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JOINT AGENCY MODELLING – A PROCESS TO DELIVER EMERGENCY RESPONSE NATIONAL GUIDANCE FOR A RADIOLOGICAL ATMOSPHERIC RELEASE

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Abstract: Joint Agency Modelling (JAM) has been developed through collaboration between several UK Government agencies. It puts in place an operational capability to support strategic decision making in central government for a radiological atmospheric release from a UK or overseas civil nuclear facility. In an emergency, JAM will receive source term information from a nuclear facility operator or from the Office for Nuclear Regulation. An atmospheric dispersion model uses this source term information together with numerical weather prediction data to forecast the dispersion and deposition of the radionuclides. From these data human dose and food and water impacts are computed. A briefing document is then generated summarising the potential protective actions that should be considered to minimise the impacts of the release. This is supported by data for analysis and provided to the UK Government in a timely manner to support the national emergency response.

Key words: *radiological, impacts, dose, atmospheric dispersion.*

INTRODUCTION

In response to the radiological atmospheric release from the Fukushima Daiichi Nuclear Power Plant in 2011, modelling and analysis from several UK agencies was brought together to provide information to the UK Government. This collaboration resulted in Joint Agency Modelling (JAM). JAM has been under development for several years, with funding from the Department for Business, Energy & Industrial Strategy (BEIS). It puts in place an operational modelling system, together with a process to ensure smooth execution of the activities, training for all involved and tests to demonstrate the functionality. During 2019, JAM is expected to become an operational national response capability ready to respond to an atmospheric radiological release within the UK or overseas. The JAM Partners (Office for Nuclear Regulation, Met Office, Public Health England, Environment Agency, Food Standards Agency, Scottish Environment Protection Agency, Northern Ireland Environment Agency, Food Standards Scotland and Natural

Resources Wales) deliver the emergency response, maintain the capability and will continue to develop JAM. The customer for JAM is the Scientific Advisory Group for Emergencies (SAGE). This is a group of experts gathered from government departments, organisations, industry and academia, that is chaired by the Government Chief Scientific Advisor to deliver timely and coordinated scientific advice to aid central government on forming the strategic emergency response.

THE JAM PROCESS

The purpose of JAM is to provide guidance to SAGE on the scale of the impacts resulting from a radiological release from a civil nuclear facility. This is provided in the form of a briefing document containing pictorial representation of the areas predicted to be affected and accompanying text describing the main points to note. Representatives from all the JAM Partner organisations are likely to be present at SAGE to provide additional explanatory information as required. Data from the modelling process are also made available on a UK national platform called RIMNET for organisations to conduct further analysis.

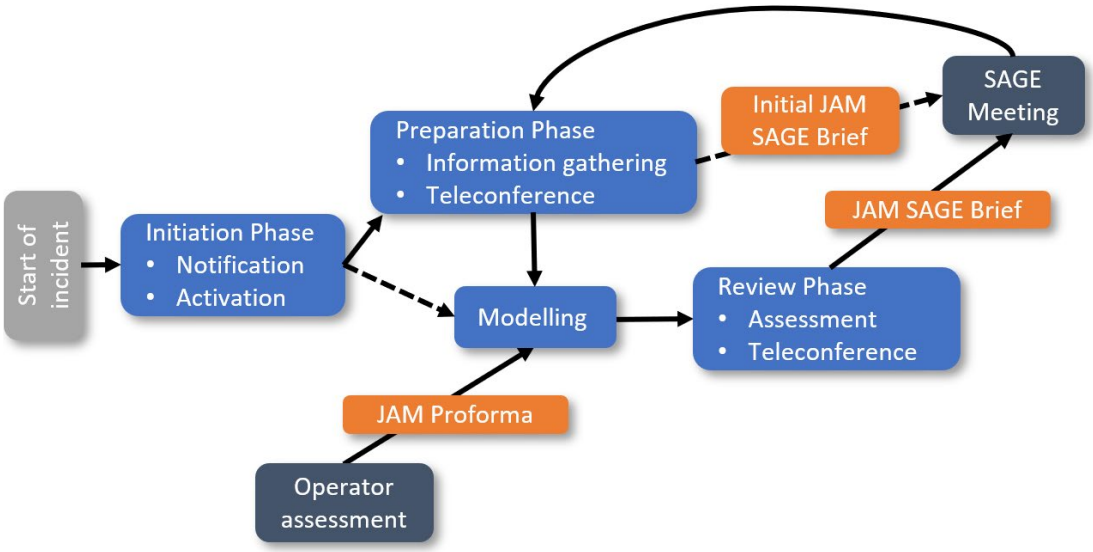

Figure 1. The JAM Process with JAM activities in blue, external activities in dark blue, and JAM information in orange. The solid black lines represent the main flow of the process with the dashed black lines representing optional process flow dependant on the available information.

The process, illustrated in Figure 1, begins with JAM Partners being notified of an incident at a civil nuclear facility. The incident may be an atmospheric release of radiological material or an event which could potentially lead to such a release. As a result, JAM is activated by any of the JAM Partners and preparatory activities begin within each organisation, e.g. gathering a response team and ensuring communication links and technical resources are in place.

The next step depends on whether source term information has been received. It is expected that UK nuclear facility operators will deliver the time-varying multi-radionuclide source term to the JAM Partners within 2-4 hours of the incident being declared. For an international incident it is likely to take longer to obtain a source term. Therefore, it is probable that JAM Partners will be ready to respond before source term information has been received. In this situation, and if a SAGE meeting is imminent, JAM Partners will gather the information available to them from the existing emergency response activities and a coordinated short initial written brief will be provided to SAGE.

The nuclear facility operator will provide source term information in a prescribed form called a JAM Proforma. For an ongoing or potential release, two source term scenarios are provided: one for the best estimate of the future release (known as the “most likely”) and one for the release that could occur if mechanisms to stop the release fail (known as the “reasonable worst case”) - this is used as a bounding case for the potential impacts. For a release that has already occurred, an estimate of the source term for the

stopped release is provided. The source terms can contain many radionuclides and have activities (in Bq) that vary with time. If for any reason the operator cannot complete a JAM Proforma or the release is overseas, the Office for Nuclear Regulation (ONR) would provide one.
Once a JAM Proforma has been received by the Met Office modelling can begin. The modelling involves preparatory activities, the running of an atmospheric dispersion model, running a radiological dose model and post-processing to compute impacts based on established thresholds and create graphics (Figure 2). In addition to the source term, numerical weather prediction (NWP) data and several parameters (e.g. assumed age for the dose calculations: infant, 10-year-old or adult) are required. Default values are set for these parameters and will typically be used in the first JAM model run; for later runs the parameters may be altered based on discussion during the preparatory teleconference.

Modelling outputs are analysed by JAM Partners and a teleconference held to form a consensus view on the concise written assessment for the JAM SAGE Brief. This assessment includes points to note relating to health impacts, food impacts, surface water impacts and uncertainties in the modelling. The completed JAM SAGE Brief is then made available for SAGE attendees ahead of their meeting to assess the national strategic response to the emergency.

SAGE will use the JAM SAGE Brief in conjunction with other scientific information to form guidance to be passed to those leading the national emergency response, typically chaired by a senior government minister. Questions arising from the SAGE discussions may be passed back to JAM requiring further modelling to take place. Similarly, an update on the source term from the operator, perhaps updated NWP data, or questions from JAM Partners themselves, would initiate a further cycle of the JAM Process. The cyclical process will continue for as long as SAGE requires.

MODELLING

Several of the JAM Partners have contributed to the modelling software and methodology. However, for efficiency all the modelling is carried out at the Met Office.

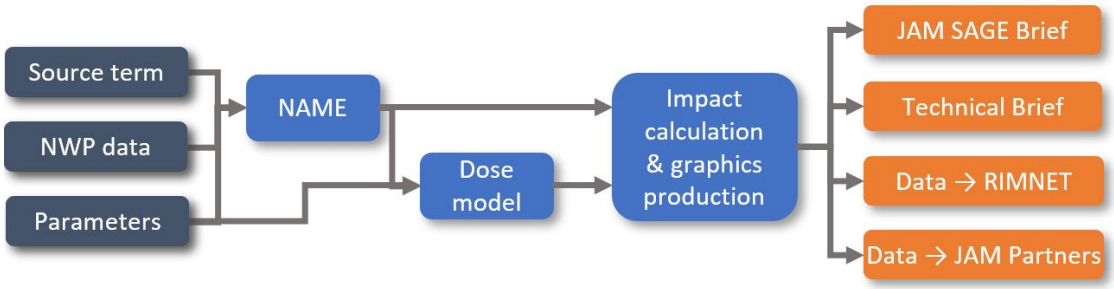

Figure 2. JAM modelling setup: input data are in dark blue, software (modelling & graphics production) is in bright blue and the outputs are in orange.

Atmospheric dispersion model

Figure 2 illustrates the modelling set-up. At the heart of this is the Numerical Atmospheric-dispersion Modelling Environment (NAME). NAME is a Lagrangian particle-trajectory model used to model the atmospheric transport and dispersion of a range of gases and particulates (Jones et al., 2007). In NAME, emissions into the atmosphere are simulated by creating a large number of computational particles where each computational particle represents a certain proportion of the mass or activity of the released pollutants. These particles are then advected by the ambient three-dimensional wind field provided by NWP data from the UK Met Office's Unified Model (Table 1), with turbulent dispersion processes being simulated using random-walk methods. The particles can also evolve with time to account for various atmospheric processes that might transform or remove the pollutants (e.g. radioactive decay, dry and wet deposition).

Table 1. Unified Model configurations used for JAM (March 2019)

Area	Horizontal resolution (km)	Forecast length	Temporal resolution (hours)
Global	10	6 days	3
UK	1.5	36 hours	1

Dose and health impact modelling

The time integrated activity concentrations in air (Bq s m^{-3}) and activity concentrations in material deposited on the ground (Bq m^{-2}) estimated by the NAME model are used to calculate indicative dose quantities that illustrate the consequences of releasing the chosen source term of radionuclides into the atmosphere using a dose model developed by Public Health England. Subsequently, these dose quantities are compared against dose criteria for protective actions (evacuation, sheltering, administration of stable iodine) to help predict areas where urgent actions may be required to protect the public.

Food and surface-water impact modelling

The Food Standards Agency uses a terrestrial food chain model, PRISM (Limer and Walke, 2017), to calculate deposited values of radionuclides that would result in exceeding Maximum Permitted Levels (MPLs) of radioactivity in foodstuffs as established by European Council Regulation 2016/52/Euratom (European Council, 2016). The MPLs are grouped into four categories: isotopes of strontium, isotopes of iodine, alpha emitting isotopes of plutonium and transplutonium elements, and all other nuclides with half-life greater than 10 days (notably caesium 134 and 137). Within JAM, the MPLs for two food groups are considered: milk (modelled as cow's milk) and non-leguminous leafy green vegetables (modelled as cabbages). The MPL thresholds are applied to the activity concentrations in material deposited on the ground (Bq m^{-2}) calculated by NAME and summed up for each of the radionuclide groups (applying scaling factors where appropriate). The radionuclide group that results in the largest geographical area of deposited activity above the MPL is selected to illustrate the potential area of restrictions for the respective foodstuffs as a result of the radiological atmospheric release.

The Environment Agency apply a similar approach to predict areas where surface water supplies could exceed the MPLs for radionuclides in liquid foods. MPLs for the same four radionuclide groups are applied to the summed deposited activity output from NAME. The radionuclide group that results in the largest geographical area of deposited activity above the MPL is selected to indicate the geographical area where there is a potential for impact on surface water which may be abstracted for drinking water supply.

JAM OUTPUTS

There are two main types of JAM outputs: data and briefing documents. The data are output from NAME and the dose model and they are disseminated to a national system called RIMNET. This is a platform that enables (a) the analysis of the data overlaid on mapping and other Geographical Information System data, and (b) the comparison of the modelling outputs with radiological measurements.

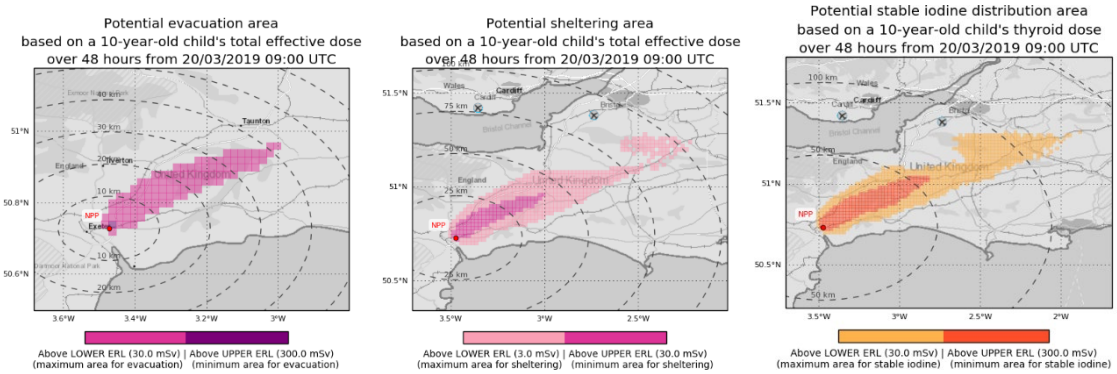

Figure 3. Potential areas for protective actions for health: evacuation area, sheltering area and distribution area for stable iodine. Two emergency reference levels (ERLs) are applied to the total effective dose for evacuation and sheltering, and two ERLs are applied to the thyroid dose for the stable iodine; these are shown below each graphic. The scenario is for the most likely release and it is a fictional source term loosely based on the Chernobyl release from a fictional nuclear power plant (NPP) using UKV and Global Unified Model data.

The JAM Briefing documents are aimed at informing the SAGE attendees about modelled impacts. The JAM SAGE Brief includes: a summary of the incident and modelling set-up, summary text provided by JAM Partners through discussion during a teleconference, maps showing potential evacuation, sheltering

and stable iodine distribution areas (Figure 3), maps showing potential restriction areas for leafy green vegetables, milk and surface water (Figure 4), and the source term used in the modelling. One JAM SAGE Brief is produced for each of the scenarios in the JAM Proforma (e.g. a most-likely release and a reasonable worst-case release). Accompanying each JAM SAGE Brief is a Technical Brief aimed at providing JAM Partners with additional information to aid interpretation of the impact areas shown in the JAM SAGE Brief, e.g. mapped total external dose, total precipitation, and tables of predicted dose for specified locations (Table 2).

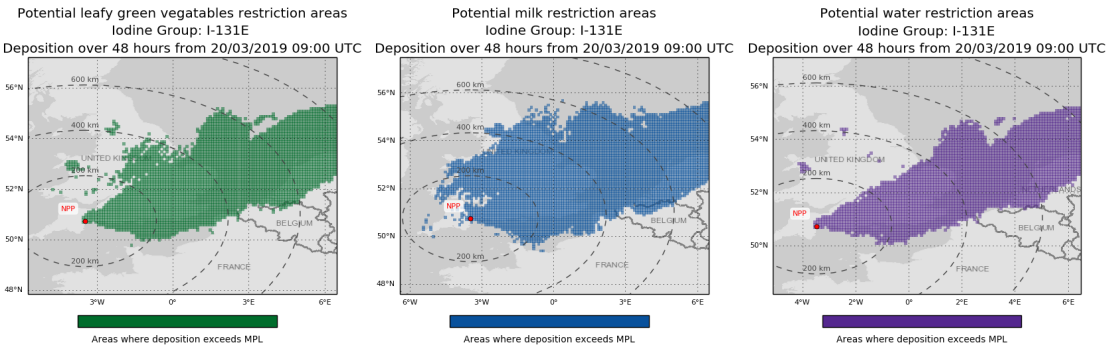

Figure 4. Potential restriction areas for leafy green vegetables, milk and surface water supplies for the same scenario as Figure 3.

Table 2. Predicted total doses over 48 hours at selected locations [mSv] for the same scenario as Figures 3 and 4.

Location	Effective total	Effective inhalation	Effective external	Thyroid Equivalent
Bristol	0.228	0.214	0.014	4.177
Brussels	0.003	0.003	0.000	0.055
Cardiff	0.009	0.009	0.001	0.168
London	1.100	1.030	0.070	19.971
Taunton	10.865	10.176	0.689	199.292

SUMMARY

JAM is a new tool for UK national emergency response to an atmospheric radiological release anywhere in the world. UK agencies work collaboratively to produce assessments on the impacts from the release for SAGE. JAM is a step-change in the modelling tools available for a nuclear incident due to its ability to combine multi-radionuclide, time-varying source terms with dispersion and dose models to automatically produce an assessment on the potential impacts on early health, food and surface water supplies.

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