Beverly Hills High School – Supplemental Report on Radiological Surveys

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I. Introduction

In 2003, the California Department of Health Services (DHS) began receiving inquiries regarding the presence of radioactive materials at Beverly Hills High School (BHHS). These concerns revolved around oil production operations at the BHHS site, located adjacent to the BHHS campus, and the potential for radioactive contamination at BHHS due to these operations. The concerns covered three distinct categories:

- Exposure to elevated concentrations of naturally occurring radioactive materials created by oil production activities;
- Radon exposure resulting from the concentration of naturally occurring radioactive materials; and,
- Exposure from the use of radioactive materials to test oil wells at the site.

DHS investigated these concerns on-site during August and September 2003, and did not identify any radiation levels or radioactive materials above normal background levels at BHHS.

This report provides information regarding the presence and use of radioactive materials at BHHS, and the investigation and testing performed by DHS in response to concerns raised by the public. Based upon this investigation, DHS has concluded there are no radioactive materials distinguishable from natural background at the BHHS site. Also provided is a primer on radioactive materials in general to enhance comprehension of the report material.

II. Radioactive Materials Primer

A. Radioactive Materials

Radioactive materials are a subset of the chemical elements that make up our world. Chemical elements are the building blocks of all matter. Examples include hydrogen, oxygen, zinc, silver, tin, radon, radium, and uranium, to name a few. Every element has at least one radioactive form. Most, but not all, also have non-radioactive forms. These forms are known as “isotopes” of the elements. Each element contains a unique number of protons in its atomic nucleus. Each isotope of an element, whether radioactive or not, contains a unique number of neutrons in the atomic nucleus of the material. So, for example, hydrogen may be stable hydrogen-1 (H-1) with one proton and no neutrons, or may be radioactive hydrogen-3 (H-3) with one proton and two neutrons in each atom.

B. Radioactive Decay

When a radioactive decay takes place, the radioactive element/isotope is transformed to another element/isotope (which may or may not be radioactive), and emits energy in the form of subatomic particles and, in most decays, photons (massless particles). For example, when H-3 decays, it emits a particle known as a beta particle (which is the same as an electron), and becomes the non-radioactive isotope helium-3 (He-3).

The most common forms of radioactive decay involve the emission of a beta particle (one electron) or an alpha particle (two protons plus two neutrons). These emissions are frequently followed immediately by the emission of one or more gamma rays (photons produced in the nucleus of an atom), or one or more x-rays (photons produced outside the nucleus of an atom). Other subatomic particles, such as positrons or neutrinos may also be emitted. Each radioactive isotope can be uniquely identified by the type of particles and/or photons emitted and the energy of those particles and/or photons.

C. Radiation and Radioactive Materials Detection

Radioactive materials can be reliably measured down to very low levels. Testing equipment may include portable instrumentation that can be used in the field, or laboratory equipment used to analyze samples collected in the field and brought to the laboratory for analyses.

Methods that can be used to test for many naturally occurring radioactive materials (known as NORM) in soils include soil sample collection for gamma (and alpha) analyses in a laboratory setting, and field (in-situ) measurements with a High Purity Germanium (HPGe) detector. These types of measurements will readily identify the NORM isotopes, based on the energy of the gamma (and alpha) emissions.

One example of NORM is radon. Because radon occurs as a gas, testing for radon requires the collection of samples in the area of interest using special charcoal canisters, and a laboratory analysis, which relies on measuring the gamma and/or alpha emissions of the materials collected in the canisters to determine the concentrations of radon in the areas from which the samples were collected.

Testing for other radioactive materials is dependent on the type of radioactive decay the radioactive material undergoes. For example, because iodine-131 (I-131) emits a gamma-ray with energy of 364 kiloelectron volts, a detector that responds to gamma radiation and identifies the energy of the gamma emissions can readily identify the presence of I-131.

D. Radioactive Half-Life

Each radioactive isotope decays at a specific rate, known as the “half-life” of the isotope. For I-131, the half-life is approximately eight days; for H-3, it is approximately 12 years; and, for uranium-238 (U-238), it is approximately 4.5 billion years. Every time a half-life passes, half of the original radioactive material has decayed into a new isotope. So, for example, if one starts with 100 units of I-131, then eight days later, approximately 50 units would remain, and another eight days after that, approximately 25 units would remain, and this will continue until essentially all the I-131 has decayed to non-radioactive Xe-131.

E. Naturally Occurring Radioactive Materials

Naturally occurring radioactive materials are extremely widespread in the environment. Some are primordial, meaning they originated at the time of earth's formation, and have not yet decayed away. Uranium, thorium, and an isotope of potassium are common examples of these radioactive materials, which are widespread throughout the earth's crust. These are present in all soil and rocks. Other naturally occurring radioactive materials are cosmogenic, meaning they are extraterrestrial in origin. These are constantly being produced by cosmic interactions in the upper atmosphere. Tritium and carbon-14 are examples of these. Cosmogenic radioactive materials are also extremely widespread, with tritium existing in essentially all of earth's waters and carbon-14 in all organic matter, whether living or dead.

Some naturally occurring radioactive materials (NORM) decay into other radioactive isotopes, forming a long chain of radioactive materials, until they finally decay to a non-radioactive isotope. So, for example, when U-238 decays, it emits an alpha particle, and becomes the radioactive isotope thorium-234 (Th-234), which emits a beta particle, and becomes the radioactive isotope protactinium-234m (Pa-234m). This process continues through many different isotopes until the atom finally becomes the stable isotope lead-206 (Pb-206). Similarly, thorium-232 (Th-232) decays through a long chain of radioactive isotopes, and finally becomes stable lead-208 (Pb-208).

One way to identify whether U-238 or Th-232 present at a site is of natural origin without having been concentrated by manmade processing is to look for the radioactive isotopes in the decay chain. If the isotopes are present in approximately equal radioactive quantities, then the material is said to be in "equilibrium," and we know that it was not processed (concentrated) as is done in the uranium and thorium refining industries.

III. Radioactive Materials Present at BHHS

DHS was presented with concerns regarding the concentration of NORM at BHHS, the potential for elevated radon (which is a radioisotope in the uranium and thorium decay chains) from concentrated NORM, and the use of I-131 to test oil wells at the BHHS site. The bases for these concerns are addressed individually, below.

A. Concentration of NORM

As discussed above, NORM is present throughout our environment. Certain activities, such as oil production, mining, or water filtration have the potential to concentrate NORM to levels exceeding those found in the local environment.

Of particular concern at BHHS were the naturally occurring isotopes U-238 and Th-232, and their decay chains, which include radium-226 (Ra-226) and radon-222 (Rn-222) from the U-238, and radium-228 (Ra-228) and radon-220 (Rn-220) from the Th-232. These materials, as well as naturally occurring potassium-40 (K-40), are all present in the surface and subsurface soils throughout all areas of California, the United States, and the world. Some of these radionuclides are also commonly found in water and air.

Because there are oil production operations at the BHHS site, there were concerns that these operations could increase the concentrations of NORM at the site, and potentially create a radiation hazard. An increase in NORM concentration may occur when oil or water is pumped out of the ground and filtered or processed in such a way that the NORM materials preferentially deposit on filters or in the pipelines used in processing. The preferential deposition of these materials is not caused by the materials' radioactive nature, but by their chemical properties. Notwithstanding the potential for increased NORM concentrations at oil well sites, California oil production operations generally produce lower levels of concentrated NORM compared to oil production operations along the Gulf coast, in northeast Texas, southern Illinois, eastern Kentucky, etc. (Department of Interior, U.S.G.S. Fact Sheet FS-142-99).

DHS tested the BHHS site to determine whether NORM was present in elevated concentrations, and determined the levels were consistent with the natural background for the area. The specific equipment and evaluations used to make this determination are discussed in Sections IV and V.

B. Radon

Both U-238 and Th-232 produce radon in their decay chains. As noted, U-238 produces Rn-222 and Th-232 produces Rn-220. Chemically, radon occurs in the form of a gas, and can present a health hazard from its inhalation. In general, control of radon is best achieved by sealing areas to minimize radon leakage into the area, or by improving ventilation in enclosed areas. Outdoor radon generally dissipates too quickly to pose a hazard.

DHS tested 113 indoor and outdoor locations at the BHHS site to determine whether radon was elevated at the site, and determined that it was not. The specific equipment and evaluations used to make this determination are discussed in Sections IV and V.

C. Radioactive Testing Materials

In addition to NORM, many radioactive materials are artificially produced for use in medicine, academia, and industry. These include radioisotopes used for the diagnosis and treatment of cancer and other disease, used for genetic and metabolic research, used in fire safety applications, manufacturing processes, and nondestructive testing, among other things.

At the operating oil wells adjacent to the BHHS site, I-131 has been used approximately annually (currently biennially) for many years to determine the flow rates in the oil wells. This I-131 usage is required by the Department of Conservation and licensed by DHS. The I-131 is injected into the oil wells adjacent to BHHS to depths of thousands of feet below the surface. Once injected, the material is not detectable at the ground surface, and does not pose any hazard. Because of I-131's half-life, after approximately 80 days only one one-thousandth of the I-131 will remain, deep in the ground, and after 160 days only one one-millionth of the I-131 will remain.

Concerns were raised regarding the potential for a surface spill of the material associated with the injection usage. While possible, such spills are not likely due to injection equipment design and precautions employed when handling the I-131. DHS tested locations around the oil wells adjacent to BHHS and on the BHHS campus for the presence of I-131, and did not detect any I-131. DHS also evaluated the potential immediate risks from a spill of I-131 at the surface, even though DHS has no knowledge that such a spill ever occurred. DHS determined that, given the distance of the wells from the campus, the low amount of I-131 used at any one time, and the intervening barriers (e.g., the 20-foot wall separating the oil wells from the BHHS campus), that an accidental spill of the material would not pose a significant risk to students at the campus. The specific equipment and evaluations used to make this determination are discussed in Sections IV and V.

IV. DHS Testing Equipment

DHS used a combination of portable instruments and laboratory analyses to survey and analyze samples from BHHS and from the local environment around the BHHS site.

Table A below shows a list of the instruments or analyses used, and what they each measure.

Table A. Instrumentation and Analytical Techniques to Measure Radiation

Instrument or Analytical Technique	Types of Radiation Measured and Information Obtained
Microrem meter	Measures ambient gamma radiation in the field and quantifies it as radiation dose per hour to humans.
Portable Plastic Scintillation Detector with Mapping Capabilities (Gamma)	Measures gamma radiation in the field, and geographically maps the gamma profile to determine whether there are unusual concentrations of gamma-emitting isotopes.
In-Situ High Purity Germanium Detector (HPGe)	Measures gamma radiation in the field at discrete locations, and identifies and quantifies radioactive soil content based on these gamma measurements.
Gamma Spectroscopy System (Gamma)	Measures gamma radiation in soils (or other materials) in a laboratory setting, and identifies and quantifies radioactive content based on these gamma readings.
Alpha Spectroscopy System (Alpha)	Measures alpha radiation in soils (or other materials) in a laboratory setting, and identifies and quantifies radioactive content based on these alpha readings.
Radon Collection System	Collects ambient radon in the field, which is later analyzed by a laboratory specializing in radon analyses.

V. Testing and Evaluations

A. Background Determination at BHHS

In order to assess whether there are elevated levels of radiation or radioactive materials at BHHS, DHS collected samples for analyses and made a series of measurements, approximately one-mile upwind of the BHHS campus, to establish the local background level of radiation and radioactive materials in the environment. Measurements were made of the radioactive materials in soils in the area, and ambient readings were taken of radiation levels in the area. Table B below shows the results of those measurements.

Table B. Background Radioactive Materials and Radiation

Location	**Matrix**	**K-40 (pCi/g)**[1]	**U-238 (pCi/g)**	**Th-232 (pCi/g)**	**Ra-226 (pCi/g)**
One mile upwind of BHHS (Kerwood and Olympic)	Soil (Gamma - *In-Situ*)	21.28	1.064	1.016	N/A[2]
One mile upwind of BHHS (Kerwood and Olympic)	Soil (Gamma – Lab)	19.9	1.03	0.878	0.991
One mile upwind of BHHS (Kerwood and Olympic)	Soil (Alpha – Lab)	N/A[3]	0.719	0.836	N/A[4]
Location	**Matrix**	**Ambient gamma radiation**			
BHHS – Local Area	N/A	5 – 6 microrem per hour[5]			

B. Microrem meter

DHS measurements at BHHS of 5 – 6 microrem per hour, including measurements of pipes used in the drilling process, were consistent with natural background gamma radiation levels. Normal background levels of gamma radiation to humans in the United States range from about 4 – 20 microrem per hour.[6]

C. Portable Plastic Scintillation Detector with Mapping Capabilities

DHS mapped gamma radiation levels from the soils at approximately 25 percent of all areas accessible to the detector at the oil production site adjacent to the BHHS campus (or approximately 12.5 percent of the total oil production site), and also mapped 25 percent of the areas of primary concern at the BHHS campus (i.e., 25 percent of the softball field, outdoor basketball courts, and athletic field).

Only natural variations in NORM concentrations were observed. These variations generally corresponded to the variations in the surfaces surveyed (such as the grassy, asphalt, and imported clay surfaces of the various areas at the BHHS campus, all of which will have different concentrations of NORM). Two small areas in the softball field had gamma radiation levels that initially registered slightly higher than the other areas. The highest of these areas was on the western side of the softball field. Additional

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[1] The term "pCi/g" stands for picocuries per gram, and represents approximately 2.2 radioactive decays per minute per gram of soil (or other materials measured).
[2] The gamma emissions from Ra-226 were only analyzed in the laboratory samples.
[3] K-40 does not emit an alpha particle.
[4] The Ra-226 had already been identified as being in secular equilibrium with the U-238 based on the gamma emissions, thus a separate alpha analysis was not conducted.
[5] "Microrem per hour," as used here, is a measure of the radiation dose to humans from gamma radiation in the area.
[6] Additional information on background radiation and radioactive materials in the environment are detailed in a report by the National Council on Radiation Protection and Measurements (NCRP) in Report No. 94, "Exposure of the Population in the United States and Canada from Natural Background Radiation."

measurements in these areas with the HPGe demonstrated they were within the range of natural local background variations. No I-131 was identified at any of the locations mapped.

D. *In-Situ* HPGe Detector

DHS took 12 field measurements with the HPGe detector at the oil production site and at the BHHS campus. Because these measurements are taken over a longer interval of time in a single location, they are generally more accurate than those taken by the Portable Plastic Scintillation Detector used in the mapping mode (discussed in the preceding section). In seven of these field measurements, DHS was able to quantify the radioactive materials concentrations, and they were all found to contain concentrations of NORM that are consistent with the local background NORM concentrations. In five of these field measurements, DHS was unable to specifically quantify the radioactive material concentrations due to uncertainties regarding the depth of the concrete or asphalt or other problems associated with the physical properties of the areas measured; nevertheless, no anomalous levels of radiation or radioactivity were identified. No I-131 or other non-NORM material was identified at any of the locations measured.

E. Laboratory Analyses – Gamma and Alpha

DHS took seven soil samples from the BHHS campus and sent them for gamma and alpha analyses at the DHS Sanitation and Radiation Laboratory. The results of these analyses verified the field measurements, and demonstrated that the concentration of NORM in the samples was within the natural variation of local background NORM. These analyses also demonstrated that the U-238 and the Ra-226 were in equilibrium, indicating that the uranium was from a natural source. No I-131 or other non-NORM material was detected in any of the soil samples.

F. Radon Analyses

The DHS Environmental Management Branch assisted in the placement and collection of 91 radon collection canisters indoors and 22 radon canisters outdoors in various locations at the oil production site, the BHHS campus (athletic field areas and most classrooms), and an off-site background location unaffected by activities in the vicinity of BHHS.

The analyses of the indoor canisters demonstrated an average radon concentration of 0.4 picocuries per liter, with a maximum measurement of 1.6 picocuries per liter. For purposes of comparison, the U.S. Environmental Protection Agency's (EPA's) action level is 4.0 picocuries per liter, or ten times the average concentration at BHHS. No remedial actions are recommended for radon in the range found at BHHS.

The analyses of the outdoor canisters demonstrated an average radon concentration of less than 0.3 picocuries per liter, which is slightly less than the national average of 0.4 picocuries per liter, reported by the EPA in its "Citizen's Guide to Radon" (4^{th} edition, revised May 2002), available at: http://www.epa.gov/iaq/radon/pubs/citguide.html, or by calling the EPA's Indoor Air Quality Hotline at 1-800-438-4318.

Based on these measurements, there is no indication that radon is elevated, either indoors or outdoors, at the BHHS campus.

G. I-131 Spill Evaluation

DHS evaluated the consequences of a theoretical surface spill of I-131 at the oil production site adjacent to the BHHS campus. DHS assumed that the amount of I-131 spilled was five to ten times the amount normally used for individual injections (tests) of oil wells adjacent to the BHHS campus, and assumed it was all spilled in one-meter square area. Using a U.S. Department of Energy dose modeling code (called HOTSPOT), radiation doses from the theoretical re-suspension of the I-131 into the atmosphere were calculated to be approximately one millirem at the fence line between the oil production site and the BHHS campus. This is one percent of the annual public dose limit, not taking into account the 20-foot wall dividing these properties. The presence of the wall would reduce the dose. The potential effects of a spill of the I-131 used at this site would pose no significant risk to students at BHHS. No I-131 spills are known to have actually occurred.

VI. Conclusions

The results of the measurements taken at the oil production site, and at the BHHS campus indicate that: 1) no unusual concentrations of NORM were detected in the area, 2) indoor radon concentrations are at a normal level and well below the EPA action level for indoor radon, 3) outdoor radon concentrations are at a normal level and below the national average, 4) no I-131 or other non-NORM material was detected at the surface at the oil production site adjacent to BHHS or at the BHHS campus, and 5) a reasonable maximum surface spill of I-131 used in the routine testing of oil wells would not pose a significant risk to students at BHHS.