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Acid Deposition in India: Emissions, Deposition and Climate Change

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ABSTRACT: Acid deposition became an issue of major concern in India in the early 1980s, nearly one decade after widespread acid deposition was recognized . Before the establishment of national monitoring networks for acid deposition in India, isolated surveys of acidity level and chemical composition of rainwater in some Indian cities indicated the occurrence of acid rain . These nation-wide monitoring networks provide the longest record of wet deposition in India. To create a common understanding of the state of acidic deposition problems in India, the Acid Deposition Monitoring Network in India (EANET) began regular deposition monitoring activities in January 2001. Monitoring of wet and dry deposition, together with ecological impacts, has been conducted as part of the activities of this network.Recently, the ensemble-mean depositions of sulfur (S) and nitrogen (N) over Eastern India was presented based on eight regional chemical models used in a model inter-comparison study for India .India is now the global hotspot of S and N deposition . Since the early 2000s, the global maximum of both S and N deposition is found in India, including regions like eastern China and South Korea.

Anthropogenic inputs of S and N into terrestrial ecosystems impact soil and surface water, causing acidification and eutrophication .Because long-term data on surface water chemistry are limited in the Indian region, the re-measurement of previously surveyed rivers and lakes or the assessment of public data on water quality are among the few options to assess the current situation regarding water acidification and N leaching . So far, very few areas have shown water acidification. This is even true for areas with acidic soils and high rates of acid deposition . In comparison, soil acidification, as indicated by a significant decrease in soil pH and increase in aluminum (Al) mobilization, and increased N leaching , has been commonly reported in India .

The critical load of acid deposition is defined as ‘‘a quantitative estimate of an exposure to one or more pollutants below which significant harmful effects on specified sensitive elements of the environment do not occur according to present knowledge’’ . The critical load concept was developed in the 1980s to support effective acid rain policy.

In this paper, we review and synthesize the current state of knowledge regarding acid deposition and its environmental effects across India, in particular India. The trends of emissions of acidifying precursors such as SO_2, NOx, and ammonia (NH_3), and deposition of S and N in recent years are summarized, and the effects of acid deposition on soil and surface water are discussed. We hope the review may be useful for future studies and policy-making.

KEYWORDS: Acid deposition, Soil acidification, Water acidification, Nitrogen saturation, Nitrification, Sulfate adsorption

I. INTRODUCTION

Driven by a dramatic economic development, Indian anthropogenic emissions of SO_2, NOx, and NH_3 show increasing proportions in the global budgets since 1970s (Fig. 1).

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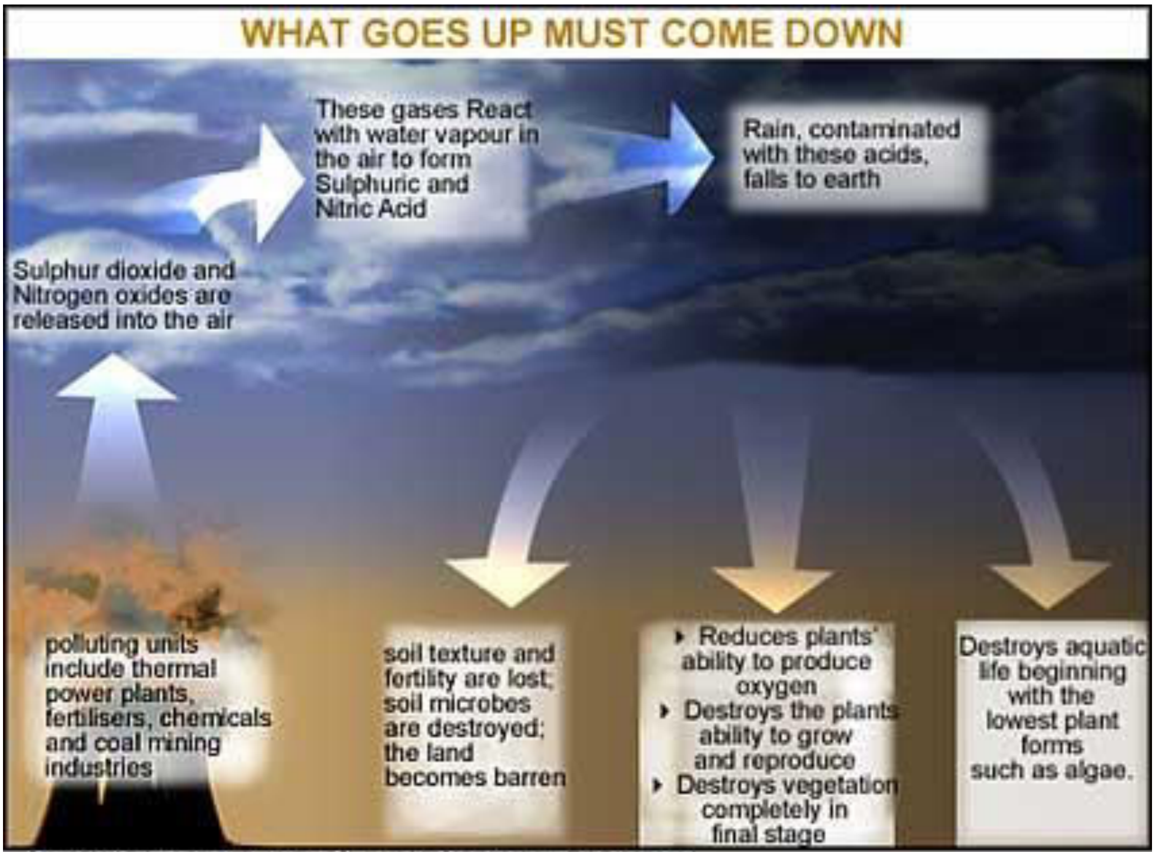
| Volume 3, Issue 3, March 2020 |



Source: Amit Nair, toxicologist, Centre for Science and Environment

Fig.1

For all of the three acidifying precursors, more than 35% of the global emissions were contributed by Indian in 2005, mainly contributed by China and India (1).

Emission trends of SO_2, NOx, and NH_3 varied significantly among Indian regions . The SO_2 emissions increased continuously before 2006, and declined after 2006 due to wide application of flue-gas desulfurization (FGD) in power plant units since 2005.

India faces an increasing threat from acid rain -- earlier believed to be the scourge of the West. The large-scale industrial growth and reliance on the use of coal and crude oil distillates like diesel have led to acidification of the atmosphere.The burning of fossil fuels is mainly responsible for creation of sulphur dioxide (SO_2) and oxides of nitrogen (NOx,) which lead to the formation of acid rain. Automobile exhaust fumes are partly to blame, but the worst culprits are coal-burning thermal power plants and the steel industry. Already, a low pH has been observed at Chembur, Maharashtra and Delhi. This is the conclusion of a study conducted by Manju Mohan and Sanjay Kumar of the Centre for Atmospheric Sciences, Indian Institute of Technology (IIT), New Delhi.

II. OBSERVATIONS

The wet deposition of SO_4^{2-} also decreased by about 5% between 2000–2002 and 2005–2007 in northIndia, one of the areas with highest S deposition in India (11.0 kg ha^{-1} yr^{-1} in 2005–2007) (2). However, the wet deposition of N increased by more than 30% in this area, which measured among the highest wet N deposition rates in the world with values of about 20 kg ha^{-1} yr^{-1} (3).

The phenomenon of rain is caused when heat from the Sun's rays on the surface of seas, lakes and rivers induces evaporation. The water vapour formed in the process rises to a height where it condenses into moisture. If ambient conditions prevail it comes down as rain. But in the case of acid rain, water vapour reaches the atmosphere, condenses, and reacts with atmospheric gases like so 2 and no x . When it rains, these atmospheric pollutants are deposited on the soil, vegetation, surface water or reservoirs. The deposition ultimately results in damage because of the acidity of the pollutants.

The main cause of substantial net loss of SO_4^{2-} within the catchment is likely the adsorption of SO_4^{2-} in soil layers (4), which produces OH^- and can neutralize soil acidification. It coincides with very low leaching of SO_4^{2-} by stream waters with high S deposition (5). The anion exchange capacity is high in these soils with low pH and a high content of Al oxides (6). By contract, soil nitrification produces H^+ to acidify soil, while denitrification mainly neutralizes surface water acidification. It seems that the acidifying effect of N deposition may be more important than S deposition in the well-drained tropical/subtropical soils. For some catchments where SO_4^{2-} saturation may occur, with the SO_4^{2-} flux in soil water similar as that in throughfall (7), the SO_4^{2-} reduction to sulfides, as implied by high groundwater table and effective denitrification, may be another SO_4^{2-} sink in the sub-soil or even more likely in the groundwater discharge zones.

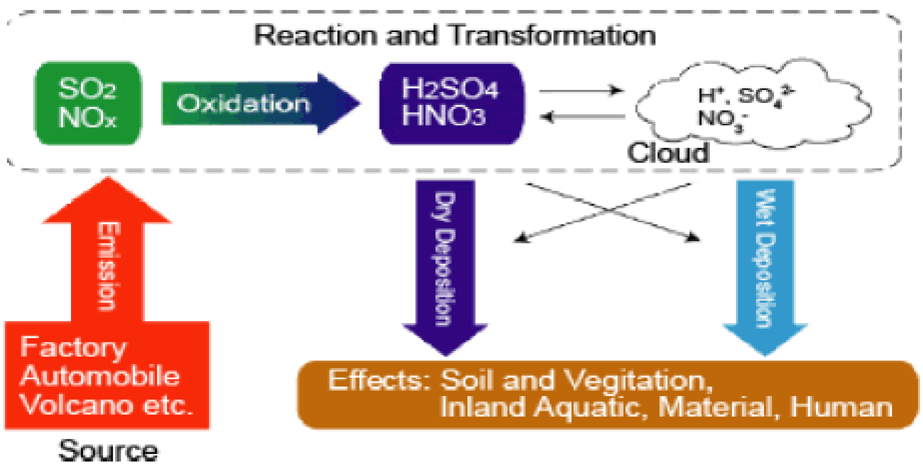
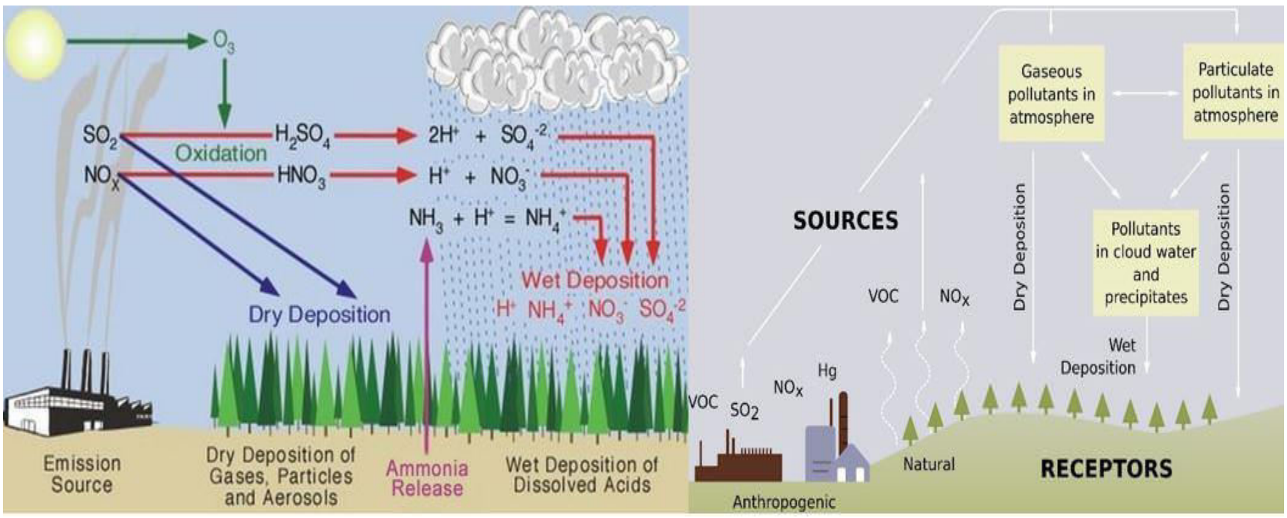


Figure 1: Flow chart that shows the formation of acid rain and its interaction with environment.

III. DISCUSSION

The elevated Ca^{2+} deposition and significant sinks of N (denitrification) and S (sorption, including reduction, adsorption and precipitation) explain the issue of why there is little surface water acidification. Other processes like SO_4^{2-} adsorption are only temporarily important (until approaching SO_4^{2-} saturation). Denitrification and SO_4^{2-} reduction may be more permanent sinks of acidity but depend on soil N status and S status. In addition, SO_4^{2-} sorption is most likely reversible, implying that SO_4^{2-} desorption may delay the increase in soil water pH after a decrease in S deposition. Moreover, modeling results by MAGIC indicated that the current regulation of SO_2 emission abatement could not significantly increase soil water pH values, the (Ca + Mg + K)/Al molar ratio, or soil base saturation to the level of 2000 before 2050, and the emission reduction of particulate matter would offset the benefits of SO_2 reduction by greatly decreasing the deposition of base cations, particularly Ca^{2+} (8). Continuous droughts in the future might also delay acidification recovery (9).



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| Volume 3, Issue 3, March 2020 |

Excess nitrogen deposition has not only led to acidification, but also resulted in ecosystem eutrophication in Eastern India, shown as changes in N dynamics, plant growth, or biodiversity. Atmospheric N deposition could stimulate enzyme activities and accelerate N transformation and cycling processes (10). For example, N addition increased rates of net N mineralization and nitrification, regulating organic matter decomposition (11).

The problem is very real in the sub-continent. India enjoys the dubious distinction of releasing the maximum pollutants in the atmosphere after China. Total sulphur emissions are expected to rise from 4,400 kilotonnes (kt) in 1990 to 6,500 kt in 2000, 10,900 kt in 2010 and 18,500 in 2020. It is, therefore, not surprising that low pH levels have been reported from Delhi, Uttar Pradesh, Maharashtra, Madhya Pradesh, Tamil Nadu and even the Andaman Islands. While this will not result in acid rain, the stage has been set for it and if conditions worsen like the setting up of a highly polluting thermal power plant in the vicinity or an industrial estate there may be acid rain. After analysing data from 10 Indian Background Air Pollution Monitoring Stations (bapmons), scientists have confirmed that rain in and around these cities is getting increasingly acidic in nature.

Although N deposition could improve soil N availability and result in an increased photosynthetic capacity and stimulation of plant growth in N-limited ecosystems (12), excess N input led to restriction to plant growth or even damage to plants due to change in soil N status (13), nutrient imbalance (14), or reduction in net photosynthesis (15). Biodiversity could also be significantly affected by N deposition, with the level depending on soil N status, vegetation composition, dose and duration of N addition, and N requirements by different species (16). Excessive N deposition normally reduced biodiversity, including forest understory species (17), grasses and forbs (18), and soil fauna (19).

The bapmons data collected during 1974-1984 shows that a few areas are already under stress conditions. During two decades, the acidic content of rain in Delhi increased, which means its pH level decreased from 7.0 (1965) to 6.1 (1984), and in nearby Agra from 9.1 (1963) to 6.3 (1984). The data also showed that pH levels in the Andaman Islands fluctuated between 5.6 and 8.9. Acidity and alkalinity are measured on the pH scale from 0 to 14. Normal water is 7 on the scale. Decreasing values on the pH scale denotes increasing acidity and, conversely, higher values show increasing alkalinity. A value below 5.6 denotes acid rain.

IV. RESULTS

Associated with rapid economic development, acid deposition has become a major issue in India, especially in India. Generally, surface waters in India are not as sensitive to acid deposition in comparison with soil. This is even true in acid forest soils in tropical and subtropical regions, which are characterized by low mineral weathering. India is different from North America and Northwest Europe as the acidification potential of atmospheric deposition is less than expected due to high base cation deposition, particularly Ca^{2+} deposition, derived from soil dust and particulate matter from cement production and fossil fuel combustion. Therefore, more attention should be paid to the trend of base cation emission (both natural and anthropogenic) and deposition in India. In addition, NO_3^- denitrification and SO_4^{2-} adsorption are processes that play a more prominent role in acid neutralization in soils of India than in Europe and North America.(20)

Moreover, the use of diesel is causing a high amount of sulphur and nitrogen emissions in the metros. Indian diesel has a sulphur content of 0.5 per cent by weight. Delhi and Agra are supplied with diesel that has a lower sulphur content. "But even this is far higher than sulphur levels in diesel used in countries like Sweden (0.001 per cent). Swedish diesel is 250 times cleaner. It means that with the rising number of diesel vehicles, the government's objective to bring down sulphur emissions may not be achievable," says H B Mathur, professor emeritus, Delhi College of Engineering. "If the government continues to encourage diesel usage, the prediction made by the iit study may well come true," adds K P Nyati, head (environmental division), Confederation of Indian Industries (CII), New Delhi.

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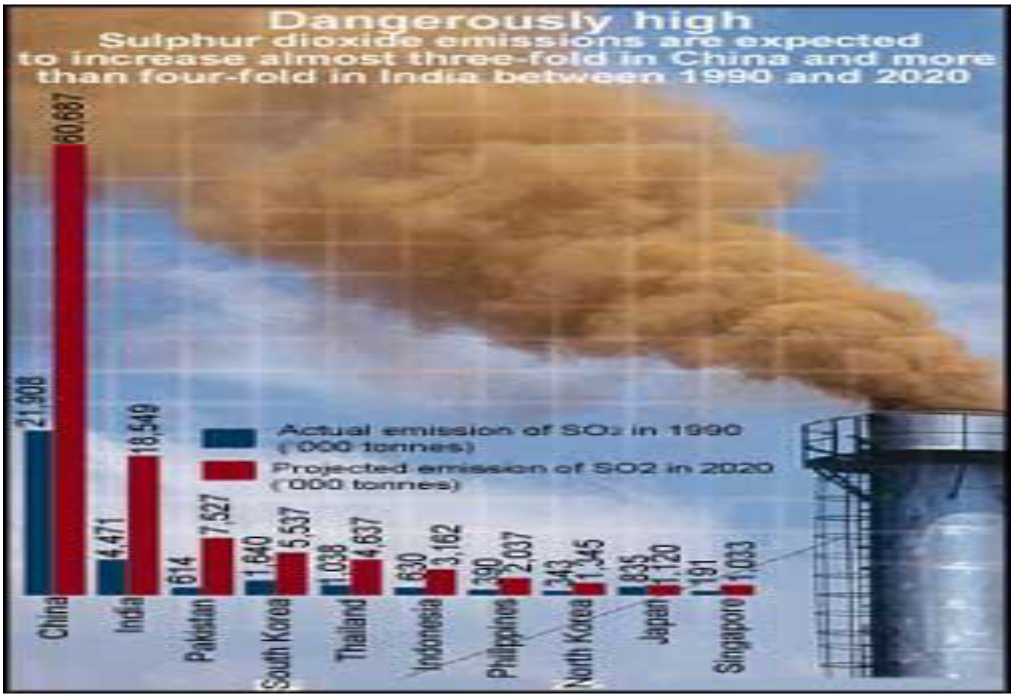
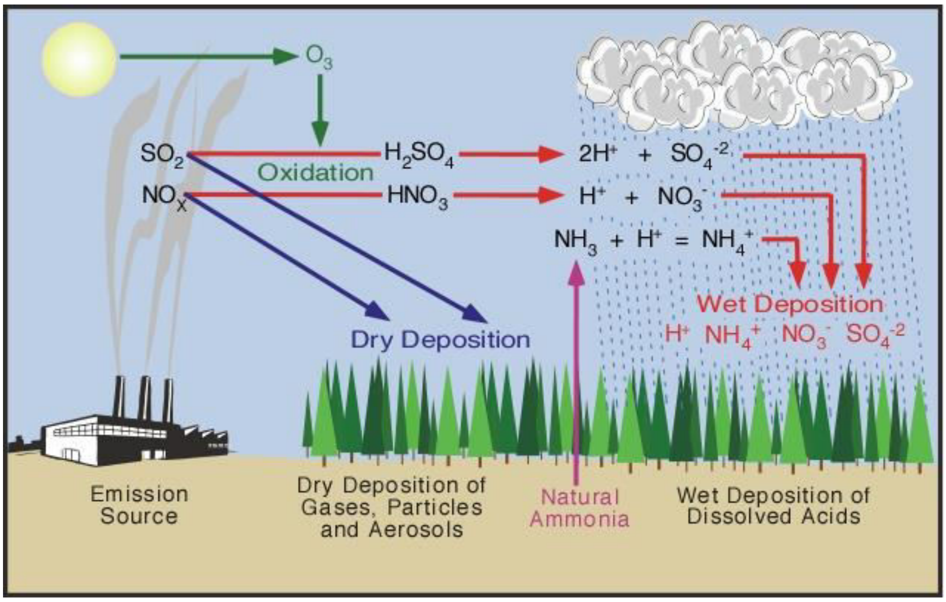
| Volume 3, Issue 3, March 2020 |



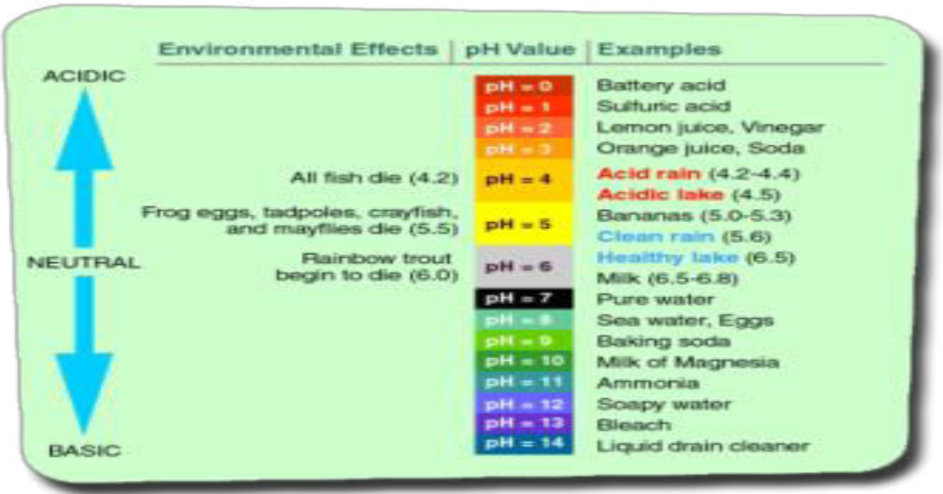
Nitrogen deposition, especially of NH_4^+, is of increasing concern in India due to nitrification and nitrate leaching in N-saturated ecosystems causing acidification of soils and water. Enhanced NO_3^- leaching has been observed. Although further studies are needed, the acidifying effect of N deposition may be more important than S deposition in well drained tropical/subtropical soils due to high SO_4^{2-} adsorption.(11)

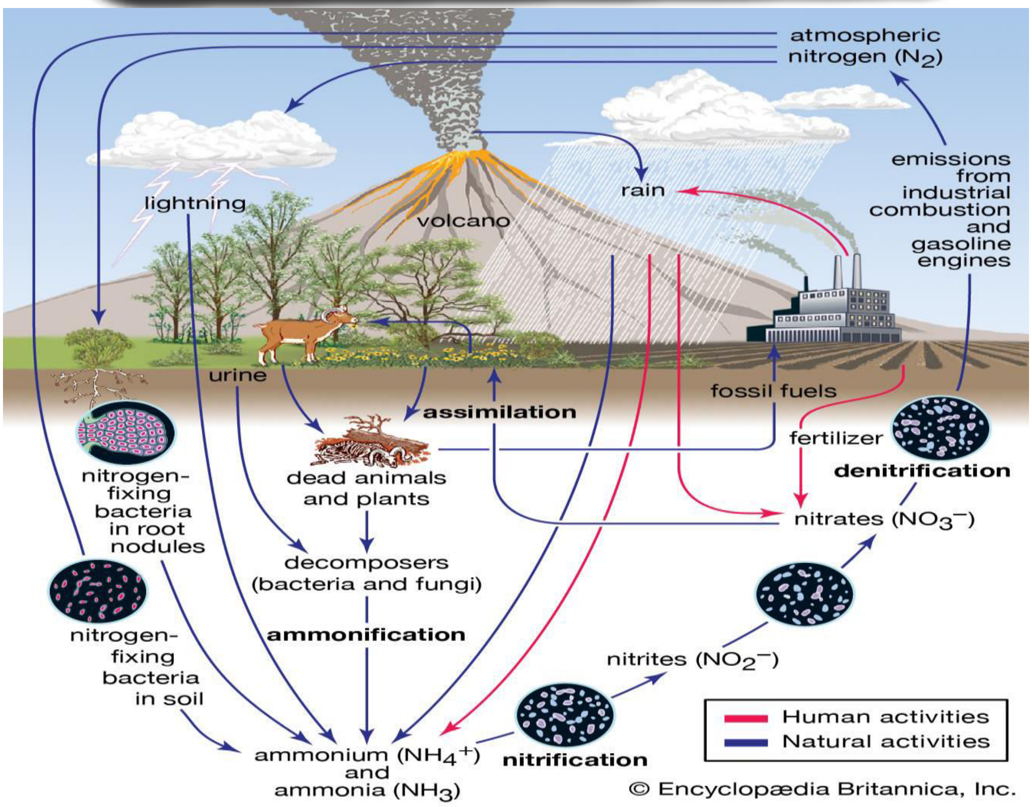


| ISSN: 2582-7219 | www.ijmrset.com |

| Volume 3, Issue 3, March 2020 |

V. CONCLUSION





As the biggest contributor of S and N emissions, a decrease in S and N deposition, and beginning of recovery from soil acidification in these countries. However, the large stores of adsorbed SO_4^{2-} are expected to be desorbed, a process which delays the recovery of the soil from acidification. Thus, how quickly soils respond to decreased deposition is uncertain. Risk of regional soil acidification still exists, as can be seen from critical load exceedance in large areas of India. Further studies on the effect of acid deposition in India are therefore needed, not only for improving our understanding, but also for supporting future policy-making.(20)

The only good news for India is that chances of acid rain occuring are unlikely. This is because tropical climatic conditions and predominantly alkaline-rich soils of the country have a neutralising effect on the pollutants, says R N Gupta, director, Environmental Meteorology Unit, Indian Meteorological Department (IMD). As dust particles in the country are alkaline in nature, acid rain-causing gases such as so 2 and no x get neutralised.

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| Volume 3, Issue 3, March 2020 |

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