ENVIRONMENTAL REMEDIATION ACTIVITIES IN JAPAN FOLLOWING THE FUKUSHIMA DAI-ICHI REACTOR INCIDENT - 12603

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ABSTRACT

In March 2011, the Fukushima Dai-ichi reactor power plant was crippled by the Great Pacific earthquake and subsequent tsunami. Much of the focus in the news was on the reactor site itself as the utility company (TEPCO), the Japanese government, and experts from around the world worked to bring the damaged plants into a safe shutdown condition and stem the release of radioactivity to the environment. Most of the radioactivity released was carried out to sea with the prevailing winds. Still, as weather patterns changed and winds shifted, a significant plume of radioactive materials released from the plant deposited in the environment surrounding the plant, contaminating large land areas of the Fukushima Prefecture. The magnitude of the radiological impact to the surrounding environmental is so large that the Japanese government has had to reevaluate the meaning of "acceptably clean." In many respects, "acceptably clean" cannot be a one-size-fits-all standard. The economics costs of such an approach would make impossible what is already an enormous and costly environmental response and remediation task. Thus, the Japanese government has embarked upon an approach that is both situation-specific and reasonably achievable.

For example, the determination of acceptably clean for a nursery school or kindergarten play yard may be different from that for a parking lot. The acceptably clean level of residual radioactivity in the surface soil of a rice paddy is different from that in a forested area. The recognized exposure situation (scenario) thus plays a large role in the decision process. While sometimes complicated to grasp or implement, such an approach does prioritize national resources to address environment remediation based upon immediate and significant risks. In addition, the Japanese government is testing means and methods, including advanced or promising technologies, that could be proven to be effective in reducing the amount of radioactivity in the environment beyond a fixed, concentration based limit. Essentially, the definition of acceptably clean includes the concept of reasonably achievable, given the available technology, means and methods, and the cost to implement such. The Japanese government recently issued three technology demonstration contracts expressly designed to test and evaluate the available technologies, means, and methods, which, if implemented, might produce the greatest risk reduction from environmental contamination for the best value. One of the Japanese contract holders, Obayashi JV, has teamed with AMEC to demonstrate the applicability and capabilities of the Orion *ScanPlot*SM and *ScanSort*SM technologies in radiologically impacted towns both inside and immediately outside the 20 km restricted zone.

This presentation provides some unique images and informative insight into the environmental radioactive impacts in and around the exclusion zone. It will provide a look at one element of the Japanese government's efforts to achieve the greatest risk reduction that is reasonably achievable.

INTRODUCTION

In March 2011, the Fukushima Dai-ichi reactor power plant was crippled by the Great Pacific earthquake and subsequent tsunami. Much of the focus in the news was on the reactor site itself as the utility company (TEPCO), the Japanese government, and experts from around the world worked to bring the damaged plants into a safe shutdown condition and stem the release of radioactivity to the environment. Much of the radioactivity released was carried out to sea with the prevailing winds[1]. Still, as weather patterns changed and winds shifted, a significant plume of radioactive materials released from the plant deposited in the environment surrounding the plant, contaminating large land areas of the Fukushima Prefecture.

The magnitude of the radiological impact to the surrounding environmental is enormous, as is the projected cost of the environmental response and remediation task (the Japanese government has estimated that environmental cleanup activities will cost more than $14 billion dollars (USD) over many years). Thus, the Japanese government has embarked upon an approach that is both situation-specific and reasonably achievable from both the technical and economic perspectives.

The Japan Atomic Energy Agency (JAEA) is currently testing means and methods, including advanced or promising technologies, that could be proven to be effective in reducing the amount of radioactivity in the environment to levels that are both safe for the public and economically reasonable. Essentially, the definition of acceptably clean includes the concept of reasonably achievable, given the available technology, means and methods, and the cost to implement such.

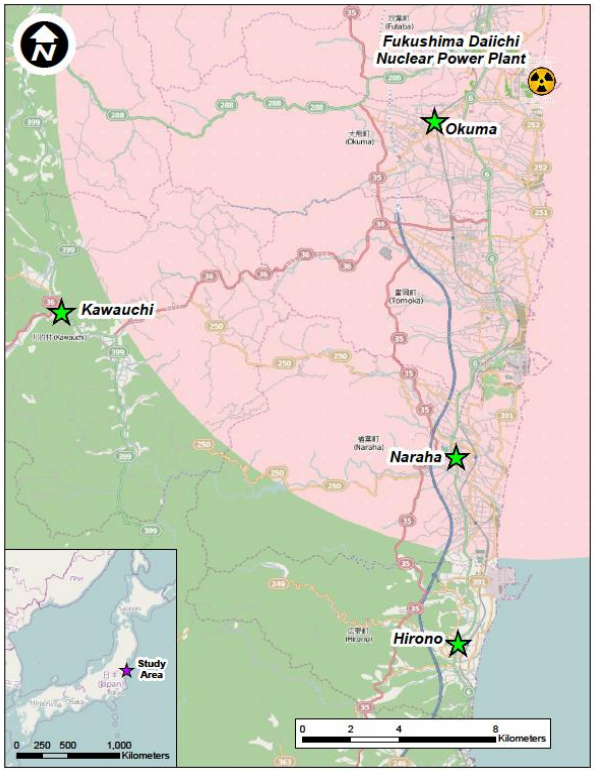

Figure 1. Japan Town Demonstration Project Pink shading represents the 20km restricted zone

The JAEA recently issued three technology demonstration contracts (commonly referred to as the "Japan Town Remediation" projects) expressly designed to test and evaluate the available technologies, means, and methods, which, if implemented, might produce the greatest risk reduction from environmental contamination for the best value. Each contract holder was assigned four towns in which they are to demonstrate their means, methods, and technologies for the JAEA to observe and evaluate.

One of the Japanese contract holders, Obayashi JV, has teamed with AMEC to demonstrate the applicability and capabilities of two unique AMEC technologies in radiologically impacted towns both inside and immediately outside of the 20 km restricted zone.

AMEC's ORION TECHNOLOGIES

Two distinct, but related, products currently comprise the Orion "family" of technologies; Orion *ScanPlot*SM and Orion *ScanSort*SM. Both employ an advanced scanning spectrometric radiation measurement process.

*ScanPlot*SM

Orion *ScanPlot*SM is an overland radiation scanning system that is used to detect and spatially map the radiation environment. The *ScanPlot*SM system combines AMEC's unique scanning spectroscopy technology with high accuracy spatial positioning detectors (e.g., GPS or optical ranging technology) to produce data files that can be readily mapped in commonly available graphical information system software packages. A variety of deployment platforms are in use in Japan in support of the Japan Town Demonstration Project. AMEC and Obayashi JV currently have backpacks, push carts, and motor vehicle platforms deployed to the restricted zone in Japan collecting data (Figure 2).

*Figure 2. ScanPlot*SM *Systems Used to Characterize Contaminated Land in Hirono Town and Naraha Town*

Surveys done prior to remediation result in maps that guide and focus the remedial efforts in the field, resulting in focused remediation and smaller waste volumes. Surveys done after the remediation graphically and mathematically demonstrate the effectiveness of the remediation and are used to guide additional remedial efforts where needed and to demonstrate compliance with the remedial objective(s).

Interactive map reports with a variety of data views and summaries are generated. Some map views are designed to reveal the spatial structure in the data, while others are used to present data in units commonly used to assess the significance of the residual radioactivity present. Still others are used to assess the residual radioactivity in terms of its compliance with the various remedial action goals that are applied. Examples of pre- and post-remediation *ScanPlot*[SM] map views are presented in Figure 3. The spatial data structure is evident in both panels of Figure 3. In both cases, the *ScanPlot*[SM] data has been presented in units of micro-sieverts per hour in order to gauge the significance of the survey results.

The pre-remediation survey (Panel A of Figure 3) clearly shows the post depositional migration of the radioactive contaminant since the Fukushima accident. Paved areas north of the school building have been "washed" by precipitation events, resulting in lower surface concentrations. The majority of the radiological survey was performed in the play yard areas to the south and east of the school building. Deposition across most of this area is relatively uniform. However, areas along the southern border of the surveyed area show significantly elevated surface concentrations, indicating a concentrating effect at the base of a retaining wall structure.

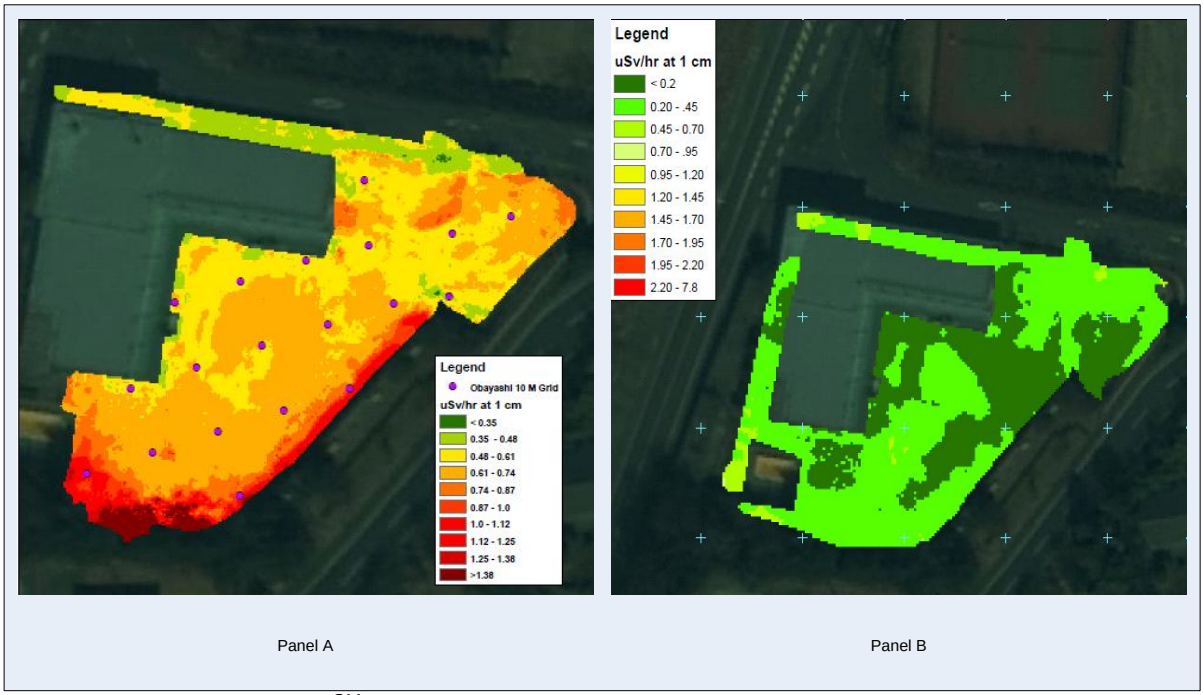

Figure 3. Orion ScanPlot[SM] *Map Report - Kindergarten in Hirono Town (Pre-Remediation) and Nursery School in Fukushima City (Post Remediation)*

The post –remediation survey (Panel B of Figure 3) shows the effectiveness of the remedial action. The green shaded area is the school's play yard that was remediated. The highest elevated areas remaining (greenish-yellow shaded areas) lie outside the play yard.

While not yet definitively promulgated, remediation standards for schools will likely involve some measure of the penetrating gamma radiation exposure rate in units of micro-sieverts per hour.

The vehicle deployed *ScanPlot*[SM] system was used to demonstrate the application of the technology to the assessment of roads and other surfaces designed to support vehicular traffic (e.g., parking lots). This application has demonstrated that the *ScanPlot*[SM] system may prove beneficial in other potentially significant ways (Figure 4). It provides a means to collect large amounts of spatially relevant, isotope-specific data in a relatively short amount of time. This application generates valuable data that could be used in locale-specific risk assessments, evaluations of the overall effectiveness of remedial actions in large sections of communities. Densely populated areas naturally have a higher density of roads and other surfaces designed for vehicular traffic. Another potentially valuable application of this data set is evaluate it for trending over the collection of many such data subsets over longer periods of time. Temporal rends in the data would indicate the areas where contaminant migration is resulting in a concentrating effect due to sedimentation. For example, Figure 4 clearly reveals spatial structure in the Cs-137 data along select roadways in Hirono Town (orange and red color contours). This spatial structure is indicative of the concentrating effect of contaminant fate and transport. Armed with such knowledge, functional sedimentation traps could be constructed and subsequently monitored in order to manage and control the consequences of contaminant mobility in the environment.

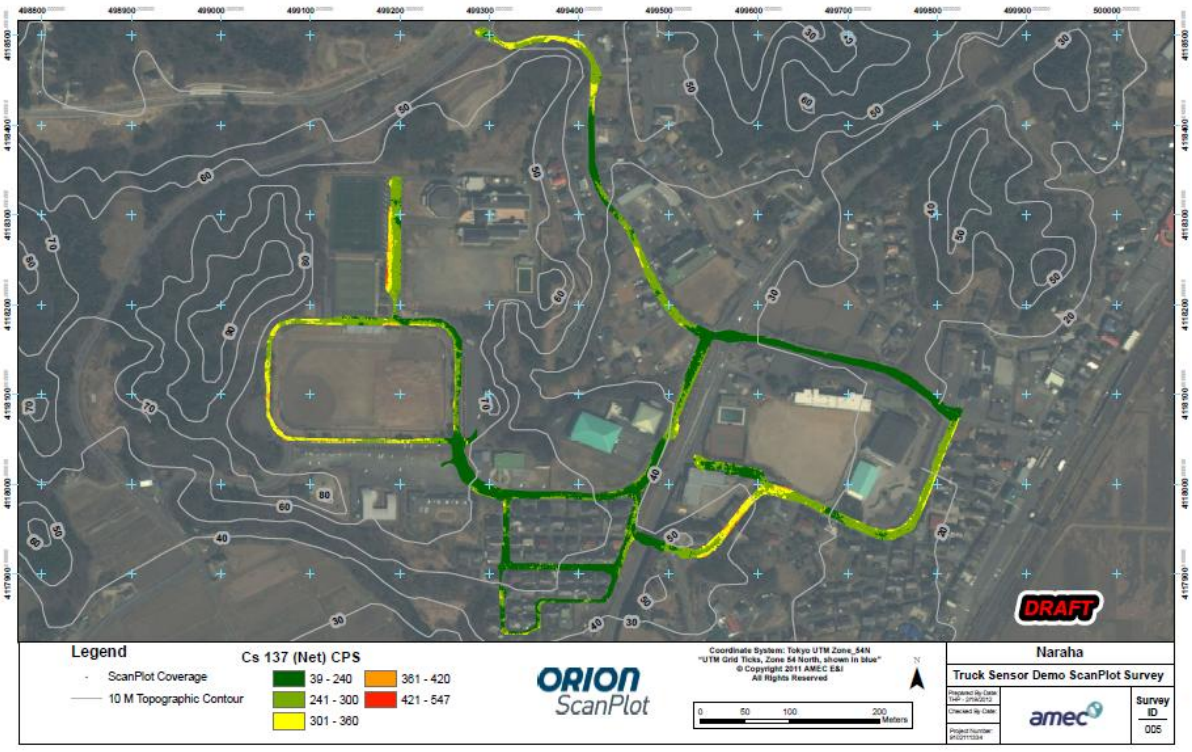

Figure 4. Orion ScanPlot[SM] *Map Report - Hirono Town Roads*

ScanSort[SM]

Orion *ScanSort*[SM] is AMEC's automated, conveyor-based radioactive measurement and sorting system. This system measures the radioactivity in soil (and other flowable debris such as crushed concrete). The proprietary Orion operating system (OS) software evaluates the data and determines whether the soil meets or exceeds the applicable criteria. The computer controls the automated reversing conveyor which, based on its radioactivity, segregates the soil into "above criteria" or "below criteria" bins in real-time. Because the project is designed to demonstrate technology, parameters such as scan speeds, throughput rates, sensitivities, etc. were 'test variables' as opposed to 'specifications' or capabilities.

Figure 4. Orion ScanSort[SM] at Naraha Town

The demonstration project sought to demonstrate the range of operational capabilities of the *ScanSort*[SM] system. A series of experiments was performed with the *ScanSort*[SM] system programmed to divert contaminated soils at various activity concentrations and with a variety of excavation and batching sequences and diversion control set points (DCSs). The data from these tests have not yet been approved for release by the JAEA therefore no statements about the data or conclusions drawn from the data can be made at this time. However, a generalized look at a subset of non-specified data generated by the *ScanSort*[SM] system is informative.

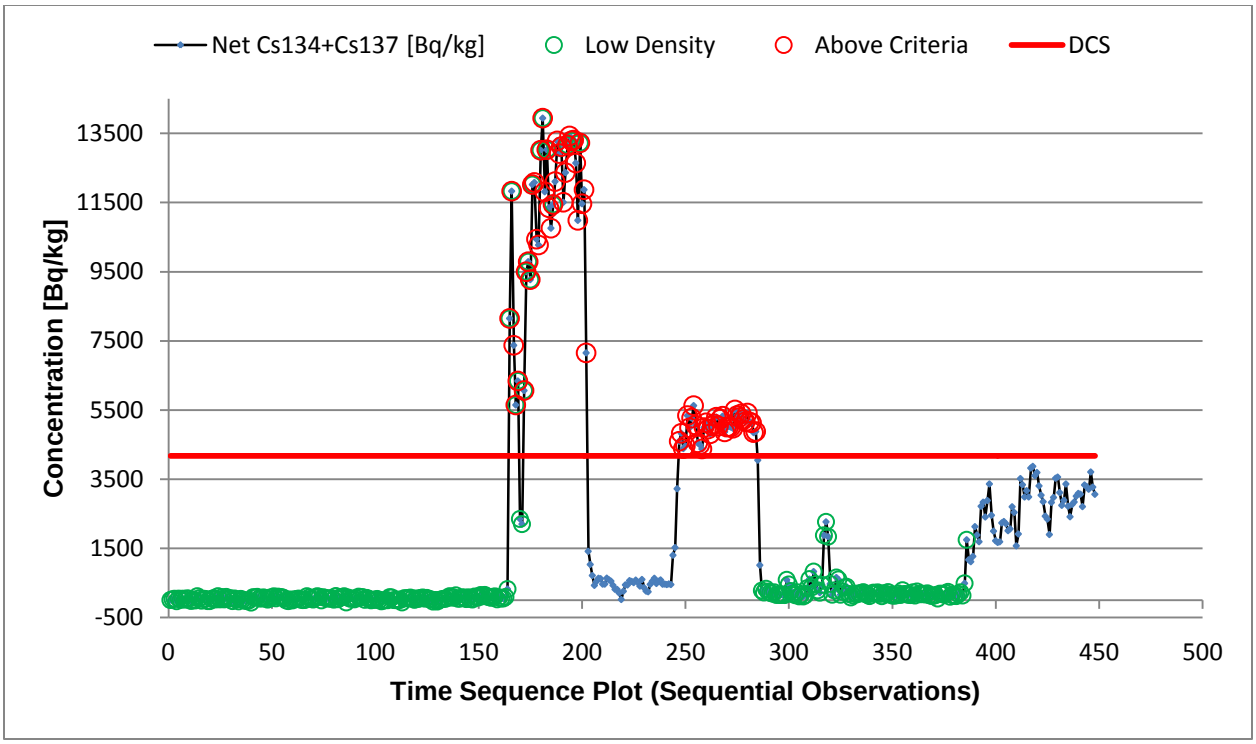

Figure 5. ScanSort℠ Time Sequence Plot Showing Radioactivity in Various Lifts of Soil

Figure 5 shows the relative variability in Cs-134+137 activity in batches of soils obtained from different vertical depth intervals below the ground surface. Soils were collected from contaminated land and processed with the *ScanSort*℠ system to test various field remedial strategies and to assess the ability of the *ScanSort*℠ system to discern and segregate soils having various radioactivity concentrations.

Again, based upon a comprehensive review of the results of the data obtained from the Japan Town Demonstration Project, it is possible that remedial goals (if not promulgated standards) will be defined in order to reduce residual radioactivity concentrations to reasonably and technically achievable. It is likely that future remedial action goals will vary based upon the existing and anticipated land use (e.g., agricultural, industrial, residential, school, etc.), technical feasibility, confidence in the ability to measure and demonstrate compliance, and the costs to achieve compliance.

CONCLUSION

The Orion *ScanPlot*[SM] and *ScanSort*[SM] are being used with success on the Japan Town Demonstration Project to assess pre-remedial action contamination levels, document the post-remedial action contamination levels and to precisely measure and segregate excavated soils based on their radioactive content and the prescribed segregation limits (DCS). Initial results suggest that these technologies could provide capabilities to the remedial action efforts that would result in considerable improvements in field data certainty and compliance with remedial objectives while reducing overall costs.

REFERENCES

1. Stohl, A., Seibert, P., 2, Wotawa, G., Arnold, D., Burkhart, J. F., Eckhardt, S., Tapia, C., Vargas, A., and Yasunari, T. J. (2011). Xenon-133 and caesium-137 releases into the atmosphere from the Fukushima Dai-ichi nuclear power plant: determination of the source term, atmospheric dispersion, and deposition. *Atmospheric Chemistry and Physics Discussions, 11*, 28319–28394.