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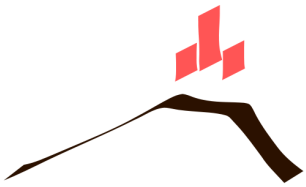

Recent Publication of the International Atomic Energy Agency Technical Document on *Volcanic Hazard Assessments for Nuclear Installations: Methods and Examples in Site Evaluation*

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Abstract

Volcanic hazards assessments for critical facilities, such as nuclear power plants, often must consider the potential effects from phenomena that have very low likelihoods of occurrence. The International Atomic Energy Agency recently released a Technical Document that provides detailed guidance on conducting practical volcanic hazards assessments that include rare phenomena, using both deterministic and probabilistic approaches. This guidance develops a graded approach to the analysis, and provides a range of model complexities for assessing hazardous volcanic phenomena. Although this guidance focuses on the safety of nuclear installations, it is applicable to other sites that warrant consideration of low likelihood volcanic hazards that have potentially high consequences.

Keywords:
volcanic hazards assessment; nuclear safety; site evaluation; probabilistic safety assessment

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Volcanic hazards represent rare natural events that warrant careful consideration for the siting, design or operation of nuclear installations at some locations around the world. To protect health and minimize danger to life and property, the International Atomic Energy Agency (IAEA) develops safety standards that Member States can use in their regulatory programs. These standards provide consensus guidance for evaluating the safety of nuclear installations, including the effects of potentially hazardous phenomena. In 2012, the IAEA published a Specific Safety Guide, *Volcanic Hazards in Site Evaluation for Nuclear Installations* (Safety Standards Series No. SSG-21), which presented a general framework and specific requirements for assessing volcanic hazards at the sites of potential nuclear installations (*IAEA*, 2012). This standard builds upon initial IAEA guidelines developed in *McBirney & Godoy* (2003).

Nuclear safety assessments must consider hazards from rare natural events, which generally occur with likelihoods on the order of 10^{-4} to 10^{-6} per year. Consequently, a volcanic hazard assessment must rely on interpreting the characteristics of poorly preserved past events, and projecting these events into the far range of potential future events. These projections also must consider the possibility that new phenomena might occur in the future, which are inconsistent with the patterns of past activity. As discussed in the Safety Standards Series No. SSG-21, these projections could be done acceptably by using either probabilistic or deterministic methods. Nevertheless, the broader scientific community has not achieved consensus on specific modeling approaches that are both generally accepted and suitable for evaluating low likelihood phenomena at facilities that have very high safety requirements.

To help Member States practically implement the requirements of its safety standards, the IAEA often publishes Technical Documents (TECDOCs) that provide detailed methods and approaches. For example, as part of the lessons learned from the March 2011 Fukushima Daiichi accident, the IAEA recently published *The Contribution of Palaeoseismology to Seismic Hazard Assessment in Site Evaluation for Nuclear Installations* (TECDOC No. 1767) on current methods to incorporate paleoseismology information into a seismic hazards assessment (*IAEA*, 2015). This TECDOC includes, for example, methods and approaches for extracting seismic information from tsunami deposits.

In the Safety Standards Series No. SSG-21, the IAEA recognized that in addition to the lack of international consensus on modeling volcanic phenomena, individual volcanic events can produce a complex range of potentially hazardous phenomena. Thus, the IAEA developed an extra-budgetary program through its International Seismic Safety Centre, which convened a series of consultations to develop additional guidance on conducting practical volcanic hazards assessments. In July 2016, the IAEA published this additional guidance as *Volcanic Hazard Assessments for Nuclear Installations: Methods and Examples in Site Evaluation* (TECDOC No. 1795), which provides detailed methodologies and examples in the application of volcanic hazard assessment to site evaluation for nuclear installations (*IAEA*, 2016). Although the focus of this TECDOC is on nuclear installations, the methods and approaches can be used for the siting, design, and operation of other facilities.

Following the staged analysis approach recommended in the Specific Safety Guide (SSG-21), TECDOC-1795 begins with an initial scoping exercise that characterizes sources of potential hazard and performs an initial screening evaluation. Example screening evaluations from the Armenian nuclear power plant, and other areas, are provided. The next stage of the hazard assessment focuses on the collection of data needed to develop hazard models, and the development of a tectono-magmatic model to understand the occurrence of volcanic activity. This assessment stage also considers different approaches for evaluating recurrence rates, including data requirements, calculational methods, and statistical models. Specific examples are provided from volcanic systems located in IAEA Member States.

Most of TECDOC-1795 is devoted to discussions of models and approaches for evaluating potentially hazardous volcanic phenomena. For each phenomenon, individual sections present an overview of currently available approaches for the evaluation of future hazards, along with examples of hazard assessments that use these approaches. These approaches generally represent a range of model complexities, from simplified physics-based conceptual models to highly coupled thermo-fluid dynamical approaches. Each of these models depend on input from detailed volcanological investigations. Although both probabilistic and deterministic approaches are discussed, TECDOC-1795 emphasizes probabilistic methods. In addition, important considerations are identified for the siting, design, and operation of a potential nuclear installation with regards to safety decisions involving these phenomena. More than 700 references are cited in TECDOC-1795 and the associated annexes, in addition to many useful figures and illustrations.

TECDOC-1795 also presents considerations for volcano monitoring, such as monitoring types and examples of monitoring used for volcanic hazards forecasting. This section is needed because volcano monitoring (as recommended in the Safety Standards Series No. SSG-21) is a relatively new concept for assuring the safety of nuclear installations. There are

many practical aspects that need to be considered in developing an appropriate monitoring network, if warranted by the conclusions of the volcanic hazards assessment.

Both the IAEA Safety Standards Series No. SSG-21 and the IAEA TECDOC No. 1795 demonstrate that volcanic hazards can be assessed systematically and traceably, using methods that are suitable to support safety evaluations at nuclear installations. This approach provides a practicable framework to develop the information needed to make transparent decisions about the safety or acceptability of a nuclear installation site, or other sites that warrant consideration of low likelihood volcanic hazards that have potentially high consequences.

The Specific Safety Guide, *Volcanic Hazards in Site Evaluation for Nuclear Installations* (IAEA Safety Standards Series No. SSG-21) and the *Volcanic Hazard Assessments for Nuclear Installations: Methods and Examples in Site Evaluation* (TECDOC No. 1795) can be downloaded without cost from the IAEA website (https://www.iaea.org/). Web links to both documents are provided in the References.

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