USE OF GEOPROCESSING TECHNIQUES IN QUANTIFYING RADIOLOGICAL EXPOSURE ASSESSMENTS

R. Keith Owenby, David M. Runyon, J. Thomas Kitchings
and Susan Walter Coker
ERCE, Denver Colorado

ABSTRACT

Atmospheric transport modeling (MICROAIRDOS™) is compiled with digital cartographic and geoprocessing techniques to enhance the conceptualization of exposure assessment scenarios. Use was made of a fictitious nuclear facility to model releases from routine plant operations and from an accident occurring at the facility. Readily available resource data, e.g. wildlife preserves, demographical distributions, farms, and waterways were mapped using AutoCad™. Contouring of the radiological dose from the MICROAIRDOS™ model over the resource maps not only identified potential exposure populations, but provided an estimate of the magnitude and frequency of exposure for each receptor. The results suggest that these techniques can be used in the risk characterization step of a baseline risk assessment.

INTRODUCTION

The focus of an exposure assessment at sites requiring a human health risk assessment is on providing an estimation of the magnitude, frequency, duration, and route of exposure of organisms to chemicals present at or migrating from the site. The assessment is primarily concerned with current as well as future exposures and is usually based on current measurement models that predict future exposures. Integral parts of the overall process include characterization of the physical setting, identification of potentially exposed populations, identification of pathways, and finally a quantification of the exposure.

The intense public scrutiny that DOE facilities have received regarding management of wastes, environmental remediation, and restoration programs, has resulted in a need to communicate complex risk-exposure data in a manner which can be easily assimilated by both public and scientific communities. To demonstrate the potential use of geoprocessing techniques in achieving this goal, a fictitious nuclear (Rifle) facility was located in central Colorado approximately 3 miles West of the town of Silt along Interstate 70. Radionuclide release source terms, pathway and meteorological data, and population data were gathered from various sources (1,2,3). The atmospheric transport model, MICROAIRDOS™, was used to a) model radiological releases from routine facility operations at the Rifle plant and b) estimate the extent of exposures resulting from an accidental or single release of the entire radiological inventory. By contouring the exposure concentrations of the released radioactivity and overlaying these upon the areal resource map, potentially exposed populations are readily identified and an estimate of the quantification of the exposure made.

THE MICROAIRDOS TRANSPORT MODEL

MICROAIRDOS™ was utilized to estimate the annual-average concentration of each radionuclide in the source term in air at ground level as a function of direction and distance from the source(4). Calculations were made for 16 compass directions and 10 downwind distances from the source.

The annual average concentration of a radionuclide in air at ground level at an environmental location was used to estimate the external dose from gamma radiation to an individual living at that location for an entire year as a result of his immersion in an assumed semi-infinite cloud of that concentration. The air concentration at each location was also used to estimate internal dose via inhalation. Input dose conversion factors for each radionuclide and organ include contributions from radioactive daughters growing in after human intake. These factors, when multiplied by intake for one year, resulted in annual dose commitment values.

Rates of deposition on ground surfaces were employed to estimate external doses resulting from gamma radiation emanating from contaminated ground. Doses are estimated for a point one meter above an infinite plane. Ingestion doses resulting from deposition of radionuclides on crop land and pasture have been estimated for vegetables, meat, and milk consumption. Intake by humans is calculated from input values assumed for daily consumption of each of the three types of food. Dose commitments are calculated using dose conversion factors.

The model was run to estimate the highest annual sector-averaged individual dose. The input parameters for calculating the effective doses resulting from routine operations are presented in Table I. The accident scenario utilized the same parameters except that the frequency of wind direction was modified to blow primarily in an easterly direction. The actual wind frequencies used were E = 0.75; ESE = 0.08; ENE = 0.15; and NE = 0.02. Pacquill atmospheric stability category C (stable) was used, and the wind speeds were assumed to be 10-12 meters per second for the duration of the release.

THE RIFLE PLANT SITE

The mapping of the facility site included a single livestock (ranching) area, one dairy operation, various wildlife habitat or areas along the Colorado River, and the towns of

TABLE I

Input Parameters for Calculating Maximum Effective Individual Sector-Averages Doses for Routine Releases Resulting From Operations at the Rifle Facility

PHYSICAL RELEASE HEIGHT IN METERS = 20
MOMENTUM-DOMINATED PLUME RISE IS CALCULATED.
STACK DIAMETER IN METERS = 2
STACK GAS VELOCITY IN METERS/SEC = 15.2
AVERAGE ATMOSPHERIC LID FOR THE AREA = 2000 METERS
LENGTH OF TIME THAT THE SOURCE HAS BEEN EMITTING RADIONUCLIDES WHICH DEPOSIT ON GROUND SURFACES = 100 YEARS

RADIONUCLIDES RELEASED	RELEASE RATE (CURIES/YEAR)
I-131	3.800E-005
Pu-238	9.900E-005
Pu-239	1.100E-004
Sr-90	2.600E-003
U-235	7.100E-004

DOSE PATHWAYS AND FOOD TYPES INCLUDED IN THIS COMPUTER RUN

INHALATION
AIR IMMERSION
SURFACE EXPOSURE
FOOD INGESTION

PRODUCE
LEAFY VEGETABLES
MILK
MEAT

RADIONUCLIDE-INDEPENDENT PARAMETERS	VALUE
PRODUCE CONSUMPTION IN KG/YEAR	176
LEAFY VEGETABLE CONSUMPTION IN KG/YEAR	18
MILK CONSUMPTION IN LITERS/YEAR	112
MEAT CONSUMPTION IN KG/YEAR	85
DRINKING WATER CONSUMPTION IN LITERS/YEAR	511
ANNUAL BREATHING RATE IN CUBIC METERS/YEAR	8030

PERCENT OF UNCONTAMINATED FOOD CONSUMED IN AREA

PRODUCE	0
LEAFY VEGETABLES	0
MILK	0
MEAT	0

VALUES FOR AGRICULTURAL PARAMETERS	VALUE
SOIL DENSITY (GRAMS/CU CM)	1.433
DEPTH OF PLOW LAYER (CM)	15.0
AGRICULTURAL PRODUCTIVITY-PASTURE (KG/SQ METER)	0.28
AGRICULTURAL PRODUCTIVITY-VEGETABLES (KG/SQ METER)	0.716
FRACTION OF YEAR ANIMALS GRAZE ON PASTURE	0.5
FRACTION OF DAILY FEED THAT IS PASTURE GRASS WHEN ANIMALS GRAZE ON PASTURE	0.5
CONSUMPTION RATE OF CONTAMINATED FEED BY ANIMAL (KG/DAY)	15.6
TRANSPORT TIME FROM ANIMAL FEED-MILK-MAN (DAYS)	2.0
MILK PRODUCTION OF COW (LITERS/DAY)	11.0
TIME FROM SLAUGHTER OF MEAT ANIMAL TO CONSUMPTION (DAYS)	20.0
MUSCLE MASS OF MEAT ANIMAL AT SLAUGHTER (KG)	200.0
FRACTION OF MEAT-PRODUCING HERD SLAUGHTERED PER DAY	0.00381
FALLOUT INTERCEPTION FRACTION FOR PASTURE	0.57
FALLOUT INTERCEPTION FRACTION FOR VEGETABLE CROPS	0.2
FRACTION OF RADIOACTIVITY RETAINED ON VEGETABLES	0.5
FRACTION ON RADIOACTIVITY RETAINED ON VEGETABLES AFTER WASHING	0.0029
REMOVAL RATE CONSTANT FOR LOSS BY WEATHERING (PER HOUR)	1440
PERIOD OF EXPOSURE DURING GROWING SEASON - PASTURE (HR)	2880
PERIOD OF EXPOSURE DURING GROWING SEASON - VEGET. (HR)	0
TIME DELAY - INGESTION OF PASTURE GRASS BY ANIMAL (HR)	2160
TIME DELAY - INGESTION OF STORED FEED BY ANIMAL (HR)	336
TIME DELAY - INGESTION OF LEAFY VEGETABLES BY MAN (HR)	336
TIME DELAY - INGESTION OF PRODUCE BY MAN (HR)	1
FRACTION OF PRODUCE INGESTED GROWN IN GARDEN	1

TABLE I
(Continued)

METEROLOGICAL DATA

FREQUENCY OF WIND DIRECTIONS

WIND TOWARD	FREQUENCY
N	0.031
NNW	0.032
NW	0.033
WNW	0.030
W	0.029
WSW	0.032
SW	0.044
SSW	0.045
S	0.050
SSE	0.096
SE	0.108
ESE	0.118
E	0.148
ENE	0.110
NE	0.052
NNE	0.042

FREQUENCY OF EACH STABILITY CLASS FOR EACH DIRECTION

WIND TOWARD	FRACTION OF TIME IN EACH STABILITY CLASS						
	A	B	C	D	E	F	G
N	0.0177	0.0079	0.0217	0.3476	0.3051	0.2000	0.1000
NNW	0.0106	0.0080	0.0186	0.3755	0.2374	0.2000	0.1500
NW	0.0143	0.0082	0.0460	0.4728	0.2288	0.1500	0.0800
WNW	0.0188	0.0113	0.0562	0.2125	0.4412	0.1500	0.1100
W	0.0086	0.0051	0.0231	0.3259	0.1873	0.2000	0.2500
WSW	0.0182	0.0125	0.0593	0.6192	0.1961	0.0500	0.0500
SW	0.0268	0.0134	0.0609	0.6745	0.1845	0.0200	0.0200
SSW	0.0314	0.0135	0.0381	0.5000	0.2511	0.1500	0.0200
S	0.0441	0.0269	0.0883	0.6010	0.1097	0.0700	0.0600
SSE	0.1206	0.0686	0.1809	0.5405	0.0603	0.0300	0.0000
SE	0.1303	0.0663	0.1919	0.5024	0.0782	0.0300	0.0000
ESE	0.2199	0.1178	0.2225	0.3743	0.0445	0.0200	0.0100
E	0.2470	0.1250	0.3659	0.2427	0.0183	0.0000	0.0100
ENE	0.2553	0.1172	0.2101	0.3537	0.0479	0.0100	0.0058
NE	0.0363	0.1162	0.2263	0.4428	0.0183	0.1600	0.0000
NNE	0.0748	0.0312	0.1121	0.5638	0.1620	0.0300	0.0300

AVERAGE WIND SPEEDS

WIND TOWARD	WIND SPEED (METERS/SEC)						
	A	B	C	D	E	F	G
N	1.67	2.21	2.90	4.17	2.97	2.04	1.00
NNW	1.59	2.06	2.55	3.19	2.30	1.71	1.00
NW	1.62	2.17	2.37	2.44	1.97	1.22	1.00
WNW	1.53	2.05	2.39	2.26	1.71	1.29	1.00
W	1.54	2.05	2.38	2.23	1.19	1.03	1.00
WSW	1.58	2.09	2.50	2.28	1.58	1.29	1.00
SW	1.50	1.98	2.52	2.60	1.74	1.39	1.00
SSW	1.41	1.80	2.67	2.45	1.75	1.37	1.00
S	1.25	1.54	2.15	2.15	1.92	1.51	1.00
SSE	1.54	2.64	2.34	2.33	2.27	1.75	1.00
SE	1.61	2.62	3.13	3.65	2.46	2.13	1.00
ESE	1.80	2.62	3.76	4.29	2.89	2.76	1.00
E	1.58	2.64	3.83	4.09	2.53	2.16	1.00
ENE	1.54	2.83	3.83	3.84	2.71	2.02	1.00
NE	1.51	2.48	3.43	3.85	2.72	1.87	1.00
NNE	1.74	2.34	3.27	4.11	3.04	1.94	1.00

Silt and Rifle. In addition, major transportation routes and other waterways were included in the base map (Fig. 1). Each potentially exposed population and/or receptor group was identified on the base map. By providing the location of each potential receptor, the dose concentration contour overlay can provide an estimate of the magnitude, duration, and frequency of exposure.

RESULTS

The releases from routine facility operations predominantly move to the east toward the town of Silt (Fig. 2). As expected, the largest effective doses are close to the facility (200-500m) with a 100-fold decrease by the 5,000m segment. The accidental or single release data display a similar pattern except that all the dose is focused on four sectors and the dose levels an order of magnitude greater further from the release point (Fig. 3). In both cases, it is relatively easy to target receptor groups who are currently at risk and those who might be at risk at some future point in time in the event of an accident at the facility.

The extent of detail of the exposure assessment is dependent on the detail of the base map. Locations of schools, hospitals, dairies, wildlife areas, etc., can be highlighted by further investigation or eliminated from consideration if outside the plume boundaries.

This technique provides an easily understood representation of the exposure assessment that can allow the risk assessor to examine and interpret the following diversity of information:

- The nature, extent, and magnitude of contamination.
- Results of environmental transport modeling.
- Identification of exposure pathways.
- Identification of receptor groups currently at risk and potentially at risk in the future.
- Activity patterns and sensitivities of receptors and receptor groups.

REFERENCES

1. NESHAPS for Radionuclides: Background Information Document; Volume 1, EPA/520/1-89-005 (1989).
2. U.S. DOE, Environmental Assessment for the Special Nuclear Materials Research and Development Laboratory Project. DOE/EA-0388, Albuquerque, NM (1989).
3. Office of Local Populations, Population data as of July, 1989, Denver, Colorado (1991)
4. Radiological Assessments Corporation. MICROAIRDOS, Version 2.0, Users Manual and Documentation. Neese, SC (1989)

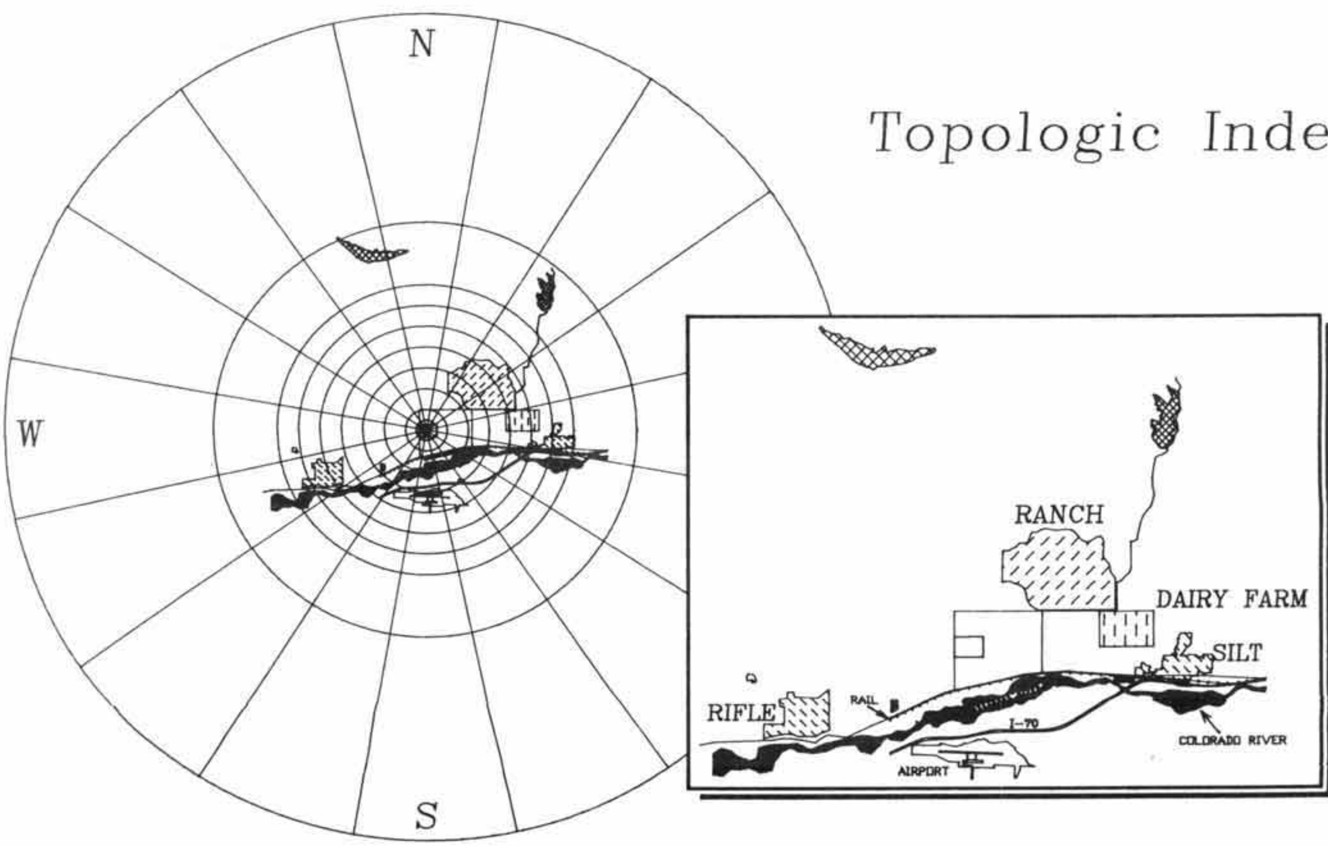

Fig. 1. Base map for the Rifle Nuclear Faciligy.

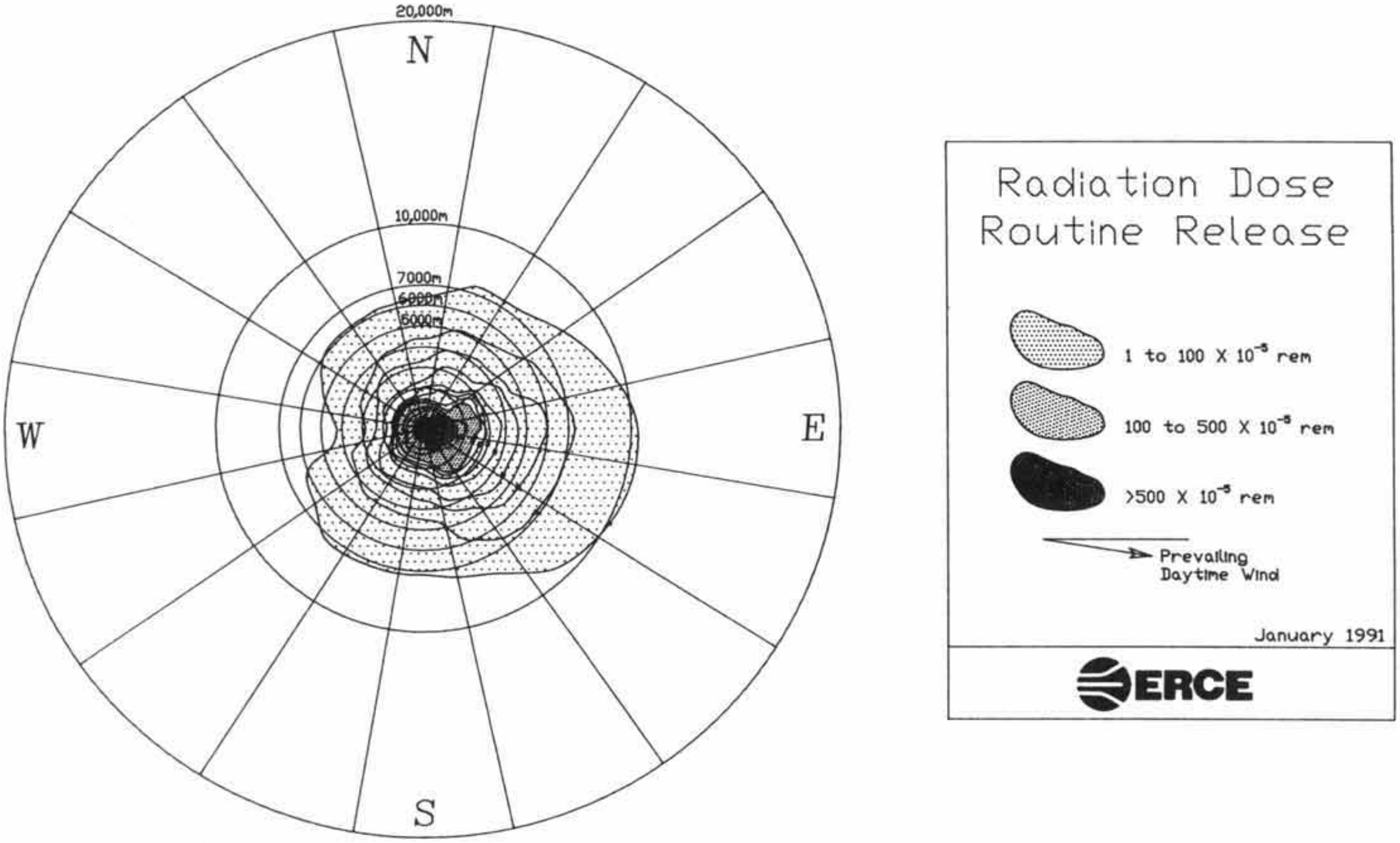

Fig. 2. Radiation dose isopleths calculated using MicroAirdos.

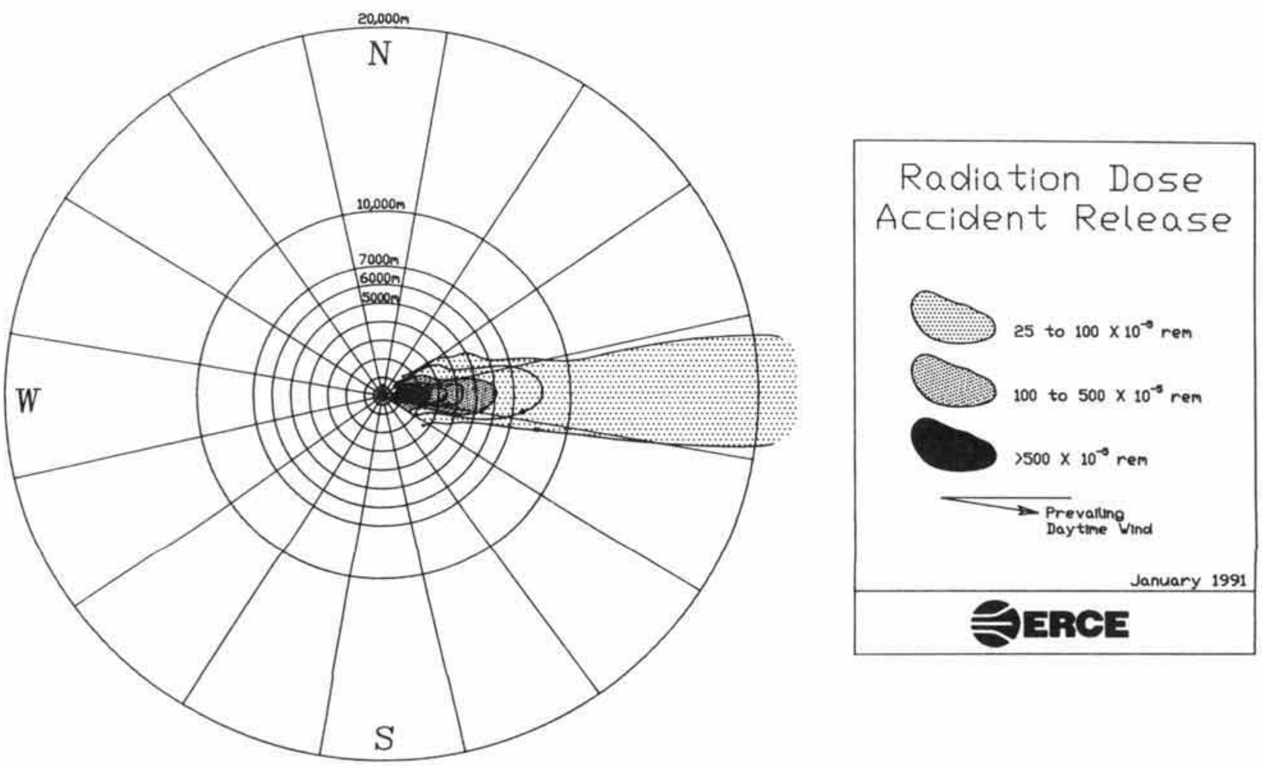

Fig. 3. Radiation dose isopleths calculated using MicroAirdos resulting from an accident at the rifle facility.