Using a Specialized Radiation Portal System to Monitor Livestock Following a Radiological Incident

C. M. Marianno, J. L. Erchinger
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Livestock is a large component of state and national economies

- Total retail equivalent value of U.S. beef industry was $79 billion in 2011
  - $5.042 billion in beef exports
  - 10.6% value of exports as a percentage of production (USDA, 2012).

For a state like Texas

- ~13 million head of Cattle
- #1 state commodity generating $6.9 billion in sales
- Feedlot industry in Texas produces ~30% of the nation’s beef
Following the Fukushima accident there were 300 livestock farms within exclusion zone

- 3000 cows
- 30,000 pigs
- 600,000 chickens

Most of these animals died of starvation
USDA’s responsibilities according to the National Response Framework Nuc/Rad Annex

- “USDA provides support for assessment, control, and decontamination of contaminated animals, including companion animals, livestock, poultry, and wildlife.”
- USDA has to provide support for stabilization and disposition of contaminated animal carcasses
Our Research

We broke our work into 4 main parts

- Do states have any existing plans?
  - Contact Conference of Radiation Control Program Directors
- Conduct computer simulations to determine the best materials and configurations for a livestock portal
- Test commercial systems
- Build and Test a custom radiation portal system
Current Emergency Response Plans

- Not addressed on a national level
  - What emergency response plans exist on the state level?
- Contacted CRCPD members in 2 consecutive years
  - Winter 2011
    - Does your state have any plans in place to handle any contaminated companion animals or livestock following a radiological event?
    - If these plans exist, would it be possible for you to send them to me?
  - Winter 2012
    - Any updates on plans or procedures, even stating absence of plan
2011 State Responses

17 state responses:
- 10 no set plan
- 7 with some sort of plan
- some local planning
- no specific plan
- companion animal plan
- comprehensive animal plan
Total State Responses

28 state responses:
- 18 no set plan
- 10 with some sort of plan

- NASAAEP and APHIS
- K9 unit
- Some local planning
- No specific plan
- Companion animal plan
- Comprehensive animal plan
“We would be guided by general health physics principals and the guidance in relevant NCRP and other documents” (2011)

“I am not aware that livestock is as big a concern up here in the frozen north as is likely to be the case in the many farming and cattle raising states of the contiguous U.S. We have more moose, bears and caribou than cattle.” (2011)

“Maybe, you-all at Texas A&M can develop a boa or python portal monitor can name it “THE FULL MONTY” (In honor of MONTY PYTHON!” (2011)

“We certainly hope that we do not have a radiological event which would result in dead animal carcasses.” (2011)

“Otherwise, elements of mass animal decontamination may continue to revolve around our collective best guess as to how to pull a rabbit out of a hat.” (2012)
Best Practices

**Washington State**
- Separate area from people, easily washed
  - Outside or shower
- Cover cuts and abrasions
  - Wear rubber gloves and apron
- Wash thoroughly with mild dish soap and warm water
  - No conditioner
- Do not contain water run-off
- Owner decontamination afterward

**Military Working Dogs**
- Treated among bio and chemical hazards as well
- Remove radioactive particles from the haircoat and skin by brushing and bathing the animal in soap and water

**Massachusetts K9 Force**
- Remove all gear
  - Wet down if in powder form
- Wash
  - High volume, low pressure warm water with soap
  - Step-by-step
- Monitor
  - Check after drying
  - Medical exam

**North Carolina**
- Using human portals and standards
  - >300 CPM above background
- Monitor and Register
- Decontaminate
  - Wash with soap and water
  - Rinse
  - Dry (20 ft shake perimeter)
  - Submersion
  - Second wash
- Release
A Monte Carlo photon/neutron transport code was developed using MCNP.

Each part of the cow was represented using simplistic geometric shapes:
- Abdomen: Ellipsoid
- Neck: Oblique Frustum
- Head: Right Frustum
- Legs: Cylinders and Cones

Material definition: Soft tissue was composed of C, H, O and Bone tissue was composed of Ca, P, H, and O.
We initially assumed we would want to scan each animal in a controlled environment such as a cattle chute

- Scared animals are hard to control
- Cause injury to people handling them
- Disturb the detector set up
- Cause harm to itself

A hydraulic squeeze chute was modeled
Several factors had to be considered:

- Ease to fabricate into large area detectors
- Ability to withstand physical changes when brought to the field use
- Intrinsic efficiency
- Cost
- Portability
- Is identification important?
Isotope identification is possible
$Z_{\text{eff}} \sim 49.7$ higher than that of HPGe and PVT
- Photoelectric cross section is higher
- High efficiency for photon detection

It can be fabricated into large size and different shapes

Low cost as compared to HPGe (also no need to maintain at liquid nitrogen temperature)

PVT could have been used but
- Could not be used for ID
- Intrinsic efficiency was almost $\frac{1}{2}$ for similar size detectors

Two detector sizes were modeled:
- 2”x4”x16” NaI detectors (6 nos.)
- 2”x4”x4” NaI detectors (8 nos.)
Multiple configurations were investigated
ideal system:

- 12 NaI detector system
- Minimum Detectable Activity $< 1 \mu\text{Ci Cs-137}$
- Ability to localize contamination
- Ability to identify gamma emitting nuclides
- Cost $\sim$ $120k$
Commercially Available RPMs

- 3 Portals
  - Ludlum 52-1-1
  - TSA TPM-903A
  - Johnson AM801
- Portal Specifications
- Field-testing
- Lab-testing
- Applicability to Livestock Response
## RPM Specifications

<table>
<thead>
<tr>
<th></th>
<th>TSA TMP-903A</th>
<th>Johnson AM-801</th>
<th>Ludlum 52-1-1</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Number of Panels</strong></td>
<td>2</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td><strong>Detector Material</strong></td>
<td>Organic Scintillator</td>
<td>Organic Scintillator</td>
<td>Organic Scintillator</td>
</tr>
<tr>
<td><strong>Volume per Panel</strong></td>
<td>324 in³</td>
<td>162 in³</td>
<td>168 in³</td>
</tr>
<tr>
<td><strong>Total Volume</strong></td>
<td>648 in³</td>
<td>648 in³</td>
<td>672 in³</td>
</tr>
<tr>
<td><strong>Alarm Level</strong></td>
<td>2.0 σ</td>
<td>10 counts &gt; bkg</td>
<td>2.5 σ</td>
</tr>
<tr>
<td><strong>Detection Mode</strong></td>
<td>Show Count</td>
<td>Drive-through</td>
<td>Walk-through</td>
</tr>
<tr>
<td><strong>Distance between panels</strong></td>
<td>44.5”</td>
<td>44.5”</td>
<td>50”</td>
</tr>
<tr>
<td><strong>Wall-side (Right of steer)</strong></td>
<td>Detector A</td>
<td>Detector 1,2</td>
<td>Left Top, Bottom</td>
</tr>
<tr>
<td><strong>Standard detection limit</strong> *</td>
<td>1.0 μCi $^{137}$Cs</td>
<td>1.0 μCi $^{137}$Cs or less</td>
<td>1.0 μCi $^{137}$Cs source in a 10 μR/hr background field</td>
</tr>
</tbody>
</table>
Field Trial Procedures

- Set up each RPM around the chute
  - Source positions
  - 5 trials with 5 μCi $^{137}$Cs source
- Set up TSA and Johnson in a walkway
  - Source positions
  - 6 trials with 5 μCi $^{137}$Cs source
  - 2 trials with 1 μCi $^{137}$Cs source
137Cs is a volatile fission product, capable of contaminating large areas

5 μCi source strength in a…
- 1 ton animal = 185 Bq/kg
- 2 ton animal = 92.5 Bq/kg
- 1000 lb animal = 408 Bq/kg
- 1500 lb animal = 272 Bq/kg

Limits of 500 Bq/kg
- Fukushima lowered to 150 Bq/kg

A 5 μCi source would be under the 500 Bq/kg limit, and even under 150 Bq/kg for large animals

RPMs also tested with 1 μCi to test lower limit detection and compare to human specs
Baseline Suppression
Special Cases: Baseline Suppression and Shadow-Shielding
# Alarm Algorithms

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<tbody>
<tr>
<td><strong>Count Rate Output</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Un-occupied/Background</td>
<td>3-s avg. every 6 s</td>
<td>20-s rolling average</td>
<td>5-s rolling average</td>
</tr>
<tr>
<td>Occupied</td>
<td>200 ms</td>
<td>200 ms</td>
<td>100 ms</td>
</tr>
<tr>
<td><strong>5 μCi $^{137}$Cs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occupancy Triggered</td>
<td>No</td>
<td>Yes</td>
<td>Yes; No</td>
</tr>
<tr>
<td>Quick CR Increase</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes; Relatively</td>
</tr>
<tr>
<td><strong>1 μCi $^{137}$Cs</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Occupancy Triggered</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Quick CR Increase</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
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### RPM Ratings

- **1 = best**
- **3 = worst**

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</tr>
</thead>
<tbody>
<tr>
<td>Ease of transport</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Ease of set-up</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Ease of modification</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Data output capability</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Software</td>
<td>2</td>
<td>1</td>
<td>3</td>
</tr>
<tr>
<td>Position Discrimination</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>Instruction Manual</td>
<td>3</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Alarm (visual, audible)</td>
<td>2</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>
Shortcomings of RPMs

- **Johnson AM801**
  - Screen dims after 10 s
  - Data output only through RS-232 port to serial printer

- **TSA TPM903A**
  - Alarm data saved, but only the last background, time, and alarm count rate
  - Data not stored when operated in Show Count mode
  - Software only for downloading data from the unit, cannot update parameters from the laptop
  - RS-232 connection to laptop

- **Ludlum 52-1-1**
  - Displays count rate in sigma during an alarm
  - Loud audible alarm that cannot be disabled
  - Only alarm data transferred, no continuous data streaming
  - Parameters only adjustable at initial startup
The Johnson and Ludlum portal systems provided greater position discrimination than the TSA
- four detector panels instead of two

The TSA and Johnson systems are easier to use, have better detection capabilities, and more display options.

The 5 µCi $^{137}$Cs source was detected in both the chute and walkway trials

The 1 µCi $^{137}$Cs source was detected for most TSA TPM903A trials, but only some of the Ludlum 52-1-1 trials

Reproducible results obtained in the lab

For a 5 µCi $^{137}$Cs point source, these pedestrian portals provide adequate detection in a commercial cattle operation, but significant modifications to hardware and software must be made for practical use in the field
Bovine Screening Portal (BSP)

- Design
  - Based on earlier simulation results
- Manufacture
  - Lowe’s shopping list
  - Machine shop work
- Lab testing
- Field testing
  - Chute trials
  - Walkway trials

Important this is a proof of concept system
OSPREY

- Portable, powerful MCA system
- Power options
  - Power-over-Ethernet
  - Power-over-USB
- Acquisition modes:
  - List mode
    - 1 μs and 100 ns
  - Pulse Height Analysis (PHA) acquisition
The software: GUI

- Three main “modes”
  - Search
  - Map
  - Viewer
- Settings
  - Acquisition mode
  - Time base
  - Alert/alarm regions
- No extraneous menus
- User-friendly
Software Features

- **Set up**
  - Unlimited detector array
  - HV input
  - Import calibrations

- **Data acquisition**
  - Live-time count rate plot
  - Live-time spectral update

- **Post-processing**
  - Individual detector data
  - Sum detector spectrum
  - Average detector spectrum
  - Mapped data
  - N42 format
Lab Trials

- MCA tubes
  - Canberra Osprey
- Software Development
  - RDS
- Passes around and through panel
  - Source positions
  - 5 μCi $^{137}$Cs source
Lab Trials

- Left Hand Trials
- >10σ above background in controlled setting
Field Trials

- **Chute trials**
  - Source positions
  - 5 trials each position
  - Trials with 5 μCi $^{137}$Cs source

- **Walkway trials**
  - Source positions
  - 6 trials each position
  - Trials with 5 μCi $^{137}$Cs source
Chute Trials

- >10σ above background at lowest

Left Rear Fetlock  

Girth
Walkway Trials: Left Rear Fetlock

- >7σ above background
Commercial RPMs vs. BSP

- Set-up
- Operability
- Software
- Ease of Use
- The BSP demonstrated both detection of a 5 μCi $^{137}$Cs source and spectral identification capabilities
- The count rate increases were clearly observed in real time with the Osprey and RDS software
- The spectral data for a selected time period (i.e. during a count rate spike) can be isolated in software program
Livestock detection and decontamination guidelines are unavailable as of yet
- Work at TAMU, CSU, and the NASAAEP working group

Pedestrian RPMs require modification and familiarity with the systems for use in agriculture settings

BSP provides superior detection, spectral, and software capabilities to pedestrian RPMs
- Meets USDA requirements in Nuc/Rad Annex of NRF