Admittedly, when I was first introduced to the term “acid rain,” a strange image was evoked, where rain falling from the sky began violently burning my skin off, drop-by-drop. Gruesome, I know. But seriously, to our gentle and exposed ecosystem, acid rain has caused a lot of turmoil in fundamental environmental cycles and has damaged overall ecosystem health.

First, before we jump to conclusions that acid rain will, like my gory image, burn us like pouring water on the Wicked Witch of the West, let’s define exactly what acid rain is, how it is produced, and how it has become a growing problem in our environment.

Acid rain is defined by precipitation exhibiting acidic properties outside of normal ranges and includes wet deposition (like snow, ice, and rain), and dry deposition (gas and dust particles). Acidity is measured based on pH. A chemical’s pH is a unitless value used to distinguish the amount of positively charged hydrogen atoms, or ions, in a given chemical solution—which corresponds to acidity or alkalinity. Lots of hydrogen in a sample, more acidic, and the absence of hydrogen (and more hydroxide) means the chemical exhibits alkaline characteristics. pH is measured on a logarithmic scale of 0-14—with smaller values indicating higher acidity and larger values indicating alkalinity and 7 being deemed as “neutral.” Think vinegar and lemon juice for acids (pH range of 0 - ≤6) and baking soda and diluted soaps for bases (pH range ≥7 -14). And think of pure water as the perfect substance in the middle (pH 7). This quality of water is vitally important; for example, water can dilute both acidic and alkaline fluids and prevent them from causing harm in our bodies. And the same can be said for the ecosystem, with one small difference.

While water is generally considered neutral, rain water is naturally a bit acidic (around 5.6 according to the EPA), and this is because it contains dissolved carbon dioxide from the atmosphere. This carbon dioxide dissolves in rain and then creates an acid, namely carbonic acid. This slight acidity in rain is also vital to the growth of plants in soils. The slight acidity in the rainwater increases nutrient penetration in soils and its availability in plants. However, too much acidity (most acid rain generally has a pH of 4.2-4.4), and elements of the environment can become pretty unstable. Think about mixing vinegar with baking soda inside one of those classic homemade children’s volcano experiments: when the vinegar touches baking soda, they react, produce water and carbon dioxide gas (and a few other things), and this causes bubbling to occur
and a subsequent “eruption” in your volcano. This is also why the combo of acids and bases like vinegar and baking soda are commonly used in cleaning products to tackle stains, as well as in baking to help rise cakes, biscuits, and cookies.

And while this reaction is excellent for our fluffy southern biscuits, or making sweet volcano models, it’s not quite the same for our ecosystem. When rain that exhibits acidity outside of the normal range, it affects and causes pollution in key players of the ecosystem: air, water, and soil. It reduces soil pH (even though soils naturally have the ability to neutralize the typical slightly acidic rainwater), which leaches nutrients from the soil which makes it harder for plant roots to take in those nutrients. Acid rain can also create acidifying water conditions being detrimental to aquatic life. And acid rain causes naturally occurring aluminum in soils to leach into waterways and is toxic to aquatic life. Acid rain, and acidic humidity can also begin to erode buildings and monuments, and the lower pH moisture in the air can be inhaled by humans and cause respiratory problems. A lot of these problems are slow growing, so you may not notice them daily, but they are definitely occurring.

But how does rain water even become acidic in the first place? Is this human induced, or is this a natural process?

Short answer: We are to blame. Our drastically increased carbon emissions in the last one hundred years have released excess amounts of carbon dioxide, methane, sulfur dioxide, nitrogen oxides, and other greenhouse gases into the atmosphere. From here, these gases interfere with the natural water cycle. And to recap from elementary school: the water cycle describes how water moves through our environment, and in its simplest form consists of precipitation, collection (which includes surface runoff and groundwater), evaporation/transpiration, and condensation.

Anyway, when greenhouse gases enter the atmosphere, specifically sulfur dioxide and nitrogen oxides, they react in the atmosphere with water, oxygen, and other naturally occurring hydrogen ions (which we know are the basis of acids), and this creates acidic compounds like nitric and sulfuric acids. Essentially, greenhouse gases react easily with molecules in our air to create harmful compounds with more positively charged hydrogen. Carbon dioxide, for instance, dissolves in water like water droplets in clouds, but in doing so, it drops the pH. Add up this and similar effects and viola! Acid rain.

Increases in sulfur and nitrogen in the atmosphere has overwhelmingly been due to human activated air pollution from burning fossil fuels for electricity, to emissions from cars, and manufacturing. And with increased industrialization around the world, acid rain has become an increasing problem. And the more we continue to pollute the environment, the worse it will get. To learn more about the global energy demands and emissions by nation and type of energy consumption, here is a link to the International Energy Agency’s 2018 Global Energy and CO2 Status Report; give it a look!

A lot of research is being done on the how human activities impact water quality (UTK is doing lots of great research on this in the Great Smoky Mountains National Park!), but to truly stop the problem from getting worse, it is going to take global AND individual efforts. The best way to “solve” acidic rain, is to prevent its formation at the source.

Most of what has been done globally involves legislative policies. In the US, the 1975 Clean Air Act, as well as amendments in 1990, introduced a cap-and-trade approach to cut sulfur emissions.
Essentially, it required the reduction of industrial sulfur emissions by half, but companies could decide how and what technologies to utilize to get those results. For example, industries have begun to use low sulfur coal, or to “wash” the coal before using it to remove excess sulfur. Also, “scrubbers” can be installed which remove the sulfur dioxide before it emitted into the air. As well, alternatives forms of energy are becoming increasingly cheaper and more popular, like solar and wind energies.

Individually, the biggest way to prevent the increase in acidic rain is to reduce your overall energy consumption. This includes turning off lights and electronics when not in use, and selectively choosing when you use air conditioners and heaters. Additionally, using public transit when possible and walking can help reduce carbon emissions. A lot of these changes will not only curb acid rain, but can also help slow down climate change as a whole.

So this global problem will not only take global solutions to solve, but an individual effort from everyone. One person’s environmentally-friendly actions may not seem to have a big difference, but collectively we can change the world for the better! I mean at the end of the day, don’t we all just want to be able to stop and smell the flowers?

Link to published article:

References
[9] “What is Being Done?”, Acid Rain Student Site, United States Environmental Protection Agency (EPA)