Volcanoes and Global Warming

- Carbon dioxide - CO_2
- Sulfur dioxide - SO_2
- Sulfate aerosols
- Greenhouse effect

WHAT YOU WILL LEARN

1. You will identify materials ejected by volcanic activity
2. You will name the volcanic gasses that act as greenhouse gasses
3. You will describe how sulfur aerosols act to cool the atmosphere
4. You will compare and contrast the effect of human activity to volcanic activity on the temperature of the atmosphere transform data into a graphic form.

Engage Your Thinking

Are volcanoes a source of atmospheric **carbon dioxide**? This question is a point of controversy concerning the **greenhouse effect** and its potential impact on global warming. In this activity you will learn how volcanic eruptions contribute to atmospheric carbon dioxide, the greenhouse effect, as well as global temperatures. Initially, when a volcano erupts, it ejects many different types of material into the air including a variety of gasses and ash (small particles of dust). Among these gasses ejected into the atmosphere are gasses such as water vapor and carbon dioxide. Both of these gasses are greenhouse gasses and can contribute to the greenhouse effect. Carbon dioxide levels in the atmosphere have been increasing—now scientists are studying whether volcanoes are playing a significant role in the greenhouse effect.

1. Which contributes more carbon dioxide per year to the atmosphere: volcanic eruptions or human activity?

2. Does a volcanic eruption cause a warming or cooling effect?

Explore and Explain

Large volcanic eruptions deposit **water vapor** (H_2O), **carbon dioxide** (CO_2), **sulfur dioxide** (SO_2), and other gasses into the environment. Volcanoes can also put great amounts of ash (small particles of dust) into the air. As you have learned, carbon dioxide and water vapor are greenhouse gasses and can contribute to global warming. Water can combine with other volcanic gasses such as hydrochloric acid (HCl) and hydrofluoric acid (HF) to fall as acid rain. Volcanoes also emit sulfur dioxide (SO_2) which converts to a fine mist of particulates that migrate high into the atmosphere. These sulfur dioxide particulates are called **sulfate aerosols**, and they reflect sunlight back into space. Sulfate aerosols encourage the formation of high clouds which also reflects sunlight back into space. Therefore

aerosols and clouds reduce the amount of warming and cause the atmosphere to cool. Sulfate aerosols tend to stay in the upper atmosphere for long periods of time (months or even years) until they finally are brought to earth in the form of sulfuric acid. The volcanic ash in the atmosphere also blocks sunlight from reaching the surface of the earth causing the air to cool. (The ash eventually falls to the ground.)

3. What greenhouse gasses are added to the atmosphere during a volcanic eruption?

4. Explain how a volcanic eruption cools the atmosphere.

Other factors need to be considered in the study of volcanic eruptions and their impact on the atmosphere. All volcanoes are not the same. The type of eruption is dependent on the circumstances that cause the volcanic activity. Volcanoes created by hotspots in the ocean are rarely explosive and do not eject much ash. Eruptions taking place at geographic plate boundaries, however, can be very explosive with much ash. Also, the types and amounts of gasses ejected by each type of volcano differ. Table 1 shows gasses ejected by three different volcanoes situated at three different geographic locations. Make a bar graph that shows the amount of **H_2O, CO_2, and SO_2** emitted by the three different volcanoes.

Table 1. Examples of Volcanic Gas Compositions. Source: USGS

Volcano Tectonic Style Temperature	**Kilauea Summit** Hot Spot 1170°C	**Erta` Ale** Divergent Plate 1130°C	**Momotombo** Convergent Plate 820°C
H_20	**37.1 %**	**77.2 %**	**97.1 %**
$C0_2$	**48.9 %**	**11.3%**	**1.44%**
$S0_2$	**11.8%**	**8.34%**	**0.50%**

5. In general, volcanoes eject which gas the most?

6. Which volcano ejected the greatest percentage of carbon dioxide?

Many people argue that volcanic eruptions are a major cause of carbon dioxide levels in our atmosphere. In reality, volcanic eruptions contribute very little to the atmosphere's carbon dioxide levels. Below are the USGS carbon dioxide emission estimates for volcanic and human activity (Table 2).

Table 2. Yearly Average Carbon Dioxide Emissions

From Volcanoes:	145 – 225 million tons of CO_2
From human activity:	30 billion tons of CO_2

Let's express the volcano amount as about 200,000,000 or 2.0×10^8 tons
The human activity amount is 30,000,000,000 or 3.0×10^{10} tons

Imagine that you will make a bar graph to compare the carbon dioxide contribution of volcanoes and human activities. (You will not actually make the graph.)

Using a scale with one centimeter representing 1.0×10^8 tons, your bar graph will represent the carbon dioxide contributed by volcanoes with a bar 2 cm. high.

Volcanoes emit 2.0×10^8 tons of CO_2 per year which gives you a bar that is 2 cm. high.

7. Calculate the height of the bar representing carbon dioxide from human activity.

8. How important are volcanoes in adding carbon dioxide to the atmosphere?

Extend Your Thinking

Mount Pinatubo is a volcano that lies near a divergent plate boundary in the Philippines. In June of 1991, Mount Pinatubo violently erupted, and this eruption is now on record as the second largest volcanic eruption of the twentieth century. The eruption had ten times the explosive power of the 1980 eruption of Mt. St. Helens in the state of Washington. Within two hours of the major Pinatubo eruption, gasses and ash reached high into the atmosphere. During the following two weeks, the sulfate aerosols created by the blast circled the globe and at the end of a year, the entire atmosphere of the earth was filled with a layer of sulfate aerosols ejected from the eruption.

The sulfur aerosols created by the Pinatubo blast reflecting solar energy (heat and light) back into space and decreased temperatures around the world in 1992 and 1993. In spite of rising amounts of greenhouse gasses and the presence of an El Nino event (factors that should warm the atmosphere), the sulfate aerosols reduced global temperatures in 1992 and 1993 by about 0.4 to 0.5ºC—a global cooling effect. The United States experienced its third-coldest summer in seventy-seven years.

The 1815 eruption of theTambora Volcano in Indonesia created an even larger global cooling effect. Global temperatures were lowered by as much as 3ºC. The year 1816 was known as the year without summer in many parts of Europe and North America. Many Midwest states experienced snowfall in June and frost in July.

9. What effect do the sulfate aerosols formed by volcanoes have on global temperatures?

Apply What You Have Learned

Draw an erupting volcano. In your drawing, draw and label the materials that are ejected by the volcano. Under your drawing, explain what effect each material might have on the temperature of the atmosphere.

Reflect on What You Have Learned

10. Which contributes more carbon dioxide per year to the atmosphere: volcanic eruptions or human activity?

11. Does a volcanic eruption cause a warming or cooling effect?

12. What is the major cause of cooling after a volcanic eruption?

13. Please explain how your ideas and thinking about greenhouse gases has changed.