Combined Use of Modelling and Measurement Results in Post-Accidental Situation

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INTRODUCTION

Immediately following an accidental deposit of radionuclides in the environment, modelling is the only means of assessing the seriousness of the situation from a radiological viewpoint and deciding on possible emergency measures for the protection of populations. The ASTRAL software has been developed by the French Nuclear Protection and Safety Institute (IPSN) for this purpose. ASTRAL is an acronym for « radioprotection in post accidental situation ». It allows to assess rapidly the evolution of radionuclides concentrations in the environment and in the food chain, derive from that the potential internal and external exposure of concerned populations, forecast the evolution in time of this exposure and propose different scenarios of remediation actions in the contaminated zones. The starting point of the evaluations is the deposited surfacic activity (Bq/m2) of radionuclides which can be previously estimated using an atmospheric transfer model or air and rain water measurements. The results given by ASTRAL are then compared to the admissible limits and intervention levels. Different simulations of management of contaminated zones, by implementation of countermeasures may be conducted. So, the ASTRAL software constitutes an element of decision making as soon as the announcement of the accident is made (Maubert et al 97).

Fairly quickly after the deposits, measurements are made in the environment. ASTRAL can then be used to establishes the correspondence between the deposited surfacic activity and the specific activities of some selective representative products in order to draw a map of the mean surfacic activities.

The purpose of this document is to present the method using these two means of investigation applied in France for the characterisation of the deposit and the reconstruction of the doses following the Chernobyl accident (Renaud et al 97).

DISCUSSION

Description of the method and results

After the Chernobyl accident, the measurements on French territory were made starting in May, 1986 by various national agencies responsible for the inspection of agricultural commodities and livestock and for public health. The Office for Protection against Ionising Radiation (OPRI) is in

charge of the control of radioactive levels of different samples among which soil, plants and cow milk. Soil and plants measures are only representatives of local deposits and often vary on a wide range. With such natural variability, a great number of measurements is needed to assess the average surfacic activity of wide areas. Milk samples are of a greater interest. From spring to winter a cow grazes a surface of several tens of square meters per day. The sampling protocol used by OPRI specify that the milk is taken from district collection centers. Thus, these samples are representatives of a wide area at the scale of a French district (4000 to 8000 km2).
The interception and the retention of radionuclides by plants during deposits depends of the relative contribution of the wet (during rain) and dry deposits, as well as the amount of precipitation during the passing of contaminated air masses. Therefore, these parameters constitute the data to be supplied to the ASTRAL software before any estimate can be made. After the Chernobyl accident, from the 1st to the 5th of May 1986, air and rain water samples been measured. Derived from the that, the ratio between wet and dry deposits for ^{137}Cs and ^{134}Cs at a few locations have been estimated. They usually rank between 2 and 7, which shows a clear predominance of the wet deposit contribution : it corresponds to 66 to 88 % of the total deposit. There are, of course, places where precipitation was very low and for which dry deposits predominate (central France). It is eastern France, with precipitation in excess of 20 mm, which was most affected by the fallout. Many towns or locations received wet deposits exceeding 2,000 Bq/m2 of ^{137}Cs. The central strip received deposits seven times smaller on the average, resulting from an amount of rainfall under 10 mm. Western France, though having received more rain, was even less affected because of the depletion of the air masses in radionuclides (washing of the cloud).

With these data, ASTRAL can simulate the evolution of milk specific activities for different values of the deposited surfacic activity. As it has been shown in figure 1, it is then possible to classify the milk measurement results and their originating districts.

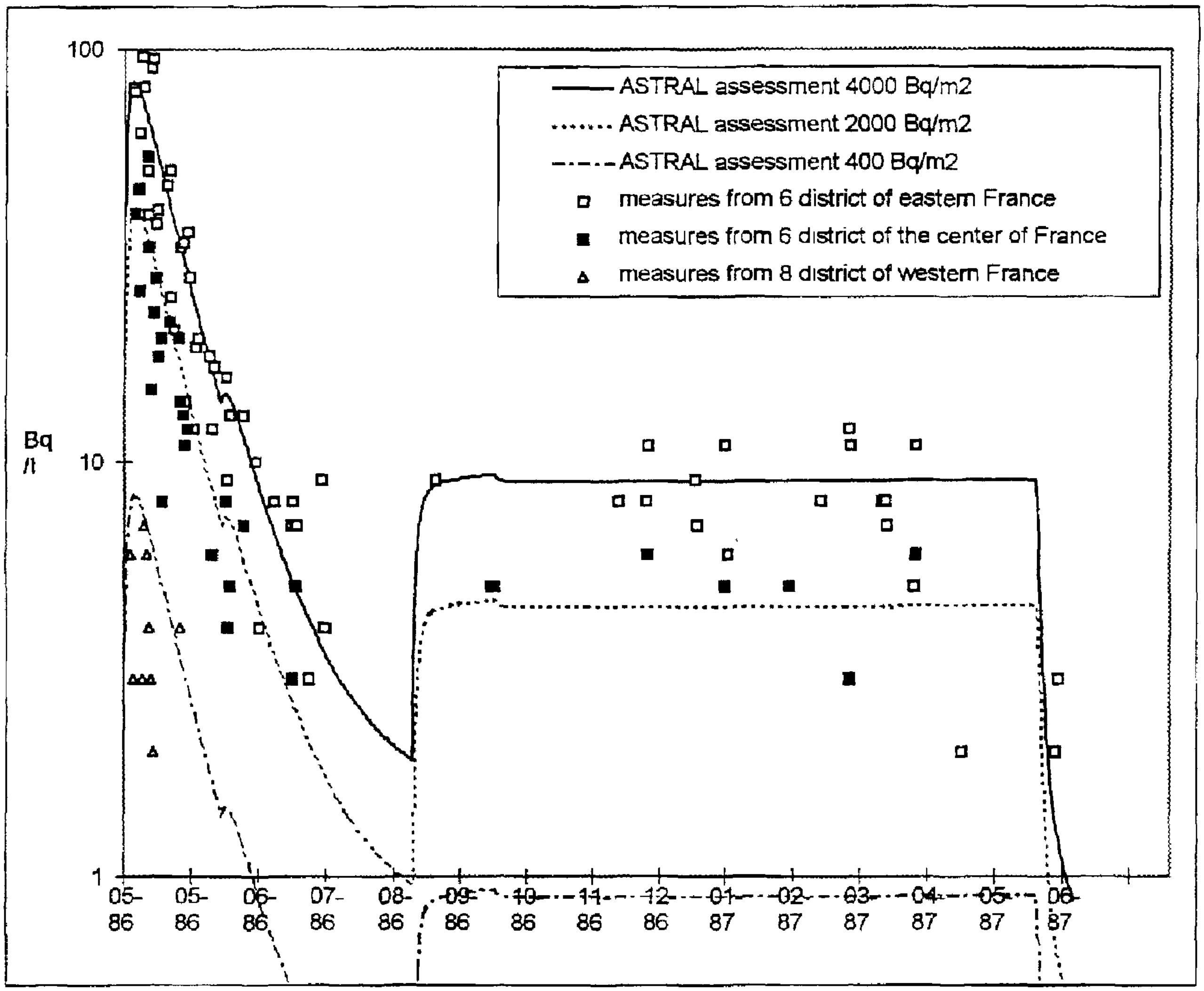
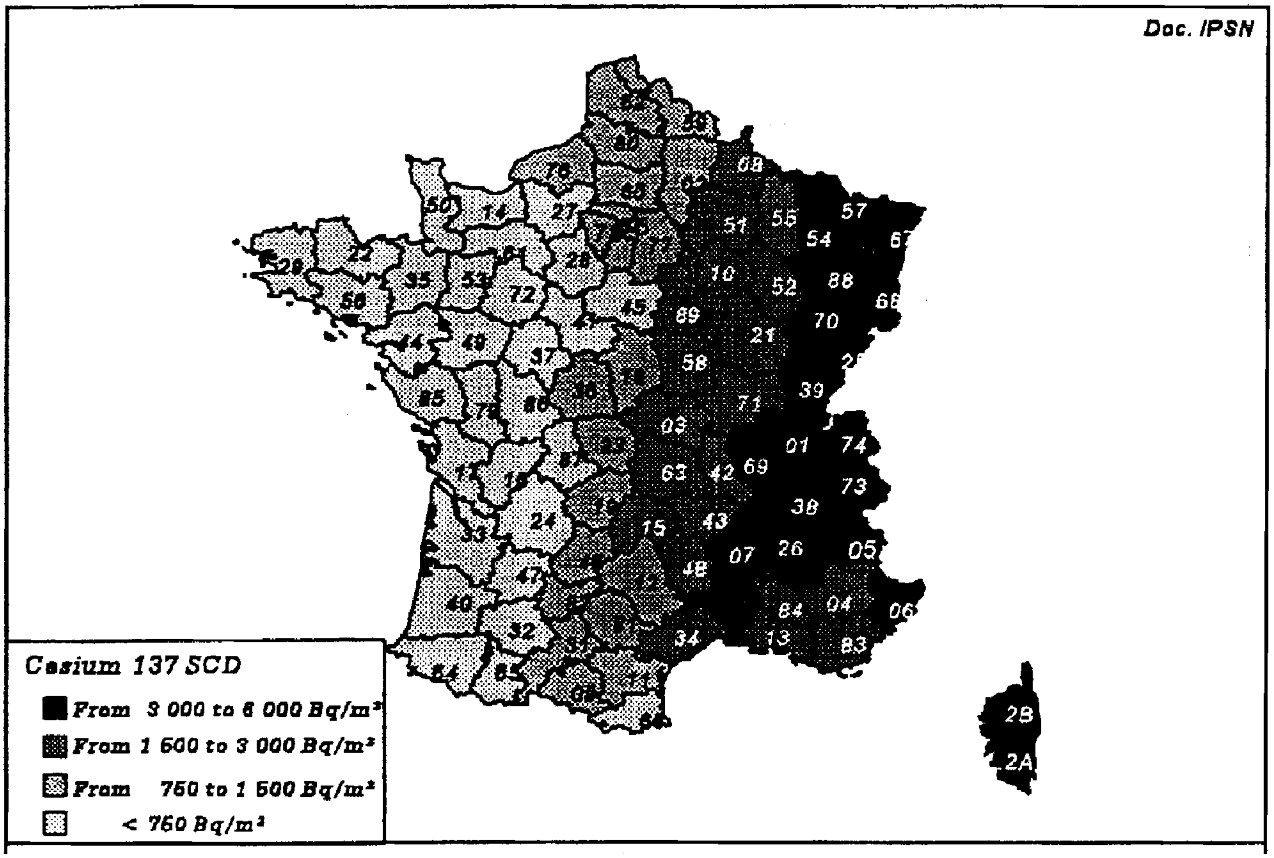


Figure 1 : Evolution of the concentration of cesium 137 in milk in different french districts and simulations given by ASTRAL for different corresponding deposits

This figure clearly differentiates between districts contaminated to a level of 3,000 to 5,000 Bq/m2 (eastern France), those less affected, with values of 1,000 to 3,000 Bq/m2 (center of the territory) and those with very low deposits. The scatter in milk measurements for a single district is fairly low given the time dependancy of the specific activity. These observed kinetics and ASTRAL forecasts show a good agreement. It is characteristic of summer grazing, and winter feeding using mainly spring hay. During the pasture period, the activity of the milk decreases with that of the grass ; during winter, it increases and stabilises : the specific activity of hay harvested in spring or in summer decreases only by radioactive decay. In the spring of 1987, the return to pasture - with renewed grass - led to a final fall of the milk contamination, with ^{137}Cs concentrations sinking below detection thresholds.
A study of this type was conducted for all districts of France, which allowed to draw a map of showing mean deposited surfacic activities of ^{137}Cs (figure 2). As inferred from wet deposition

determinations, there is a strong surfacic activity decrease from east to west in a result of plume depletion. This map is in good agreement with the one established by OPRI on the basis of results of "ground + plant" sample measurements.

Figure 2 : Average cesium 137 surfacic activities deposited on agricultural surfaces and meadows after the Chernobyl accident



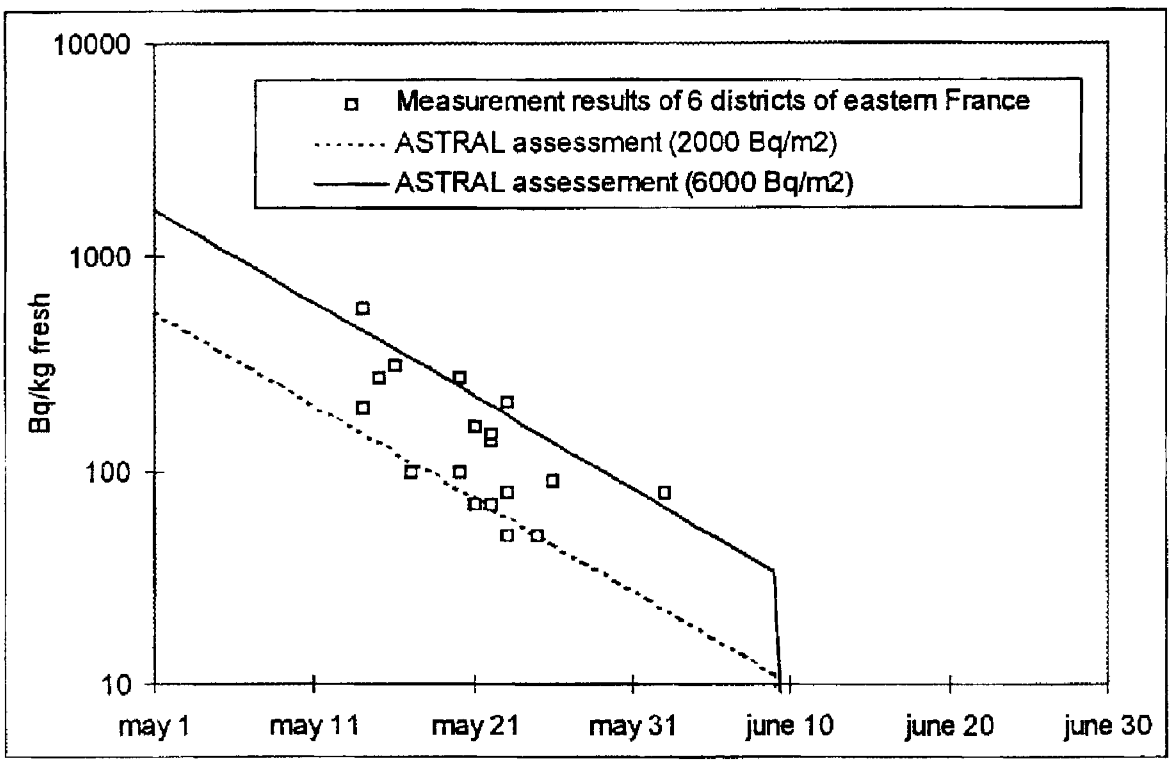
Maps of ^{134}Cs and ^{131}I have been drawn also. The well-known ratio ^{137}Cs/^{134}Cs of 2 is confirmed. For iodine the mean surfacic activity of the eastern most severely contaminated part of France range between 20,000 and 50,000 Bq/m^2. In the least contaminated zone (western France) activities of this radionuclide are lower than 5,000 Bq/m^2.

Among others foodstuffs regularly sampled by the french ministry of Agriculture are the leafy vegetables : salad, spinach...ASTRAL can be used to verify the coherence between these measurements and milk ones for each district. Figure 3 shows the measurement results for leafy vegetables sampled in the six districts of eastern France chosen in the figure 2. It appears that specific activity of cesium ^{137} in leafy vegetables and milk are coherent.

Leafy vegetables present a greater variability of their specific activities due to their greater sensitivity to local variations of the deposits. In eastern France, their specific activities is sometimes representative of surfacic activities as high as 6,000 Bq/m2.

ASTRAL also allows to compensate for inadequacies affecting certain types of measurement or certain time periods by assigning them theoretical values, validated by comparison between measurements and calculations when this is possible. Thus this comparison has been done for few cereals sampled punctually after the first three harvests in 1986, 1987 and 1988, for hay during the winter 1986-1987, for grass from 1986 to 1987 but only in particular places, and for beef and sheep meats. Usually, ASTRAL assessments and measurements results are in good agreement with sometimes the need to adapt some parameters, mainly dates of harvest and feeding practices for animals.

Figure 3 : Evolution of the concentration of cesium 137 in leafy vegetables in different French districts and simulations given by ASTRAL for different corresponding deposits



At the end of this work we have got a complete set of validated data : maps of deposited surfacic activities and foodstuff specific activities with their evolution in time during the firsts three year. ASTRAL may then be used to assess the evolution of the daily human intake of activity. The comparison of these assessments with anthropometric measurements is the last level of validation before dosimetric estimations. Whole body gamma counting and urine measurements are usually made in France by OPRI and different nuclear operators for the health protection of workers The evolution of the intake of cesium for different time steps have been derived from these measures. The discrepancy with ASTRAL assessments is about 20 to 50 % except during the firsts three months where ASTRAL overestimate the cesium intake by a factor 2 to 3. This is probably due to the use in ASTRAL of conservative values for the consumption rates of leafy vegetables and milk.

CONCLUSION

The combined use of modelling and measurement results developed in this paper allows to characterize radioactive deposits for a widespread contamination of the environment, with a limited number of measurements. Using milk as pilot, the mean surfacic activity deposited over few thousand square kilometers can be evaluated with less than a few tens of samples distributed over three months. Some complementary measurements of grass or leafy vegetables enables experts to valid these assessments and to study the heterogeneity of deposits. The advantage is to keep the rest of the measurement capacity to locate the most affected areas in relation with rainfall, altitude, orography or wooded surfaces.

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Agricultural Impact Of Accidents Postulated For Missions Proposed For The US DOE Pantex Plant

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INTRODUCTION

Two new missions are currently under consideration for the USDOE Pantex Plant. The first mission would involve conversion of the plutonium metal center of the warhead, referred to as a "pit," into one of two forms. The first option possible would be to convert a plutonium hemi-shell into a solid metal "puck," of declassified shape. The second option would be to convert the plutonium into plutonium dioxide (PuO_2) powder. The former outcome is the most acceptable for storage of weapons-usable material. The latter outcome is a necessary precursor to MOX fuel production. These processes would be performed in the disassembly/conversion facility (DCF)[1]. The second mission would involve fabrication of mixed-oxide (MOX) reactor fuel. MOX fuel fabrication would take place in the MOX fuel fabrication facility (MOXF)[2]. To date, various steps in the conversion process have been tested successfully at the laboratory scale. MOX fuel fabrication has been accomplished at production-scale for the past several decades in Europe.

DISCUSSION

An independent, scoping-level health-risk and environmental impact assessment of the proposed missions was performed at the request of the Governor's Office of the State of Texas. Four groups of professionals were assembled by the Amarillo National Resource Center for Plutonium (ANRCP), to perform the assessments: process identification, risk assessment, environmental transport, and agriculture issues. The primary goal of the study's initial phase was a comparative societal risk assessment wherein the impact of proposed missions would be compared to that of existing missions.

The preliminary risk assessment considered a wide range of accident scenarios. Bounding postulated accidents were chosen for further study, as this approach would give the citizens of Texas a perspective on "worst case" impacts. As such, no fault tree analysis was performed. Rather, the research team used environmental impact statements (EISs), environmental assessments (EAs), safety analyses reports (SARs) and a battery of source and reference documents consistent with existing DOE analyses, due to the comparative nature of the study[1-5]. The "bounded" approach above had the advantage of allowing the assessment to go on without the need to obtain fault trees possibly beyond the scope of the Freedom of Information Act. Results were based on the best information deemed available in the professional judgement of assessment team members. Site specific data were used where possible, e.g., meteorological data and some accident probability frequencies[4]. Surrogate facility data were used in the absence of site specific data, the emphasis being on DOE facilities that had handled PuO_2 in powdered form[6,7].

During the risk assessment, it was noted that the usual endpoint in an environmental impact statement was a collective or population dose. No account was taken of potential impacts on local agriculture, impacts that may prove quite severe if the locale adjacent to the nuclear facility is dependent upon some form of agribusiness. Therefore, in addition to the differential risk assessment, computational models were used to determine the impact of postulated accidents on agricultural areas surrounding the Pantex Plant.

Areas of land contaminated to different levels by an accident are a measure of agricultural consequence Derived response levels (DRLs) were calculated, which correspond to Environmental Protection Agency (EPA) Protective Action Guides (PAGs) for the intermediate phase of an accident[8]. These values were used in conjunction with the HotSpot computer code to determine the areal extent of land where calculated deposition levels for the various accident scenarios, and various deposition pathways, exceed the DRLs corresponding to particular PAGs[9]. Determinations of the areas affected were made for both DRLs based on the dose to bone surfaces (generally the limiting case for plutonium) and DRLs based on the committed effective dose equivalent.

A DRL is the level of a measured indicator that corresponds to a particular limit of interest. For example, deposition of radioactive material on the ground can be correlated with dose to an individual or group of individuals. This correlation allows protective action decisions to be made based upon deposition measurements.

For this analysis, only a subset of the possible accident scenario exposure pathways was chosen. These were: inhalation of resuspended material following deposition; ingestion of fruit, vegetables, or grain directly contaminated by deposition; ingestion of beef from cattle grazing on contaminated forage; ingestion of milk from cattle grazing on contaminated forage; and ingestion of leafy vegetables grown in contaminated soil. Values for many parameters must be determined or assumed in order to calculate DRLs for the various pathways. Information for these calculations came from publications of the International Atomic Energy Agency (IAEA), International Commission on Radiological Protection (ICRP), National Council on Radiation Protection and Measurements (NCRP), U.S. Department of Energy (DOE), U.S. Environmental Protection Agency (EPA), and the U.S. Nuclear Regulatory Commission (NRC).

The HotSpot code uses a straight-line Gaussian dispersion and transport model[9]. The default deposition velocity used in HotSpot for determining the rate of deposition of plutonium onto the ground is 1.0-cm s^{-1} and was used for these calculations. All calculations assumed a release height above the ground of zero. Meteorological data typical for the Pantex Plant was used in the calculations: stability class D and a wind speed of 6 m s^{-1}. These meteorological conditions corresponded to those used by DOE.

There are many variables that affect the extent of the area contaminated following an accident. The calculations performed for this evaluation give estimates of the areas potentially involved, but cannot be presumed to be exact predictions of the areas that would be contaminated in the event an accident were to occur. Results are shown in Table 1. These are the areas for which dose mitigation techniques would need to be implemented in order to keep the offsite dose below the PAG level. As can be seen, DRLs for ingestion of vegetables directly contaminated with plutonium are more restrictive (by a factor of approximately 400) than the DRLs for vegetables grown in contaminated soil, which become subsequently contaminated via root uptake (no wash-off or rain-off was assumed).

Table 1. Acres affected for selected accident scenarios based on PAGs (typical meteorological conditions: D Stability Class, 6-m s^{-1}).

		Acres affected Based on bone surface doses (BSD) (Based on committed effective doses (CEDE))						
Value Based on BSD (Based on CEDE)		A*	B	C	D	E	F	G
µCi m^{-2}	g Pu ha^{-1}							
0.6	0 04	--	7	30	60	110	250	4,940
(2.1)	(0.15)		(2)	(6)	(20)	(20)	(50)	(960)
0.5	0.04	--	8	30	80	130	320	6,180
(1.6)	(0.12)		(2)	(8)	(20)	(30)	(80)	(1,360)
0.5	0.04	--	8	30	80	130	320	6,180
(1.7)	(0.12)		(2)	(8)	(20)	(30)	(70)	(1,360)
0.8	0.06	--	5	20	40	80	180	3,460
(2.8)	(0.20)		(1)	(5)	(10)	(20)	(40)	(670)
22	1.6	--	--	1	1	2	4	50
(43)	(3.1)			(0)	(1)	(1)	(2)	(20)
43	3.1	--	--	--	1	1	2	20
(160)	(12)				(0)	(0)	(0)	(5)
180	13	--	--	--	--	--	--	5
(710)	(52)							(1)

A. BEB** Cell fire – 0.64 g Pu * – is negligible dose
B. Fire on the loading dock – 9.0 g Pu **BEB is Beyond Evaluation Basis
C: Truck (diesel fire) – 30 g Pu ***A/C is Aircraft Crash
D: DCF oxyacetylene explosion – 64 g Pu
E: BEB (maximum credible) earthquake (DCF) – 100 g Pu
F: A/C*** into DCF – 200 g Pu
G: A/C into oxide storage – 2,000 g Pu

CONCLUSION

Modeling results indicate that material would be released beyond Pantex Plant boundaries under certain accident scenarios, for certain assumed siting decisions. Areal deposition is possible wherein EPA PAGs can be exceeded. Such deposition would require protective actions to be taken; therefore, a study that features methodology such as this may prove useful as an emergency response planning tool for personnel at Pantex Plant should the siting decision dictate that either of the proposed material disposition activities be placed on Texas soil. In addition, such a study would afford the State of Texas an informed input in the siting decision prior to ground breaking A similar study would provide results of similar nature for any disposition option-siting candidate.

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