A Retrospective Assessment of Correlation between Occupational & Public Radiation Protection Programs Performance Metrics at a FUSRAP Site – 17546

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ABSTRACT

A retrospective assessment of the occupational & environmental radiation protection programs includes the consideration of performance metrics at the qualitative & quantitative level. When key radiation protection (RP) program metrics are tracked over the course of several years, correlations may present themselves. Strong correlations between variables may be considered when establishing or validating baseline RP Program elements (i.e., controls, monitoring regimes, and additional ALARA measures) for the safe excavation and handling of naturally occurring radioactive materials comingled in soil-like wastes at FUSRAP sites.

INTRODUCTION

In 1997, Congress directed the USACE to conduct assessment, remedial action, and site closure activities for FUSRAP sites in accordance with a Memorandum of Understanding between the USACE and the US DOE. Through this program, the USACE addresses the environmental remediation or control of sites where the Manhattan Engineer District or Atomic Energy Commission activities were performed during the 1940s, 1950s and 1960s. Upon completion of remedial action and site closure activities, these sites are then transferred back to the USDOE for disposition.

The primary site addressed in this paper is the FUSRAP Maywood Superfund Site (FMSS). The FMSS includes the Maywood Interim Storage Site (MISS), as well as nearly 100 residential, commercial, and governmental vicinity properties located in densely populated Bergen County, New Jersey.

The overall ongoing mission of the remediation team for the FMSS has been to safely and effectively remediate a waste stream consisting primarily of soils contaminated with thorium-232 (Th-232). In addition to Th-232, lesser concentrations of other naturally occurring radionuclides (i.e., radium-226 [Ra-226], uranium-238 [U-238], and other radionuclides in the natural Th/U decay series). Other rare earth elements and non-radiological contaminants are sometimes present in the waste stream.

At the Waste Symposium in 2003, two of this paper's authors prepared and presented a paper topic on the "Health Physics Considerations for Remediation and Exposure Monitoring of a Th-232 Waste Stream in a Commercially Active Environment". The focus of the 2003 paper was identifying the radiological hazards and; addressing the planned radiation protection program elements (monitoring and controls) to ensure doses are maintained ALARA.

A key challenge for the remediation team at that time and throughout the subsequent investigation & remediation efforts, was to ensure work was performed in a manner that was protective of the workers supporting the remediation, as well as the general public, and the environment.

The purpose of this paper is to present findings from an initial retrospective assessment of radiation safety performance metrics as the project matured leading to the excavation and off-site shipment and disposal of over 835,000 tons of radiologically contaminated soils & debris within the assessment window.

METHODS

Since 2001, the Maywood Health Physicists and Radiation Safety Officers have been collecting and evaluating metrics that are derived from data used to support the implementation of the occupational radiation protection program, a key component of the Contractor's Site's Safety & Health Plan, as well as; data obtained from the Site's Annual Environmental Monitoring Program Report and supporting compliance model parameter inputs and outputs. Modeling of resident and non-affiliated worker dose equivalent is performed to comply with 10 CFR 40.61, Subpart H requirements using the latest version of the EPA Clean Air Protocol – 88 (CAP-88) software program. The CAP-88 model accounts for the excavation, storage, and handling of contaminated soils wherever it is happening on the overall site and calculates the corresponding dose equivalent to the worst-case resident & worker at each "emission" point.

Thirty-four individual metrics, collected & trended annually for the period 2001-2015, were considered and included in the correlation assessment. Of these, the following key metrics are noted:

Population Metrics

- Number (#) of externally monitored workers
- Percentage (%) of externally monitored workers who had one or more quarterly result in excess of the assigned dosimeter's lower limit of detection (LLD) (10-100 microsieverts/quarter).
- # of internally monitored workers
- % of internally monitored workers with intake exceeding 0.02% of the FMSS source term-derived Annual Limit on Intake (ALI)

Work Activity / Source Term Metrics

- Total hours worked in posted radiological areas requiring internal & external dose monitoring
- # of breathing zone (BZ) representative air samples collected
- Tons of contaminated soil & debris excavated, managed, and shipped off-site
- Average & Total activity of key radiological parameters (Th-232, Ra-226, and U-238), in Gondola Railcar Waste Shipments

Radiation Protection Program Metrics

- % of breathing zone air samples exceeding the Alpha Critical Level (S_C) during post-decay gross counting
- % of breathing zone air samples exceeding 10% off the site-specific Derived Air Concentration (DAC) during post-decay gross counting
- Maximum BZ air sample result
- % of annual total dose equivalent for site workers attributable to intakes of radioactive materials
- Maximally exposed site radiological worker (internal & external)
- Annual cumulative radiological worker dose

Environmental Monitoring Dose Metrics (modeled annually via CAP-88)

- Total site-impacted population dose
- Maximally exposed site worker
- Maximally exposed nearby resident

Other metrics were considered but, eventually excluded from cross-comparison as they would offer little additional detail not identified through other more relevant comparisons. Examples include the metrics associated with maximum worker doses to the skin and lens of the eye, recorded with a dosimeter, which were 100% consistent with reported deep dose result.

Qualitative Assessment of Annual Metrics

Overall, the RP Program at the FMSS has very effectively minimized doses to both the public and workforce. Some key ceiling features of the metrics selected from the 15-year window (2001-2015) support this assessment:

- Maximum single year dose to a single site worker: 2.0 millisieverts (mSv) in 2010
- Maximum single year cumulative dose to all site workers: 35 mSv for 172 monitored radiological workers in 2010 who shipped nearly 100,000 tons of soil & debris waste and spent over 33,500 work hours in posted areas where internal & external monitoring was required
- Maximum modeled dose to the worst-case exposed nearby resident: 0.00016 mSv

- Zero (0) Site workers with an annual occupational dose exceeding 5.0 mSv (equivalent to 10% of the annual occupational dose limits established in 10 CFR 20.1201)

Quantitative Assessment of Annual Metrics

Annual metrics for 2001-2015 were obtained from the Annual RP Program Dosimetry reports & CAP-88 model outputs and arrayed into identical rows & columns in Microsoft Excel™. The Excel "Correlation - CORREL" function was used to calculate the "Pearson's Correlation Coefficient (PCC) for the arrayed metric data and is the measure of linear dependence between two variables. The PCC is generally defined as the covariance of two variables divided by their standard deviations. A correlation coefficient of +1 indicates a perfect positive correlation. A correlation coefficient of -1 indicates a perfect negative correlation (anti-correlation). A correlation coefficient near 0 indicates no correlation. The following graphic illustrates correlation coefficient values for different datasets:

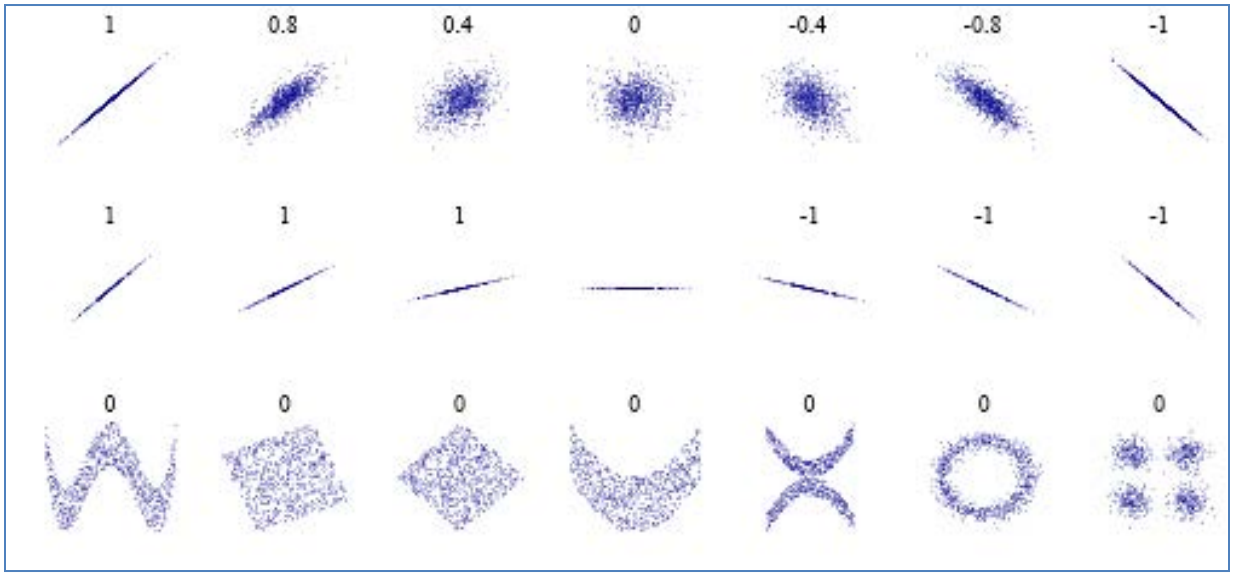

Fig. 1 Example X-Y Data Plot Dispersion for PCC statistics outcomes between -1 and 1. [1]

For the purposes of this assessment, a PCC of 0.7 to 0.9 was considered a strong correlation with a PCC >0.9 indication a virtually perfect correlation between metrics.

Weaker correlations were observed for most assessed metrics related to occupational dose to site workers and the source term or wastes handled. It is likely that the lack of correlation for individuals is attributable to the use of

conservative methods when determining target receptors, when assigning lapel samplers to worst-case exposed workers and, when calculating the internal doses from lapel air samples with short sampling windows and gross counting results below the S_C (i.e., a “non-detect”). This logic is supported by the notable stronger correlations between is the cumulative dose for all monitored site rad workers which correlates well (0.72-0.93) to the number of BZ samples collected and the number of worker entries into posted radiological areas. The key take-away is that the variability within individual worker metrics is essentially “noise” and, as noted in the earlier qualitative assessment, the very low doses received are representative of an effective RP Program.

A strong correlation (0.78) were identified between the total activity shipped and the frequency of workers who had an annual dose in excess of the 10 CFR 20.1301(a)(1) limits to a member of the public (1 mSv per year). Similar relationships were identified for Th-232 (0.78) and Ra-226 (0.80) in shipped soils when compared to the one mSv/year threshold.

Strong correlations were identified between the activity of individual key radionuclides in shipped wastes and the frequency of BZ air samples exceeding 10% of the applicable DAC in a given year. The PCC values for key radionuclide parameters Th-232, Ra-226, and U-238 were calculated as 0.76, 0.73, and 0.95, respectively. For the benefit of perspective, the average frequency of BZ samples exceeding 10% of the DAC is less than two percent and; no BZ samples have ever exceeded the applicable DAC indicating effective ALARA implementation. The correlation between key radionuclide activity concentrations and frequency of elevated BZ sample results is a strong indicator that it may be possible to scale future occupational dose potential from intakes of NORM radionuclides, when basic protective measures (e.g., misting dust suppression, effective use of protective clothing, routine frisking, radiological boundary controls & technician coverage) are applied. A near-perfect PCC (0.95) was calculated between the average U-238 activity in waste shipped off-site and the % frequency of BZ air sample results exceeding 10% of the DAC and; is likely attributable to the use of a derived DAC value that is based on the mixture of Th/U decay series radionuclides in FMSS soils being shipped off-site. Over the assessment period (2001-2015), the DAC has ranged from 2.6 x 10-12 uCi/ml to 4.23 x 10-12 uCi/ml depending on the ratios of nuclides in wastes handled in a given year. The current DAC value is 3.5 x 10-12 uCi/ml and has been in use since 2007. It is likely that the current DAC is still slightly conservative in situations where a greater percentage of the total waste activity is attributable to uranium content because the DAC for Th-232 is more restrictive than U-238.

PCCs in excess of 0.82 were calculated for all parameters derived from the CAP-88 emissions models (i.e., modeled individual and cumulative doses to workers, nearby residents, and the exposed population), when compared to the total radioactivity (Th-232 + Ra-226 + U-238) shipped from site or; when compared against any of the three key component radionuclides. A direct relationship to the radioactivity excavated, handled, and shipped each year is expected given the inputs and methodologies of the CAP-88 model and; when one considers that the single largest contributor to overall population dose is the main railcar loading areas on the government-owned MISS parcel (i.e., local receptors are exposed every year to the subsequent handling and packaging of waste soils and debris collected from other vicinity properties in surrounding communities.

CONCLUSIONS

Notable correlations were identified between key project metrics and dose-based outcomes which suggest that the standard approaches to internal & external monitoring (BZ air sampling and luminescent dosimeters) are effective at capturing changing airborne radioactivity and external radiation conditions as a result of increased waste radioactivity levels and; that occupational/public doses for the assessed project remain ALARA thanks to the effective and consistent implementation of basic protective measures during soils remediation and subsequent handling.

REFERENCES

1 Wikipedia contributors. "Pearson product-moment correlation coefficient." Wikipedia, The Free Encyclopedia. Wikipedia, The Free Encyclopedia, 20 Dec. 2016. Web. 20 Dec. 2016.