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Atmospheric dispersion and impact modeling systems: How are they perceived as support tools for nuclear crises management?

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ABSTRACT

This paper focuses on the use of Atmospheric Dispersion and Impact Assessment Modeling (ADIAM) in nuclear emergency management. As a complement to field measurements, these tools participate in emergency decision support regarding the assessment of impacted areas and population protection countermeasures. This paper aims to study how this expertise is used during crisis situation and question the notion of “decision support”.

Semi-structured interviews have been conducted in 2012–2013 with representatives of the French civilian protection community taking part in the emergency response. Analysis is based on a conceptual framework that assesses how individuals and group of individuals make sense and react to a situation in difficult conditions.

Results suggest that if ADIAM systems are used as main emergency support tools by scientific organization to assess areas affected by the release and their potential health impact, their use as a support to civilian protection decision makers is still seeking its place regarding current organization and practices. Results suggest that the main challenge in further integration of ADIAM cartographic results to support population protection decisions needs to take into consideration efforts of the nuclear crisis organization to preserve the balance between different stakeholders' expertise. We argue that in this context, ADIAM cartographic results may find their place as a communication support between scientific advisors and decision makers contributing to favor a shared radiological situation assessment.

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1. Introduction

Disasters linked to the release of toxic material in the atmosphere mark society's industrial evolution. Whether in the chemical domain such as Seveso (1976) or Bhopal (1984) or in the nuclear domain with Chernobyl (1986) and more recently Fukushima (2011) disasters, they are well known for their potential large scale of damages regarding their environmental, health, socio-economical and psychological impacts. Radiological accidents are considered as a major threat that requires, in addition to prevention actions, a rapid reaction of public authorities to take population protection countermeasures. The latter are mainly associated with absorbed dose reference values that cannot be measured directly on the field. Consequently, in regard to other risks, population protection decisions are mainly based on recommendation of scientific organizations that cooperate tightly with civilian protection emergency services.

The assessment of potential health hazard of a radiological atmospheric release is increasingly supported by the development of Atmospheric Dispersion and Impact Assessment Modeling (ADIAM) systems. They allow the analysis of the current distribution over space and time of the contamination based upon information on the material released in the environment, meteorological data and weather forecasts. ADIAM can provide different result levels. The most common information levels regard (i) estimated airborne and soil concentrations (instantaneous and time integrated) regarding the distribution of the contamination and (ii) estimated dose exposure (Sievert) providing a better understanding of potential health consequences. Further development also allows ADIAM systems to simulate potential countermeasures impact on population dose exposure (e.g. sheltering, evacuation, etc.). This is, for example, the case with the development of the European Real-time Online Decision Support (RODOS) system for radiological crisis management (Ehrhardt, 1997). To achieve these requirements, ADIAM systems are constituted as a complicated chain of a number of components including physical models, data bases, pre- and post-treatment programs and man-machine interfaces. The heart of

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these tools is generally centered on physical dispersion models from simple approaches such as Gaussian models to more advanced computation ones based on Eulerian and Lagrangian approaches (see for e.g. reviews of [Holmes and Morawska \(2006\)](#) and [Yao \(2011\)](#)).

Scientific publications regarding ADIAM systems are a good indicator of the increasing role that they can play in the scientific community during emergency situation. If they were firstly developed in R&D and academic contexts, the Chernobyl accident (1986) led to consider the usefulness of their support in the management of nuclear accident. Consequently, they are more and more implemented as an element of nuclear emergency response (see for e.g. [Sørensen et al., 2007](#)). This evolution of the last 25 years can be illustrated by their use by several organizations across the world during the Japanese nuclear disaster in 2011 as support tools to assess the contaminated areas and help supporting decisions regarding population protection countermeasures ([Benamrane et al., 2013](#)).

2. ADIAM use in crisis decisional contexts

Despite these recent developments, they do not guarantee the effective operational performance of ADIAM systems regarding the constraints associated to crisis management (uncertain conditions, time-pressure and high stakes). Few scientific papers investigate their effective support to crisis decision makers in charge of population protection countermeasures. [French et al. \(2007\)](#) underlined two main issues regarding their use in emergency management: the accuracy of their results in uncertain environment and the sociological environment of their use at the boundary between scientists and emergency managers.

2.1. ADIAM use in emergency contexts: an issue of accuracy and trust

The use of ADIAM systems as decision support is linked to confidence and trust issues about the accuracy of their results. Indeed, it is well known that deterministic modeling of dynamic physical phenomena is not comprehensive and include an inherited degree of uncertainty. Validation tests are conducted to evaluate ADIAM systems performance in comparison to empirical experiments (see for e.g. [Van Dop et al., 1998](#); [Allwine and Flaherty, 2007](#)) or from accident feedback such as Chernobyl (see for e.g. [Brandt et al., 2000](#); [Terada and Chino, 2005](#)). Furthermore, ADIAM systems implemented for nuclear crisis response are mainly designed to be operating in anticipated contexts. However, crises can quickly escalate to complex or chaotic situations in which ADIAM systems may not be operated in the conditions initially planned such as illustrated during the Fukushima nuclear accident ([Benamrane et al., 2013](#)).

2.2. The use of ADIAM systems at the boundary between scientific advisors and decision makers

This paper focuses on the social context in which ADIAM use is grounded at the boundary between scientific organizations which develop and operate them and emergency decision makers in charge of population protection countermeasures. As the management of nuclear accidents requires a good coordination between scientific advisers and civil protection teams on the field and at command centers, many national response systems involve scientific agencies that analyze situations and provide information and warnings about the relevant hazard to the authorities. However, the global nuclear crisis management process that implies interactions between scientific organizations and decision makers has evolved without necessarily taking into account the evolution and the potential of these technologies ([EVATECH, 2005](#)). The issue

of sharing knowledge between both organizations is known as a main contributor of the difficulties linked to ADIAM use ([French et al., 2007](#)). In addition to differences in their respective frames of references ([Mitroff and Shrivastava, 1984](#)), difficult conditions such as urgent need of actions, uncertainty, ambiguity and stress can also impact the boundary between them ([Lagadec, 1991, 1997](#); [Rosenthal and Hart, 1991](#)). An important contributor of difficulty deals with the crossing of role specifications: it is possible that crises contexts lead experts to move into decision making roles and/or decision makers to give too much leeway to scientific advisors, forgetting that decision is the result of the consideration of multiple factors. [French et al. \(2007\)](#) argue that this phenomenon may be accentuated by the presentation of ADIAM cartographic results conducting decision makers to give too much confidence in the data. Consequently, interdisciplinary teams, although essential in the management of complex situations, introduce differences in expertise and decision that can threaten coordination among actors ([Edmonson, 2003](#)).

This paper aims to study how ADIAM expertise and tools are used during emergency situation and question the notion of “decision support” regarding population protection countermeasures. This analysis is conducted with a focus on the nuclear emergency organization in charge of population protection decision.

3. Literature survey of individual and collective response to crisis situations

The first step of the study consist of a survey of the scientific literature addressing how individuals and group of individuals make sense of an emergency situation and act in consequences in difficult conditions. When an industrial disaster occurs such as a nuclear one, the response phase goal is directed to bring back the system in a safety state and to mitigate the consequences on population and its environment. The organization of crisis response is therefore engaged in a number of activities regarding gathering information, situation assessment, rescue commitment, emergency procedures and means deployment (human, financial, material), communication inside the affected organization and toward media, population, international administrations, etc. Thus, crisis management implies individual and group of individuals distributed into the response organization structure that evolve in complex or chaotic environment (time-constrained, complex and highly instable events, uncertainty, high stake threatening). Consequently, the kind of support ADIAM systems and expertise can provide in crisis situation needs to be connected to the way individuals and group of individuals perceive their environment, understand it, and act in consequences.

3.1. Crisis management: from sensemaking to action at individual level

Response behavior to a situational context is embedded in a cognitive information processing system that allows individuals to make sense of a situation and act accordingly. This process is mainly based on perceiving elements of the environment, making sense of them in regards of presumptions, interpretations, and inferences allowing for mental projections in the future. [Endsley's \(1995\)](#) concept of Situation Awareness (SA) described this psychological model. This reasoning process depends on mental constructions of an individual about its environment, the situation he copes with, its assumptions, its past experiences, its culture, etc. These mental constructions are also called mental models ([Johnson-Laird, 1983, 2004](#); [Doyle and Ford, 1998](#); [Jones et al., 2011](#)). Mental models are dynamic by nature and evolve as a function of experience, learning and practices ([Johnson-Laird, 1983](#)). As physical models, mental models are a partial, limited

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