ARMS-72.6.1

AERIAL RADIOLOGICAL MEASURING SYSTEM

AERIAL RADIOLOGICAL MEASURING SURVEY
OF THE LAKE ONTARIO ORDNANCE WORKS
AND VICINITY IN JUNE 1972

U. S. Atomic Energy Commission

MASTER

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AERIAL RADIOLOGICAL MEASURING SURVEY OF THE LAKE ONTARIO ORDNANCE WORKS AND VICINITY IN JUNE 1972

EG&G, Inc., Las Vegas, Nevada

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This report is part of a series on the continuing activities of the Aerial Radiological Measuring System operated for the U. S. Atomic Energy Commission. The ARMS program is managed by the Division of Operational Safety and is a cooperative effort among various offices and divisions of the Commission.

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ABSTRACT

The Aerial Radiological Measuring System (ARMS) was used to perform an aerial radiological survey of the Lake Ontario Ordnance Works and surrounding area 17 June 1972. The data included a survey of the terrestrial background gamma radiation and an analysis of selected soil samples.

A high-sensitivity detection system collected gamma-ray spectral and gross-count data. The data were then computer processed into an isoexposure contour map, 3 feet above the ground, of a 21-square-mile area. Results indicated the presence of two storage areas with a high concentration of Ra-226 and its daughters.

In addition, an independent ground survey was conducted by the United States Atomic Energy Commission, Oak Ridge Operations Office (USAEC/ORO), during June 1972, following cleanup operations. These results are compared with the ARMS measurements.

Results from both surveys confirm that, with the exception of Six Mile Creek and areas adjacent to the storage sites, the measured levels in the uncontrolled areas surrounding the site did not exceed 50 μ R/hr.

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1.0 INTRODUCTION

1.1 Identification of Survey Area

The Lake Ontario Ordnance Works site is located approximately 2 miles east of the Niagara River and about 3 miles northeast of Lewiston, New York. The terrain is low farmland with a few small streams and ponds. The area surveyed consisted of 21 square miles and is sparsely populated.

The Lake Ontario Ordnance Works was used as a USAEC storage site for certain materials related to the processing of uranium. This survey was part of a cleanup program being carried out at the site.

Figure 1 is an aerial photo mosaic of the survey location.

1.2 ARMS Program

The Aerial Radiological Measuring System (ARMS)¹ operated by EG&G, Inc., Las Vegas, Nevada for the U. S. Atomic Energy Commission, was used to perform an aerial radiological survey of an area surrounding the Lake Ontario Ordnance Works during June 1972.

This survey was made as part of a continuing nationwide ARMS program started in 1958 to document radiation levels surrounding facilities maintaining or utilizing radioactive materials. The present survey represents the first such performed in the Lake Ontario Ordnance Works area.

The high-sensitivity detection system on board the aircraft collects gamma-ray spectral and gross-count data on each flight line of the survey. The gamma-radiation and aircraft-position information are documented for processing by a computer into an isoexposure contour of the area surveyed.

1.3 ARMS Equipment and Procedures

The ARMS aircraft and its on-board radiation detection equipment were used to measure the terrestrial radiation from the site and the surrounding area. The ARMS equipment and procedures have been discussed in detail elsewhere¹ and, hence, will only be described briefly here.

FIGURE 1

The ARMS surveys are flown in a Beechcraft Twin Bonanza at an altitude of 300 to 500 feet above the ground level (AGL) at a ground speed of about 140 knots (235 ft/sec). The ground position of the aircraft as well as its altitude AGL are measured and recorded every second via a radar-navigation-computer system. The position and altitude measurements are accurate to ± 350 and ± 5 ft, respectively.

The aerial radiation measurements are of two distinct types and both are made simultaneously: gross gamma count (intensity) measurements and gamma spectral (identity) measurements. The detector system, common to both, consists of an integrated package of fourteen 4 x 4-inch NaI(Tl) scintillation crystals, each mounted on its own photomultiplier assembly. The detector system signal is recorded in both the gross gamma count computing system and in the multichannel spectrum analyzer. The data collection system is shown in Figure 2.

The gross gamma count system consists of an amplifier-discriminator-computer package that counts and records the total number of gamma-rays of energy greater than 50 keV that are detected during a precisely determined 1-second time interval. The gross gamma count rate (number of detected gamma-rays per second) is measured every second and is simultaneously and automatically recorded along with the aircraft position and altitude. Gross gamma count rates, typical of background, are several thousand per second. As a backup and complement to the digital readout of the gross gamma count data, a record is made on a continuous strip chart plot of both gross gamma count rate and altitude as a function of distance.

Whereas the gross gamma count data specify the intensity of radiation as a function of position, the gamma spectral data identify the isotopic species. A pulse height analyzer automatically sorts detected gamma-rays according to energy, thereby generating a number-per-unit-energy versus energy spectrum. In wide area surveys, the typical acquisition time for a gamma-ray spectrum is several minutes, thereby characterizing the average radiological properties of a tract several miles in length. However, if an area of interest is indicated by an increase in the gross gamma count data, spectral data acquisition times of only a few seconds are used to isolate the area spatially. If further investigation is warranted, a similarly equipped ground mobile unit with better areal and energy resolution is available as part of the ARMS program.

FIGURE 2. View of the interior of the Aerial Radiological Measuring System (ARMS) aircraft showing detector package and electronics data collection system.

1.4 Reduction and Presentation of Data

The raw data from the gross gamma count and the gamma spectral measurements are permanently recorded on paper tape in a form which permits computer processing and analysis to characterize the radiological properties of the area surveyed. From calibration measurements over a field of uniformly dispersed natural radioactivity, the altitude dependence of the gross gamma count rate is determined and a conversion factor is computed. Using this conversion factor and the survey altitude data, the raw gross count rate is converted to exposure rate ($\mu\text{R/hr}$) at 3 feet above ground (designated as "terrestrial exposure rate").

This exposure rate conversion factor was obtained by repeated flights, from 200 to 1000 feet above terrain containing known distributions of natural isotopes. Such conversion factors have proved valid over distributed fission product fields, with a variation of less than 25%. In practice, variations of 2 $\mu\text{R/hr}$ or greater can be reliably observed in repeated flights over the same area.

At an altitude of 300 feet, the field of view of the system is approximately 1/4 mile wide for a mean energy of naturally occurring isotopes.

2.0 SURVEY PLAN

2.1 Specification of Flight Lines

The planned survey area for the Lake Ontario Ordnance Works consisted of 15 flight lines approximately 7 nautical miles long and spaced 0.2 nautical miles apart. The flight lines were oriented in an east-west direction. The gamma-ray spectral, gross-count, aircraft position, and meteorological information were collected along the flight lines. These lines are shown in Figure 3(b).

2.2 Specification of Ground Truth Measurements

Prior to the survey, Mr. Richard Smith, United States Atomic Energy Commission, Oak Ridge Operations Office (USAEC/ORO), was contacted at the site. He provided information on the exact site boundaries and soil sample locations. These samples were spectrum analyzed with the on-board aircraft system, providing identification of isotopes present in the survey area.

2.3 Coordination with Local Authorities

Approvals for the low level flight were obtained from the FAA and from a military radar site located on the northern side of the Lake Ontario Ordnance Works. Public announcements were published in the local newspapers to inform the public of the planned low level survey flights.

3.0 RADIOLOGICAL SURVEY

3.1 Survey Mission

The aerial survey to collect radiological data at the Lake Ontario Ordnance Works area was conducted on 17 June 1972. This survey required a total flying time of 3 hours. The base of operations for this survey was Buffalo, New York.

Gross count and spectral data were simultaneously collected at an altitude of 300 feet. Spectral collections were accumulated over approximately 2 minute live-times during which the aircraft traveled approximately 6 miles; consequently, 1 spectrum per line was collected.

3.2 Gross-Count Data

The gamma-ray gross-count data and aircraft position information collected on the flight lines are processed by the computer to make an overlay on U.S.G.S. topographical maps (1:24000 scale). The typical nonterrestrial background encountered during a survey consists of cosmic ray, aircraft and airborne radioactive contributions³. The gross-count data, after being compensated for these contributions, are normalized to a standard air mass. The resultant net count data are computer processed to give an exposure rate in microroentgens per hour ($\mu\text{R/hr}$) at the 3-foot level above terrain. The cosmic ray exposure rate is then added to the terrestrial exposure rate to give a composite exposure rate. The various exposure rates are processed into an iso-exposure contour map, which is superimposed upon a map of the area.

Figure 3(c) is a topographical map for the Lake Ontario Ordnance Works on which an isoexposure contour map has been overlaid. A cosmic radiation contribution of $3.3 \mu\text{R/hr}$ is included in the data shown on the overlay.

The exposure rates over the "Waste Storage Area" and the "Silo Waste Storage" areas, shown in Figure 3(c), were significantly above the nominal terrain exposure levels (8 to $10 \mu\text{R/hr}$). The increase in the terrestrial exposure rate for the lines flown near the Silo Waste Storage was attributable to the material stored in the silo. The maximum ground exposure rate inferred from ARMS data, directly over the Waste Storage Area, was 0.70 milliroentgen per hour. The field of view of the detector

FIGURE 3(a)

FIGURE 3(b) (Figure continues on pages 10 and 11.)

system is approximately 1/4 mile wide. The exposure rate measured by the aircraft is an average exposure rate over the entire area of the field of view of the detector system.

3.3 Spectral Data

Prior to takeoff on the survey mission, the system was calibrated with an yttrium-88 source. Yttrium-88 has two prominent gammas: at 0.898 and 1.836 MeV. The calibration source is used to set the gain of each crystal of the 14-crystal array. Each gamma-ray detector is a 4 x 4-inch sodium iodide, thallium-activated, crystal. Spectral data are recorded from 0.0 to 3.0 MeV.

A spectrum collected over the Waste Storage Area is included in Appendix A. The table preceding the spectral plot lists the energies and isotopes identified from the data. Only the more prominent photo-peaks have been included in the tabulation A-1.

The spectral data revealed a normal distribution of naturally occurring isotopes in the Lake Ontario area, Figure 4, except over the material storage sites. Over these areas, the high concentrations of radium-226 and its daughters appear to be responsible for the increased exposure rates.

3.4 Soil Samples

A soil sample was collected in the Waste Storage Area and returned to the laboratory for analysis. Only naturally occurring isotopes of the uranium series were detected in the soil samples. The radium-226 concentration of 10 ± 5 picocuries per gram of soil was determined with a calibrated 4 x 4-inch sodium iodide crystal.

Figure 5 is a sodium iodide spectrum of the soil sample (0 to 3.5 MeV). In Figure 5, the uranium series isotopes detected were radium-226 (the parent), lead-214 and bismuth-214 (daughters of radium-226), and thallium-208 (daughters of thorium-232).

Figure 6 is a sodium iodide spectrum of the soil sample (0.0 to 0.80 MeV).

SPECTRUM NO. 45
 DATE 06-17-72
 LIVE TIME 1.49
 INTEGRATED CT. 240131.
 TYPE GROUND DEPOSITION
 ALTITUDE 300.
 AIRCRAFT (ARMS)

Figure 4 Typical background spectrum of the Lake Ontario area.

GAMMA ENERGY SPECTRUM OF LAKE ONTARIO
ORDNANCE WORKS SOIL SAMPLE

FIGURE 5

4.0 COMPARISON WITH GROUND SURVEY RESULTS

4.1 Conduct of Ground Survey

The ground survey² was conducted by a team from the United States Atomic Energy Commission, Oak Ridge Operations Office (USAEC/ORO). The instruments used for the ground survey were low-level sodium iodide scintillation counters, Baird-Atomic Model NE 148A. On the medium (0 to 300 $\mu\text{R/hr}$) and high (0 to 3000 $\mu\text{R/hr}$) ranges, these instruments were calibrated with an NBS standard radium gamma ray source at USAEC/ORO. The low range scale (0 to 30 $\mu\text{R/hr}$), on which most of the measurements were taken, was calibrated at USAEC/ORO using natural radiation background (~ 10 $\mu\text{R/hr}$ as determined by a shielded G-M detector, which had been calibrated with an NBS radium source).

4.2 Comparison of Data

In performing the ground measurements, the site was divided into several different survey areas [see Figure 3(d)]. These same areas were also used for an intercomparison of results. Some of these regions were quite small with no flight lines passing directly over them, while others were large enough that two or three flight lines crossed over the area. Since the objectives of the ARMS survey were to provide broad area coverage and an overall confirmation of the ground measurements, the pattern flown was not optimum for comparison of ARMS and USAEC/ORO data.

Table 1 lists the data to be compared. The first column indicates those survey areas for which both ARMS and USAEC/ORO results were available. In the next column are the ARMS composite terrestrial exposure rates in $\mu\text{R/hr}$. These values were determined by averaging the individual one-second measurements over those portions of the flight lines that are above the survey area considered. The last column refers to the USAEC/ORO ground measurements². The values listed were determined by numerically averaging over the equally-spaced measured values in each region. A standard deviation σ also was calculated for each area. The values presented are the range within one standard deviation of the average $\bar{D}$, i. e., $\bar{D} - \sigma$ to $\bar{D} + \sigma$. It should be pointed out that all data listed here are post-cleanup.

The maximum and minimum ground measurements in each survey area are outside the range of the maximum and minimum ARMS values.

Table 1 Comparison of Exposure Rates for ARMS and
USAEC/ORO Surveys

<u>AREA</u>	<u>ARMS, $\mu\text{R/hr}^*$</u>	<u>USAEC/ORO $\mu\text{R/hr}^{**}$</u>
B	8 ± 2	12 ± 3
C	13 ± 4	16 ± 7
D	8 ± 2	12 ± 2
F	13 ± 4	20 ± 10
G	10 ± 2	17 ± 5
H	9 ± 2	14 ± 5
N	11 ± 2	17 ± 7
N'	9 ± 2	19 ± 6
Q	9 ± 2	14 ± 3
S	10 ± 2	17 ± 7
T	9 ± 2	18 ± 7
V	8 ± 2	12 ± 3
Waste Storage	700 ± 100	1200 ± 900

---

*Values shown are averaged over the flight line(s) crossing the area.

**Values shown are averaged over the entire area designated.

This is to be expected since the 3-ft USAEC/ORO ground measurements do not have nearly the averaging effect that the 300-ft ARMS measurements do. Or, stated another way, the ARMS detectors respond to radiation from a much larger surface area (typically about 1/4 mile wide) than do the detectors held at 3 ft above the ground. For an isolated point source, the ARMS system will tend to spatially smooth out the source distribution, which results in a more widely distributed source with a smaller peak intensity. This effect is seen in the Waste Storage Area. The same effect would be found for other nonuniformly distributed sources, such as a line source or an areal hot spot. For example, in regions T, U, V, and W a contaminated central drainage ditch flows at right angles to the ARMS flight lines.

The mean radiation levels in the ditch are approximately four times background. However, because of the much smaller surface area and depth of the ditch, the total radiation level seen by the ARMS aircraft increases less than 20% above background, which is consistent with the 8 to 10 $\mu\text{R/hr}$ levels observed by ARMS. Nevertheless, ARMS could map such sources explicitly by flying at a lower altitude or along the line source.

As indicated in Table 1, in general the USAEC/ORO results are about 40% higher than the ARMS measurements. However, the range of the USAEC/ORO and ARMS values overlap for most of the survey area. The ARMS calibration procedures are reported in Reference 3. Experience⁴ has shown that a single conversion factor can be applied to ARMS data for a variety of sources and locations with an uncertainty of about $\pm 20\%$. Reference 2 states that the USAEC/ORO calibration technique used may overestimate gamma ray levels by as much as 15 to 20% if a significant portion of the gamma ray spectrum were less than 200 keV. In fact, about half of the gamma rays detected by the ARMS system at the 300-ft altitude are less than 200 keV. Other factors could also account for differences between the ARMS and USAEC/ORO results. Since the surveys were not performed at exactly the same time, the meteorological and soil moisture conditions were different for each survey. The ARMS survey was made immediately after a rain. Thus, the increased soil moisture could account for a 10 to 20% reduction in radiation levels on the day of the ARMS survey⁵.

5.0 SUMMARY

5.1 Survey Results

The 21-square-mile aerial survey of the area surrounding the Lake Ontario Ordnance Works revealed that both the concentration and relative abundance of isotopes are consistent with normal background radiation throughout the United States.

The isolated storage sites revealed higher concentrations of the isotopes from the uranium series. These areas, as designated in Figure 3(c), were significantly above normal background. Ground surveys by USAEC/ORO corroborated these results. The flight lines were close enough together to overlap the field of view of the detector system, thus assuring complete coverage.

5.2 Soil Samples

Only naturally occurring isotopes of the uranium series were detected in the soil samples.

5.3 Conclusion

The ground exposure rates, derived from the aerial radiation survey, over most of the area were predominantly in the 8 to 10 $\mu\text{R/hr}$ range, 3 feet above the ground.

For areas other than the two storage sites and the central drainage ditch, each of which will remain under USAEC control, and Six Mile Creek, the following can be concluded from both the ARMS and USAEC/ORO survey results: (1) No point sources emitting gamma rays above 1.0 MeV equal to or greater than 10 millicuries existed on the ground surface; (2) no large area (1/4 mile diameter) existed in which the ground exposure rates were significantly above normal background; (3) with the exception of areas adjacent to the storage sites and Six Mile Creek, the measured levels in the uncontrolled areas surrounding the site did not exceed 50 $\mu\text{R/hr}$.

Differences between ARMS and USAEC/ORO results may be explained by: (1) USAEC/ORO data may be overestimated by 15 to 20% because of calibration techniques; (2) ARMS data were taken immediately after a rain. Increased soil moisture may have reduced the

radiation levels by 10 to 20% on the day of the ARMS survey; (3) the ARMS system averages incremental radiation contributions over large areas. For instance, USAEC/ORO did not take data over swampy areas. The lower radiation levels normally found above water-covered areas will be averaged in the ARMS response.

APPENDIX A GAMMA-RAY SPECTRAL CHART

This section contains a spectrum that was taken over the Waste Storage Area.

The tabulation preceding the spectrum shows the energies present and the isotopic contributor associated with the photopeaks observed.

Table A-1 Gamma-ray energies and isotopes consistent with spectral data collected over the Waste Storage Area

OBS. ENERGY (MEV)	RADIONUCLIDES CONSISTENT WITH SPECTRAL PHOTOPEAKS											
	FISSION PRODUCTS						ACTIVATION PRODUCTS				BACKGROUND	
0.35	.	.	.	.	.	.	.	.	.	.	Pb-214	
0.61	.	.	.	.	.	.	.	.	.	.	Bi-214	
0.94	.	.	.	.	.	.	.	.	.	.	Bi-214	
1.12	.	.	.	.	.	.	.	.	.	.	Bi-214	
1.46	.	.	.	.	.	.	.	.	.	.	K-40 + Bi-214	
1.76	.	.	.	.	.	.	.	.	.	.	Bi-214	
2.20	.	.	.	.	.	.	.	.	.	.	Bi-214	
2.62	.	.	.	.	.	.	.	.	.	.	Tl-208	

SPECTRUM NO. 48
DATE 06-17-72
LIVE TIME 1.00
INTEGRATED CT. 285458.
TYPE GROUND DEPOSITION
ALTITUDE 500.
AIRCRAFT (ARMS)

FIGURE A-1 Spectrum collected over Waste Storage Area.

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