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Characterization of Radioactivity in Hot Springs National Park, Arkansas

C. E. Epperson
University of Arkansas for Medical Sciences

N. R. Rhodes
University of Arkansas for Medical Sciences

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What about the future? We must shift our emphasis from courses that use computers as tools to courses that use computers as an integral part of the learning process. Cognitive science and neuroscience are being used to create new models that can be used to analyze the behavior of students in problem solving. We need to find ways to combine the computing power available in the new microcomputers with this model to improve our educational techniques.

The latest revolution in microprocessors has been used to create computers that look like a PC but have the multi-tasking multi-user capability of mini computers and main frame computers. To utilize fully these capabilities, advanced operating systems such as OS/2 or UNIX must be used. Evolutionary and revolutionary changes in computers are occurring so rapidly that many educators and educational institutions have been unable to utilize fully the phenomenal computing power that is available today. As educators, we need to find ways to use these new computers as an integral part of the learning process.

ROBERT L. DOUGLAS, Computer and Electronics Engineering Technology, Herff College of Engineering, Memphis State University, Memphis, TN 38152.

CHARACTERIZATION OF RADIOACTIVITY IN HOT SPRINGS NATIONAL PARK, ARKANSAS

The objective of this study was to determine the types and measure the levels of radioactive emissions found within the Hot Springs National Park boundaries. The study should help determine if the emissions pose a significant health hazard to the public or to park workers.

The thermal springs of the Hot Springs National Park at Hot Springs, Arkansas, are radioactive. These springs have been a natural resource of international renown for many years. Many tourists are attracted to the spa city and visit the park each year.

The National Park is nestled in the eastern portion of the Ouachita Mountains in west Central Arkansas. The springs emerge in a compact belt about one-fourth mile long and a few hundred feet wide, along the southwestern slope of Hot Springs Mountain. Excavation and covering of springs, to increase and concentrate flows, have reduced the number of spring openings from 72 to less than 40. Each spring opening is completely encased in metal and concrete and capped with a gas-tight metal hatch. A gravity collecting system (Figure 1) channels the flow of the springs to a central reservoir (Hanor, 1980), from which the water is redistributed to individual bathhouses and to public drinking fountains (Bedinger, *et al.*, 1979).

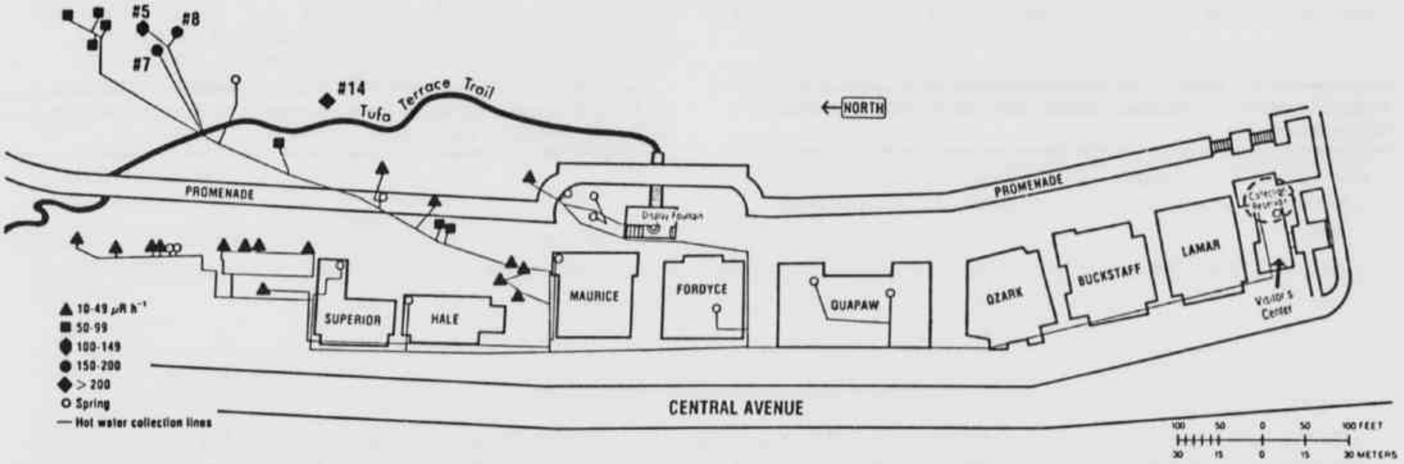

Figure 1. Distribution of the springs and bathhouses. Measured exposure rates of springs are depicted by geometric symbols. Units are μRh^{-1}.

The combined flow of the hot springs is currently about 670,000 gallons per day. The flow of the springs is highest in the winter and spring and is lowest in the summer and fall. While the temperature of individual springs may vary, the temperature of the combined hot springs waters is about 62°C.

The radioactivity of the hot springs waters is due mostly to dissolved radon and radon daughters with a small contribution from radium. USEPA reported a radium concentration in the waters of 2.1 ± 0.22 pCi L^{-1} (Bedinger, *et al.*, 1979). The radon concentration of 25 hot springs ranged from 140 to 30,500 pCi L^{-1} with a model value of 820 pCi L^{-1} (Kuroda, 1953).

Radon concentrations were measured using passive alpha track monitors (ATM) (Ronca-Batista and Magno, 1988) and, in some cases, activated charcoal (AC) canisters (Gray and Windham, 1987). A pressurized ion chamber (PIC) and environmental thermoluminescent dosimeters (TLD) were used to make differential and integral exposure measurements of radon daughters. Gamma ray identities were confirmed using a portable multichannel analyzer (MCA) with a sodium iodide probe. A proportional probe and counter were used for charged particle detection. Several consecutive PIC readings were taken and averaged for each measurement. ATMs and TLDs were left in place for at least 90 days. AC canisters were placed for 48 hour periods. Some measurements have been made year round over the past 2 years.

External gamma fields were measured by placing the PIC in direct contact with spring covers or as close as possible to the region of interest. A map of the area and the exposure levels are shown in Fig. 1. The springs are numbered according to the Park Service's system. The largest exposure rates were observed from springs located at higher elevations. Rates decrease considerably at lower levels. This is probably due to the migration of radon gas back up the gravity collection system to higher elevations.

A highly localized area of relatively intense gamma radiation was found at an abandoned spring site on the upper slopes. This was the former site of the Ral Spring (#14). The spring has been filled in with gravel and soil. The reason for the unusually high exposure rate at this particular spot is presently unknown.

A portable shelter was erected at the Ral spring site to protect monitors and instruments from rain. The low levels of radon and abundance of gammas (Table 1 and 2) indicate that the activity is below ground. This area is an external, not internal hazard. The 2 tables illustrate the reasonably good agreement between different monitoring methods for radon and for daughters.

An ATM and a TLD were placed side by side in each bathhouse basement for 110 days. Short term PIC readings were taken at the same location and averaged. The results are displayed in Table 3.

All bathhouses except one, the Buckstaff, are closed. Elevated radiation readings were found in those basements with flowing springs that leaked or seeped onto the basement floor. Radon levels were surprisingly low, since the bathhouses were sealed and had little or no ventilation.

Family dwellings and other buildings within the reservation were assayed in the same manner as before. Results are tabulated in Table 4. The Park Service ranger station basement was found to be slightly elevated in radon levels.

Table 1. Outdoor Measurements of Radon Over Inactive Spring (Ral)

Measurement Number	2-Day Charcoal Adsorption	90-Day Alpha Track
	pCi L^{-1}	
1.	3.4	2.5
2.	3.4	2.0
Average	3.4	2.25

Table 2. Outdoor Measurements of Gamma Rays Over Inactive Spring (Ral)

Measurement Number	PIC[a] µR h^{-1}	TLD[b] mrem
1.	326	888
2.	316	925
Average	321[c]	907

[a] Instantaneous rates measured over a few minutes

[b] Integrated over 110 days

[c] 321 µR h^{-1} = 847 mR over 110 days

Table 3. Results Obtained from Spa Bath House Basement Measurements

Bath house	Radon[b] pCi L^{-1}	TLD[c] mrad	PIC[d] µR h^{-1}
Lamar	3.1	30	9.6
Buckstaff	3.8	40	6.8
Ozark	8.3	30	12.0
Quapaw[a]	8.0	87	60.0
Fordyce[a]	1.3	49	13.2
Maurice[a]	2.7	30	6.7
Hale[a]	43.7	49	20.3
Superior[a]	9.9	52	12.5

[a] Active spring in basement.

[b] 110 day alpha track monitors.

[c] 110 day thermoluminescent gamma monitors. These include normal background of about 30 mrads.

[d] Averaged instantaneous exposure rates measured over a few minutes.

Table 4. Results Obtained from Basements of Family Dwellings and Buildings Within Reservation

Location	Radon[a] pCi L^{-1}	TLD[a,b] mrad	PIC[c] µR h^{-1}
Ranger Station	5.1	42	10.3
Dwelling 1	2.6	47	9.8
Dwelling 2	2.5	46	10.5
Dwelling 3	2.0	42	10.2
Health Club	1.5	37	7.4
Visitor's Center	1.5	55	10.0
Maintenance Shop	0.8	36	7.9

[a] Integrated over 110 days

[b] This includes an average TLD background of 30 mrads

[c] Instantaneous rates measured over a few minutes

The effect of exposing thermal spring enclosures to the ambient atmosphere is demonstrated in Table 5. Initially the exposure rates of 3 springs were measured with the PIC in contact with the spring covers. Two of the spring covers were then removed, exposing the spring opening to the outside atmosphere. After 1 hour, the covers were replaced and exposure rates re-measured. Two days later the readings were back to normal. The results indicate that once disturbed, equilibria between radon gas and radon daughter plateout under the spring hatch lid is quickly restored.

The exposure rates measured at various times during a year are shown in Table 6. Radioactivity appears to decrease somewhat during the colder months. More likely, this reflects the seasonal decrease in spring flow rates. Repeat measurements are very consistent.

Salient observations from this study include the following:

—Radon levels in dwellings and other park buildings are below any current action level.

—Bathhouse basements have some potential for becoming hazardous but this can probably be remedied with ventilation and sealing of cracks.

—The highest external exposures exist over and immediately adjacent to thermal spring openings.

—Essentially all spa areas were found to be well within acceptable radiation exposure limits.
—Radon and daughters comprise essentially all of the radioactivity present in the park.
—Dried up springs no longer emit gamma rays. The presence of water is evidently necessary for gamma emissions to exist.

Table 5. PIC Reading Over Hatch Covers - Before and After Opening

Spring Number	Before Hatch Removal	$\mu R\ h^{-1}$ After Hatch[a] Replacement	48 hours Later
5.	133	65	136
7.	189	b	190
8.	151	55	161

[a] Spring was opened to ambient atmosphere for one hour before replacing hatch cover.

[b] Hatch not removed.

Table 6. PIC Measurements at Spring Hatch Covers Across Time

Date	Spring Number		
	#5	#7 $\mu R\ h^{-1}$	#8
July 1987	142	185	-
Oct 1987	116	163	-
Nov 1987	119	171	-
Feb 1988	119	-	158
Apr 1988	122	-	164
May 1988	133	189	151
May 1988	136	190	161

- No reading taken

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C.E. EPPERSON and N.R. RHODES, University of Arkansas for Medical Sciences, College of Pharmacy, 4301 West Markham, Little Rock, AR 72205.

STATUS OF THE ACCELERATOR PROJECT AT U.C.A.

A 2.5 MV Van de Graaff accelerator is being installed in a new facility at the University of Central Arkansas. The accelerator and some ancillary hardware was donated to the school approximately 10 years ago, while the area in the building became available almost 4 years ago.

The accelerator itself is one of many variants in a series produced by High Voltage Engineering Corporation. Built in the late 1950's, it has passed through several institutional hands in the interim, but has acquired relatively little actual running time. It was originally intended for use with a negative terminal potential to accelerate electrons, as part of an industrial X-ray system. Our use for the machine has required a conversion to positive terminal operation to produce positive ion beams. A more detailed discussion of these modifications and the installation to date appears below.

The laboratory housing the accelerator was designed expressly for that purpose as part of an addition to the science building completed in 1986. It consists of 4 rooms on the main (upper) floor of the building and one large room below them. Figure 1 shows a plan view of the upper floor area and Fig. 2 shows the lower room.

In Fig. 1 we see 2 primary rooms, the control room and the accelerator vault. The control room is outside the curved shield wall of the vault; it houses the control console for the machine as well as providing space for data acquisition equipment. The 2 smaller rooms to the left of the vault will provide office and research area to faculty and students using the machine.

The accelerator vault is 7.9 m in diameter and is enclosed by a high density concrete radiation shield wall; this room and the entire lower room, equally shielded, constitute the high radiation area of the laboratory. This area is protected against entry when radiation may be produced by a system of interlocks on all entrances.

The accelerator is mounted vertically at the vault center so that the beam will immediately exit into the target room below. The machine's baseplate (A) is shown in Fig. 1, and is approximately 1.2 m square. The accelerator pressure tank stands roughly 2.4 m high and is removed and installed with an overhead track crane. A floor slot (B) allows crane access to the target room below. A large conduit (C) carries control cables from the machine baseplate to the console (D). Gas storage and piping equipment for the insulating tank gas will be installed in the vault.

A stairway leads down to the target room, which occupies the area below all of the upper floor rooms plus a short extension to the west. The target room will contain all of the beam handling system as well as the experimental areas. A wide door on the lower floor allows access for large equipment. A corner of the room houses a shielded neutron irradiation source for use in student experiments.