Acid Rain is a Local Environment Pollution but Global Concern

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Abstract

The harmful effect of acid rain is considered as one of the most serious environmental problems in the modern globalized world. The effects of acid rain have reached dramatically mainly in the industrialized countries which fall on global ecology. It becomes a major local ecological problem in most of the countries of the world. International concern about acid rain has increased recently because of global ecological pollutions, such as fish kills, dying forests, dead of lakes and other marshes, and damage to monuments and other historic artifacts. Acid rain also creates various health problems of the human body like eye, nose, and throat irritations, and lung disorders, such as dry coughs, asthma, headaches, and bronchitis. The excess presence of sulfur dioxide and oxides of nitrogen in rainwater is the main cause of acid rain. Emissions of these gases have increased in the atmosphere due to human activities, such as combustion of fossil fuels in thermal power plants, burnable wastes, automobiles, and airplanes. Some developed countries have taken steps to reduce the emission of the gases that cause acid rain. To reduce and protect global acid rain it is necessary to identify the causes and control strategies of it. An attempt has been taken here to reduce the acid rain for the welfare of the global ecology.

Keywords: Acid Rain, pH Value, Pollution, Corrosion

1. Introductions

Acid rain is considered one of the most dangerous factors of local pollutions. This rain possesses higher levels of hydrogen ions (H^+) because of contamination of sulfuric and nitric acids. It decreases the pH (potential hydrogen) scale of aquatic ecosystems (Singh & Shishodia, 2007). Northeast America, Central Europe, and China have been identified as the three largest acid rain affected regions in the world (Menz & Seip, 2004; Zhang et al., 2011).

Distilled water has a neutral pH of 7. Liquids with a pH less than 7 are acidic, and those with greater than 7 to 14 are alkaline. If pH value lies in 1–5, the solution is felt like acid. For example, pH value of battery acid is 1, lemon juice is 2, and that of vinegar is 3. Typical pH values of acid rain for anthropogenic emissions may be in the range of 3.5–5 (Kim et al., 2007). Rainwater mixed with carbon dioxide (CO_2) in the air to form the weak carbonic acid (H_2CO_3) with a pH of 5.6 (Reuss, 1977);

$$H_2O\ (l) + CO_2\ (g) \rightarrow H_2CO_3\ (aq).$$

Weak carbonic acid has a concentration of H^+ ions greater than 2.5 μeq^{-1} is slightly acidic, but not harmful for the environment (Menz & Seip, 2004). Acid rain with pH<3 is considered as harmful for germination and growth of various plant species (Balasubramanian et al., 2007). The pH scale is logarithmic, which means that an increase of one unit in pH, the content will be 10 times more acidic; if pH value increases two units, the content will be 100 times more acidic, and so on. To measure the acidity of a solution pH value is calculated by using formula;

$$\mathrm{pH} = \left[-\log\left(\mathrm{H}^+\right) \times 10 - 7\right].$$

Acid deposition (acid rain) is defined as the atmospheric acids deposited on the earth as wet deposition (snow, rain, fog, mist, sleet, hail, dew, etc.), and dry deposition (gas, dry particles, vapor, and aerosols) that is created from the combustion of fossil fuels (coal, oil, natural gas, etc.) and other industrial processes through complex chemical reactions (Baedecker et al., 1992; Kita et al., 2004).

Acid rain is caused by the emissions of sulfur dioxide (SO_2) and nitrogen oxides (NO_x; mainly nitric oxide NO and nitrogen dioxide NO_2) through the combustion of fossil fuel, which react with the water molecules in the atmosphere (oxidation) to produce H_2SO_4 and HNO_3 acids respectively (Schwartz, 1989). The procedures of formation of these two acids are as follows:

Formation of sulfuric acid (H_2SO_4):
Sulfur in coal burns in oxygen to form SO_2. Typically, less than 5% of the sulfur is dissolved into SO_2;

$$S\ (\text{from coal}) + O_2(g) \rightarrow SO_2(g).$$

This SO_2 reacts with O_2 in atmosphere to form sulfur trioxide (SO_3);

$$SO_2(g) + O_2(g) \rightarrow SO_3(g).$$

This SO_3 reacts with moisture in the atmosphere (water) to form H_2SO_4;

$$SO_3(g) + H_2O(l) \rightarrow H_2SO_4(aq).$$

In the presence of sunlight (hυ), SO_2 and OH^- combine to form H_2SO_4;

$$SO_2(g) + 2OH^- + h\upsilon \rightarrow H_2SO_4(aq).$$

Formation of nitric acid (HNO_3):

Nitric oxide (NO) can react with oxygen (O_2) to form nitrogen dioxide (NO_2), which can be broken down again by sunlight (hυ) to produce NO and an oxygen radical O^{2-};

$$2NO(g) + O_2(g) \rightarrow 2NO_2(g),$$

$$NO_2(g) + h\upsilon \rightarrow NO(g) + O^{2-}.$$

This O^{2-} reacts with O_2 to create ozone (O_3);

$$O^{2-} + O_2(g) \rightarrow O_3(g).$$

In the presence of O_3, NO forms more NO_2;

$$NO(g) + O_3(g) \rightarrow NO_2(g) + O_2(g).$$

The O^{2-} reacts with H_2O to produce hydroxyl radical (OH^-);

$$O^{2-} + H_2O(l) \rightarrow 2OH^-.$$

This OH^- reacts with NO to produce nitrous acid (HNO_2), and reacts with NO_2 to produce nitric acid (HNO_3);

$$NO(g) + OH^- \rightarrow HNO_2(aq),$$

$$NO_2(g) + OH^- \rightarrow HNO_3(aq).$$

When acid is mixed with rainwater, the pH falls below 5.6 (Dondapati et al., 2013). Most of the SO_2 and NO_x come from three main sources (Gould, 1985): i) the burning of fossil fuels (coal and oil) in thermal power plants, ii) the burning of gasoline in motor vehicles, and iii) the smelting operations of plants which refine nonferrous metal ores. Power plants and industrial sources release most of the SO_2 pollutants; motor vehicles, airplanes, boats, steamers, ships, and other forms of transportation emissions are the largest single source of NO_x in the atmosphere (EPA, 1990).

Winds transport SO_2 and NO_x to up to 2,000 kilometers (on average about 400–1200 km) in a few days before they are converted to acids (Brøgger, 1881). For example, Sweden and Norway claim that most of the SO_2 they receive comes from other countries, most notably from Poland. So that one country unofficially can export harmful acid emissions to other neighboring countries, which creates a complex problem. Acids impair quality of air and damage public health, acidify lakes and streams, harm sensitive forests and coastal ecosystems, degrade visibility of human and animals and accelerate the decay of building materials. According to the US electric power industry, about 67% of total US SO_2 emissions (20 million tons) and 22% of total US NO_x emissions are from man-made sources. The most acidic rain falls in the northeastern USA, where the pH averages 4–4.2 (Environmental Protection Agency, EPA, 2006a).

Acid rain is a dangerous ecological factor, which strongly influences the decreasing of forest ecosystem productivity and reproduction. More than 50 years, scientists, government officials, environmentalists, and industry representatives have investigated the causes and consequences of acid rains and proposed many solutions.

2. Literature Review

Anita Singh and Madhookia Agarwal have shown the effect of acid rain and its ecological effects (Singh & Agrawal, 2008). Haradhan Kumar Mohajan has discussed SO_2 emissions in China. He also enlightens aspects of SO_2 and its reduction policies in China (Mohajan, 2014). Y. Somu Naidu and C. Kavitha have analyzed the data of the average annual pH, electrical conductivity, and SO_4, NO_3, NH_4 and Ca of rain waters for Visakhapatnam of India over a period from 1983 to 2005. They have found alarming acidic nature of rainwater in the industrial zone of that city (Naidu & Kavitha, 2012). Y. F. Fan, Z. Q. Hu, and H. Y. Luan have evaluated the tensile properties of concrete exposed to acid rain environment. They have examined the voids, micro cracks, chemical compounds, elemental distribution, and contents in the concrete (Fan et al., 2012).

Richard A. Livingston has stressed that acid rain damages the cultural heritage, particularly outdoor marble and bronze sculptures (Livingston, 2016). Aadit Gandhi, Parth Patel, and Girish Bagale have discussed the ecological effects of acid rain in streams, lakes, and marshes. They observe that acid rain also damages man-made materials and structures. They have found that human activities, such as combustion of burnable waste, fossil fuels in thermal power plants and automobiles are the main causes of acid rain (Gandhi et al., 2017). Thomas V. El-Mallakh, Yonglin Gao, and Rif S. El-Mallakh have examined the effect of simulated acid rain on the root systems of a common tropical vine (El-Mallakh et al., 2014).

Fredric C. Menz and Hans M. Seip have discussed the evolution of science and acid rain control policies, the costs and benefits of reducing acid rain in Europe and the USA over the past several decades (Menz & Seip, 2004). Douglas Burns, Julian Aherne, and David Gay have analyzed that acid rain causes the acidification of surface waters and toxic effects on vegetation, fish, and another biota. They have observed that acid rain affects North America and Europe, and later affects China and some other Asian countries (Burns et al., 2016).

Yinjun Zhang, Qian Li, Fengying Zhang, and Gaodi Xie reveal that China is facing the severe acid problem which causes economic loss, corrosion, and damage to materials, and the reduction of material lifespan (Zhang et al., 2017). Duan et al. (2016) have studied acid deposition its environmental effects across Asia. They have observed that sulfur deposition has decreased in recent years but nitrogen deposition is increasing in Asia and becomes a major threat in Eastern Asia. I. M. Hilmi, K. Susilawati, O. H. Ahmed, and Nik M. Majid have identified that rapid industrialization and unsustainable agricultural practices are some of the possible causes of acid rain in Malaysia (Hilmi et al., 2013).

3. Objectives of the Study

This study has tried to discuss the effects of acid rain in soil, lakes and marshes, plants and trees, the human body, and the structures. The main objective of this study is to reduce global acid rain for the welfare of all nations. The study also tried to bear some other related objectives as follows:

- to highlight the historical background of acid rain,
- to identify the causes of acid rain, and
- to indicate the more acid rain prone areas.

4. Methodology of the Study

The method is a word coined of two Greek elements: *meth-* and *odos*. The *meth-* is an element meaning ‘after’, *odos* means ‘way’. A method is, therefore, a following after the way that someone found to be effective in solving a problem, of reaching an objective, in getting a job done. Greek element *ology* means ‘the study of’. Hence, the *methodology* is merely the study of a particular method, or methods, for reaching the desired end in a continuous procedure (Leedy & Ormrod, 2001). According to C. R. Kothari research methodology is the systematic procedure adopted by researchers to solve a research problem that maps out the processes, approaches, techniques, research procedures, and instruments (Kothari, 2004).

The methodology of this study is to discuss aspects of acid rain. In this study, historical background, causes, and effects of acid rain are introduced. It also has tried to highlight more acid affected areas, and finally reduction policies of acid rain. Secondary data are used here to prepare this article. For the collection of necessary data, various publications, research reports, online databases, magazines, books of various authors, theses, journals, websites, and other sources of published information are used.

5. Historical Background

In ancient period, people believe that if the pollutions were sent high into the air these would no longer be a problem. So that governments advised the industry owners to construction lofty smokestacks for sending smoke high into the air. But scientists have proved that the ancient belief was wrong. In the USA the height of the tallest smokestack has more than doubled, and the average height of smokestacks has tripled since the 1950s (Patrick et al., 1981).

The corrosions on limestone (CaO, $Ca(OH)_2$) and marble were noted by John Evelyn in the 17th century (de Beer, 1955). In that period it was also observed that deleterious effects of industrial emissions on plants, animals, and humans in England and France (Graunt, 1662). Before the Industrial Revolution, the pH of rain was usually between 5 and 6. The emissions of SO_2 and NO_x into the atmosphere have increased since the Industrial Revolution and become a threat to nature (Weathers & Likens, 2006).

Acid rain was first recognized by the pharmacist M. Ducros in 1845 (Ducros, 1845). The term "acid rain" was coined by a fellow of the Royal Society and British Chief Alkali Inspector Robert Angus Smith in 1872 from his studies of air pollution "Air and Rain: The Beginning of a Chemical Climatology" in Manchester, England. He observed that ammonium carbonate ($(NH_4)_2CO_3$) was in the air over the farming area, ammonium sulfate in the suburbs, and sulfuric acid (H_2SO_4) in the city area which created acid rain (Smith, 1872; Likens et al., 1972). Then fossil fuel combustion was considered as the main cause of air pollution and had taken it as a local urban problem into a national and international one (Gould, 1985). SO_2 was the first atmospheric pollutant to be recognized as an important toxic agent to plants (Katz & Ledingham, 1939). Atmospheric SO_2 has increased 20-fold globally since the 1800s. About 200 years later, the effects of acid rain were taken seriously since 1980 (Lehmann et al., 2008).

From Smith's period to the mid-20th century there was no remarkable research on acid rain until the late 1960s (Likens et al., 1972). Research on the deposition of atmospheric SO_4^{2-} was conducted in Sudbury, Ontario, Canada, and later at locations in Europe, North America, and Australia. In the late 1960s, modern understanding of acid rain has established by Svante Oden, a Swedish soil scientist a network to measure surface-water chemistry in Scandinavia and in North America by Gene Likens (Likens & Bormann, 1974; Odén, 1976).

An American limnologist, Eville Gorham, and his colleagues published a series of papers on acid rain between 1955 and 1965 (Gorham, 1976). During the 1980s measurement of the acidity of rain and snow due to industrial pollution was done for the first time in the USA (EPA, 1980). In 1976, a National Acid Deposition Program (NADP) was initiated by J. N. Galloway and E. B. Cowling in the USA. The NADP found that acid deposition was very high in the northeastern portion of the country (Galloway & Cowling, 1978). In 1980, the US Congress established the National Acid Precipitation Assessment Program (NAPAP) which incorporated the original NADP network into a nationwide network called the National Trends Network (NTN). Main activities of NAPAP were to conduct a comprehensive 10-year program to research, monitor, and assess the problem of acidic precipitation in the USA. NADP is a network of over 100 federal agencies, universities, tribal nations, and companies which provides long-term, accurate acid emissions (NAPAP, 1990).

The demand for industrial products and services has increased due to population growth and economic development. Development and availability of new technologies, the discovery of new uses for the resources and products, development of transportation facilities influence the emissions of SO_2 and NO_x (Singh, 1994).

Rapid and unplanned industrialization is the main cause of acid rain. About 60–70% SO_2 is responsible for global acid deposition. More than 90% of SO_2 in the atmosphere is created from human activities as; industrial combustion (69.4%), transportation (3.7%), coal burning (2–3%), smelting of metal sulfide ores to obtain the pure metals (about 14%). The remaining 10% SO_2 is emitted from volcanic eruptions, forest fires, sea spray, rotting vegetation, plankton, organic decay, etc. (Ramadan, 2004).

About 95% NO_x is emitted in the atmosphere from human activities as; firing process of extremely high temperature in automobiles (56%), the chemical reaction in fertilizer production (5%), fuel combustion (34%), etc. The remaining 5% emits from forest fires, rotting vegetation, bacterial action in the soil, volcanic action, lightning, etc. (United States Geological Survey, USGS, 2013). Acid rain causes due to air pollution in many developed and industrialized countries mainly in the North-eastern section of the USA, the South-eastern section of Canada, India, Japan, China, and Central Europe (Kolhe & Deshmukh, 2016).

6. Effects of Acid Rain

Acid rain not only affects on ecosystems but also affects human health. Sulfur dioxide and nitrogen oxide emissions from acid rain create eye, nose, and throat irritations, and lung disorders, such as dry coughs, asthma, headaches, and bronchitis (EPA, 2004). Use of urea and animal manure causes ammonia (NH_3) accumulation in the atmosphere and long-term addition may cause acid deposition (Wang et al., 2004). Acid rain has broad economic, social and medical problems and has been called an unseen plague of the industrial age (Acid News, 1984).

6.1. Effects on Fish and Other Aquatic Life

Acid rain affects ponds, rivers, streams, lakes, gulfs, seas, oceans, etc. by increasing their acidity. As a result fish and other aquatic creatures can no longer live (Ekmekyapar et al., 2009). Acid rain affects on fishes directly or indirectly. Direct effects are the alteration of blood chemistry, retardation of egg development, etc. Indirect effects are the reduction in the kinds and supply of food available to fish, the creation of toxic to fishes, etc. Some lakes in Sweden have become so acidic that they are no longer able to support fish life (EPA, 2004). At pH, lower than 5 most fish eggs will not hatch, and also kill adult fishes. At pH 6, freshwater shrimp cannot alive and at pH< 4.5, all fish die. Snails, crayfish, and certain other invertebrate animals are very sensitive to acid and may rapidly disappear if acidity increases. Some microorganisms, plankton, insects, and blue-green algae are the food of fishes; these are affected by acid rain, ultimately fishes are declined due to the lack of food (EPA, 2006b).

6.2. Effects on Plants and Trees

The pH value between 5 and 8 is the ideal pH range for the plants' growth, and out of these ranges in soils, plants face difficulties to germinate or grow. No plants grow if pH is less than 3.7 (Larssen et al., 2006).

Acid rain reduces plant growth and yield due to foliar injury. It decreases vital nutrients of soil that is formed by nitrogen (N), calcium (Ca), magnesium (Mg), and potassium (K), etc. Abundant of aluminum (Al), mercury (Hg), manganese (Mn), cadmium (Cd), and lead (Pb) in the soil is in the non-toxic form; in the presence of acid rain these becomes toxic in soil and cause damage or death to plants and trees (Curtis & Childs, 2010; Liu et al., 2011). When calcium is decreased from the needles of red spruce, trees become less cold tolerant and exhibit winter injury and even may dead (Lazarus et al., 2006). Acid rain changes the chemistry of leaf surfaces, decreases pollen germination, fertilization and seed development, and fruit formation. It adds H^+ to the soil which reacts with compounds of calcium, magnesium, and potassium from soil particles. Useful micro-organisms which release nutrients from decaying organic matter, into the soil are killed off. As a result plants and trees loose nutrients. The roots of plants and trees are affected by acid rain; and hence they are killed (Ulrich et al., 1980). Although some plants can survive in the effects of acid rain but, become very weak and unable to survive in natural calamities like heavy rainfall, strong winds, and drought. Experimentally it is obtained that herbaceous plants are more sensitive to direct injury by acid rain than trees (Heck et al., 1986). Leaf surface wax layer, chlorophyll and other constituents of the cells are destroyed by acid rain.

On the earth, all living organisms are interdependent on each other. If a lower life form is killed, other species up the food chain that depend on it will also be affected (Brunnee, 1988).

6.3. Effects on Structures

Acid rain of pH value 3 to 5 is known as 'stone cancer'. It is observed that lots of buildings, historical monuments are harmed worldwide because of acid rain. At present both railway and airplane industries have to spend a lot of money to repair the corrosive

damage done by acid rain. Marble, limestone, sandstone, and ancient monuments are dissolved by acid rain. Metals, paints, textiles, and ceramic can readily be corroded due to acid rain. It can downgrade leather and rubber (EPA, 2004). In building and monuments, acidic water reacts with calcium carbonate ($CaCO_3$) to form powder type calcium sulfate (gypsum), and calcium nitrate, and destroy the structures (Likens & Bormann, 1974).
$CaCO_3$ (lime) + $H_2SO_4 \rightarrow CaSO_4$ (gypsum) + $2H^+ + CO_3^{2-}$.
$CaCO_3$ (lime) + $2HNO_3 \rightarrow Ca(NO_3)_2 + CO_2 + H_2O$.

Man-made cultural attractions, such as the Taj Mahal in India, St. Paul's Cathedral in London, Westminster Abbey in England, the Sphinx in Greece and Egypt, the Parthenon in Greece, the Statue of Liberty in New York, and the Cathedral Cologne in Germany are also affected, as they corrode and dissolve in the face of acid precipitation. Acid rain can destroy stained glass windows, steel bridges, and railway tracks. It corrodes metal, ruins the paint color, weakens leather, and forms a crust on glass surfaces of the modern structures (Okochi et al., 1982).

6.4. Effects on Human Body

Acid rain can harm human indirectly. Human being depends upon plants, fishes, and animals for food. If they decline due to acid rains will suffer due to the shortage of food (Bennet, 1998; Liu et al., 2011). The discharge toxic metals due to acid rain are absorbed by the water, crops, or animals that human consumes that cause severe nerve damage, lung problems (asthma and bronchitis), brain damage, kidney problems, cancer, and Alzheimer's disease, that may cause death (Okita, 1983).

7. Global Acid Rain Problems

Acid rain becomes a major environmental problem in the USA, Canada, England, Scotland, Sweden, Norway, Denmark, West Germany, The Netherlands, Austria, Switzerland, Russia, Poland, Southwest China, and Japan (Bouwman et al., 2002).

7.1. Effects of Acid Rain in China

Acid rain is a serious environmental problem in China. China is the largest coal producers and consumers (about 2 billion tons) in the world. China is the largest sulfur-emitting country in the world. SO_2 emission from coal combustion is a primary cause of acid rain in China (Energy Information Agency, EIA, 2001). S and N deposition increased in China from the 1980s-2000s, most likely due to increased SO_2 and NO_x emissions but S deposition in China started to decrease as early as 2006 (Zhao et al., 2011).

China started acid rain monitoring network across the country in the late of the 1970s and early of the1980s (Liu et al., 1997). The First National Symposium on Acid Rain was organized in November 1981. In 1982, the National Environmental Protection Agency (NEPA) organized and sponsored the National Survey of Acid Rain (Zhao et al., 1988). During 1986-1995, Chinese scientists analyzed the effects of acid rain on crops and forests, and estimated associated economic losses. They have identified the principles, methodology, and indicators to apply control plans of acid rain. During 1996-2000, control plans were applied in SO_2 affected areas (Hao et al., 2000). In 1998, the country adopted national legislation to limit ambient SO_2 pollution and effects of acid rain (ESMAP, 2003).

Rapid economic growth and increased energy demand is the main cause of severe air pollution problems around the large cities of China. Acid rain is higher in the southwest, south, and the southeast coastal areas of China. Recently it is increasing remarkably in the north of China. The neighboring countries of China (e.g., Japan, South Korea, and India) are complaining that they are affecting due to acid rain for huge coal burning of China (Wang et al., 2002).

Sulfur emissions in China have decreased in the late 1990s, increased by about 28% from 1999 to 2000, and remained stable up to 2002; increased again in 2005 and decreased by about 10% in 2010. In recent years, NO_x emissions have increased in China due to increased on-road motor vehicle emissions (Li & Gao, 2002; Schreifels et al., 2012).

7.2. Effects of Acid Rain in America and Canada

Acid rain becomes a great problem in the Eastern Canada and the Northeastern in the USA. In 2000, Canada emitted about 2.4 million tons of SO_2. About 41% of lakes in the Adirondack Mountains region of New York and 15% of lakes in New England exhibit signs of chronic acidification where median pH is 4.34. The most acidic rain in the western Pennsylvania, eastern Ohio, southwestern New York, and northern West Virginia, and nearby areas has an average pH of 4.2 (Kulp, 1995).

Extensive vegetation dieback and soil erosion have occurred in the Canadian province of Ontario. In 1980, eight states of the USA; Illinois, Indiana, Ohio, Kentucky, West Virginia, Pennsylvania, Missouri, and Tennessee emitted 46% of the US SO_2. In the USA, during the 1990s sulfur emissions have reduced substantially (Stoddard et al., 2003). It is estimated that about 50,000 lakes in the USA and Canada have a pH value of less than 5.3. SO_2 emissions have reduced about 40% in the USA from 1980 to 2000, and NO_x emissions have remained relatively stable from 1980 to 1999 (EPA, 2001).

Temporally Integrated Monitoring of Ecosystems (TIME) monitors a total of 145 lakes and 147 streams in Midwest, New England, the Adirondack and the Catskill Mountains, the northern Appalachian Plateau, and Ridge and Blueridge Provinces of Virginia of the northern and eastern parts of the USA. The experiment has found that 1% to 8% of lakes and streams are acidic (NAPAP, 2005). In 1990, the US Congress established the Acid Rain Program under the Clean Air Act which reduced 10 million tons of SO_2 and 2 million tons of NO_x (EPA, 1999).

7.3. Effects of Acid Rain in Europe

Ecosystems in the Scandinavian countries, central Europe are affected by acidification. In Poland and Germany about 50% and in Switzerland 30% of forests have been damaged by acid rain. Large-scale acidification of surface waters in Sweden could be attributed to pollution from the UK and central Europe (Odén, 1968). Norway has faced a great damage due to the effect of acid rain. According to the State of the Environment in Norway, 18 salmon stocks have been lost, and 12 are endangered and have been wiped out of all of the large salmon rivers in southern Norway (Beychok, 2013).

In 1991, more than 4 million tons of sulfur and 1.25 million tons of nitrogen fell as precipitation on the territory of Russia which affected seriously in the Kemerovo region and Altai Krai, Norilsk (Zaikov et al., 1991). Scandinavia has taken an attempt to reduce sulfur emissions. At a site in southernmost Norway has reduced by 50% between the 1976–1985 and 1995–2001 time periods (Aas et al., 2002). SO_2 emissions have reduced about 65% in Europe from 1980 to 2000, and NO_x emissions have reduced by about 30% from 1990 to 2001 (Vestreng, 2003).

8. Reduction Policies of SO_2 and NO_x

Emission of SO_2 and NO_x from industries and power plants should be reduced by using pollution control equipment, such as efficient boilers, cleaning technologies, and fluidized combustion beds. Liming (use of limestone and lime) of lakes and soils should be done to reduce the adverse effects of acid rain. Ponds and small lakes that have become highly acidic can be neutralized by using large quantities of alkaline, such as quicklime (Driscoll et al., 1989). Efficient use of limestone injection burners, re-burners, flue gas desulfurizers, in-duct sprayers, and low NO_x burners can reduce both SO_2 and NO_x emissions. Instead of burning coal to produce electricity renewable energy sources, such as nuclear power, windmills, hydroelectric projects, solar cells, biofuels, etc. can be increased.

9. Recommendations

Recently the acid rains have increased due to natural and man-made activities, lack of necessary maintenance, etc. Sometimes acid rain is called "the unseen plague". The effects of acid rain must be reduced for the welfare of the global ecosystem. Power plants use coal, gas, and oil to produce electricity. Consequently, these plants produce SO_2 and NO_x that causes acid rain. Low sulfur coal must be used in coal-dependent electric power plants to reduce sulfur pollutions in the atmosphere.

Human can reduce the amount of use of electricity in various ways and can contribute to reducing acid rains. To reduce the use of electric power lights, fans, air cooler, and other electrical instruments need to switch off when do not use. Also, televisions, music systems, microwave ovens, etc. should not keep in stand-by and must switch them off. The production of renewable energy, such as wind power, solar panels, tidal power, etc. must increase to reduce acid rain pollution.

To reduce NO_x it is needed to avoid private cars and use public buses for a long journey. The governments take necessary actions to reduce the use of private cars. Increase use of more trains, carpools, larger public buses, etc. can reduce nitrogen, sulfur, and lead emissions in the atmosphere. Governments can make compulsory to fit catalytic converters to vehicle exhausts which remove the NO_x. Walking or bicycle use will improve health and reduce the tendency of acidification for short journey. Use of waxes, special coatings, and paints can reduce erosion of metals and structures.

10. Conclusion

This study has tried to discuss aspects of acid rain with its harmful effects. It tries to enlighten historical background, causes, and effects of acid rain. It also highlighted on the global acid rain problems and reduction policies of acid rain. Scientists and environment experts around the world are trying to reduce future damages due to acid rain. Every country must try uniformly to reduce the acid rain but the industrialized and developed countries must be more effective in this regard. Future researchers must try to invent new efficient technologies to reduce acid rain more efficiently than the existing technologies. In this respect global concern on acid rain must be created among the common people and civil societies. For the global welfare of the ecosystem there is no alternative but the reduction of acid rain.

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