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Effects of Volcanicity in Iceland

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Abstract

Iceland is greatly known for its volcanicity as there are several eruptions that have occurred over the years. The country's volcanology is due to its location on the Mid-Atlantic Ridge, which is a divergent tectonic boundary (Promote Iceland, n.d.). Due to this, the country is known to be responsible for a third of all the fresh lava on earth (Marteinn, 2018).

This research provides a deep dive into the effects of volcanicity and how the Icelandic people have adapted to it. The methods used to collect data for this research were secondary sources and interviews. It was evident that the volcanic activities have had tremendous effects on the Icelandic people and the surrounding countries. Some of the affected sectors include aviation, soil, agriculture, tourism, research and many more.

Introduction

Due to Iceland's location on the Mid-Atlantic Ridge, the country experiences a lot of seismic activities. The ridge is a 40,000 km crack in the ocean floor caused by the separation of the North American and Eurasian tectonic plates (Marteinn, 2018). In addition to that, the country has 30 active volcanic systems that feature all volcano types and eruption styles known on earth (Promote Iceland, n.d). The volcanic systems are in such a way that among the 30 volcanic systems; 12 of them are comprised of a fissure swarm and a central volcano, seven of a central volcano, nine of a fissure swarm with a central volcano, and two are the central domain alone (Thordarson and Larsen, 2007) . When people hear of volcanic eruptions they think of death, property destruction and other negative effects. However, there are several positive effects that result from volcanic eruptions. Thus, this research seeks to look at the negative effects of volcanic activities, but also the positive attributes that result from it. Some of the positive effects such as land formation, soil fertility, and rock formations have greatly contributed to the growth of Iceland's economy through tourism. In addition, the research covers details of mechanisms that Iceland has adopted for handling the volcanic eruptions. Using Iceland as a case study allows other countries can learn and develop their own responses.

There are two types of eruptions, *effusive eruptions* when more than 95 percent of the erupted magma is lava or an *explosive eruptions* when more than 95 percent of the erupted magma is tephra (dense rock materials) (Thordason and Larsen, 2007). Through Iceland's geological record, magma volume extruded by individual eruptions ranged

from 1 m³ to 20km³ reflecting variable magma compositions, effusion rates, and eruption durations (Thordason and Larsen, 2007). The most recent eruptions are listed below to give an idea of the active nature of Iceland's volcanos. These volcanic eruptions have had tremendous effects on Iceland a whole. Some eruptions have emitted toxic ash into the atmosphere thus causing health problems. The ash also during some eruptions has led to the disruption of flights and a good example is the 2010 Eyjafjallajökull eruption that led to the cancellation of flights that lead to losses of about \$5 billion U.S. dollars (Bowler, 2013). Other effects of eruptions include landslides, flooding, property destruction, and death of livestock and animals. However, there are several positive effects such as land formation that create a dramatic scenery that attracts tourists.

Eruptions in Iceland (Icelandic Meteorological Office, 2010)

- 2011: Grímsvötn
- 2010: Eyjafjallajökull
- 2004:Grímsvötn
- 2000:Hekla
- 1998:Grímsvötn
- 1996:Gjálp
- 1991:Hekla
- 1984:Krafla
- 1983:Grímsvötn
- 1981:Krafla 2 eruptions
- 1981:Hekla
- 1980:Hekla
- 1980:Krafla 3 eruptions
- 1977:Krafla 2 eruptions
- 1975:Krafla
- 1973:subaquatic eruption 5 km south of Landeyjar coast
- 1973:Heimaey
- 1970:Hekla
- 1963-1967:Surtsey
- 1961:Askja
- 1947:Hekla
- 1938:Grímsvötn
- 1934:Grímsvötn

Methodology

There were several methods used to collect data for the research. These methods included interviews and review of secondary sources. The research methods are described in greater detail below.

Interviews

Several interviews were carried out with different people in a variety of locations in Iceland. It was important to interview people from different cities in Iceland to gather varying perspectives of people who grew up in active volcanic areas and compare their perspectives from those who grew up in less active volcanic areas. Some of the interviewees included Icelandic locals, tour bus drivers, tour guides among many others.

The interviews were done in informal settings to provide a calm environment that enabled the interviewees to share their opinions and ideas openly. The structure of the interview was done in a semi-structured format with open-ended to allow for a more conversational manner. The aim of this structure was to make the interviewees comfortable and thus enable them to share their thoughts freely. It also enabled the interviewee to share more information than what was asked thus providing more qualitative data for the researcher.

Review of the Literature

To obtain a more complete picture the researcher conducted a literary review. The main sources of data used for this research were journals, magazines, published articles, newspapers and different credible online news sites. Most of the secondary sources were acquired from the

Hunt Library and google scholar. Some articles were written by Icelanders while others by explorers who had visited the country. Thus, it was vital to identify the different perspectives of the writers based on whether they were explorers or Icelanders. Some of the articles solely covered particular volcanic activities that had occurred such as the 2010 Eyjafjallajökull eruption while others covered decades of volcanic activities in Iceland. In addition, some articles focused more on the negative effects of eruptions while other more on the positive effects. A few articles went on to cover the mechanisms that Iceland had adopted to deal with the volcanic activities. The variety in the type of sources brought forth different ideas and views that contributed to the whole aspect of this research.

Literature Review

There are several effects of volcanic activities in Iceland; some are negative while others are positive. This literature review focuses on a number of positive as well as negative effects. The negative effects are flight disruptions, health, economic, environmental, livestock and crop destruction. The positive effects identified with the literature include land formation, soil fertility, and tourism. Also a major theme found looks at the measures Iceland has taken to cope with the volcanic activities. These themes will be explored in greater detail below.

Negative Effects

Flight disruptions

During volcanic eruptions, one of the industries that is greatly affected is aviation. During the 2010 Eyjafjallajökull volcanic eruption, thousands of flights were cancelled due to the volcanic ash cloud that was generated by the eruption. Though the eruption was of low intensity, it produced an enormous ash cloud that spread much faster than usual thus making flight difficult.

The volcanic ash posed a risk to aircraft engines as well as caused poor visibility during flight. Due to this, 108,000 flights were cancelled and a tremendous number of passengers were stranded in Europe (Thora, 2014). People from all over the world were startled at how an eruption from a small island, such as Iceland, could affect other countries that were thousands of miles away. The eight day period from April 15 to April 22 in 2010 affected about 48 percent of the expected air travel traffic during the time period (Thora, 2014). Apart from Iceland, the three other countries greatly affected by the crisis were the United Kingdom, Ireland, and Finland. The International Air Transport Association (IATA) estimated that airlines were collectively losing about \$150 million U.S. dollars per day in lost revenues (BBC News, 2010). The figure below shows how the flights reduced in number during the days when the eruption took place:

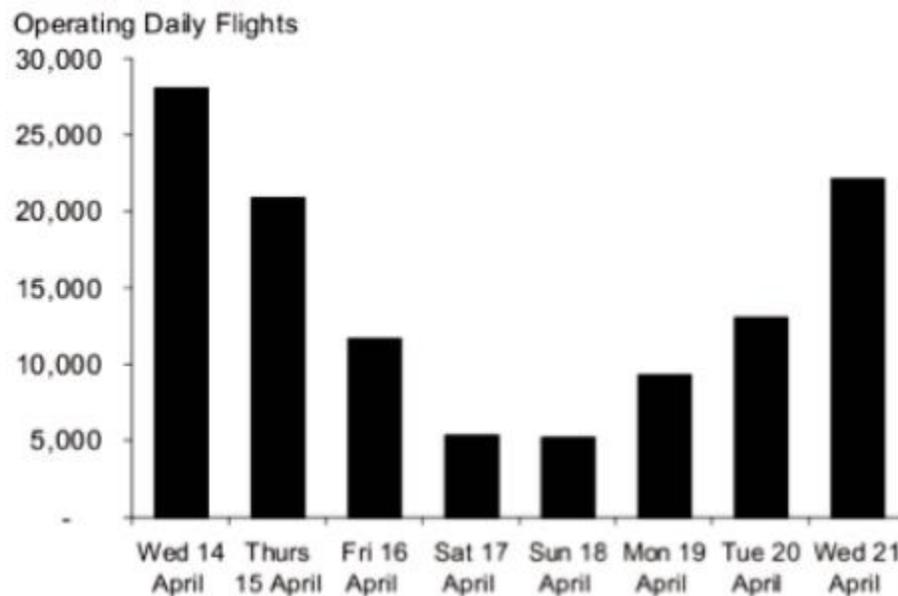


Figure 1: Air traffic in Europe during the 2010 Eyjafjallajokull volcanic eruption (Thora, 2014)

The cancellation of flights also affected international trade especially for perishable goods such as flowers. Being that Africa is the main exporter of flowers to the EU, the continent

experienced huge financial losses as a result of the flight disruptions brought about by the 2010 eruption. The World Bank president in 2010 Robert Zoellick, estimated that African countries were at a risk of losing \$65 million US dollars as a result of the airspace shutdown (Thora, 2014). This would have been a huge loss being that in the previous year (2009), Africa had provided over half of the monthly value of fresh-cut flowers imported into the EU, amounting to 46 million US dollars (Thora, 2014).

Not only was the agricultural sector affected but also the industrial manufacturing sectors. A good number of firms that needed crucial parts could not receive them on time and this affected the production process. The Korea International trade Association estimated losses for local domestic companies that were waiting for delivery of certain commodities at \$112 US million dollars that year (Thora, 2014).

Health Effects

The volcanic eruptions greatly affect the health of the Icelandic people due to the toxic substances contained in the volcanic ash. Some of the gases and particles contained in the ash include carbon dioxide, sulfates, hydrochloric acid, and hydrofluoric acid (Gudmundsson, 2010). Each of these has serious effects on human health if exposed. An example is the Laki eruption that took place in 1783 that released clouds of poisonous fluorine and sulfur dioxide that killed off around 50 percent of Iceland's livestock population (Williams, 2016). The movement of volcanic ash depends on certain factors such as eruption column height, ash particle size, amount of ejected ash and wind strength. Large eruptions can carry ash over thousands of kilometers, and one similar case is the 2010 Eyjafjallajökull eruption that carried ash over to Europe. The acute respiratory manifestations seen after heavy ash falls include irritation of the chest, runny nose, sore throats, wheezing, bloodshot eyes, and tearing. In addition to that, it causes increased

cases of people suffering from acute asthma, bronchitis and silicosis (lung impairment) (Williams, 2016). Volcanic ash also contaminates water and making it not fit for consumption.

Environmental Effects

Some of the gases and particles released during volcanic eruptions such as sulfur dioxide play a major role in ozone depletion and short term climate change. Sulfur dioxide mixes with water in the atmosphere to produce fine particles of sulfuric acid which combines with atmospheric chlorine molecules to form chlorofluorocarbons that produce a compound that reacts with the ozone layer depleting it and exposing the earth to ultraviolet rays (Tiny Scientist, 2010). High concentrations of sulfuric acid in the atmosphere can reflect back a significant amount of solar energy keeping it from reaching the earth's surface. This radiative transfer can cause short term global cooling. However, actual evidence supporting this thesis is limited as there have not been many large scale volcanic eruptions on Earth. On the other hand, studies have shown short term shifts in climate change of areas around recently erupted volcanic zones (Tiny Scientist, 2010). The figure below depicts how the 1783 eruption in Iceland affected temperatures in Europe and other areas:

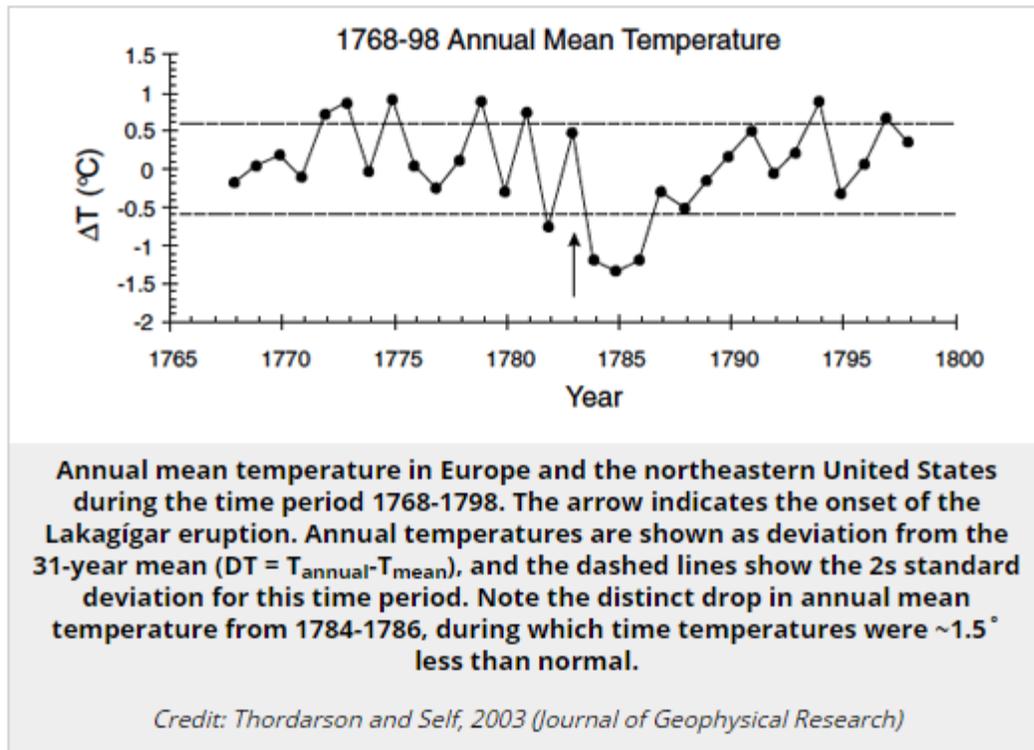


Figure 2: Effects of the Laci eruption on temperatures on earth (Tiny Scientist, 2010)

Crop Destruction and Death of Livestock

The Icelandic word *móðuharðindin* meaning ‘mist hardships’ is an Icelandic term used to describe the difficult times following the Lakagigar eruption in 1783. There was acidic rain that destroyed crops and about three quarters of the island’s livestock (Robinson, 2018). Animals that grazed on plants or drank from the rivers after the eruption suffered from skeletal fluorosis due to the fluorine contaminated water. This was one of deadliest eruption as more than 9,000 people about 20 percent of the population were estimated to have died within Iceland due to the starvation and disease that followed after the eruption (Robinson, 2018). In addition, approximately 10,000 to 20,000 deaths occurred in Europe due to respiratory diseases and crop

failure (Robinson, 2018). The figure below depicts how the sulfur released created a haze that destroyed crops, contaminated rivers and killed livestock:

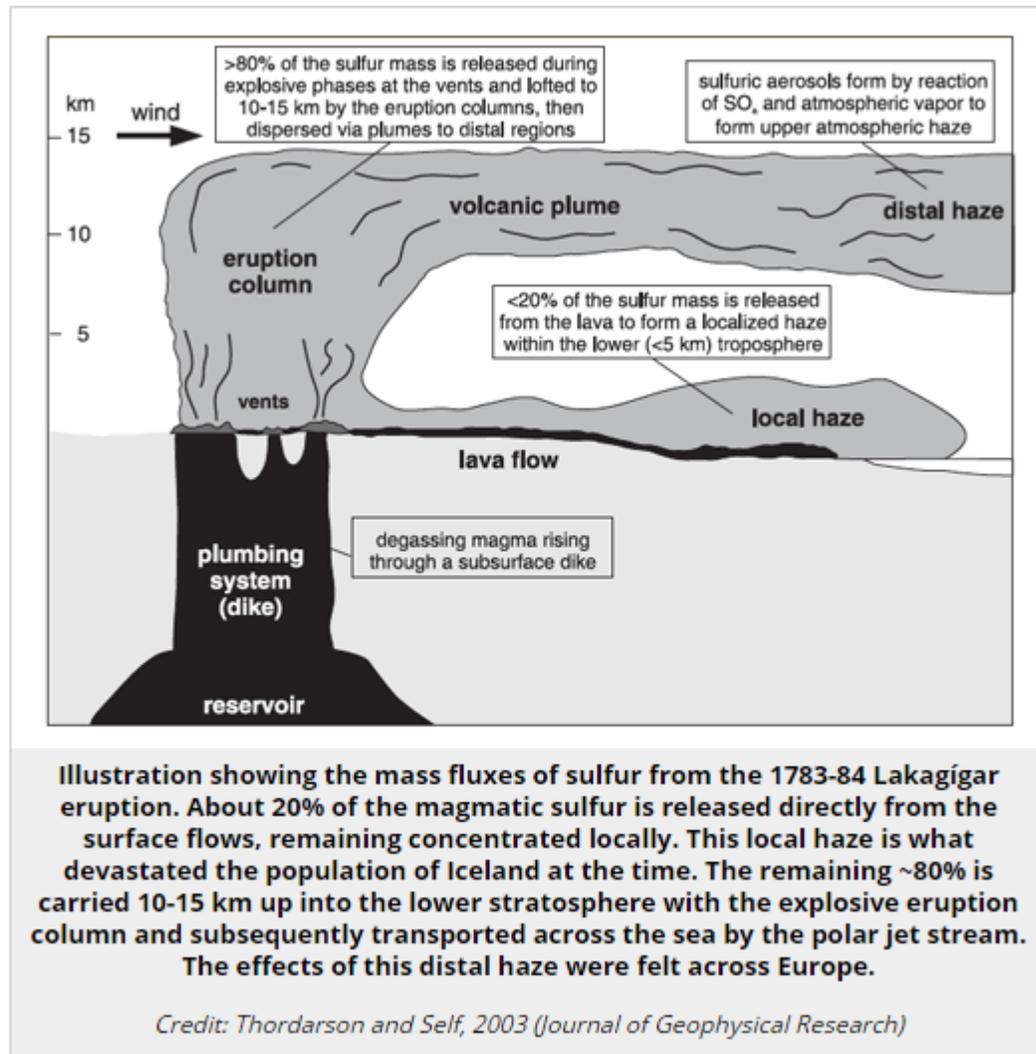


Figure 3: Depicts how sulfur particles are carried away to regions further away creating a haze
(Robinson, 2018)

Positive Effects

Land Formation

In 1963, volcanic eruptions originating from below the sea surface lead to the formation of a new island. The eruption went on for several years and by April 1965 the volcanic ash was blocking water from the crater (Byrd, 2016) The lava flows formed a hard cap over the lower slopes of the new island. This prevented the waves from washing away the island⁴. After three and a half years Surtsey Island was born (Byrd, 2016). Since then, there has been increased research on the island in regards to how new life begins on new land. Scientists have found vegetation on the island as well as other forms of life thus arousing curiosity on how life forms on a new island. This research could lead to the discovery of new plant and animal species. Moreover, other volcanic activities have led to the discovery of minerals that have become vital to industrial production. In addition to that, volcanic activities have led to the formation of beautiful rocks sceneries such as the Dimmuborgir that attract tourists to Iceland. The image below depicts Surtsey Island:



Figure 4: Surtsey Island (Sigurdsson, 2010)

Soil Fertility

Volcanic ash is viewed as destructive to crops, property and even livestock. However, once the volcanic ash settles on the soil it deposits minerals such as iron and potassium that make the soil more fertile for agricultural produce (Williams, 2017). The volcanic soil formed as a result of the interaction of soil with volcanic ash forms strong bonds with organic matter which accumulates on the surface thus becoming more accessible to plants. Moreover, volcanic soils are light and fluffy and in so being are easily tilled thus improving the efficiency of farming. Thus, volcanic soils have greatly improved the fertility of the soil in Iceland and contributed to the growth of agriculture.

Increase in Tourism

A lot of people around the world had never heard of Eyjafjallajokull and could even barely pronounce it before the 2010 eruption. When the 2010 eruption in Iceland occurred, it aroused people's curiosity from all around the world. People were intrigued that a small island could have an eruption that could disrupt flight operations in countries that were many kilometers away. After the eruption, Iceland responded with self-promotion of the various beautiful sceneries in the country (The Associated Press, 2016). This led to a tourist boom as many people began learning about the different wonderful tourism sites that Iceland has. The increase in tourism boosted economic growth especially in the aviation, accommodation, and the culinary sector. The graph below shows how tourism has increased employment in Iceland since the 2010 eruption:

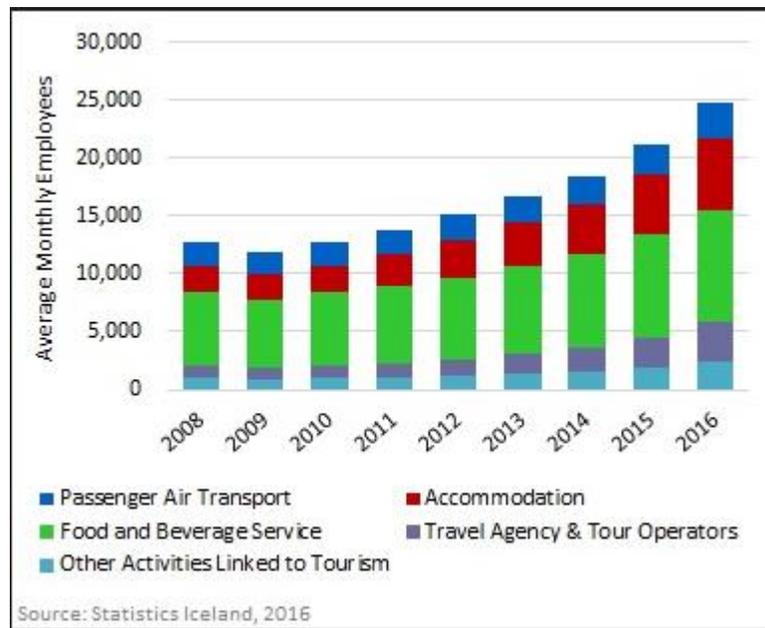


Figure 5: Depicts how tourism has increased in Iceland since the 2010 eruption thus increasing the country's employment rate (Collins, 2017)

Measures Taken

Due to the several eruptions that have occurred in Iceland, there have been several measures developed to better prepare for the volcanic eruptions. There are several seismic detection devices around active volcanoes. At the Icelandic Meteorological Office in Reykjavik, meteorologists, seismologists and volcanologists watch hundreds of sensors that monitor seismic activity, signs of volcanic inflation, and gas emissions which are evidence that magma from deep underground is being pushed to the surface (Iceland Ministry for Foreign Affairs, 2018).

Once the volcanologists discover that there is a threat they alert the National Commissioner of Icelandic Police (NCIP). The NCIP runs a Department of Civil Protection and Emergency Management which is responsible for daily administration of civil protection matters, maintains a national coordination/command center which can be activated at any time and is also responsible for operating the center in emergency situations (Iceland Department of Civil Protection and Emergency Management, 2017). The NCIP is also responsible for monitoring and supporting research and studies related to risk factors and natural catastrophes. Coordination and supporting measures aimed at reducing risks of bodily harm is done by the NCIP as well (Iceland Department of Civil Protection and Emergency Management, 2017).

The day-to-day functions of the Department of Civil Protection and Emergency Management of the NCIP include risk analysis, mitigation and co-ordination (i.e. planning, training and equipment) and recovery (Iceland Department of Civil Protection and Emergency Management, 2017). The role of the NCIP during emergency operations is to procure and deliver all outside assistance (national or international) for a stricken area, which is deemed necessary by the local Chief of Police (Iceland Department of Civil Protection and Emergency Management, 2017). The civil structure is as follows:

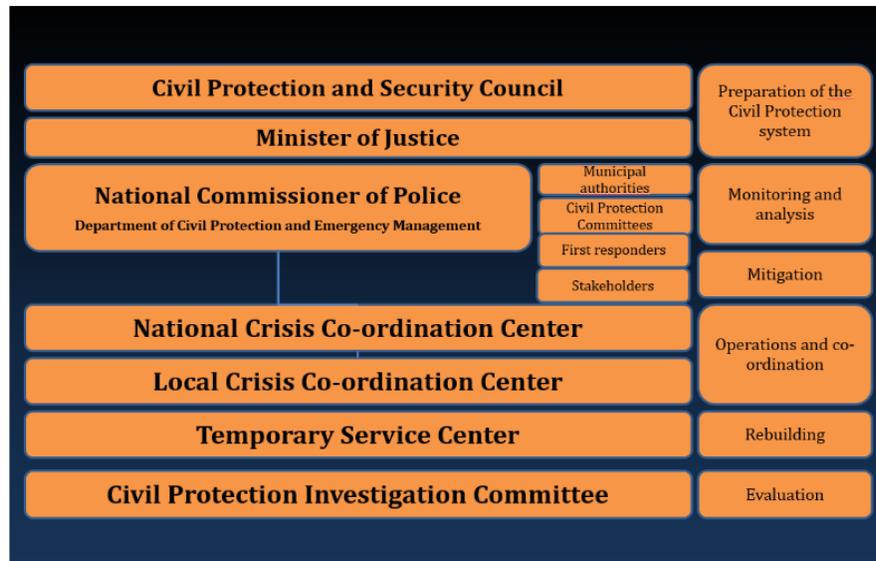


Figure 6: The civil protection structure (Iceland Department of Civil Protection and Emergency Management, 2017)

The Department of Civil Protection and Emergency Management works in hand with the local police of the affected area to inform people about the progress of the eruption. This is done through radio, TV, websites, social media and mobile phone texts. The alerts are broadcast to the affected areas and any capable devices are able to pick up the alerts. Currently, Iceland is promoting the widespread use of Wi-Fi in different areas so as to make the propagation of information easier. In the case of an emergency, there is an emergency number which is 112 (Iceland Department of Civil Protection and Emergency Management, 2017).

Being that volcanic eruptions are associated with earthquakes the Department of Civil Protection and Emergency management informs people about emergency procedures such as securing cabinets, shelves and heating equipment. They also help during evacuations for moving people to safety. This shows that Iceland has a structure in place for handling the volcanic activities.

Results

The researcher interviewed several people during a one-week research abroad trip to Iceland that was organized by the Office of Undergraduate Research at Embry-Riddle Aeronautical University. Each interviewee had their own unique perspective on the effects of volcanic activities. One common theme among the interviewees was that they were all excited for the next volcanic eruption. This was interesting because the researcher initially assumed that Icelanders would be scared of the volcanic eruptions due to the immense negative effects that result from them. Other common themes included flight disruptions, health effects, destruction of crops, death of livestock and tourism increase among many others. The interviewees also went in depth in regards to measures taken by both the government and the people to handle the volcanic activities.

Negative Affects

Flight disruptions was a very common theme among the interviewees. Gunnar, a receptionist at the Lake Myvatn hotel mentioned that he was stuck in London during the 2010 Eyjafjallajokull eruption. Furthermore, he mentioned that there were tons of other passengers who could not fly out of London to other areas in Europe (Gunnar, personal communication 03/11/2018). Baldur Gylfasson, a tour guide elaborated that several passengers got stuck at airports in Europe during the eruption leading to tremendous losses for the airlines. Baldur, continued to explain that the cloud of ash was blown to Europe affecting visibility for flights in that area however flights from Iceland to North America were still operational (Gylfasson, personal communication, 03/16/2018). In addition to that, local policemen that the researcher met at a local restaurant mentioned that road transportation became difficult especially during the 2010 eruption as the ash affected road visibility as well in Iceland (Ng'ang'a, personal

communication, 03/14/2018). Thus, a lot of people had to stay indoors until the ash cleared away. These responses brought out how the eruptions greatly affected the common transportation modes for Icelanders as well as Europeans in the affected countries.

Another common theme that the researcher noticed among the interviewees was the negative health effects that arise from the volcanic eruptions. Gunnar, disclosed that the 2014 Bardarbunga volcano eruption released gases that made it hard for people to breathe, in so being many people had to wear gas masks in order walk outside (Gunnar, personal communication, 03/11/2018). Moreover Baldur, mentioned that the volcanic ash greatly affected people who were already suffering from respiratory diseases. He elaborated that the gases released during some eruptions contained chemicals that were harmful to human health (Gylfasson, personal communication, 03/16/2018). Therefore emphasizing the health effects attributed to the volcanic gas emissions.

The local policemen pointed out that there was immense crop destruction that resulted from the ash that settled on crops during the 2010 eruption (Ng'ang'a, personal communication, 03/14/2018). The ash blocked out the leave pores thus suffocating the plants. Destruction of crops consequently lead to death of livestock as there was very little vegetation available to feed them on. Baldur, brought out an interesting perspective on the cause of death of livestock. He mentioned that some chemicals such as sulphur released during some eruptions mixed with water to form acidic rain that destroyed crops and in so being livestock lost their teeth feeding on the affected vegetation (Gylfasson, personal communication, 03/16/2018). This lead to the death of livestock as the vegetation was contaminated. These responses brought out the intensity of how the eruptions affect vegetation as well as livestock.

An expert in hostel and hotel management disclosed that his hotel/hostel business lost a lot of money during the 2010 volcanic eruption as there were hardly any tourists visiting Iceland during those few months after the eruption (Ng'ang'a, personal communication, 03/13/2018). Furthermore, he mentioned that previous eruptions had caused tremendous loss of property especially for the hotel/hostel industry where floods and landslides destroyed buildings. Baldur, added on to the conversation when he mentioned that in some eruptions, homes were destroyed and people had to be relocated (Gylfasson, personal communication, 03/13/2018). Thus, bring out the negative aspect of property destruction by volcanic activities.

Soils erosion was another common theme that stood out among the interviewees. During a visit to the soil conservation museum, the researcher interviewed Augusta Helgadottir, a soil conservation expert. She went into depth about how volcanic eruptions contribute to soil erosion. The basalt ash destroys crops, exposing the bare soil to floods and strong winds. These strong winds and floods carry the top soil away thus eroding it. However, she emphasized that the Soil Conservation Service of Iceland was making avid efforts to restore soil fertility by terracing and planting lime grass that hold onto the soil preventing it from being washed away by floods and winds (A. Helgadottir, personal communication, 03/15/2018).

Positive Affect

Baldur didn't fail to mention the positive attributes that arise from volcanic activities. He deeply elaborated how the volcanic activities lead to land formations such as Surtsey Island that has now become a research hub for scientists trying to understand how new life begins on new land. He mentioned that rock formations arise from volcanic activities that attract tourists leading to growth of Iceland's economy. Baldur also noted that the volcanic ash that settles on the soil

make the soil more fertile in the long run thus improving the soil quality (Gylfasson, personal communication, 03/16/2018).

Preparedness

Some of the interviewees mentioned that the government has put in place different strategies to deal with the volcanic eruptions such as a text message system that alerts people of volcanic activities in their areas. There are also several online data websites that track and inform people of the level of seismic activities in their different areas. The main means of communication in case of an eruption is the TV news stations, radio as well as amber alerts on people's phones. Baldur, mentioned that it is a requirement for tour guides to sleep in rooms with TVs so as to keep themselves updated with the current news on volcanic activities so that they are in a position to advise the tourists (Gylfasson, personal communication, 03/12/2018). He also mentioned that it is common knowledge to Icelanders not to hang picture frames on the walls right next to their beds in case of an earthquake which would result from intense seismic activities (Baldur, personal communication, 03/12/2018).

During the eruptions, churches and schools are converted into shelters for the people relocating from affected areas. People in Iceland come together during such crisis to help the affected by donating food and clothes. For example, after the 2010 eruptions, Icelanders went ahead to help farmers living around Eyjafjallajokull to shovel out ash from their farms. According to Baldur, the government has set aside funds to help resettle the people displaced by volcanic eruptions. However he pointed out that Iceland was working on figuring out how to protect tourists especially during such catastrophes as they are not as informed as the local people on emergency procedures (Baldur, personal communication, 03/16/2018). It was evident from the interviews that Iceland has robust preparation measures for volcanic eruptions.

Analysis

From the analysis of both the literature review and the interview there are quite a number of similar themes in regards to the negative aspects as well as positive aspects of volcanic activities. There was a lot of resemblance in the data from both the literature review and the interviews regarding flight disruptions during the 2010 eruption in Iceland. However, the interviews went on to point out that the road transportation was affected as well which was data that the literature review didn't mention. In addition to that, there was homogeneity in the data of the health effects brought about by the volcanic eruptions from both the secondary as well as primary sources of information. Information on death of livestock as well as crop destruction from the literature review was parallel with the interviews as well. Both the literature review and the interviews mentioned the positive effects of volcanic activities that included land formation and rock formations.

There were a few differences in the data from the literature review and the interviews. The interviews brought out the perspective that during the first few months after the 2010 eruption, tourism reduced due to fear that Iceland had experienced damage caused by the eruption thus making it not a good time period to tour the country. On the other hand, the literature review focused on the increase in tourism over the next years after the eruption and failed to mention the immediate decline that was experienced in 2010 before the big tourism boom. Moreover, the literature review and the interviews differ in perspectives of certain themes such as soil. The interviews shed more light into soil erosion and how the volcanic activities contribute to soil erosion while the literature review mainly elaborates how volcanic ash increases soil fertility in the long run. One of the interviewees mentioned that climate change was caused by global

warming due to industrialization and not volcanic activities however, the literature review differs by claiming that the volcanic activities have some effect on climate change.

All in all, it was evident from both the literature review and the interviews that the Iceland government has systems in place to monitor seismic activities as well as measures to handle the occurrence of these volcanic activities. The people work together with the government to mitigate the effects of the volcanic activities. Therefore, it was vital to gather data from both the literature review as well as the interviews so as to get different perspectives of the topic. This contributed to making the research all-inclusive and deeply informative.

Conclusion

From the analysis of the data provided in this research, it is evident that despite the fact that volcanic eruptions have vast negative effects they also have vast positive effects that lead to tremendous growth in the economy. In addition to that, it is evident that the Icelandic government has robust measures in place to manage disasters that come about due to volcanic eruptions. They have highly educated volcanologists and seismologists who study the seismic activities thus determining whether there is a need for alarm or not. This gives the Icelandic people confidence and even explains the reason as to why they are excited for the next eruption.

Gathering primary data for this research was bit difficult as the researcher was in Iceland for only one week and thus had limited time to gather data from people. However, the data acquired was adequate to use to make conclusions. As such it was evident that one of the possible areas to explore with this topic is ways that Iceland can better prepare tourists for calamities that come with the volcanic activities. This would be very vital as most of the tourists who travel to Iceland are barely aware of the emergency or evacuation procedures associated with volcanic activities.

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