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PENETRATING IONIZING RADIATION LEVELS OBSERVED IN THE LOWER ARKANSAS AND WHITE RIVER VALLEYS OF ARKANSAS

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ABSTRACT

Environmental levels of penetrating ionizing radiation were measured in the lower Arkansas and White River valleys of Arkansas. Measurements of environmental gamma and cosmic rays were made using a portable high pressure ionization chamber. The surveyed area encompassed a large coal-fired industrial plant. Observed exposure rates ranged from 5.9 microRoentgens per hour (μR/h) to 13.4 μR/h. The average exposure rate for the region was 8.8 μR/h. This value corresponds to 77 millirem (mrem) or 0.77 milliSieverts (mSv) per year. In comparison, a prior state-wide survey reported an average dose equivalent rate of 78.2 mrem (0.782 mSv) per year in Arkansas.

INTRODUCTION

Man has always been exposed to radiation since the environment in which we evolved is radioactive. This environmental radio-activity is composed of natural radioactivity (terrestrial and cosmic) as well as man's contribution from nuclear fallout and industrial practices. Until less than a century ago however, natural radiation was man's only source of exposure. The exposure to man has increased over the past 40 years because of widespread fallout from nuclear weapons tests, increased use of nuclear energy, and a greater use of radioisotopes. Nevertheless, natural background still remains the greatest contributor to the radiation exposure of the United States population today (Spires, 1956; Salon, Lowder, Shambon and Blatz, 1960; Oakley, 1973; and Harley, 1975).

There have been few systematic studies of environmental penetrating radiation exposure. Most such efforts in the United States have been devoted to aerial surveys of limited areas around large nuclear installations. A variety of instruments and methods have been applied to measuring environmental exposure rates (Lowder, Beck and Condon, 1967; Lowder and Condon, 1965) which are typically at levels of microRoentgens per hour (μR/h). The recent advent of portable, rugged and highly sensitive large volume, high pressure ionization chambers has vastly simplified the process of environmental surveys.

Ion chambers measure ionizing radiation exposure. The Roentgen is the unit of Exposure to X- and gamma rays. It is a direct physical measure of the ionization produced per unit mass of air. For regulatory and administrative purposes, a Dose Equivalent unit is used. The Dose Equivalent combines absorbed energy per unit mass with estimates of biological detriment to produce a single normalized value. The SI unit of Dose Equivalent is the Sievert (Sv) which replaces the old unit, the rem (ICRU, 1980). For X- and gamma rays, one Roentgen is essentially equal to .01 Sievert (or 1 rem).

Portable pressurized ion chamber surveys have recently been reported for some areas in the United States and in Europe (Stranden, 1977; Powers and Watson, 1978; and McAuley and Colgan, 1980). A Georgia survey reports 3.5 to 40 μR/h. Surveys in Norway (6.2 - 9.1 μR/h) and Ireland (10.2 - 14.3 μR/h) have been reported.

The measured average exposure rate in the United States from naturally occurring gamma-ray emitters is about 8.2 μR/h at one meter above the soil. Natural radiation contributes a dose equivalent of 70 to 200 mrem (0.70 to 2.0 mSv) per year to the United States population (Oakley, 1973, and Harley, 1975).

Rolniak (Rolniak, 1982) conducted a population weighed study in 1980-1981 with a pressurized ion chamber to establish the natural penetrating radiation background component in all Arkansas cities with a population greater than 5,000. He found readings in the Arkansas and White River Valleys, south of Interstate Highway 40 to be higher than the rest of the state. There was no apparent reason for these higher exposure rates. It was suggested that this area be more extensively surveyed in the future.

The purpose of the study was twofold. The major objective was to more clearly define the magnitude and profile of environmental penetrating background radiation in the Arkansas and White River valleys south of the U.S. Interestate Highway 40. Was this area really more radioative than the rest of the state of Arkansas? Additionally, a detailed survey of the area would for future reference generate an exposure baseline for the entire area.

MATERIALS AND METHODS

The area surveyed was bounded on the north by Interstate 40 from North Little Rock to Brinkley; on the east by Highway 49-S and 1-S from Brinkley to McGehee; on the south by a line from McGehee to Monticello to Fordyce; and on the west by Highway 167 from Fordyce to North Little Rock.

The area encompasses the counties of Arkansas, Jefferson, Lincoln, most of Cleveland, Southern Prairie and Lonoke, northern Drew and Desha, and eastern Grant. A large coal-fired electric power plant is located in the Northwest quadrant of this area. Measurements were also made over the plant's coal pile and fly ash waste dump. Total coverage represents approximately 5600 sq. miles.

Exposure measurements were made with a Reuter-Stokes Model RSS-111 Environmental Radiation Monitor, a portable high-pressure ionization chamber (PIC) especially designed for environmental surveys. The spherical detector, containing ultra-pure argon gas at 25 atmosphere of pressure, responds to X- and gamma rays only. Accuracy is ±5% at 10 μR/h. Exposure readings are displayed by an instantaneous digital reader (in μR/h), by an integral strip chart recorder and by a mechanical scaler (in accumulated μR.)

The PIC was initially calibrated with Ra-226 by the manufacturer. During the study, instrument reproducibility was checked daily using a calibrated disc source of Co-60 affixed to a reference point on the PIC housing. The Co-60 disc was of sufficiently low activity as to produce an instrument response twice that of normal background. The value of the standard was determined to be 81.18 μR/μCi Co-60 with a permissable error of ±5% as this was the manufacturers stated accuracy for the RSS-111. Calibration checks using the Co-60 source were performed both before and after each day of field use. Variance of daily check source readings never varied more than +3% of calibration value.

Two different modes of data collection were used. Stationary integrated readings at selected sites and instantaneous readings while driving from site to site were made.

The PIC was mounted in a low density foam rubber housing while travelling from site to site. The detector, about one meter above ground level, was located in the rear of the vehicle which was used throughout the survey. Instantaneous readings were made every eight kilometers (5 miles) while travelling from one location to the next. An instantaneous reading was also made at every county line, city limit, train track, and major road intersection. The vehicle acted as a shield for the radiation from outside. Values measured inside the vehicle had to be multiplied by a factor of 1.21 to obtain the proper value for unshielded external radiation exposure.

The survey area was divided into a 16.1 by 16.1 kilometer (10 x 10 mile) grid for stationary open-air measurements. At least one stationary measurement was made within each of the grids. Readings were made as close as feasible to the grid center. Sites were also chosen to be near a location which would be easily found on a state or county road map, such as major road intersections. Measurement locations were from 75 to 100 meters (246-328 feet) off the highway, usually utilizing dirt-access roads. In all cases, the chosen area was level, with good soil permeability, and where no overwash would occur. The detector was tripod-mounted well away from the car at one meter above ground level. One meter was chosen as the sampling height since this is the accepted gonadal dose level to man and because gamma flux and exposure are nearly identical at one meter above the ground. Ten minute measurements were made at each site. The instantaneous value was recorded once every 30 seconds. The mean of these 20 values was used to develop an environmental penetrating radiation contour map (Figure 1).

Table 1. Averaged stationary exposure rates observed in the surveyed area. Units are μR/h.

Fairendale	7.0	Sherrill	8.4
Monticello	6.2	Gethsemane	9.3
Backgate	5.9	Hwy 165 E/England	9.4
Redfield	8.0	England	8.8
Noble Lake	10.4	Scott	8.6
Gould	8.2	Hwy 161 N/England	9.9
Garrett Bridge	8.7	Hwy 31 North of Pettis	9.2
Hazen	8.9	Hwy 381 North of Culler	8.7
Wattensaw Wildlife Area	8.8	Humphrey	8.7
Hwy 33 & 86	8.0	Bayou Meto	8.4
Preston Ferry	9.2	St. Charles	9.7
Hwy 146 E/Preston Ferry	9.4	Hwy 146 E/Holly Grove	9.0
Almyra	8.7	Hwy 1 N/Crossroads	9.5
Hwy 152 S/Dewitt	8.9	Hwy 65, 167	13.4
Hwy 276 & 11	8.3	Dixon Road (S/L. Rock)	11.0
Hwy 343 (end of road)	8.9	Hwy 46 North of Sheridan	11.3
Hwy 86 South of Carlisle	8.2	Hardin	8.4
Hwy 343 & 165	7.5	Pine Bergen	7.1
Crockets Bluff	8.3	Nebo	9.1
Hwy 153 W/Crockets Bluff	8.4	Ticnor	9.4
Hwy. 153 & I	8.0	Ethyl	9.7
Hwy 33 & 130	8.4	Clarendon	8.9
Hwy 165 West of Dewitt	8.4	Hwy 190 South of Hardin	7.6
Rydel	10.0	Hwy 54 E/Grapevine	8.0
Hwy 88 South of Altimer	9.1	Toltec	9.8
Hwy 15 & 79	9.2	Hwy 161 South of Scott	9.8

RESULTS

Stationary outdoor exposure rate measurements obtained at the selected locations within the study area are shown in Table 1. These values are expressed as μR/h and include all background contributions. The values range from 5.9 to 13.4 μR/h with a mean of 8.8 μR/h and a standard deviation of $\pm$1.2 μR/h. The value of 8.8 μR/h compares favorably with Rolniak's (1982) average value, 9.3 μR/h for the state of Arkansas. Forty-eight of the 52 values fall within two standard deviations of the mean. Two values were greater than plus two standard deviations from the mean and two were less. The two high deviations are believed due to outcrops of ignious rocks from Granite Mountain. The two low deviations were made in regions of sand and sandy-loam soils which are high in silica.

A few highly localized areas in Arkansas exhibit significantly high exposure rates. Two prime examples are Granite Mountain near Little Rock with 14-16 μR/h and the thermal springs in Hot Springs National Park with 50-80 μR/h. Even portions of Interstate 40 East and West of Little Rock show readings as high as 14.8 μR/h.

Measurements made in the middle of the power plant's coal field registered exposure rates of 6 μR/h. Readings in the plant's flyash dumps were 12 μR/h. Flyash was expected to be higher than coal, since it represents a coal "ash" residue consisting mainly of silica and concentrated metals.

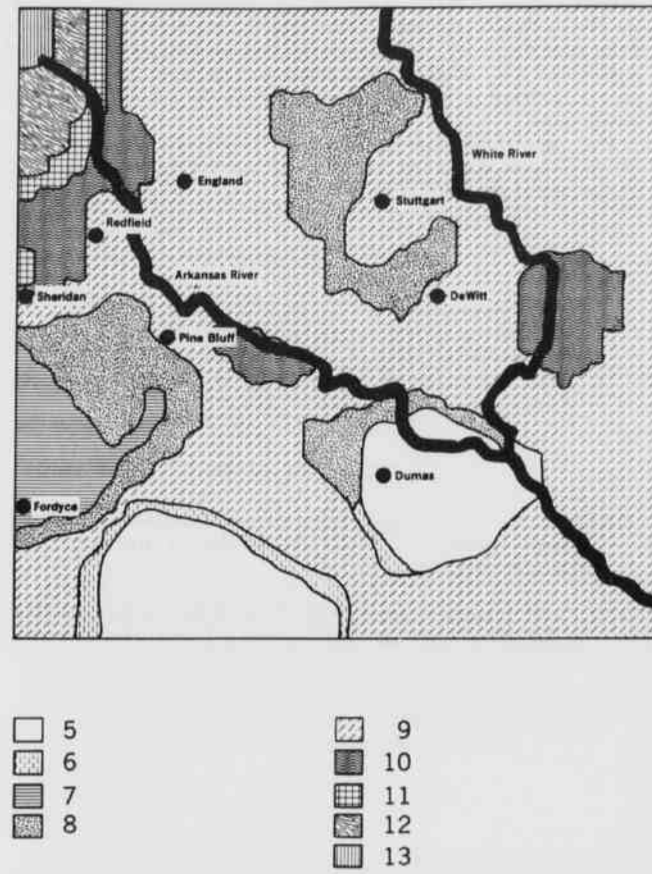

Figure 1. Background penetrating radiation contour map of study area. Units are μR/h.

A background penetrating radiation contour map of the study area is depicted in Figure 1. This map was computer-generated using the data obtained by this study. The contours are approximations since they were generated by mathematical extrapolations from observed data points.

DISCUSSION

Potassium-40, cosmic radiation, and a half dozen members of the uranium/thorium-series radioactive chain produce almost all the natural-occurring gamma rays. Igneous rock (granite), clays and dark shales (organically enriched) are usually enriched in K-40 and members of the uranium and thorium chains. Sand and sandstones are typically very low in radionuclidic species. Rolniak (1982) found this to be true of most all sandy soils, sandstones and clays in Arkansas. This was also born out in our survey.

Rolniak's observations in east central Arkansas were based largely on highway measurements. The elevated readings were due to roadbed materials, such as granite and clay foundations and igneous chat used in road surfacing materials. Readings as high as 14 μR/h have been observed on the roadbed, whereas the surrounding countryside has usually read no more than 6 to 8 μR/h.

A roadbed effect was noted in this study. Subsequently, highway readings were excluded from the data. Only those readings taken off-road and outside the vehicle were used to generate usable data in the final results.

The flyash from the western coal burned by the power plant measures somewhat higher than the average for the ıtire area surveyed. However, the plant's electrostatic precipitators remove more than 99.9% of flyash from stack discharge. Virtually all flyash is scrubbed, recovered from stack gases, and stored on plant property. The flyash from the power plant is believed to make no contribution to the area-wide radiation background.

The range of exposure rates found in East Central Arkansas speak for themselves. Radiation levels in this area are essentially the same as the rest of the state of Arkansas.

ACKNOWLEDGEMENTS

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LITERATURE CITED

HARLEY, J. H. 1975. Natural Background Radiation in the United States. National Council on Radiation Protection and Measurements, Report No. 45.

ICRU. 1980. Radiation Quantities and Units. International Commission on Radiation Units and Measurements, Report No. 33:11-14.

LOWDER, W. M., H. L. BECK, and W. J. CONDON. 1964. Spectrometric determination of dose rates from natural and fallout gamma-radiation in the United States. Nature 202:745-749.

LOWDER, W. M., and W. J. CONDON. 1965. Measurement of the exposure of human populations to environmental radiation. Nature 206:658-662.

McAULEY, I. R., and P. A. COLGAN. 1980. Gamma ray background radiation measurement in Ireland. Health Phy. 39:821-826.

OAKLEY, D. T. 1973. Natural Radiation Exposure in the United States. Environmental Protection Agency 3:12.

ROLNIAK, R. M. 1982. Population exposure to environmental penetrating radiation in Arkansas. Unpubl. M.S. Thesis. College of Pharmacy, University of Arkasnas for Medical Sciences, Little Rock.

SOLON, L. R., W. M. LOWDER, A. SHAMBON, and H. BLATZ. 1960. Investigations of natural environmental radiation. Science 3:903-906.

SPIRES, F. W. 1956. Radioactivity in man and his environment. Brit. J. Radiology 8:409-417.

STRANDEN, E. 1977. Population doses from environmental gamma radiation in Nörway. Health Phy. 33:319-333.