Effects of Acid Rain on Forest Organisms and Countermeasures

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Abstract. Acid rain acidifies the surface water and affects the life on the surface. Acid rain seeps into the soil, forest soil is degraded, tree growth is seriously harmed, and forests will die in a large area. Acid rain can damage ecosystems by killing populations, eliminating food sources, and reducing biodiversity. At present, forests in many parts of the world are facing serious harm caused by acid rain, so the purpose of this paper is to let people know about acid rain and its harm, and raise the awareness of forest protection. This paper summarizes the effects of acid rain on forest organisms and the harm to the whole ecosystem. Firstly, the formation process and causes of acid rain are introduced. Secondly, the paper focuses on the effects of acid rain on forest organisms, including microorganisms, plants and animals, and then on the whole ecosystem. Finally, the paper puts forward some measures to solve the human causes of acid rain formation. The paper discusses three aspects: reducing pollution (reducing emissions from heavy chemical industry, etc.), using plants (planting trees) and technological input (developing utilizable clean energy and reducing emissions from automobile exhaust). This paper hopes to find better and more useful ways to solve the occurrence of acid rain and the related harm to forests, and hopes to raise the protection awareness of the government and people.

Keywords: Acid rain formation; effects; forest creatures; ecosystem; control measures.

1. Introduction

Acid rain was discovered by the British scientist Smith in 1872, shortly after the development of the modern Industrial Revolution. From then on, acid rain has been threatening the human environment for more than 100 years. Acid rain acidifies the surface water and affects the life on the surface. Acid rain infiltrates into the soil, acidifying the soil and activating the harmful substances such as aluminum in the soil. When soluble aluminum reaches a certain concentration, the forest soil is degraded, the growth of trees is seriously harmed, the resistance to diseases and pests is reduced, and the forest will die in a large area. The occurrence and development of acid rain are closely related to the growth of energy consumption in the world. Due to the reasons of economic development, world's energy consumption will continue to grow. Acid rain has become a widespread pollution problem in China, especially impact forest organisms and countermeasures, because of the massive use of coal as an energy source.

The research on the effect of acid rain from 1940s and many researchers have done research on it. The recent research on acid rain sedimentation in some countries is computer simulation technology The experiments in this paper are all from the data on the Internet. However, this paper does not only focus on the impact on a certain type of animal, but systematically summarizes the impact on all forest organisms, and even the entire ecosystem, covering a wider area.

In this paper, the process of acid rain and the human and natural causes of its formation are introduced first, so that people can understand this field better. Secondly, this paper divides forest organisms into microorganisms, plants and animals, and summarizes the impacts on the entire ecosystem in the form of food chains. Finally, this paper focuses on the causes of acid rain, especially the man-made causes, and puts forward corresponding solutions from the causes of two kinds of acid rain, respectively, and puts forward requirements to the people and the government, hoping to increase the public's attention to acid rain, and hope to reduce the occurrence of acid rain and its harm to forests as much as possible.

2. Acid Rain Formation

Acid rain is the mixture of pollutants and water in the air. Sulfuric acid rain and nitric acid rain are two main sorts of acid rain, which formed by the reaction of pollutants sulphur dioxide (SO_2) and nitrogen oxides (NOx). The formation of acid rain is firstly SO_2 dissolved in air and reacts with water molecule in cloud to form sulfurous acid (H_2SO_3), which is easily oxidized to more acidic sulphuric acid (H_2SO_4). The chemical equation is shown in equation (1) and (2). In the same way, Nox can react with water molecule to form nitric acid (HNO_3), as shown in eaution (3). H_2SO_4 and HNO_3 are dissolved in rain and descended to the ground, thus, acid rain is formed. The formation of acid rain is related to human activities and natural process.

$$2SO_2 + 2H_2O = H_22SO_3 \quad (1)$$

$$2H_2S_33 + O_2= H_2SO_4 \quad (2)$$

$$3NO_2+ H_2O = 2HNO_3 + NO \quad (3)$$

2.1. Human Causes of Acid Rain Formation

Human activity is the most important element affecting the formation of acid rain, as the pollutants mainly come from human emission, which change the mix of gases in the atmosphere. The most of human emissions come from various industrial process, for instance, the smelting of metallic mineral (Fe, Zn and Cu) and the combustion of fossil fuel (coal and petroleum) and bumble waste [1].

Human activities can cause sulfur pollution. Worldwide anthropogenic emissions of sulfur dioxide are about 150 million tons per year, more than 70% are contributed by fossil fuel. Most of the sulfur dioxide emissions come from the northern Hemisphere, especially in cities and industrial areas，of which combustion accounts for more than 90% of the sources, causing various air pollution problems [2]. The main sulfur pollutants in wastewater are sulfate and hydrogen sulfide. Human excrement is the main source of the sulfate ions in domestic sewage. The sulfate in the soil is hardly degraded and enters the surface water and groundwater through leaching, which cause sulfur pollution. Solid particles are the main form of sulfate present in the atmosphere which fall to the ground with rain or gravity, so-called acid rain.

Power stations, vehicle exhausts and industrial emission are the main source of nitrogen oxides (NO_x). Nitrogen oxides stands for a mixture of nitric oxide (NO) and nitrogen dioxide (NO_2), which are gases. Most of NO_x produced from high-temperature combustion process of fossil fuels. Although nitric oxide is relatively harmless, it is easily oxidized to NO_2 by ozone in the air in a short period of time. Burning nitrogen-based fuels, such as coal, can also release nitrogen dioxide directly. In the city, one of the major sources of nitrogen oxides is the emissions from motor vehicle. The vast majority of NO_x come from vehicle exhaust emissions in large cities. High temperature and oxygen-rich conditions during combustion of internal combustion engine produce NO_x. Acid rain forms when NO_2 dissolves in water in the atmosphere.

2.2. Natural Causes of Acid Rain Formation

Although human activities cause most sulphur emissions and be the main reason for acid rain formation, natural process also contributes to it, although it just plays a small part. Volcanic eruptions eject a considerable amount of sulphur dioxide gases, release high concentration of SO_2 into the atmosphere and form the volcanic acid rain. Lightning also plays a part in acid rain formation. Nitric oxide (NO) is released when lightning strikes and it has chemical reaction with water molecules and bring out product of nitric acid. Forest fires are another reason for formation of acid rain. Fires caused by dry heat or lightning will have a large amount of sulfur dioxide and carbon dioxide emissions into the atmosphere. Rotting vegetation releases volatile gases which combine with nitrogen oxides and contribute to acid rain. Biological processes also can be the reason for acid rain. Some organisms decay in the soil, for instance, dead animals and plant leaves. Sulfur compounds are generated during the decomposition under the action of bacteria, and then convert them into SO_2.

3. Effects of Acid Rain on Forest Creatures

Acid rain acidifies surface water and affects the life on the surface. Acid rain infiltrates into the soil, acidifying the soil and activating the harmful substances such as aluminum in the soil. When soluble aluminum reaches a certain concentration, the forest soil is degraded, the growth of trees is seriously harmed, the resistance to diseases and pests is reduced, and the forest will die in a large area [3]. Soil acidification can seriously harm crops, and can also produce large areas of crop loss or crop death. The annual loss of Chinese agriculture due to acid rain is more than 1.5 billion yuan. Acid rain also kills a lot of pasture, which affects the development of animal husbandry.

3.1. Effects of Acid Rain on Microorganism

Microorganisms make up a large part of the biome and are closely related to ecosystems, nutrient cycles and the environment. Acid rain will lead to the intensification of soil acidification, which will reduce the pH value of the soil, cause the deterioration of the soil environment, and reduce the microbial biomass.

As time passes by, acid rain can cause the gradual increasement for acidity of the soil and the soil microbial community is chronically impacted. After decades of observation and research, scientists found that acid rain have severe effects on diversity, structure and biomass of microbial community [4]. The experiment focus on how does acid rain affect biomass and structure of microbial community. The data of the experiment shows that in the group pH 3.0, the biomass of bacteria increased at the early stage, but did not have any changed at the later changed. Group pH 5.0, however, did not have any changed at the early stage, but shown an increasing trend in the later stage. The biomass of fungi did not alter in both groups. In conclusion, acid rain with high level of acidity facilitates bacteria growing in the soil and the fungi to bacteria ratio is varied as well. The microbial community composition of soil is changed correspondingly. At the early stage, the increasing concentrations of NO_3^- is considered as applying fertilizer and has positive effects on the soil microbial community, and the increasing concentrations of hydrogen ions (H^+) induces soil acidification and inhibit the soil microbial community contrarily. However, the “fertilization effect” is greater than the “inhibitory effect” at the early stage so hen it lead to the increasing of the soil microbial biomass. Nevertheless, with the continued increasement of hydrogen ions, the inhibition effect of soil acidification is becoming more and more serious, and will be greater than the positive ones and have negative effect on the soil microbial biomass eventually.

Meanwhile, another experiment proved that higher acidic environment inhibits the overall growth of bacteria and reducing their growth rate [5]. The experimental objects were Escherichia coli (E. coli) and Staphylococcus. The researchers carried out a one-week microbial culture, and measured the growth area and growth quantity of the two microorganisms in different concentrations of acidic environments one week later. The figure in experiment shows that, regardless of the strain, the more acidic environment both inhibits the overall growth of the bacteria and reduces its growth rate.

3.2. Effects of Acid Rain on Forest Plants

Impacts of acid rain on the terrestrial environment are significant. Some of them are direct, for example, cause foliar leaching, or indirect, via influence forest soils. According to the empiricism and speculation by refreshers, effects of acid rain on forest plants mainly on the soil nutrients, which are indirect ones. Direct effects on vegetation are secondary [6].

3.2.1 Effects on soil fertility

The soil is the basis for all of forest vegetation to survive. In the whole process of plant life, the soil has the ability to supply and coordinate the nutrients, water, air and heat which are the essential factors being in need of normal growth and development of plants. This capability of soil is named “soil fertility”. However, acid rain can increase in acidity of soil, which decreases the level of important nutrients found in it, and soil fertility is reduced consequently. Soil nutrients are present in the form of positive charge, such as calcium (Ca^{2+}), potassium (K^+) and magnesium (Mg^{2+}). The acid

rain contains an excess of hydrogen ions (H^+). So under the action of acid rain, the increased positive charges (H^+) will replace basic nutrient cations and balanced by abundant of anions form of SO_4^{2-} and NO_3^-, both of which are available forms of essential plant nutrients [6]. And this process is called cation leaching.

3.2.2 Effects on forest vegetation

Direct influences of acid rain on forest ecosystems include foliar leaching and seed germination. Water from rain can take plant nutrients, nitrogen, for instance, away from the leaf surface. And this process is called "Foliar leaching". The acid rain can cause the nitrogen leaching of tree crowns. And the degree of leaching is based on various of factors, such as age, physiological and phenological state and species composition of the vegetation [7]. In addition, acid rain can affect the seed germination according to the research. When the PH of soil is lower than 4.5, there is a substantial inhibitory effect on the germination of seeds. And this influence can indirectly reduce the agricultural productivity.

3.3. Effects of Acid Rain on Animals and Ecosystem

Acid rain can kill plants and other producers that are at the base of the food chain, which can lead to a chain reaction of effects up to the top predators.

3.3.1 Effects on animals

Because acid rain increases the acidity of waterbodies, including lakes, streams, ponds and rivers, it adversely influences all animals that live in water. When water has a pH lower than 5.0, fish and arthropods will die. Acid rain also kills individual fish, reduces population numbers of fish, gets rid of fish species, even decrease biodiversity. Furthermore, acid rain also can decrease population of some kind of bird, such us the wood thrush. That is because female wood thrushes need more calcium to solidify their eggs [8]. However acid rain causes serious leaching of soil calcium. Without enough calcium intake, the eggshell will have defects and cannot be hatched successfully. In addition, acid rain can impact other animals, such as mammals indirectly, for they rely on animals like fishes and arthropods as food sources.

Ecosystem is a geographic area with all kinds of lives, such us plants, animals and other organisms, together with their living environment, which include air, water and soil. Everything in an ecosystem is connected, and if one part in it is harmed, it will have impacts on everything else. As we discussed above, acid rain has severe effects on all the things in ecosystem. It can make the soil barren, cause the plants withering, and reduce the variety of animals. As a consequence, biological population will be reduced and the following impact will be the damage to biodiversity.

When SO_2 and NO_x are released into the atmosphere, the process is started. The SO_2 and NO_x are in a photooxidation with the precent of sunlight and oxygen, water and other components. The acidic substances are spread by wind and air over long distances. They precipitate down in the form of wet deposits such us rain, fog, snow, or dry deposits as dust, gas and smoke, adversely impacting soil heath and aquatic life (Fig. 1) [9].

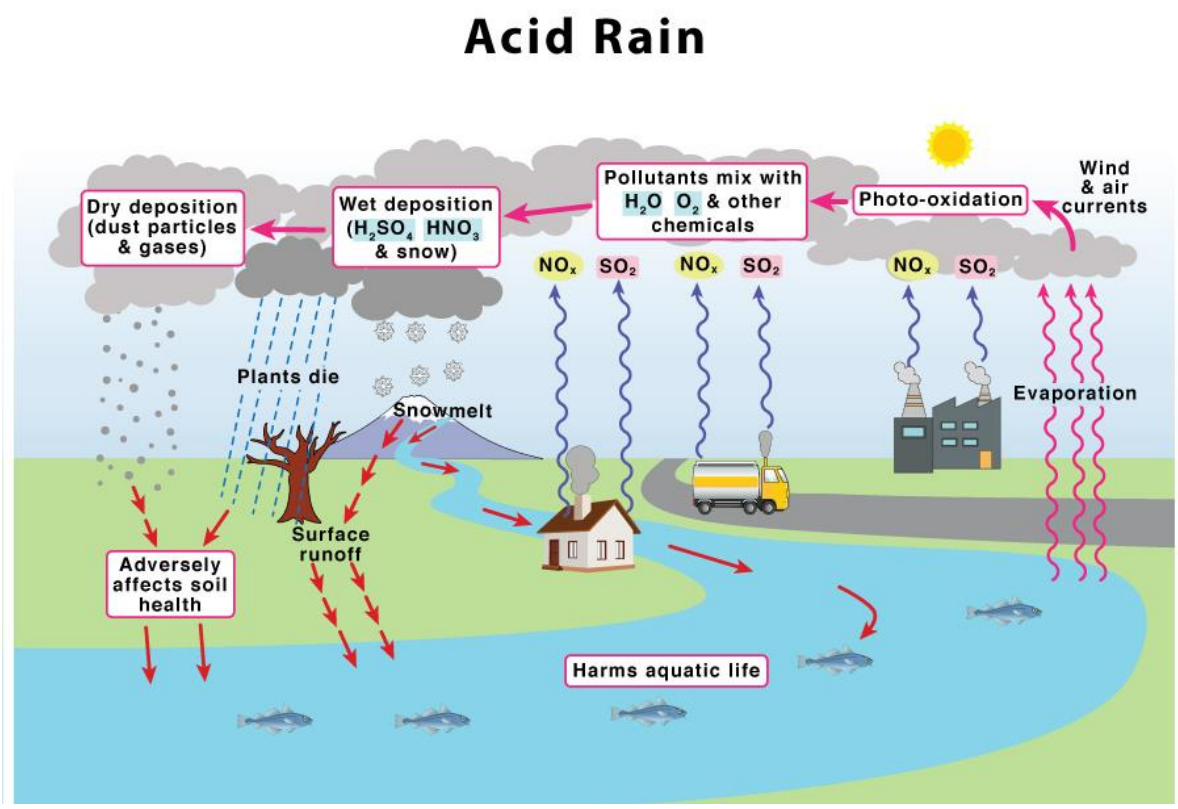


Fig 1. Effects of Acid rain on ecosystem. https://www.sciencefacts.net/acid-rain.html

4. Acid Rain Control Measures

Acid rain is caused by SO_2 and NO_x, so measures to reduce acid rain should start with the reduction of SO_2 and NO_x emissions by human beings. In order to effectively alleviate acid rain, in addition to individual efforts, government departments and all sectors of society should play an important role in jointly promoting the process of acid rain mitigation.

4.1. Reducing Pollution

Factory emissions will produce a large number of pollutants (SO_2 and NO_x). Therefore, for coal-fired power plants, in order to reduce SO_2 emissions, one can choose to use coal with low sulfur content. The second is to add a coal-fixing agent so that no SO_2 is emitted when the coal is burned. The third is that coal can be “washed” to remove some of the sulfur. In terms of reducing NOx, because it is produced in the process of burning and other fossil fuels, the way of burning coal can be changed to reduce NO_x emissions. Improving the energy structure, decreasing the use of fossil fuels to produce energy and using renewable energy (solar and wind energy) are primary ways to reduce the impact of acid rain on forest organisms.

Deeply understanding the significance of reducing harmful emissions and sustainable usage of clean energy sources are especially important for human. Government departments of each country should strengthen supervision and management in measures and rationalize industrial layout and urban planning to push the reduction of acid rain. Many administrative measures have been shown to be very effective. Measures are widely used in countries all over the world through fines and taxes to reduce pollutions, for example, higher SO_2 emission tax and fuel taxes are collected by governments. Nowadays, various subsidies are being used to reward business reduce harmful emissions. Grants, Low-interest loans and beneficial tax treatment are frequently used measures for governments in many countries. Emission trading is an environmental policy to control pollution by setting the limitation of emission for each country according to the economic development level, energy structure, population size and other factors of different countries and regions, as well as the impact

of global climate change. And emission trading plays a very important role in environmental protection today.

4.2. Using Plants

Expanding green areas can effectively reduce acid rain, as trees can absorbing harmful compounds in the atmosphere and depositing them in the soil, which as a natural filter. This process can clean the air, protecting vulnerable plant from damage. In addition, trees help regulate the weather patterns in sensitive areas, minimizing the negative effects from acid rain. As a result, planting trees is an effective way to reduce acid rain [10].

4.3. Technology Input

Use scientific and technological means to reduce pollutant emissions and mitigate the impact of acid rain. For example, technology can be used to control automobile exhaust. The catalytic converter technology used in automobiles has been used for more than 20 years to reduce nitrogen oxides emitted by automobiles [11]. At the same time, the popular new energy vehicles and the use of unleaded gasoline in recent years have effectively reduced the pollutants produced by gasoline combustion, so the application and invention of clean fuels are also very important methods to reduce acid rain.

5. Conclusion

The formation of acid rain is not only a natural geological activity, but also closely related to the energy utilization and industrial production of human society. The paper discusses the causes of acid rain and its harm to forest microbes, plants and animals, including the impact on the entire ecosystem, and the measures we can take to deal with it. However, ongoing industrial emissions and energy combustion are contributing to the formation of acid rain, which is also affecting ecosystems around the world. In the future, government personnel should increase the importance of acid rain, promulgation of relevant laws and policies, researchers should focus on the development of technology in related fields, the development of more useful, more economical, more durable clean energy and degradation technology, to reduce the frequency of acid rain, and the protection of forests. Some suggestions on inhibiting acid rain and protecting forest environment are put forward in this paper.

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