0	1.2	13.79	0.69	**14.3**	-0.6	0.0	1.4	13.68	0.85	**14.3**	-0.6	0.0	1.7	0.0	2.5
VDH DR51	23	14.22	0.69	**13.3**	1.0	1.0	1.4	15.86	0.80	**14.3**	1.5	1.5	1.6	15.56	1.22	**14.3**	1.3	1.3	2.4	3.8	3.2
VDH DR52	24	14.52	0.84	**13.3**	1.3	1.3	1.6	16.01	0.91	**14.3**	1.7	1.7	1.8	15.23	0.78	**14.3**	1.0	1.0	1.5	3.9	2.9
VDH DR53	25	15.34	0.81	**13.3**	2.1	2.1	1.6	16.08	0.69	**14.3**	1.7	1.7	1.4	16.18	0.77	**14.3**	1.9	1.9	1.5	5.7	2.6
VDH T03	26	13.78	0.91	**13.3**	0.5	0.5	1.8	14.90	0.90	**14.3**	0.6	0.6	1.8	14.42	0.85	**14.3**	0.1	0.1	1.7	1.2	3.0

Site boundary dosimeter measurements are bolded.

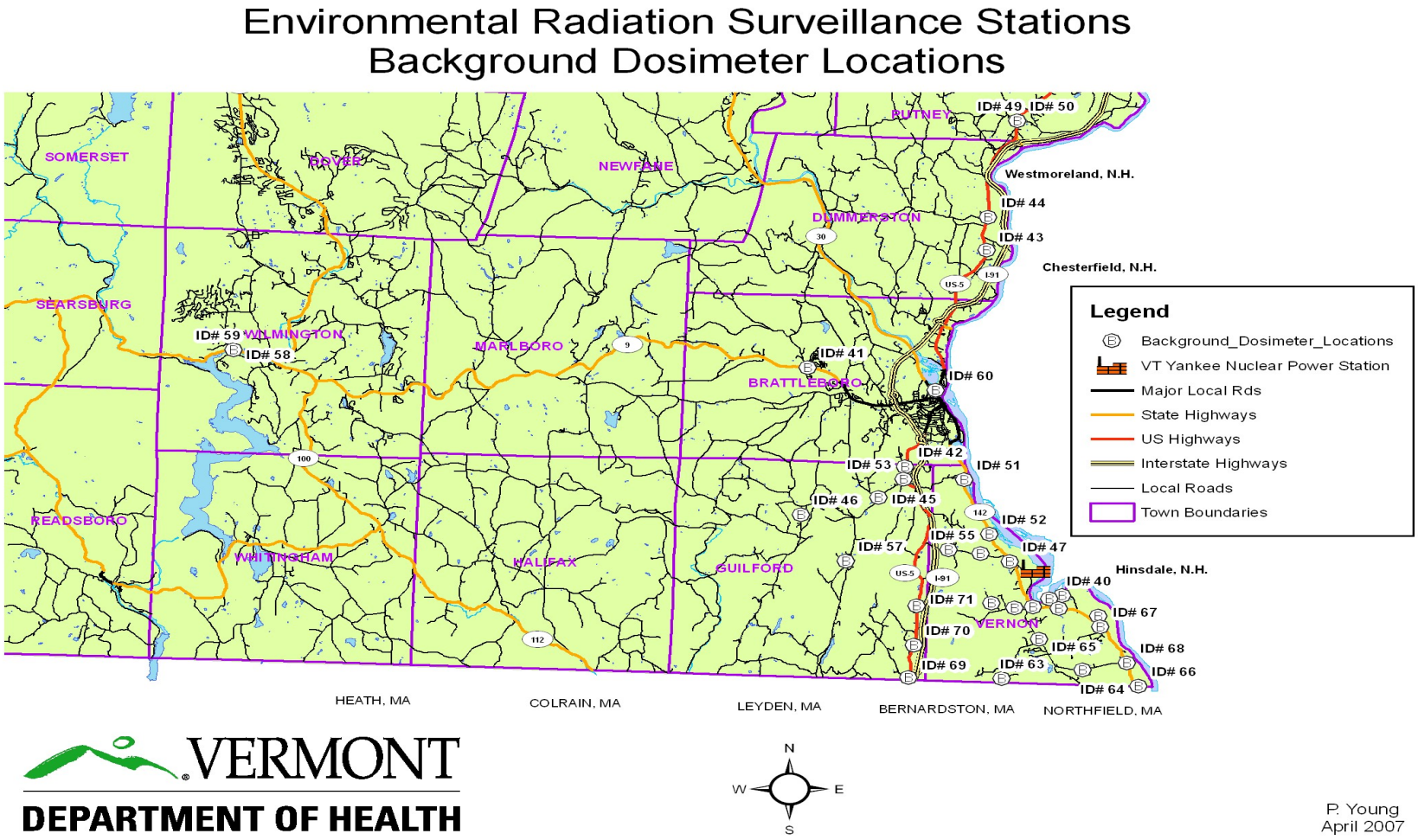
Table 10 (continued). 2020 Thermoluminescent Dosimeter Exposure Measurements and Net Gamma Radiation: Station Area & Site Boundary Locations

2020 **Site Boundary and Station Area** Dosimeter Exposure (milliroentgen)

Location	Map ID #	Half1 Gross	1SD Error	Avg Bkgrd	Half1 Net	Net H1 >=0	2SD Error	Qrtr3 Gross	1SD Error	Avg Bkgrd	Qtr3 Net	Net Q3 >=0	2SD Error	Qrtr4 Gross	1SD Error	Avg Bkgrd	Qtr4 Net	Net Q4 >=0	2SD Error	Annual Net	2SD Error
VDH T05	28	13.89	0.84	**13.3**	0.6	0.6	1.6	14.55	0.79	**14.3**	0.2	0.2	1.5	14.86	0.70	**14.3**	0.6	0.6	1.4	1.4	2.6
VDH T04	29	12.30	0.40	**13.3**	-1.0	0.0	0.8	14.21	1.05	**14.3**	-0.1	0.0	2.1	13.81	0.81	**14.3**	-0.5	0.0	1.6	0.0	2.7
VDH T06	30	14.10	0.75	**13.3**	0.8	0.8	1.5	15.61	1.07	**14.3**	1.3	1.3	2.1	14.37	0.69	**14.3**	0.1	0.1	1.4	2.2	2.9
VDH DR07	31	14.48	0.61	**13.3**	1.2	1.2	1.2	15.44	0.87	**14.3**	1.1	1.1	1.7	14.85	0.71	**14.3**	0.6	0.6	1.4	2.9	2.5
VY North Fence	**32**	**10.92**	**0.60**	**13.3**	**-2.3**	**0.0**	**1.2**	**12.25**	**0.77**	**14.3**	**-2.1**	**0.0**	**1.5**	**12.48**	**0.65**	**14.3**	**-1.8**	**0.0**	**1.3**	**0.0**	**2.3**
VY North Fence #2	**33**	**11.41**	**0.53**	**13.3**	**-1.9**	**0.0**	**1.0**	**12.45**	**0.77**	**14.3**	**-1.9**	**0.0**	**1.5**	**12.55**	**0.74**	**14.3**	**-1.7**	**0.0**	**1.5**	**0.0**	**2.3**
VY Parking Lot #2	34	14.28	0.59	**13.3**	1.0	1.0	1.2	15.79	1.19	**14.3**	1.4	1.4	2.3	14.83	0.76	**14.3**	0.6	0.6	1.5	3.0	3.0
VY Parking Lot, ID	35	14.61	0.64	**13.3**	1.3	1.3	1.3	15.61	0.69	**14.3**	1.3	1.3	1.4	14.29	0.71	**14.3**	0.0	0.0	1.4	2.6	2.3
VY SW Fence	**36**	**12.18**	**0.83**	**13.3**	**-1.1**	**0.0**	**1.6**	**13.52**	**0.73**	**14.3**	**-0.8**	**0.0**	**1.4**	**14.98**	**1.05**	**14.3**	**0.7**	**0.7**	**2.1**	**0.7**	**3.0**
VY SW Fence #2	**37**	**12.59**	**0.89**	**13.3**	**-0.7**	**0.0**	**1.7**	**14.21**	**0.58**	**14.3**	**-0.1**	**0.0**	**1.1**	**14.95**	**0.82**	**14.3**	**0.7**	**0.7**	**1.6**	**0.7**	**2.6**
VDH T02	38	12.84	0.62	**13.3**	-0.4	0.0	1.2	14.14	0.97	**14.3**	-0.2	0.0	1.9	13.56	0.75	**14.3**	-0.7	0.0	1.5	0.0	2.7
Meteorology Tower	n/a	13.00	0.72	**13.3**	-0.3	0.0	1.4	14.70	0.73	**14.3**	0.4	0.4	1.4	14.12	0.62	**14.3**	-0.2	0.0	1.2	0.4	2.3

Site boundary dosimeter measurements are bolded.

Map 4


Environmental Radiation Surveillance Stations
Background Dosimeter Locations
SOMERSET
ROYER
NEWFANE
PUTNEY
DUMMERSTON
SEARSBURG
WILMINGTON
MARLBORO
BRATTLEBORO
READSBORO
WHITINGHAM
HALIFAX
GUILFORD
VERNON
Westmoreland, N.H.
Chesterfield, N.H.
Hinsdale, N.H.
ID# 49
ID# 50
ID# 44
ID# 43
ID# 59
ID# 58
ID# 41
ID# 60
ID# 53
ID# 42
ID# 51
ID# 46
ID# 45
ID# 52
ID# 57
ID# 55
ID# 47
ID# 40
ID# 71
ID# 67
ID# 70
ID# 65
ID# 68
ID# 69
ID# 63
ID# 66
ID# 64
HEATH, MA
COLRAIN, MA
LEYDEN, MA
BERNARDSTON, MA
NORTHFIELD, MA
Legend
Background_Dosimeter_Locations
VT Yankee Nuclear Power Station
Major Local Rds
State Highways
US Highways
Interstate Highways
Local Roads
Town Boundaries
VERMONT
DEPARTMENT OF HEALTH
N
W
E
S
P. Young
April 2007

Map 5

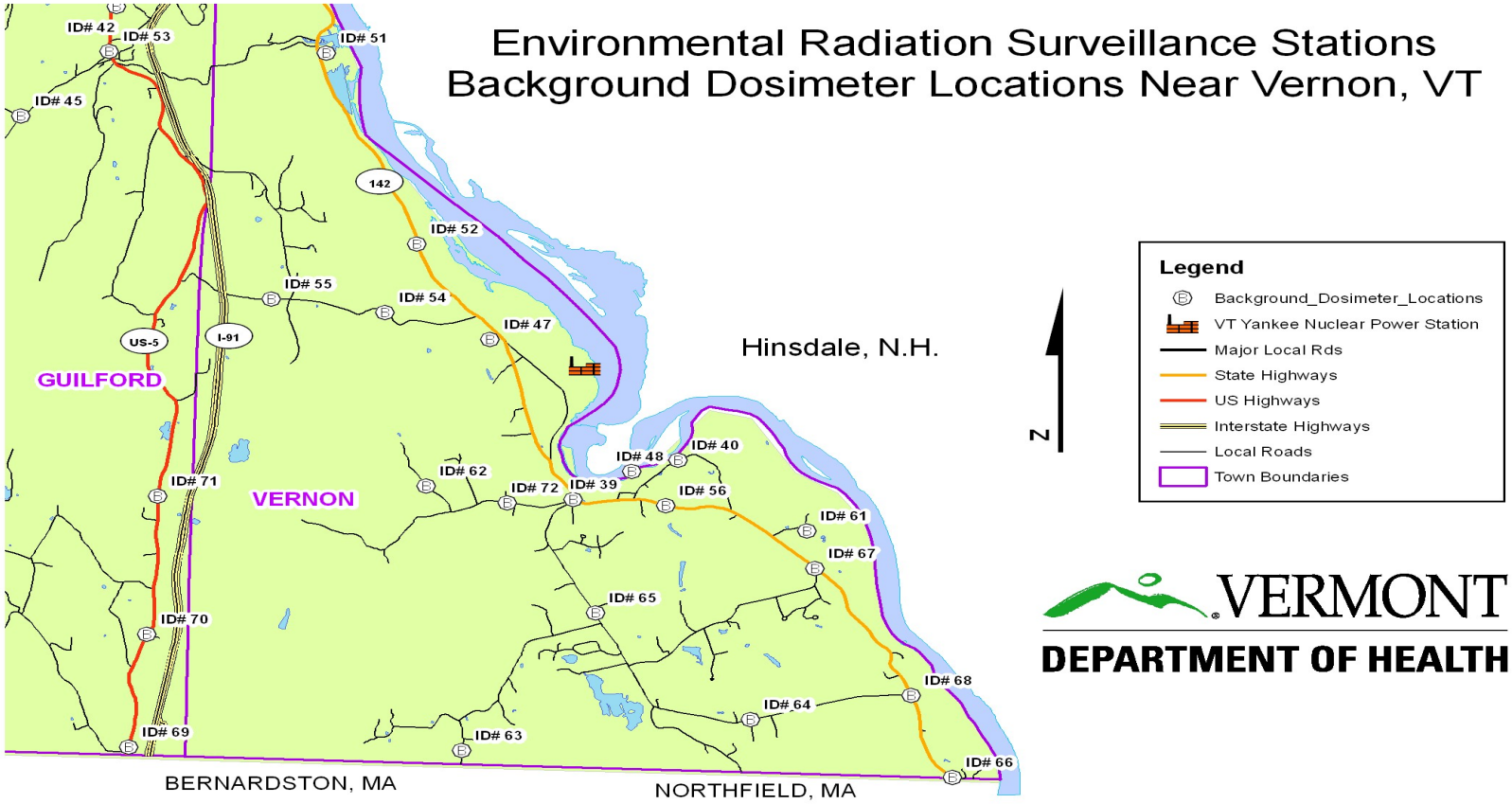

Environmental Radiation Surveillance Stations
Background Dosimeter Locations Near Vernon, VT
ID# 42
ID# 53
ID# 51
ID# 45
142
ID# 52
ID# 55
ID# 54
ID# 47
US-5
I-91
GUILFORD
Hinsdale, N.H.
ID# 48
ID# 40
ID# 62
ID# 71
VERNON
ID# 72
ID# 39
ID# 56
ID# 61
ID# 67
ID# 65
ID# 70
ID# 68
ID# 64
ID# 69
ID# 63
ID# 66
BERNARDSTON, MA
NORTHFIELD, MA
N
Legend
Background_Dosimeter_Locations
VT Yankee Nuclear Power Station
Major Local Rds
State Highways
US Highways
Interstate Highways
Local Roads
Town Boundaries
VERMONT
DEPARTMENT OF HEALTH
P. Young
April 2007

Table 11. 2020 Thermoluminescent Dosimeter Exposure Measurements and Net Gamma Radiation: Background Locations

2020 **Background** Dosimeter Exposure (milliroentgen)

Location	Map ID #	Half1 Gross	1SD Error	Avg Bkgrd	Half1 Net	Net >=0	2SD Error	Qrtr3 Gross	1SD Error	Avg Bkgrd	Qtr3 Net	Net >=0	2SD Error	Qrtr4 Gross	1SD Error	Avg Bkgrd	Qtr4 Net	Net >=0	2SD Error	Annual Net	2SD Error
142/Pond Road (N)	39	13.02	0.61	**13.3**	-0.2	0.0	1.2	13.39	0.59	**14.3**	-1.0	0.0	1.2	13.73	0.72	**14.3**	-0.5	0.0	1.4	0.0	2.2
A&M Auto/Smead Rd	40			**13.3**	-13.3	0.0	0.0	16.00	1.03	**14.3**	1.7	1.7	2.0	13.85	0.76	**14.3**	-0.4	0.0	1.5	1.7	2.5
West Brattleboro State Police	41	11.78	0.59	**13.3**	-1.5	0.0	1.2	12.69	0.91	**14.3**	-1.7	0.0	1.8	12.67	0.80	**14.3**	-1.6	0.0	1.6	0.0	2.6
D&E Tree, Rt 5, Guilford	42	14.82	0.65	**13.3**	1.6	1.6	1.3	16.26	0.77	**14.3**	1.9	1.9	1.5	16.35	0.99	**14.3**	2.1	2.1	1.9	5.5	2.8
Dummerston AOT	43	13.33	0.68	**13.3**	0.1	0.1	1.3	13.96	0.78	**14.3**	-0.4	0.0	1.5	14.68	0.87	**14.3**	0.4	0.4	1.7	0.5	2.6
Dummerston School	44	13.78	0.62	**13.3**	0.5	0.5	1.2	14.09	0.58	**14.3**	-0.3	0.0	1.1	14.26	0.77	**14.3**	0.0	0.0	1.5	0.5	2.2
Guilford Center Rd/Tater Rd	45	12.90	0.79	**13.3**	-0.4	0.0	1.5	13.95	0.99	**14.3**	-0.4	0.0	1.9	14.06	0.75	**14.3**	-0.2	0.0	1.5	0.0	2.9
Guilford Town Garage	46	13.99	0.63	**13.3**	0.7	0.7	1.2	14.63	0.76	**14.3**	0.3	0.3	1.5	14.91	0.78	**14.3**	0.6	0.6	1.5	1.6	2.5
Miller Farm	47	11.31	0.52	**13.3**	-2.0	0.0	1.0	11.79	0.52	**14.3**	-2.6	0.0	1.0	12.66	0.97	**14.3**	-1.6	0.0	1.9	0.0	2.4
Power Line River Crossing	48	13.33	0.53	**13.3**	0.1	0.1	1.0	14.71	0.87	**14.3**	0.4	0.4	1.7	14.21	0.53	**14.3**	-0.1	0.0	1.0	0.4	2.3
Putney Pole	49	14.27	0.62	**13.3**	1.0	1.0	1.2	15.10	0.74	**14.3**	0.8	0.8	1.5	15.02	0.95	**14.3**	0.7	0.7	1.9	2.5	2.7
Putney Town Clerk	50	14.72	0.73	**13.3**	1.5	1.5	1.4	15.03	0.79	**14.3**	0.7	0.7	1.5			**14.3**	-14.3	0.0	0.0	2.1	2.1
Rt 5/Guilford Ctr Rd	53	12.45	0.53	**13.3**	-0.8	0.0	1.0	13.50	0.78	**14.3**	-0.8	0.0	1.5	13.37	0.51	**14.3**	-0.9	0.0	1.0	0.0	2.1
Tyler Hill Road	54	13.51	0.64	**13.3**	0.2	0.2	1.3	14.81	0.98	**14.3**	0.5	0.5	1.9	15.31	0.70	**14.3**	1.0	1.0	1.4	1.7	2.7
Tyler Rd/Franklin Rd	55	13.90	0.58	**13.3**	0.6	0.6	1.1	15.11	0.77	**14.3**	0.8	0.8	1.5	15.32	0.62	**14.3**	1.0	1.0	1.2	2.4	2.2
Vernon Fire Station	56	12.39	0.58	**13.3**	-0.9	0.0	1.1	13.17	0.79	**14.3**	-1.2	0.0	1.5	13.40	0.66	**14.3**	-0.9	0.0	1.3	0.0	2.3
Weatherhead Hollow Rd	57	11.39	0.75	**13.3**	-1.9	0.0	1.5	12.54	0.71	**14.3**	-1.8	0.0	1.4	13.83	1.37	**14.3**	-0.4	0.0	2.7	0.0	3.4
Windham County Court	60	15.37	1.06	**13.3**	2.1	2.1	2.1	16.29	0.77	**14.3**	1.9	1.9	1.5	16.09	1.08	**14.3**	1.8	1.8	2.1	5.9	3.3
Blodgett Farm	61	13.35	0.48	**13.3**	0.1	0.1	0.9			**14.3**	-14.3	0.0	0.0			**14.3**	-14.3	0.0	0.0	0.1	0.9
Fairman Road	62	11.99	0.59	**13.3**	-1.3	0.0	1.2	13.91	1.87	**14.3**	-0.4	0.0	3.7	13.64	0.66	**14.3**	-0.6	0.0	1.3	0.0	4.1
Huckle Hill Rd VT	63	15.18	0.65	**13.3**	1.9	1.9	1.3	17.17	0.81	**14.3**	2.8	2.8	1.6	16.40	0.85	**14.3**	2.1	2.1	1.7	6.9	2.6

Table 11. 2020 Thermoluminescent Dosimeter Exposure Measurements and Net Gamma Radiation: Background Locations (continued)

2020 **Background** Dosimeter Exposure (milliroentgen)

Location	Map ID #	Half1 Gross	1SD Error	Avg Bkgrd	Half1 Net	Net >=0	2SD Error	Qrtr3 Gross	1SD Error	Avg Bkgrd	Qtr3 Net	Net >=0	2SD Error	Qrtr4 Gross	1SD Error	Avg Bkgrd	Qtr4 Net	Net >=0	2SD Error	Annual Net	2SD Error
Pond Rd & Houghton	64	12.53	0.88	**13.3**	-0.7	0.0	1.7	14.40	1.11	**14.3**	0.1	0.1	2.2	13.44	0.83	**14.3**	-0.8	0.0	1.6	0.1	3.2
Pond Rd/Vernon Rec	65	11.60	0.55	**13.3**	-1.7	0.0	1.1	12.61	1.07	**14.3**	-1.7	0.0	2.1	12.42	0.51	**14.3**	-1.9	0.0	1.0	0.0	2.6
Rt 142 & Depot St	66	13.31	0.62	**13.3**	0.0	0.0	1.2	14.31	0.66	**14.3**	0.0	0.0	1.3	14.67	0.61	**14.3**	0.4	0.4	1.2	0.4	2.1
Rt 142 & Newton Rd	67	11.80	0.61	**13.3**	-1.5	0.0	1.2	12.90	0.65	**14.3**	-1.4	0.0	1.3	13.06	0.69	**14.3**	-1.2	0.0	1.4	0.0	2.2
Rt 142 & Pond Rd (S)	68	14.56	0.57	**13.3**	1.3	1.3	1.1			**14.3**	-14.3	0.0	0.0	14.65	0.76	**14.3**	0.4	0.4	1.5	1.7	1.9
Route 5/Wolosko Rd	69	15.12	0.52	**13.3**	1.9	1.9	1.0	16.32	1.06	**14.3**	2.0	2.0	2.1	15.61	1.04	**14.3**	1.3	1.3	2.0	5.2	3.1
Rt 5/Andrews Cmtry	70	13.65	0.76	**13.3**	0.4	0.4	1.5	14.52	0.83	**14.3**	0.2	0.2	1.6	14.45	0.63	**14.3**	0.2	0.2	1.2	0.7	2.5
Rt 5/Tkaczyk Frm Rd	71	12.76	0.64	**13.3**	-0.5	0.0	1.3	14.86	0.95	**14.3**	0.5	0.5	1.9	14.60	0.71	**14.3**	0.3	0.3	1.4	0.8	2.6
West Rd/Edgewood	72	12.71	0.49	**13.3**	-0.6	0.0	1.0	13.58	0.83	**14.3**	-0.8	0.0	1.6	13.85	0.76	**14.3**	-0.4	0.0	1.5	0.0	2.4
Average Background (Avg)		**13.3**						**14.3**						**14.3**						**41.9**	

Continuous Flow Air Sampling Results

The Health Department uses continuously operating air samplers to monitor the air near Vermont Yankee. They are located in Vernon, Guilford, Brattleboro, Dummerston and Wilmington. The locations of the air samplers are shown on Map 6. In 2011, to provide comparison, another air sampler was sited in Burlington at the Health Department.

Air filters are tested monthly for alpha- and beta-emitting materials and are then grouped quarterly to test for gamma-emitting materials. Air cartridges are tested monthly for iodine-131 (I-131) and other gamma-emitting materials at the Health Department Laboratory. Data associated with the air filters are provided in Appendix A.

For 2020:

- 44 air cartridges were tested for iodine-131 and gamma-emitting materials.
- 44 air filters were tested for total alpha and beta radioactivity.
- 2 sets of air filters were grouped and tested for gamma-emitting materials.

Air Filter Total Alpha and Beta Radioactivity Results

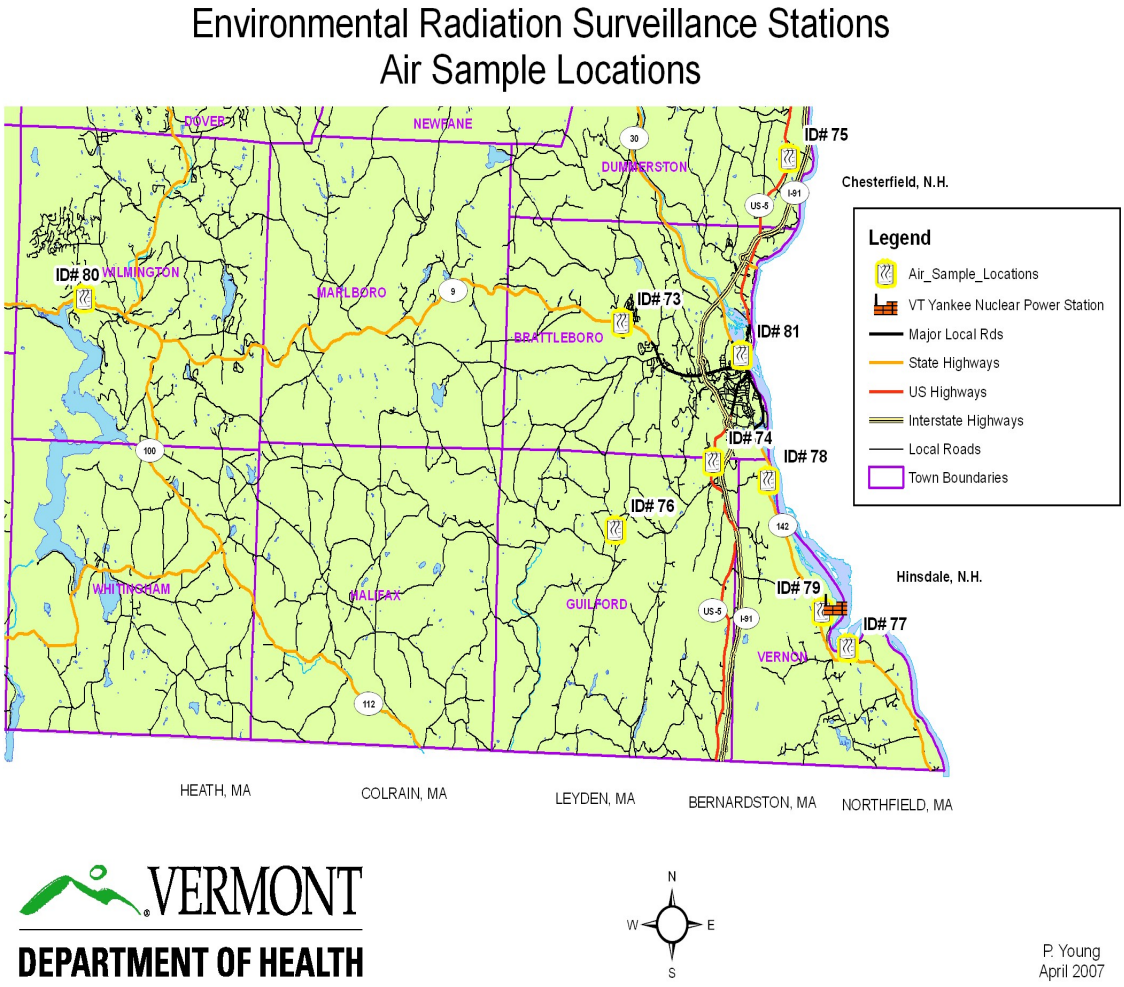
In 2020, the average result for total alpha radioactivity was 0.001580 picocuries per cubic meter (pCi/m^3). The 2020 average result for total beta radioactivity was 0.01805 pCi/m^3. The 2020 total alpha and beta radioactivity air filter results are presented in Appendix A.

Figures 2 and 3 show the average total alpha and beta radioactivity for the sample locations compared to the 2016, 2017, 2018 and 2019 results. Results that were uncertain because of noted collection problems were removed prior to calculating the average result. This is a conservative approach and results in an increased average.

Air Cartridge and Air Filter Gamma-Emitting Materials Results

No iodine-131 was detected in any air cartridge in 2020. Only naturally-occurring gamma-emitting materials were detected, specifically beryllium-7.

Map 6



Sample Location	Map ID	Sample Location	Map ID
D & E Tree	74	Vermont State Police-Brattleboro	73
Dummerston State Garage	75	Vernon Elementary School	79
Guilford Town Garage	76	Wilmington State Highway Garage	80
Power Line River Crossing	77	Windham County Courthouse	81
Renaud Brothers	78	108 Cherry St. Burlington	n/a

Figure 2. 2016-2020 Average Alpha Radioactivity in Air

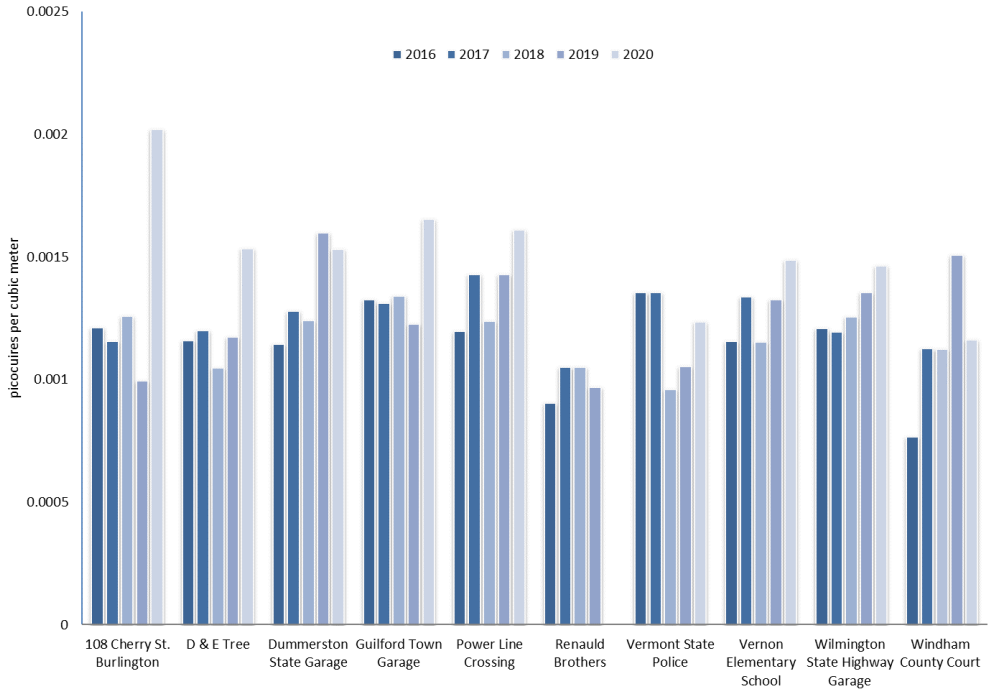


Figure 3. 2016-2020 Average Beta Radioactivity in Air

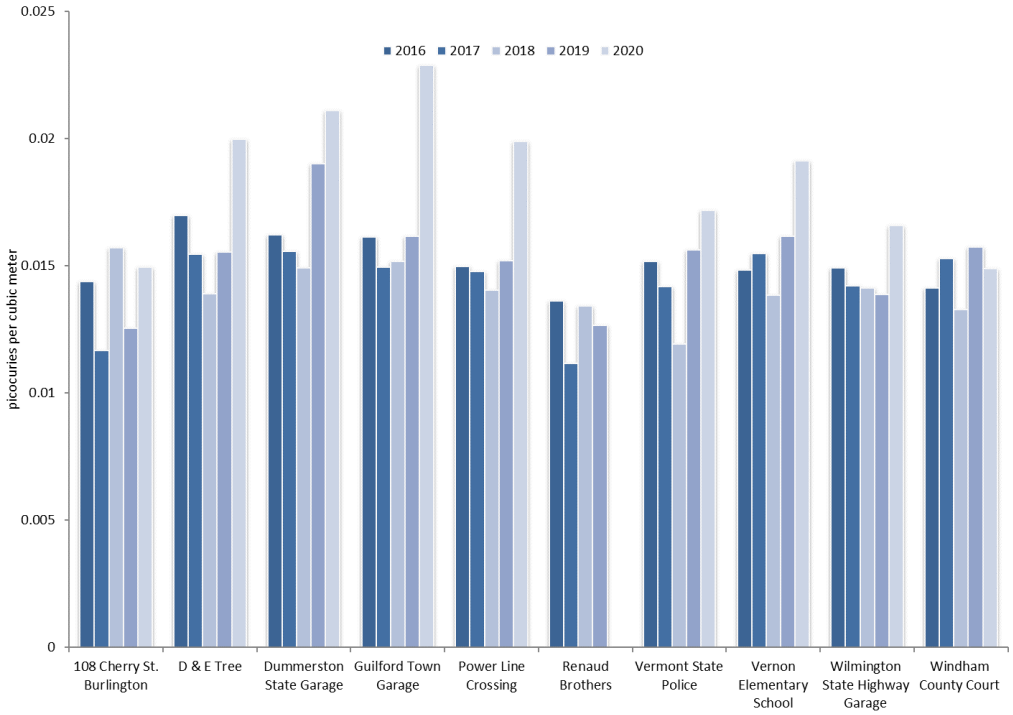


Table 12. 2020 Air Filter Composite Results (Gamma Spectroscopy)

Quarter	Last Date of Quarter	Element	Concentration +/- error (pCi)
1st Quarter	3/31/2020	Beryllium-7	9,350 +/- 590
2nd Quarter	6/30/2020	Beryllium-7	Not Sampled
3rd Quarter	9/30/2020	Beryllium-7	Not Sampled
4th Quarter	11/30/2020	Beryllium-7	4,460 +/- 320
Historical Range	2010-2019	Beryllium-7	1,690-17,500

In 2020, no alpha, beta or gamma radioactivity related to the activities of Vermont Yankee was identified in the continuous flow air samples. Results were consistent with historical ranges.

Water Sampling Results

The Health Department has routinely collected off-site monthly water samples from six locations around Vermont Yankee. Samples are collected from drinking water wells (3), a public water supply (1) and the Connecticut River (2). These sample locations are shown on Map 7. Additional off-site samples are collected at a private residence and a nursing home.

In addition, Vermont Yankee routinely collects at two Connecticut River sites monthly: Stations 3-3 and 3-8. These sample locations are shown on Map 8. Vermont Yankee also collects at four on-site monitoring wells quarterly: WVN0201, WVN0202, WVN0203 and WVN0204. Other on-site monitoring wells are also sampled by Vermont Yankee. The samples Vermont Yankee takes from the Connecticut River and on-site monitoring wells are split so the Health Department Laboratory can analyze them for comparison.

Routine off-site water samples are tested by the Health Department Laboratory for total alpha and beta radioactivity, gamma radioactivity and tritium. The Connecticut River on-site monitoring wells are tested for tritium and gamma radioactivity.

For 2020:

- 67 water samples were tested for total alpha and beta radioactivity
- 110 water samples were tested for tritium
- 110 water samples were tested for gamma-emitting materials

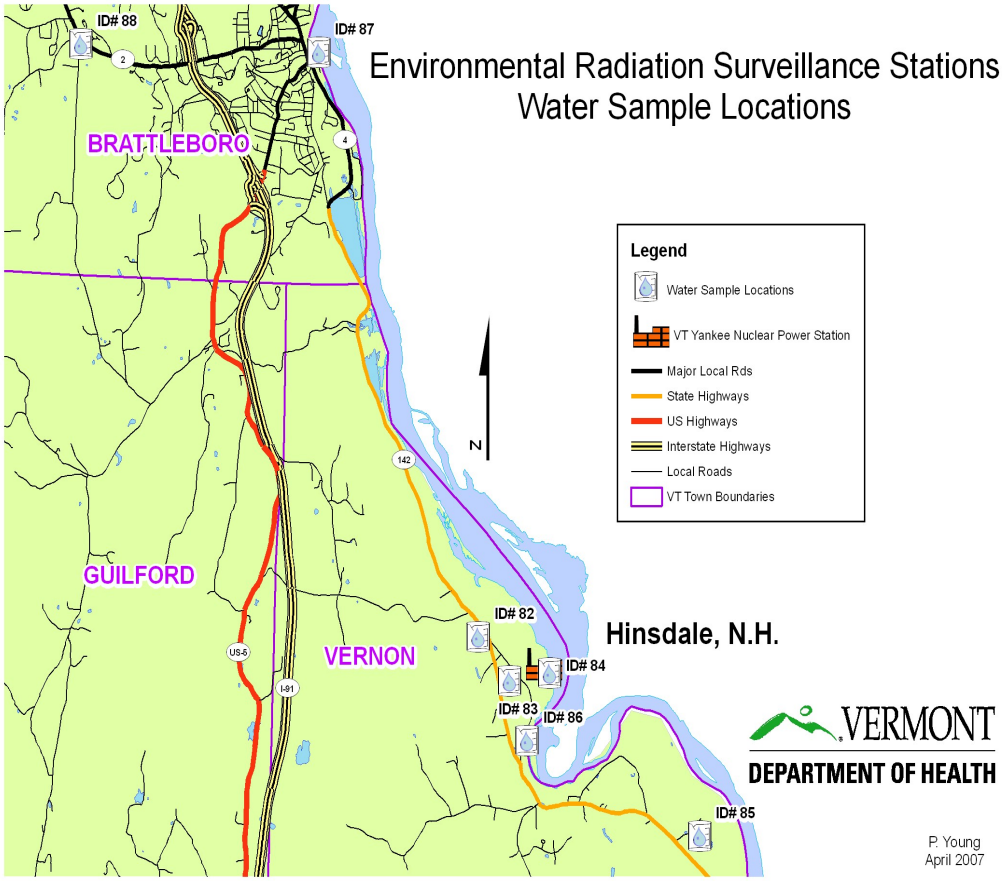
Due to the large number of results associated with tritium and gamma spectroscopy, the individual data for these tests are presented in Appendices B and C.

Water Total Alpha and Beta Radioactivity Results

The alpha and beta radioactivity measured in the water samples is within the historical range for both types of radioactivity. Water alpha and beta radioactivity measurements around Vermont Yankee have both historically ranged from below the lower limit of detection to 15 picocuries per liter (pCi/L). The U.S. Environmental Protection Agency has established maximum contaminant levels (MCLs) of 15 pCi/L for alpha radioactivity and 50 pCi/L for beta radioactivity. In 2020, the range for alpha radioactivity was -0.28 to 9.62 pCi/L. The 2020 range for beta radioactivity was 0.00 to 19.80 pCi/L. Results from 2020 are presented in Table 13. Comparisons of 2016-2020 data are presented in

Figures 4 and 5. Trends for both alpha and beta results are similar to past years: Vernon Elementary School and Blodgett Farm have historically had higher levels of natural radioactivity in the water, principally isotopes of uranium and radium and their daughter products.

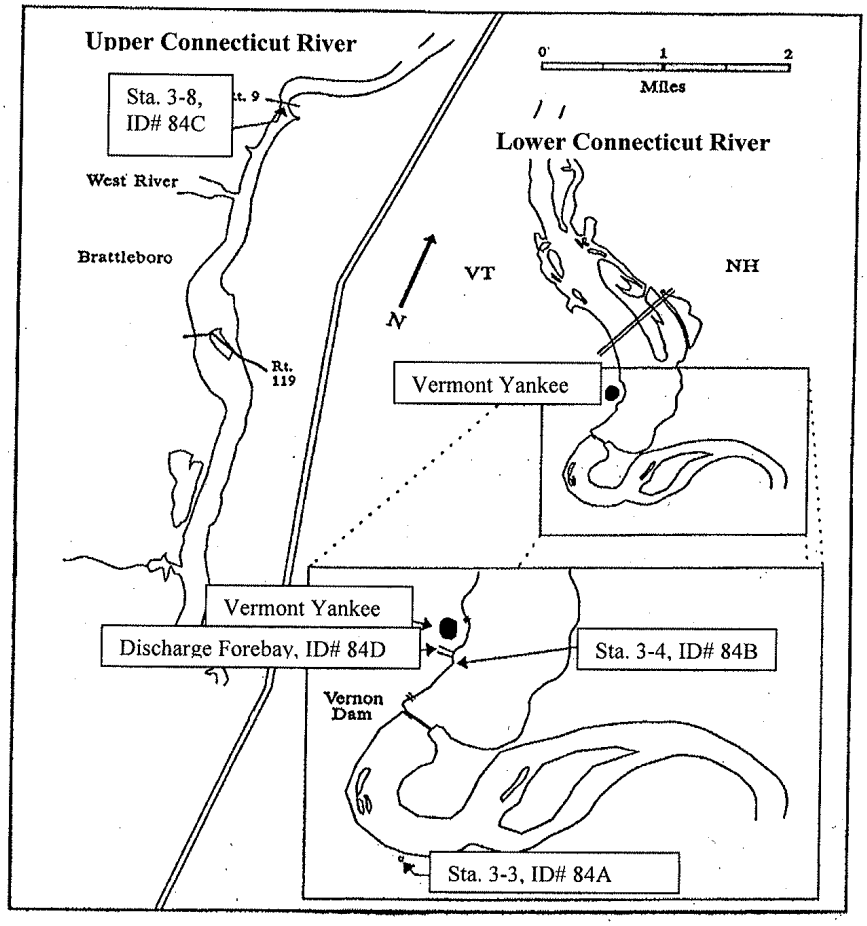
Map 7



Sample Location	Map ID
Miller Farm	82
Vernon Elementary School	83
Blodgett Farm	85
Connecticut River, Downstream	86
Connecticut River, Upstream	87
Brattleboro Fire Dept., West Station	88

Map 8

Routine Connecticut River Water Sample Locations



Sample Location	Map ID
3-3 Connecticut River Station	84A
3-4 Connecticut River Station	84B
3-8 Connecticut River Station	84C
Discharge Forebay	84D

Table 13. 2020 Total Alpha and Beta Radioactivity Water Results

Sample Location	Date of Sample	Total Alpha Radioactivity +/- error (pCi/L)	Total Beta Radioactivity +/- error (pCi/L)
3-3 Connecticut River Station	1/16/2020	0.00 +/- 0.52	1.21 +/- 0.99
	2/14/2020	0.25 +/- 0.59	1.44 +/- 0.99
	3/16/2020	0.51 +/- 0.55	0.69 +/- 1.09
	4/15/2020	0.75 +/- 0.58	5.43 +/- 1.21
	5/14/2020	0.25 +/- 0.49	1.28 +/- 1.06
	6/17/2020	0.51 +/- 0.55	1.26 +/- 1.09
	7/16/2020	-0.26 +/- 0.51	1.72 +/- 1.00
	8/13/2020	2.31 +/- 0.87	1.16 +/- 0.98
	9/14/2020	0.00 +/- 0.56	1.72 +/- 1.00
	10/15/2020	0.00 +/- 0.48	1.16 +/- 1.04
	11/16/2020	0.31 +/- 0.61	1.80 +/- 1.17
	12/16/2020	0.00 +/- 0.55	2.35 +/- 1.19
3-8 Connecticut River Station	1/16/2020	0.00 +/- 0.21	0.57 +/- 0.40
	2/14/2020	-0.10 +/- 0.19	0.80 +/- 0.41
	3/16/2020	0.26 +/- 0.28	0.93 +/- 0.57
	4/15/2020	0.74 +/- 0.58	1.50 +/- 1.07
	5/14/2020	0.00 +/- 0.22	0.29 +/- 0.52
	6/17/2020	0.26 +/- 0.52	1.52 +/- 1.13
	7/16/2020	0.00 +/- 0.55	1.60 +/- 1.00
	8/13/2020	0.00 +/- 0.56	1.61 +/- 1.00
	9/14/2020	0.26 +/- 0.61	1.05 +/- 0.97
	10/15/2020	0.27 +/- 0.54	0.53 +/- 1.03
	11/16/2020	0.60 +/- 0.65	2.21 +/- 1.18
	12/16/2020	0.58 +/- 0.63	1.93 +/- 1.17
Blodgett Farm	1/7/2020	4.68 +/- 0.94	4.36 +/- 1.13
	2/4/2020	4.41 +/- 0.97	3.57 +/- 1.09
	3/3/2020	8.85 +/- 1.44	5.62 +/- 1.25
	9/8/2020	3.68 +/- 0.82	3.85 +/- 1.10
	10/6/2020	3.70 +/- 0.83	6.37 +/- 1.24
	11/3/2020	4.39 +/- 1.18	3.48 +/- 1.32
Brattleboro Fire Dept, West Station	1/7/2020	-0.24 +/- 0.47	1.54 +/- 1.00
	2/4/2020	0.00 +/- 0.53	0.99 +/- 0.97
	3/3/2020	0.00 +/- 0.43	0.66 +/- 1.07
	9/8/2020	-0.24 +/- 0.47	0.83 +/- 0.96
	11/3/2020	0.31 +/- 0.61	1.79 +/- 1.17

Table 13. 2020 Total Alpha and Beta Radioactivity Water Results (continued)

Sample Location	Date of Sample	Total Alpha Radioactivity +/- error (pCi/L)	Total Beta Radioactivity +/- error (pCi/L)
Connecticut River Downstream	1/7/2020	0.76 +/- 0.66	2.21 +/- 1.03
	2/4/2020	-0.26 +/- 0.50	1.55 +/- 1.00
	3/3/2020	0.53 +/- 0.57	1.86 +/- 1.09
	9/8/2020	0.26 +/- 0.60	1.49 +/- 0.99
	10/6/2020	0.56 +/- 0.60	1.97 +/- 1.11
	11/3/2020	0.62 +/- 0.67	2.35 +/- 1.19
Connecticut River Upstream	1/7/2020	-0.04 +/- 0.31	2.05 +/- 1.05
	2/4/2020	0.47 +/- 0.47	1.25 +/- 1.01
	3/3/2020	0.00 +/- 0.48	0.17 +/- 1.05
	9/8/2020	0.27 +/- 0.62	2.50 +/- 1.04
	10/6/2020	0.00 +/- 0.52	1.30 +/- 1.05
	11/3/2020	0.96 +/- 0.74	2.35 +/- 1.19
Miller Farm	1/7/2020	0.34 +/- 0.40	8.12 +/- 1.26
	2/4/2020	1.67 +/- 0.67	7.56 +/- 1.23
	3/3/2020	0.22 +/- 0.52	6.78 +/- 1.30
	9/8/2020	0.54 +/- 0.47	7.51 +/- 1.23
	10/6/2020	0.08 +/- 0.35	6.59 +/- 1.24
	11/3/2020	0.64 +/- 0.69	4.15 +/- 1.27
Vernon Elementary School	1/7/2020	7.04 +/- 1.10	5.01 +/- 1.15
	2/4/2020	8.47 +/- 1.23	5.45 +/- 1.16
	3/3/2020	9.62 +/- 1.50	6.51 +/- 1.27
	9/8/2020	6.13 +/- 1.05	5.52 +/- 1.16
	10/6/2020	5.85 +/- 1.30	5.06 +/- 1.22
	11/3/2020	8.32 +/- 1.49	6.96 +/- 1.45
GZ-2S	11/19/2020	8.43 +/- 1.50	19.80 +/- 2.10
GZ-12S	11/19/2020	1.24 +/- 0.84	3.88 +/- 1.47
GZ-13D	11/19/2020	6.30 +/- 1.34	8.70 +/- 1.61
GZ-19D	11/19/2020	3.60 +/- 1.10	7.19 +/- 1.50
GZ-19S	11/19/2020	1.12 +/- 0.82	2.34 +/- 1.33
GZ-22D	2/14/2020	4.23 +/- 0.92	8.07 +/- 1.43
GZ-23S	2/14/2020	0.92 +/- 0.54	3.48 +/- 1.19
	11/19/2020	2.02 +/- 0.79	3.15 +/- 1.34

Figure 4. 2016-2020 Average Alpha Radioactivity in Water

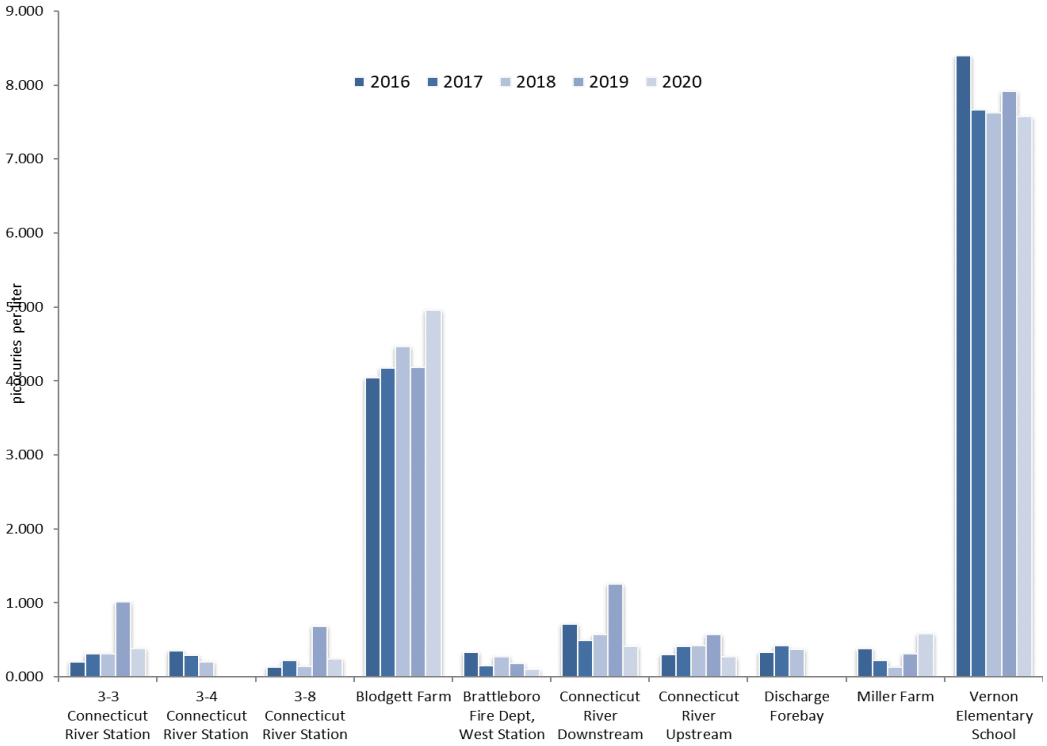
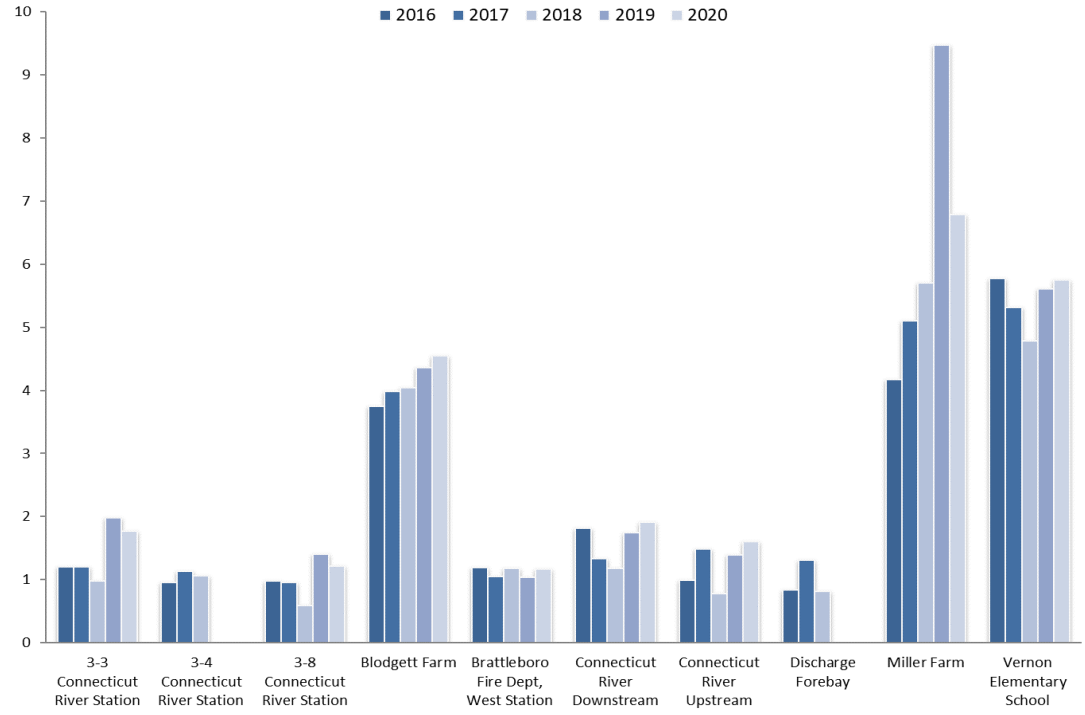


Figure 5. 2016-2020 Average Beta Radioactivity in Water



Water Tritium Results

In 2020, the Health Department Laboratory tested 110 drinking, ground and surface (Connecticut River) water samples from off-site and on-site locations for tritium. No tritium was detected from any off-site water sample, including Connecticut River samples, in 2020. The Health Department Laboratory's lower limit of detection for tritium is 500 picocuries per liter. All tritium data are presented in Appendix B.

Table 14. 2020 Water Sample Locations, Number of Tritium Tests

Wells near Vermont Yankee	
Blodgett Farm	8
Brattleboro Fire Department, West Station	6
Miller Farm	8
Residence - 1	8
Vernon Elementary School	8
Vernon Green Nursing Home	8
Connecticut River Sample Sites	
3-3 Connecticut River Station	12
3-8 Connecticut River Station	12
Connecticut River Downstream	8
Connecticut River Upstream	8
On-Site Wells	
GZ-2S	1
GZ-12S	1
GZ-13D	1
GZ-19D	1
GZ-19S	1
GZ-22D	1
GZ-23S	2
WVN0201	4
WVN0202	4
WVN0203	4
WVN0204	4
Total number of samples tested for tritium	110

Water Gamma Spectroscopy Results

A total of 110 drinking, ground and surface (Connecticut River) water samples were collected from both off-site and on-site locations in 2020 for gamma-emitting materials. No radioactive materials other than naturally-occurring were identified in any water

sample collected in 2020. The Health Department calculated limits of detection for gamma-emitting materials are listed in Table 8. All results are presented in Appendix C.

_____

In 2020, all off-site water sample locations showed no significant dose impact from activities at Vermont Yankee for total alpha, total beta, tritium and gamma spectroscopy, and VDH dose limits were not exceeded. No human-made radioactive elements were measured in water samples in 2020.

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Food Chain Sampling Results

Monitoring the food chain involves direct monitoring of some foods such as milk and fish. It also involves testing the sediment that supports land and aquatic species.

For 2020:

- 10 milk samples were tested for iodine-131 and gamma-emitting materials
- 36 Connecticut River sediment samples were tested for gamma-emitting materials
- 4 fish samples collected in the Connecticut River were tested for gamma-emitting materials

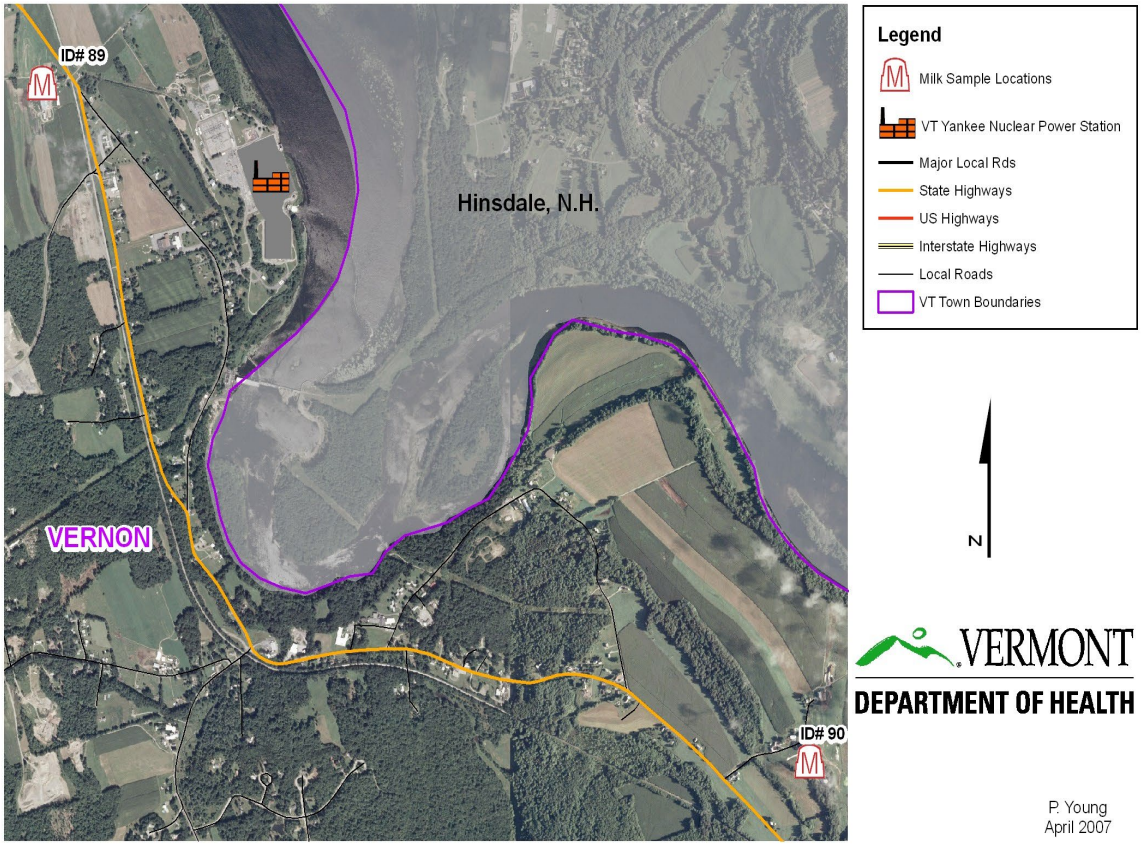
Milk Sample Results

Cows' raw milk is sampled monthly from two farms in Vernon. One farm is about one-half mile north of Vermont Yankee and the other is about three miles south of Vermont Yankee. Map 9 shows the locations of these two dairy farms.

Potassium-40 (K-40) was the only radioactive material found in milk samples. Potassium-40 is a primordial radioactive material with a half-life of 1.28 billion years. Primordial radioactive materials are those created with the formation of the earth. In 2020 potassium-40 was detected in all milk samples. Results are shown in Table 15. The potassium-40 results for all milk samples range from 1,260 to 1,480 picocuries per liter (pCi/L), and fall within the historical range of 1,200 to 2,000 pCi/L. The average potassium-40 result in 2020 was 1,396 pCi/L. No iodine-131 (I-131) was found in any milk sample in 2020.

Map 9

Environmental Radiation Surveillance Stations
Milk Sample Locations



Sample Location	Map ID
Miller Farm	89
Blodgett Farm	90

Table 15. 2020 Milk Iodine-131 and Gamma Spectroscopy Results

Sample Location	Date of Sample	Iodine-131 Result	Gamma Spectrometry Result	Potassium-40 Result +/- error (pCi/L)
Blodgett Farm	1/7/2020	< LLD	Natural	1430 +/- 220
	2/4/2020	< LLD	Natural	1370 +/- 210
	3/3/2020	< LLD	Natural	1310 +/- 210
	9/8/2020	< LLD	Natural	1260 +/- 200
	10/6/2020	< LLD	Natural	1450 +/- 230
	11/3/2020	< LLD	Natural	1340 +/- 210
Miller Farm	2/4/2020	< LLD	Natural	1480 +/- 230
	9/8/2020	< LLD	Natural	1430 +/- 220
	10/6/2020	< LLD	Natural	1420 +/- 220
	11/3/2020	< LLD	Natural	1470 +/- 230

< LLD = Less than the laboratory's Lower Limit of Detection
Natural = gamma-emitting materials measured are not related to nuclear reactions

Sediment Sample Results

Sediment samples were collected from the bottom of the Connecticut River. The sediment samples were taken from four areas of the Connecticut River: Station 3-3 (south of Vernon Dam), Station 3-4 (near Vermont Yankee discharge), Station 3-8 (upstream near the Route 9 Bridge) and the North Storm Drain area. In 1997, the North Storm Drain area was identified as having been contaminated with cobalt-60 from Vermont Yankee operations. The North Storm Drain area is sampled at 15 distinct locations: S-1, S-2, T-1, T-2, T-3, U-1, U-2, U-3, U-4, V-3, V-4, V-5, W-4, W-5 and X-5. These sample locations are shown in Map 10. Prior to 2016, cobalt-60 was last detected in a sediment sample obtained and tested in 2005. Cobalt-60 (Co-60) was detected in three samples collected in October 2016 and in two samples collected in May 2019. No cobalt-60 was detected in any sediment samples in 2020.

All sediment locations are sampled each spring and fall. A sediment sample is taken with a mass ranging from 0.2 to 0.5 kilograms. Sediment samples are dried and tested by gamma spectroscopy. Tested sediments contained naturally-occurring beryllium-7 (Be-7) and potassium-40 (K-40) as well as cesium-137 (Cs-137), which is related mostly to fallout from above-ground weapons testing and global nuclear incidents like Chernobyl and Fukushima. The results are presented in Table 19. Concentrations of beryllium-7, potassium-40, cesium-137 and cobalt-60 were within historical ranges for Vermont. Comparisons to previous years' data are presented in Figures 6 and 7.

Table 18. 2020 Sediment Gamma Spectroscopy Ranges as Compared to Historical Ranges

Radioactive Element	2020 Sediment Concentration Range (pCi/kg)	Historical Sediment Concentration Range (pCi/kg)
Potassium-40	7,760-23,200	6,000-30,400
Cesium-137	< LLD-104	< LLD-500
< LLD = Less than the Laboratory's Lower Limit of Detection		

Map 10

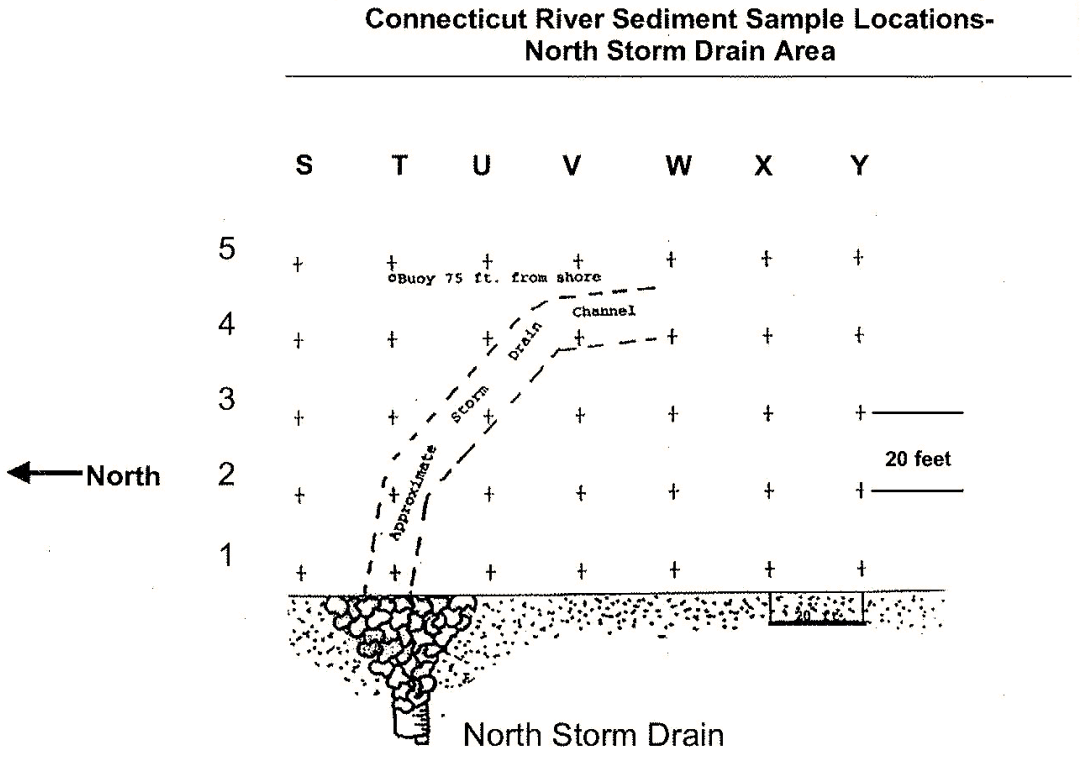


Table 19. 2020 Sediment Gamma Spectroscopy Results

Sample Location	Date of Sample	Potassium-40 Result +/- error (pCi/kg)	Cesium-137 Result +/- error (pCi/kg)
3-3	5/18/2020	14,000 +/- 2,500	68.8 +/- 17.4
3-4	5/18/2020	16,100 +/- 2,800	74.5 +/- 18.4
3-8	5/18/2020	7,760 +/- 1,370	26.0 +/- 9.3
S-1	5/18/2020	20,600 +/- 3,600	97.1 +/- 22.3
S-2	5/18/2020	21,200 +/- 3,700	101 +/- 24.0
T-1	5/18/2020	9,780 +/- 1,720	43.3 +/- 11.8
T-2	5/18/2020	20,600 +/- 3,600	88.6 +/- 21.3
T-3	5/18/2020	22,800 +/- 4,000	84 +/- 21.9
U-1	5/18/2020	21,800 +/- 3,800	80 +/- 23.4
U-2	5/18/2020	22,800 +/- 4,000	81.4 +/- 23.1
U-3	5/18/2020	21,200 +/- 3,700	71.0 +/- 20.9
U-4	5/18/2020	18,500 +/- 3,200	63.8 +/- 17.3
V-3	5/18/2020	22,000 +/- 3,900	88 +/- 22.1
V-4	5/18/2020	20,100 +/- 3,500	104.0 +/- 21.0
V-5	5/18/2020	17,500 +/- 3,100	79.5 +/- 17.5
W-4	5/18/2020	18,100 +/- 3,200	72.4 +/- 18.7
W-5	5/18/2020	17,200 +/- 3,000	63.4 +/- 18.4
X-5	5/18/2020	16,900 +/- 3,000	64.0 +/- 17.5
3-3	10/20/2020	7,910 +/- 1,400	< LLD
3-4	10/20/2020	14,700 +/- 2,600	52.6 +/- 15.6
3-8	10/20/2020	12,900 +/- 2,300	57.4 +/- 15.2
S-1	10/20/2020	21,800 +/- 3,800	83.1 +/- 21.6
S-2	10/20/2020	22,700 +/- 4,000	86.6 +/- 22.4
T-1	10/20/2020	13,500 +/- 2,400	Evidence of
T-2	10/20/2020	21,600 +/- 3,800	83.8 +/- 21.1
T-3	10/20/2020	20,500 +/- 3,600	91.6 +/- 22.0
U-1	10/20/2020	23,000 +/- 4,000	59.5 +/- 21.9
U-2	10/20/2020	20,000 +/- 3,500	80 +/- 20.9
U-3	10/20/2020	23,200 +/- 4,100	81.1 +/- 22.3
U-4	10/20/2020	19,700 +/- 3,400	79.8 +/- 20.0
V-3	10/20/2020	22,600 +/- 4,000	104 +/- 25.0
V-4	10/20/2020	18,400 +/- 3,200	73.6 +/- 19.3
V-5	10/20/2020	16,100 +/- 2,800	59.2 +/- 17.7
W-4	10/20/2020	16,400 +/- 2,900	66.5 +/- 17.6
W-5	10/20/2020	18,100 +/- 3,200	69.0 +/- 20.2
X-5	10/20/2020	16,200 +/- 2,900	48.2 +/- 16.7

< LLD = Less than the laboratory's Lower Limit of Detection

Figure 6. 2017-2020 Average Potassium-40 Levels in Sediment

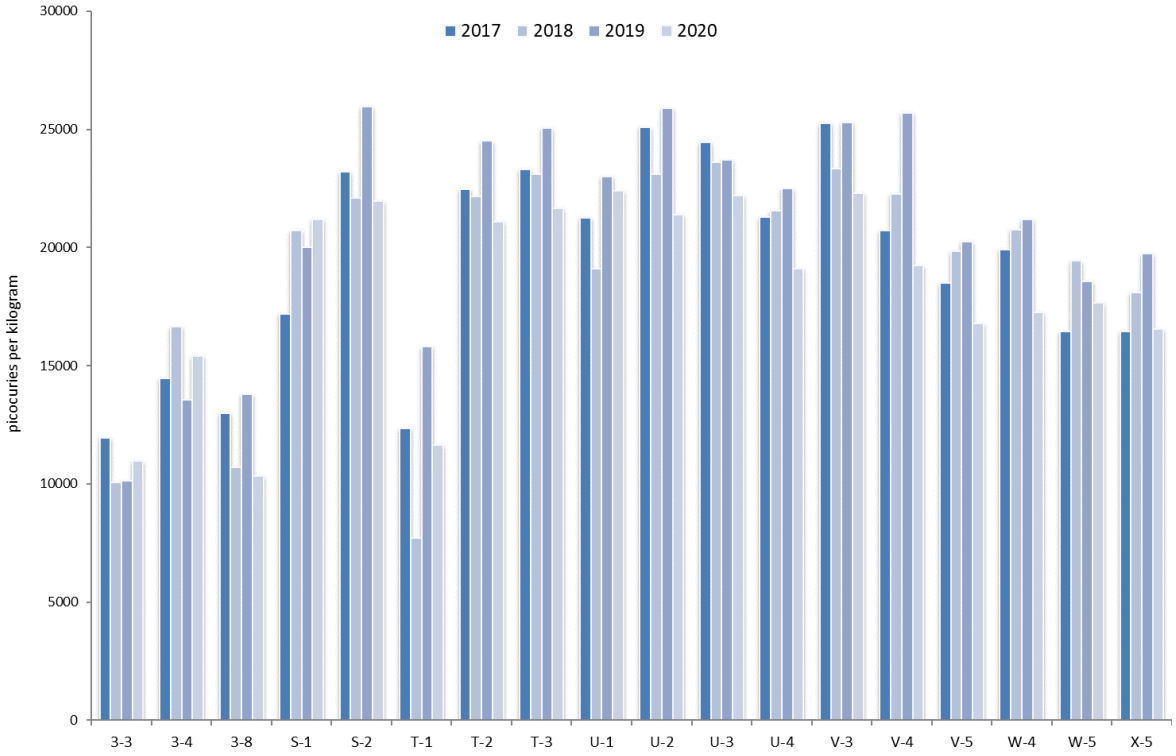
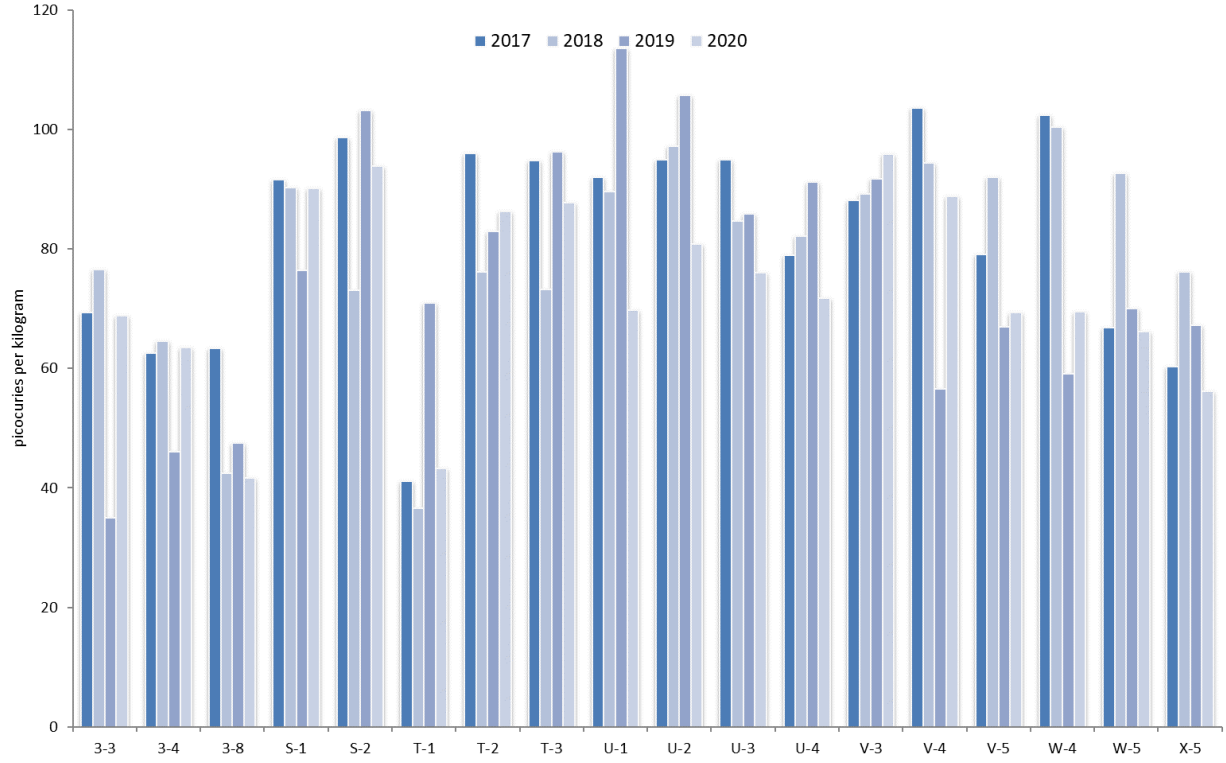


Figure 7. 2017-2020 Average Cesium-137 Levels in Sediment



Fish Sample Results

Each year, fish are collected at two sites in the Connecticut River by an environmental contractor. One site is near the Vermont Yankee discharge and the other site is about nine miles upstream from Vermont Yankee, where the Route 9 Bridge crosses the Connecticut River.

The Health Department Laboratory tests fish samples for gamma-emitting materials. Fish gamma spectroscopy results are presented in Table 20.

Potassium-40, a naturally-occurring radioactive material was measured in all Connecticut River fish sampled in 2020. Samples of fish taken in 2011 from Lake Carmi and in 2012 from Lakes Bomoseen and Hortonia contained levels of cesium-137 between 23.3 and 73.9 pCi/kg, indicating that the radionuclide is related to fallout from weapons testing and global incidents. Cesium-137 was found in one Connecticut River fish sampled in 2020.

Table 20. 2020 Connecticut River Fish Gamma Spectroscopy Results

Month Sample Collected	Sample Location	Potassium-40 +/- error (pCi/kg)	Cesium-137 +/- error (pCi/kg)
May 2020	Near VY Discharge	3,100 ± 480	9.80 ± 2.95
	Upstream of VY	2,800 ± 430	< LLD
October 2020	Near VY Discharge	2,220 ± 350	< LLD
	Upstream of VY	2,630 ± 410	< LLD
< LLD means less than the Laboratory's Lower Limit of Detection			

In 2020, no radioactivity in food chain inputs was measured above historical and background ranges. Radioactivity measured in the food chain inputs can be attributed to either natural sources or human-made sources released in above-ground weapons testing or global nuclear incidents.

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Appendix A

2020 Air Filter Data for Total Alpha & Beta Radioactivity

Alpha and beta radioactivity results for all air filter samples tested by the Health Department in 2020 are provided in this appendix. Results are presented in order by sampling date.

Sample Location	Date of Sample	Total Alpha Radioactivity +/- error (pCi/m^3)	Total Beta Radioactivity +/- error (pCi/m^3)
108 Cherry St Burlington	1/7/2020	0.00091 +/- 0.000148	0.017 +/- 0.0005
D & E Tree	1/7/2020	0.00131 +/- 0.00025	0.0153 +/- 0.0006
Dummerston IFO	1/7/2020	0.00154 +/- 0.0003	0.0206 +/- 0.0008
Guilford Town Garage	1/7/2020	0.00141 +/- 0.00021	0.0198 +/- 0.0006
Power Line Crossing	1/7/2020	0.00201 +/- 0.00024	0.0205 +/- 0.0006
Vermont Courthouse	1/7/2020	0.00102 +/- 0.00022	0.0111 +/- 0.0005
Vermont State Police	1/7/2020	0.000918 +/- 0.000182	0.0141 +/- 0.0005
Vernon Elementary School	1/7/2020	0.00129 +/- 0.00019	0.0182 +/- 0.0005
Wilmington State Highway Garage	1/7/2020	0.00133 +/- 0.00026	0.0162 +/- 0.0007
108 Cherry St Burlington	2/4/2020	0.000743 +/- 0.000144	0.0121 +/- 0.0004
D & E Tree	2/4/2020	0.00126 +/- 0.00027	0.0148 +/- 0.0007
Dummerston IFO	2/4/2020	0.00128 +/- 0.0003	0.018 +/- 0.0008
Guilford Town Garage	2/4/2020	0.00134 +/- 0.00023	0.0174 +/- 0.0006
Power Line Crossing	2/4/2020	0.00128 +/- 0.00022	0.0168 +/- 0.0006
Vermont Courthouse	2/4/2020	0.00106 +/- 0.00025	0.0123 +/- 0.0006
Vermont State Police	2/4/2020	0.000914 +/- 0.000199	0.0134 +/- 0.0006
Vernon Elementary School	2/4/2020	0.00116 +/- 0.0002	0.0145 +/- 0.0005
Wilmington State Highway Garage	2/4/2020	0.000873 +/- 0.000239	0.0115 +/- 0.0006
108 Cherry St Burlington	3/4/2020	0.00149 +/- 0.0002	0.0198 +/- 0.0005
D & E Tree	3/3/2020	0.0012 +/- 0.00027	0.0183 +/- 0.0008
Dummerston IFO	3/3/2020	0.00133 +/- 0.00031	0.0226 +/- 0.0009
Guilford Town Garage	3/3/2020	0.00124 +/- 0.00022	0.0198 +/- 0.0007
Power Line Crossing	3/3/2020	0.00176 +/- 0.00026	0.0217 +/- 0.0007
Vermont Courthouse	3/3/2020	0.0013 +/- 0.00028	0.0186 +/- 0.0008
Vermont State Police	3/3/2020	0.00122 +/- 0.00023	0.0185 +/- 0.0007
Vernon Elementary School	3/3/2020	0.00148 +/- 0.00023	0.02 +/- 0.0006
Wilmington State Highway Garage	3/3/2020	0.00153 +/- 0.00031	0.0192 +/- 0.0008
108 Cherry St Burlington	10/6/2020	0.00104 +/- 0.00015	0.015 +/- 0.0004
D & E Tree	10/6/2020	0.00133 +/- 0.00031	0.0212 +/- 0.0009
Dummerston IFO	10/6/2020	0.00207 +/- 0.00041	0.0279 +/- 0.0011
Guilford Town Garage	10/6/2020	0.00098 +/- 0.0002	0.0217 +/- 0.0007
Power Line Crossing	10/6/2020	0.00139 +/- 0.00024	0.0206 +/- 0.0007
Vermont Courthouse	10/6/2020	0.00115 +/- 0.00027	0.0192 +/- 0.0008
Vermont State Police	10/6/2020	0.00168 +/- 0.00026	0.0216 +/- 0.0007
Vernon Elementary School	10/6/2020	0.00162 +/- 0.00025	0.0219 +/- 0.0007
Wilmington State Highway Garage	10/6/2020	0.00171 +/- 0.00033	0.0191 +/- 0.0008
108 Cherry St Burlington	11/4/2020	0.00149 +/- 0.00019	0.0159 +/- 0.0005
D & E Tree	11/3/2020	0.00257 +/- 0.00037	0.0302 +/- 0.001
Dummerston IFO	11/3/2020	0.00144 +/- 0.00021	0.0164 +/- 0.0005
Guilford Town Garage	11/3/2020	0.0033 +/- 0.00043	0.0357 +/- 0.0011
Vermont Courthouse	11/3/2020	0.00128 +/- 0.00026	0.0132 +/- 0.0006
Vermont State Police	11/3/2020	0.00145 +/- 0.0002	0.0183 +/- 0.0005
Vernon Elementary School	11/3/2020	0.00188 +/- 0.00025	0.021 +/- 0.0006
Wilmington State Highway Garage	11/3/2020	0.00187 +/- 0.00033	0.0169 +/- 0.0007

Appendix B

2020 Tritium Water Data

Tritium results for all water samples tested by the Health Department in 2020 are provided in this appendix. Results are presented in order by sample location and by sampling date.

The Health Department's Lower Limit of Detection for tritium is 500 picocuries per liter (pCi/L).

Sample Location	Date of Sample	Tritium Result +/- error (pCi/L)
3-3 Connecticut River Station	1/16/2020	< 500
	2/14/2020	< 500
	3/16/2020	< 500
	4/15/2020	< 500
	5/14/2020	< 500
	6/17/2020	< 500
	7/16/2020	< 500
	8/13/2020	< 500
	9/14/2020	< 500
	10/15/2020	< 500
	11/16/2020	< 500
	12/16/2020	< 500
3-8 Connecticut River Station	1/16/2020	< 500
	2/14/2020	< 500
	3/16/2020	< 500
	4/15/2020	< 500
	5/14/2020	< 500
	6/17/2020	< 500
	7/16/2020	< 500
	8/13/2020	< 500
	9/14/2020	< 500
	10/15/2020	< 500
	11/16/2020	< 500
	12/16/2020	< 500
Connecticut River, Downstream	1/21/2020	< 500
	1/7/2020	< 500
	2/4/2020	< 500
	2/18/2020	< 500
	3/3/2020	< 500
	9/8/2020	< 500
	10/6/2020	< 500
	11/3/2020	< 500
Connecticut River, Upstream	1/21/2020	< 500
	1/7/2020	< 500
	2/4/2020	< 500
	2/18/2020	< 500
	3/3/2020	< 500
	9/8/2020	< 500
	10/6/2020	< 500
	11/3/2020	< 500

Sample Location	Date of Sample	Tritium Result +/- error (pCi/L)
GZ-2S	11/19/2020	< 500
GZ-12S	11/19/2020	< 500
GZ-13D	11/19/2020	< 500
GZ-19D	11/19/2020	< 500
GZ-19S	11/19/2020	< 500
GZ-22D	2/14/2020	2250 +/- 150
GZ-23S	2/14/2020	< 500
	11/19/2020	< 500
WVN0201	3/16/2020	< 500
	6/30/2020	< 500
	9/22/2020	< 500
	12/18/2020	< 500
WVN0202	3/16/2020	< 500
	6/30/2020	< 500
	9/22/2020	< 500
	12/16/2020	< 500
WVN0203	3/16/2020	< 500
	6/30/2020	< 500
	9/23/2020	< 500
	12/16/2020	< 500
WVN0204	3/16/2020	< 500
	6/30/2020	< 500
	9/22/2020	< 500
	12/18/2020	< 500
Blodgett Farm	1/21/2020	< 500
	1/7/2020	< 500
	2/4/2020	< 500
	2/18/2020	< 500
	3/3/2020	< 500
	9/8/2020	< 500
	10/6/2020	< 500
	11/3/2020	< 500
Brattleboro Fire Dept, West Station	1/7/2020	< 500
	2/4/2020	< 500
	2/18/2020	< 500
	3/3/2020	< 500
	9/8/2020	< 500
	11/3/2020	< 500

Sample Location	Date of Sample	Tritium Result +/- error (pCi/L)
Miller Farm	1/21/2020	< 500
	1/7/2020	< 500
	2/4/2020	< 500
	2/18/2020	< 500
	3/3/2020	< 500
	9/8/2020	< 500
	10/6/2020	< 500
	11/3/2020	< 500
Residence - 1	1/7/2020	< 500
	1/21/2020	< 500
	2/4/2020	< 500
	2/18/2020	< 500
	3/3/2020	< 500
	9/8/2020	< 500
	10/6/2020	< 500
	11/3/2020	< 500
Vernon Elementary School	1/21/2020	< 500
	1/7/2020	< 500
	2/4/2020	< 500
	2/18/2020	< 500
	3/3/2020	< 500
	9/8/2020	< 500
	10/6/2020	< 500
	11/3/2020	< 500
Vernon Green Nursing Home	1/7/2020	< 500
	1/21/2020	< 500
	2/4/2020	< 500
	2/18/2020	< 500
	3/3/2020	< 500
	9/8/2020	< 500
	10/6/2020	< 500
	11/3/2020	< 500
pCi/L = picocuries per liter		

Appendix C

2020 Gamma Spectroscopy Water Data

Gamma spectroscopy data for all water samples tested by the Health Department in 2020 are provided in this appendix. Results are presented in order by sample location and by sampling date.

"Natural" means that gamma-emitting materials detected are not related to nuclear power stations or above-grounds weapons testing.

< LLD means less than the Laboratory's Lower Limit of Detection.

Sample Location	Date of Sample	Gamma Spectroscopy Result
3-3 Connecticut River Station	1/16/2020	<LLD
	2/14/2020	<LLD
	3/16/2020	<LLD
	4/15/2020	<LLD
	5/14/2020	<LLD
	6/17/2020	<LLD
	7/16/2020	<LLD
	8/13/2020	<LLD
	9/14/2020	<LLD
	10/15/2020	<LLD
	11/16/2020	<LLD
	12/16/2020	<LLD
3-8 Connecticut River Station	1/16/2020	<LLD
	2/14/2020	<LLD
	3/16/2020	<LLD
	4/15/2020	<LLD
	5/14/2020	<LLD
	6/17/2020	<LLD
	7/16/2020	<LLD
	8/13/2020	<LLD
	9/14/2020	<LLD
	10/15/2020	<LLD
	11/16/2020	<LLD
	12/16/2020	<LLD
Connecticut River, Downstream	1/21/2020	<LLD
	1/7/2020	<LLD
	2/4/2020	<LLD
	2/18/2020	<LLD
	3/3/2020	<LLD
	9/8/2020	<LLD
	10/6/2020	<LLD
	11/3/2020	<LLD
Connecticut River, Upstream	1/21/2020	<LLD
	1/7/2020	<LLD
	2/4/2020	<LLD
	2/18/2020	<LLD
	3/3/2020	<LLD
	9/8/2020	<LLD
	10/6/2020	<LLD
	11/3/2020	<LLD

Sample Location	Date of Sample	Gamma Spectroscopy Result
GZ-2S	11/19/2020	Natural
GZ-12S	11/19/2020	Natural
GZ-13D	11/19/2020	Natural
GZ-19D	11/19/2020	Natural
GZ-19S	11/19/2020	Natural
GZ-22D	2/14/2020	Natural
GZ-23S	2/14/2020	Natural
	11/19/2020	Natural
WVN0201	3/16/2020	<LLD
	6/30/2020	Natural
	9/22/2020	Natural
	12/18/2020	Natural
WVN0202	3/16/2020	<LLD
	6/30/2020	Natural
	9/22/2020	Natural
	12/16/2020	Natural
WVN0203	3/16/2020	<LLD
	6/30/2020	Natural
	9/23/2020	Natural
	12/16/2020	Natural
WVN0204	3/16/2020	<LLD
	6/30/2020	Natural
	9/22/2020	Natural
	12/18/2020	Natural
Blodgett Farm	1/21/2020	Natural
	1/7/2020	Natural
	2/4/2020	Natural
	2/18/2020	Natural
	3/3/2020	Natural
	9/8/2020	Natural
	10/6/2020	Natural
	11/3/2020	Natural
Brattleboro Fire Dept, West Station	1/7/2020	<LLD
	2/4/2020	<LLD
	2/18/2020	<LLD
	3/3/2020	<LLD
	9/8/2020	<LLD
	11/3/2020	<LLD

Sample Location	Date of Sample	Gamma Spectroscopy Result
Miller Farm	1/21/2020	Natural
	1/7/2020	Natural
	2/4/2020	Natural
	2/18/2020	Natural
	3/3/2020	Natural
	9/8/2020	Natural
	10/6/2020	Natural
	11/3/2020	Natural
Residence - 1	1/7/2020	<LLD
	1/21/2020	Natural
	2/4/2020	Natural
	2/18/2020	Natural
	3/3/2020	Natural
	9/8/2020	Natural
	10/6/2020	Natural
	11/3/2020	Natural
Vernon Elementary School	1/21/2020	Natural
	1/7/2020	Natural
	2/4/2020	Natural
	2/18/2020	Natural
	3/3/2020	Natural
	9/8/2020	<LLD
	10/6/2020	Natural
	11/3/2020	Natural
Vernon Green Nursing Home	1/7/2020	Natural
	1/21/2020	Natural
	2/4/2020	Natural
	2/18/2020	Natural
	3/3/2020	Natural
	9/8/2020	<LLD
	10/6/2020	Natural
	11/3/2020	Natural
< LLD means less than the Laboratory's Lower Limit of Detection		