Effects of freshwater acidification and countermeasures

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Abstract—Nowadays, pollution has become a serious problem with the development of industry and the exploitation of the earth's resources. Acid rain and lake acidification caused by pollutants such as sulfur dioxide and nitric oxide has caused serious effects in many places. Nowadays people do not know the ecological influence of acidification, how to detect it and how it recovers. This paper examines the effects of acid rain on fish, plants and microorganisms in freshwater lakes, as well as how to detect acid rain and how to manage and recover from it. The results are not always clear, but there is a lot of evidence that acidification is changing lakes in many aspects, whether living or non-living things, small or widespread factors, acidified freshwater is no longer what it used to be. By examining those problems, people can protect the environment more effectively. Reducing the occurrence of acid rain and the damage it causes in the future. The significance of this paper is analyzing the ecological influence of acid rain, studying and discussing the negative impact on species, and giving some solutions for people, governments and companies for acidification. Furthermore, lake water self-cleaning is also considered in the solution as well. Acid rain causes acidification of the soil, which has a negative impact on agriculture. And it also damages the breeding environment of animals, reducing their reproductive success. For example, fish, microorganisms, and plants can be negatively affected by acidification of the lake water, even leading to extinction.

1. Introduction
Since the industrial revolution in the last two centuries, human has made remarkable development on science and technology; however, with the building of large numbers of factories, air pollution is becoming an irreparable environmental issue. The emission of polluted gases, such as sulfur dioxide and nitric dioxide, are the source of acid rain. Acid rains are destructive to the planet in many aspects: firstly, it would erode the soil, having it lose the plants cover and be re-certificated; secondly, it could directly erode the leave and root system of plants, preventing them from growing healthily; thirdly, the precipitation would change the lakes’ composition thus affects the whole aquatic ecosystem. Therefore, the destruction of air pollutant emission and acid rain lead to serious consequences.

At present, the public are aware of the harms of acid rain, and they are able to tell serval destructions that could be brought. However, the effects of acid rain on plants and soil seem to be more familiar by people, while the effect on fresh-water lakes are not paid the enough attention. Acid rain leads to lake
composition change by anions, including aluminum, phosphorus, and nitrate. As a result, the lake pH would change, thus affects the reproduction and birth of fishes, plants, microorganism, and each important biological system. In specific, the fish population will reduce with the mortality of juveniles in the group, the reproduction of fresh-water plants will be lagged, and the physiological responses of some microorganisms will be inhibited. The population dynamics of each aquatic system are affected directly or indirectly. There are multiple studies on lake acidification on each biological systems, but they rarely summarize all the systems together. Moreover, those studies seldom trace the problems to each public groups and provide systematic solutions. Therefore, it is needed to summarize a relatively complete logic of cause and effects.

As Europe being one of three largest acid rain regions, the article mainly explores the impact of acidification on freshwater lakes in Europe, from the aspect of lake-water plants, fish, and microorganisms. In addition, this article provides possible solutions of recovering from acidification, by analyzing the principle of chemical recovery and the efforts that the public can make.

2. Effect on Organisms

2.1 Effect on Fishes
Acidic chemicals, such as sulfuric or nitric acid enter the water body by different forms. Due to the tight correlation of various species among ecology, the acidification on water body will impact abundant creatures partly. My hypothesis is that the acidification of freshwater lakes will seriously reduce the population of freshwater fishes. In addition, the acidic components in fresh water are going to negatively impact the reproduction rate and the survival rate. For example, the survey of the comparison of present and past fish status mirrors the actual consequence of acidification on freshwater lakes. Chosen Lakes are located in severely affected areas; subsequently. Recordings of fish populations from 1971-1975 to 1986 indicate that in 1971-1975, 30% of these lakes were barren, 23% had no significant changes, and 47% had one or more reduced fish population [1]. However, in 1986, the percentage of barren lakes rose to 64% and sorely 10% of these lakes had little or no impact [1].

Different types of fishes have different tolerance of acidity, as the decline on the pH value, some spices will go extinct. Generally, juvenile are more sensitive to acidity than mature ones. Therefore, the acidity of freshwater lakes have apparent influence on total population of freshwater fish. For instance, the reproduction of roach was negatively impacted at lakes with pH values below 5.5. Roach population disappeared from approximately 10 of the lakes that were surveyed, and some old roaches survived in surplus lakes [2]. However, due to the decline of general population and inhibition of reproduction, the growth rate increased enormously. The population of perch was also threatened, the rapid incline of the growth rate of perch in a few lakes indicated the decrease of overall population. Analysis of the food components reveals that fishes which made up the food of perch were mainly replaced by invertebrates. Likewise, due to the acidification, the water hog-louse, Asellus aquaticus, which is the primary food resource for perch was replaced by Corixa bugs [2]. The Pike, Esox lucius, minnow, Phoxinus, and brown trout, Salmo trutta, were disappearing because of their sensibilities of acidic water. However, the population of Eel, Anguilla vulgaris, which reproduce in sea was unaffected [2].

As acidic rain flows into soil, the aluminum can be brought out from the soil, then flow into freshwater lakes. The more acidic the substance in a place, the more aluminum is produced. In barren, slightly affected and severely affected lakes, the freshwater fish population is determined by the concentration of aluminum and pH value. The lower the pH value, the higher the aluminum content and the lower the number of freshwater fish. For example, in slightly affected freshwater lakes, the concentrations is much lower and the pH value is much higher than severely damaged lakes. Furthermore, Lakes with pH values from 4.6 to 4.8 have nearly 40% more calcium and 15% less aluminum in slightly and severely acidic lakes than barren lakes. Most Fishes have higher survival rates in lakes of the same pH value with high calcium levels than high aluminum levels. So, the level of concentration of chemicals also play a role on the population of freshwater fish.
2.2 Effect on plants

Plant is one of the most important parts of fresh lake ecology. They are the food source and habitat of other species; they absorb carbon dioxide and release oxygen during photosynthesis; they can absorb part of the harmful elements such as heavy metals and organic pollutants; also, they could protect the lake bank by improving its soil structure with strong root system. Lake plants’ growth and recruitment are largely related to water quality, and acid rain, as a frequent environmental issue in modern ages, changes the water component and the living condition of lake plants. Martina Čtvrtlíková et al. showed that the reproductive capacity of Isoetid was significantly reduced and its numbers significantly reduced under the condition of intense water acidification [3].

2.3 Effect on Microorganisms

After the lakes being affected by acidification, the microbial communities are likely to feed back some of the problems which everything in the lakes is undergoing. The decrease of pH value is one of the factors affecting N$_2$O production, and acidic soils tend to produce more H$_2$O. Certain lakes also experience pH decreases since human activities released acid-forming gases (e.g., CO$_2$, sulfur dioxide, and nitrogen oxides). Acidification may affect the rate of N$_2$O production by ammonia oxidizers. Some evidence suggests that acidification will cause ammonia oxidation rates to decline. For instance, the ammonia monoxygenase enzyme (AMO) is believed to act only on the substrate which is in free base form (NH$_3$). But in natural aquatic system (pH 6-8), NH$_4^+$/NH$_3$ will tend to present as NH$_4^+$, the fraction of NH$_4^+$/NH$_3$ will be reduced after acidification, thus the substrate concentration for ammonia oxidizer reduced. In condition with lower pH (below~6.5), AOB batch cultures’ ammonia oxidation is furthered inhibited, and the reason of this inhibition is more likely to be the toxic built up under acidic condition [4]. Percent S.F [5] examined bacterioplankton community diversity and structure of 18 lakes located in the Adirondack Park, New York. The lakes studied were all affected by acidification to various degrees. The study investigated the relationship between bacterial communities and lake acidity. The richness and diversity of bacterial communities were positively correlated with pH (Fig. 1). In another word, according to the distribution trend of the data, the richness and diversity of bacteria in the lake will decline with pH as acidification occurred as they are inversely proportional to the degree of acidification.
3. Ways to Reduce Acidification

3.1 Recovery

Chemical recovery is achieved through the balance of cation and anion in the lake, reducing lake water pH and concentration of ions under the threshold, while biological recovery is achieved when all species in the lake went back to their pre-acidification state, which delays after chemical recovery [6]. Lake’s acidity is also defined by the amount of anions, which are important components of aqueous acid solutions, in lake water. The main kinds of anion, which are S²⁻, N³⁻ and Cl⁻ in most lakes, different from lake to lake. Even if the amount of anion drop, lakes can still be acidified due to Calcium deficiencies [7]. Obviously, lakes can automatically recover if the emission of pollutants that causes acidification, usually sulfur and nitrogen, decreases [8]. However, self-recovery is a slow process [6], and it’s also vulnerable against human activities, even regular activities such as road salting can increases the concentration of Cl⁻ ion and confound the recovery of highly acidified lakes [7]. That explains the current condition of most lake’s recovery phases shown in Fig. 2.
Fig. 2 Schematic diagram that summarizes the current literature regarding acidification (red) and recovery (blue) phases of lake and stream chemistry as a function of acidic deposition levels [7].

So far, there are two ways to accelerate lakes’ recovery: adding lime directly to the surface of lakes or terrestrial liming of hydrologic source areas [7]. Both of these methods have their drawbacks. Although liming seems to be an inexpensive and straightforward way to increase pH and acid-neutralizing capacity, adding lime to lake surfaces is unstable due to the community’s adaptation to severe acidification, and liming of hydrologic source areas can damage the vegetation of naturally acidic wetland ecosystems [7].

3.2 Government

According to *A new look at liming as an approach to accelerate recovery from acidic deposition effects*, it is not difficult to think of a national environmental action plan which involves a lot of experts to calculate the amount of base needed to add into lakes and determine the release site so that the lake can recover to its normal state and the side effects of liming is reduced to an acceptable extent. However, so far there are no successful cases of that kind of policy.

What is proved to be practicable is that the government can enforce laws to limit acidic pollution. During the last 50 years, there are a lot of successful cases of pollution-limiting laws [9]. Based on the successful policies, it is reasonable to think of funding as a way to encourage companies to reduce pollution. The government can subsidize the equipment needed for reducing emission or purifying by-products that causes acidification, or directly give subsidies to companies that limit their pollution. Actually, government funding can also apply to colleges and research institutes. The government can give financial support to colleges and research institutes that are focusing on the development of eco-friendly industries, like the Swedish case study and the OECD project supported by the Swedish government [9]. Since the government can get companies, colleges, and research institution, they can hold forum on regulating acidic pollution, in which different organizations can both learn about the latest developments and learn from each other as well. In addition, the government can also unite scholars from different universities and research institutions to do research, as the Swedish government did, and they can also facilitate the collaboration between scholars and companies to provide possible solutions for companies to lower their acidic pollution [9]. Furthermore, governments from different nations can reach agreement on issues associated with acidic pollution and launch international projects.
3.3 Companies
While companies may not be able to deal with acidification as effectively as governments, there are still effective treatments that can be taken to keep freshwater systems safe and clean. The Germany waterworks have come up with a powerful concept, which is to set up a wide range of water protect zone, strictly regulate the supply of fresh water, and actively mobilize the surrounding people and institutions to cooperate with the plan. Water protect zone would greatly limit the use of toxic substances, fertilizers and other chemicals. The reserves would be fenced in, access would be restricted, and all industrial and even agricultural practices in the surrounding areas would be halted to ensure clean freshwater system. All enterprises need to invest effort and capital to implement the plan: in order to ensure the smooth implementation of the plan, the staff need to undergo strict training. On the other hand, in order to reach a consensus with the farmers around the protected area, some water supply authorities in Germany have signed a compensation agreement that they must take responsibility for any agricultural losses in order to protect water resources [10].

The acidification of the atmosphere is the root cause of the acid rain problems. If the acid rain issue can be solved, the acidification threat to the lakes will be greatly reduced. Enterprises emit large amounts of nitrogen oxides, sulfur dioxide and hydrocarbons during production, which react with water in the atmosphere to form acid rain. In this case, in order to find the treatment of soot emissions, enterprises vigorously developed desulfurization and denitrification technology. In recent decades, scientists created four kinds of desulfurization and denitrification technology: Wet lime, gypsum denitrification, Ammonia reduction denitrification, Electron beam irradiation desulfurization and denitrification, and Pulse plasma chemical desulfurization and denitrification. In addition, low-temperature atmospheric plasma decomposition of harmful gases can also convert many industrial emissions that contribute to air pollution into harmless. Nowadays, these technologies have been widely used in firms in many countries as treatments used to control acid rain. Even though some countries are still in the stage of desulphurization, the technologies definitely played an effective role in limiting harmful substances released from factories. Desulphurization and denitrification will keep performing as a new trend of acid rain treatment in factories in the future.

3.4 The General Public
The maintaining of the equilibrium of ecology is vital to reduce pollution. In order to develop low-carbon green life, people should concentrate on the reduction of carbon emissions and low-carbon green technology. The emergence of new energy car should act like a substitute of traditional gasoline and diesel cars. Likewise, environmentally friendly modes of travel such as walking and cycling should also be more widely used by the public. The recycling of resources and standardize the clean production process are actions people should take too. Regardless of the technology, the production of products will produce more or less pollution, so the right thing to do is to use products that can be reused to reduce unnecessary pollution. For example, reducing the use of plastic and increasing the use of cloth. Here's a simple but effective action that can reduce pollution: waste separation. It allows plants to effectively break down waste that may produce sulfur dioxide and nitric oxide.

People should improve their awareness of environmental protection, more understanding of environmental protection. At the same time, community should publicize and school should carry out the environmental protection education. Now a lot of times it's not that people don't want to reduce acid rain, it's that they don't know the formation of acid rain, and what can be done to reduce acid rain, sometimes they don't know that their behavior is harmful. At the same time, farmers should use suitable fertilizers to minimize the factors that can cause acid rain. The use of acid-resistant, acid-resistant crops can reduce pollution and protect profits. Other professions should also improve.

4. Conclusion
Nowadays, pollution has become a serious problem with the development of industry and the exploitation of the earth's resources. Acid rain caused by pollutants such as sulfur dioxide and nitric oxide has caused serious effects in many places. This study showed that acidification has dramatically
reduced the population of freshwater fishes. The reproduction rate and survival rate are lowered by acidification as well. For microorganisms, the reduction in the pH value of the freshwater lakes will inhibit the physiological responses of some microorganisms that are normally carried out, and will even inhibit the growth of some microbial groups thus changing the composition of the microbial community in the whole lake. At present, freshwater lakes have to rely on the lake to recover itself from acidification. Alkali application (lime/liming) can accelerate the recovery of the lake, but there are several drawbacks. For people, using electronic vehicles, reusable products and rising conciseness of alleviation of acidification are proper responses to implement. For the government, there are success stories in terms of policy development, grant research, etc. Companies can limit atmospheric acidification by limiting emissions and purifying emissions to reduce the amount of some harmful chemicals in them.

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