Review of the impacts of volcanic ash fall on urban environments

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Volcanic ash – what’s the problem?

Volcanic ash is produced from the explosive fragmentation of magma within a volcanic conduit, or from the collapse of viscous lava domes. The ash can be widely dispersed in eruptive plumes the extent of which is determined by eruption explosivity, wind speed and direction. As a result, populations are vulnerable to the impacts of volcanic ash fall, both near and distant from volcanic centres. Ash fall is the volcanic hazard that most frequently affects the most people, and ash fall impacts are physically, socially and economically disruptive.

Volcanic ash has highly variable grain size, shape, texture, and vesiculosity. The ash composition depends on the mineralogy of the parent magma, and the soluble surface coatings of the ash vary with the gas types and concentrations emitted and entrained during eruption. Ash is dense, abrasive, chemically corrosive, mildly electrically conductive, and has highly variable grain size (<2mm diameter). These properties cause a range of impacts across sectors, including: power outages caused by electrical flashover, roof collapse from vertical loading, corrosion of metals including roofing materials, reduced road traction, reduced visibility, impacts on respiratory health, contamination of water supplies, abrasive damage and blockages to: machinery, aircraft engines, water networks and drains. In combination with rain, acidic rain can form which can burn crops and vegetation. Ash falls have extensive costs associated with the damage, emergency management and clean-up of ash.

Project Outline

This project aims to gain an understanding of the impacts of ashfall on critical infrastructure systems. Critical systems such as power generation facilities, hospitals, schools, and lifeline services are essential to the functionality of modern society. During a crisis, maintaining the operability of critical services is vital to reducing the felt impacts (physical, social and economic), and to restoring life to normal as quickly as possible after an event.

This project takes a holistic view of whole system vulnerability, using a systems thinking framework to understand the interdependency of lifetime services and volcanic ash impacted sectors. A holistic view of vulnerability can be taken by understanding: the physical dependencies of a critical system on lifelines, and the knock-on impacts from other ash-affected sectors onto critical facilities. And the potential cascading disruptions caused, physical, social and economic, by disruptions or failures at each critical facility.

By understanding the vulnerability of communities and critical infrastructure in affected regions, critical dependencies can be identified and these vulnerabilities can be addressed to enhance the systems resilience. Adaptation and mitigation of the affects of volcanic ashfall can be employed to relieve critical points of stress, and to support more sustainable living in volcanic ash environments.

Research Methods

This project uses case studies to explore the impacts of relatively recent volcanic eruptions on critical infrastructure services and to identify the social importance and vulnerability of these systems. A pilot study has been undertaken to understand the effects of volcanic ash in Montserrat and has revealed some insights into the main causes of system stress, brought on by volcanic ash impacts.

Montserrat will form the main case study, as an ongoing eruption, used to look at adaptations, mitigations and infrastructure system resilience in long-term ashfall environments. Other case studies will provide supporting insights, and field sites will include: Chaitén, Chile; Tungurahua, Ecuador.

Research methods vary for this project and include:
- Case studies from field work in ash-impacted areas;
- Qualitative data collected from semi-structured interviews with infrastructure facility staff;
- Quantitative data from laboratory testing of critical infrastructure components.

Challenges of mitigation

Mitigation measures must be planned in advance, and the changes induced in system as a result of mitigation, or evolution of the system over time, must be considered from the outset. Mitigation planning for sustainable and effective solutions can also be based on the principles of systems engineering. Figure 2 shows a systems engineering approach to planning mitigations to ensure that end user needs are met and that a complete and viable solution is delivered (After Martin, 2006). Adaptations to systems under stress may also be effective, simple and often can be adopted quickly. They can reduce and relieve critical stress from the system.

Key criteria for adaptations and mitigations in volcanic ash environments, and objectives of this research are: affordable solutions, resilient solutions which are robust and flexible, and sustainable solutions that meet local needs, have local collaborators and are easily maintainable.

Future applications

The results of this vulnerability study are intended to provide a robust and holistic vulnerability assessment methodology and lead to mitigations and adaptations to critical infrastructure services in ash-impacted regions. The aim is to identify the key points of stress, in order to reduce the impacts. This work can also be used as a holistic overview of the complexities of impacts, and applied to emergency plans to perform a gap-analysis of resource allocation for critical systems.