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ACID RAINS AND RAINS CAUSING ACIDITY OF SOILS IN SRI LANKA

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ABSTRACT

Acid rains are not a common phenomenon in Sri Lanka, though there is some suspicion of acid rains from polluted atmosphere. However, in the context of atmospheric air pollution, rains that cause soil acidity and subsequent destruction of the crop is equally important and as bad as acid rains *per se*.

Raindrops can combine with NO_2 and SO_2 to yield acid droplets. Although acid rains were not considered a problem in the country, recent research indicates that it occurs in some parts of the country. High levels of sulphur and nitrogen interception by fog in Horton plains supports the suspicion that forest die back at the site is due to acid rains. However it may also possible because of the country's position that the pollutants reaching Horton plains are not from national sources but from cross national boundaries due to wind effects.

Rainfall causing soil acidity and saline conditions was commonly observed during the last three decades in rain-fed paddy lands of southern Sri Lanka. Nilwala Ganga Flood Protection and Drainage project in Matara, was completed in late 1980's and caused nearly 8,000 ha of paddy lands uncultivable due to excessive drainage and subsequent acid sulphate conditions. The paddy farmers who are the poorest of the poor in Sri Lanka were thrown from the 'frying pan to the burning fire'. .Research conducted found that it was due to the oxidation of acid sulphate causing parent material present in the soil catena at about 1 to 1.5 feet below the surface which move upwards to the root zone and causes soil acidity and parched up the broadcast sown or transplanted rice plants.

Paddy soils in the project area have pH values ranging from 4.2 to 2.8, together with the appearance of orange yellowish 'jarosite like material' on the soil surface. Moreover, during the dry weather with the sharp increase in acidity there was a slow but steady increase in salinity too. Owing to erratic rainfall, the young rice crop is subjected to acid sulphate conditions and other toxicities, namely aluminium and iron toxicities, together with low phosphate availability causing the death of rice plants.

Key words: Acid rains, Soil acidity, Atmospheric Pollution, Jarosite, Rain fed Paddy

1. INTRODUCTION

Acid rain is a common term used to describe any form of acid precipitation (rain, snow, hail, fog, etc.). Atmospheric pollutants, such as oxides of Sulphur and Nitrogen, can cause rain to become more acidic when converted to Sulphuric and Nitric acids and therefore relates to the chemistry of air pollution and moisture in the atmosphere. Acid rain is really a series of interactions and reactions among various factors in environment and society and to better understand it we can trace it through five stages, emission, transport, transformation, deposition and effects (Zhao Dianwu and Zhang Xianshan (1981). Because of its nature in transport acid rains has become a global problem instead of a localized problem.

Rainfall is naturally weakly acidic due to the presence of carbon dioxide in the atmosphere which combines with rainwater to form weak carbonic acid. Coal, oil and gas are called fossil fuels because they form over millions of years through the decay, burial and compaction of rotting vegetation on land (coal), and marine organisms on the sea floor (oil and gas). The combustion of fossil fuels produces waste gases such as oxides of N and S and to a lesser extent, chloride. Coal was the first fossil fuel to be exploited on a large scale during the 19th century with the beginning of the Industrial Revolution.. These pollutants such as NO_2 and SO_2, chlorides, can be converted, through a series of complex chemical reactions, into sulphuric acid, nitric acid or hydrochloric acid, increasing the acidity of the rain or other type of precipitation, such as snow and hail.

Rainfall acidity is measured in pH units. ‘Normal’ or ‘unpolluted’ rainfall has a pH of 5.6. This is slightly acidic due to the presence of carbon dioxide in the atmosphere which forms weak carbonic acid in water. The pH scale in acid rain takes a logarithmic scale, and there is a ten fold increase in acidity with each pH unit. Pollutants can be carried many hundreds of kilometers by winds cutting across boundaries of different countries, thus, acid pollutants emitted in one country may be deposited as acid rain in other countries. Some countries emit small quantities of pollutants yet deposition can be several times greater. Thus acid deposition has become an international problem in today’s context. This problem is highlighted by the fact that emissions of a particular pollutant from one country do not equal the deposition of that pollutant in the same country. The most recent UNECE Convention on Long Range Trans-boundary Air Pollution protocol was signed by 27 countries in December 1999. The Gothenburg Protocol, designed to Abate Acidification, Eutrophication and Ground-level Ozone aims to cut emissions of four pollutants: SO_2 NOx, volatile organic compounds (VOCs), and ammonia (NH_3), by setting country-by-country emission ceilings to be achieved by the year 2010.

The UK is committed to reducing sulphur emissions through the 1998 Gothenburg protocol. This Protocol requires UK to reduce sulphur emissions by 85% and nitrogen emissions by 49% by year 2010 (from 1980 levels). To meet these requirements, emissions of sulphur dioxide in UK are being reduced, through the use of cleaner technology within the power generation industry, and the use of cleaner fuels and car engines in the transport sector.

Impacts of Acid Rain

Unpolluted rain normally has a pH of 5.6 it is somewhat acidic because carbon dioxide in the atmosphere combines with water to form carbonic acid. Virtually all plants and animals can neutralize the acidity in normal rainfall and therefore not damaging. However when large quantities of pollutants are expelled in to the air, oxides of N and S, acids are formed and pH values of rainfall can drop. Acid rains can affect the natural ability of plants and animals and their habitats to neutralize acids. When terrestrial and aquatic ecosystems can no longer handle the stress of extra acidity, i.e. they cannot neutralize, and system becomes acidic. Acid deposition, more commonly known as acid rain, results from man-made emissions of SO_2 and NO_x through the burning of fossil fuel for energy and transportation. Acid rain has negative effects on the environment in which we live. Since acid rain is a trans-boundary pollution problem, acidic emissions produced by one country can be deposited in another. Sweden and Norway, for example, both receive more than 90% of their sulphur pollution from abroad. In Sri Lanka the scientists suspects the death of forest plants in the central hills is due to acid rain experienced in the area. If large quantities of acid rain are deposited they may have detrimental consequences for wildlife, forests, soils, freshwater and buildings. Acid rain acidifies the soils and waters where it falls, killing off plants and animals. Surface water acidification can lead to a decline in, and loss of, fish populations and other aquatic species including frogs, snails and crayfish. Acid rain affects trees by damaging their leaves. Certain types of building stone can also be dissolved in acid rain.

Effect on Environment

Acid rain can have serious impacts on trees and forests. Acid rain does not usually kill trees directly. Instead, it is more likely to weaken them by damaging their leaves, limiting the nutrients available to them in the soil, or poisoning them with toxic substances. The main atmospheric pollutants that affect trees are nitrates and sulphates. Forest decline is often the first sign to show that trees are in trouble due to air pollution. Sometime it takes many years of acid deposition for effects to be noticeable.

Scientists believe that acidic water once deposited on soil dissolves the nutrients and other helpful minerals in the soil and then washes them away before absorption by the flora. At the same time, the acidity that develops in the soil causes the release of toxic substances such as aluminum into the soil. These are very harmful to trees and plants, even in minute quantities. If large quantities of acid rain are deposited they may have detrimental consequences for wildlife, forests, soils, freshwater and buildings. Acid rain acidifies the soils and waters where it falls, killing off plants and animals. Surface water acidification can lead to a decline in, and loss of, fish populations and other aquatic species including frogs, snails and crayfish. Certain types of building stone can be dissolved in acid rain.

Forests in high mountain regions receive additional acid from the acidic clouds and fog that often surround them. These clouds and fog are often more acidic than rainfall. When leaves are frequently bathed in this acid fog, their protective waxy coating can wear away. The loss of the coating damages the leaves and creates brown spots.

Industrial revolution

Over the past several decades scientists have been keeping records of pH values of precipitation and compare the past and the present. Amount of acid in rains is insignificant in early 1800. Industrial revolution increased burning of coal and oils sending many acid forming gasses and particles into the air. In 1872 Robert Smith UK indicated the link between coal burning to rusting of metals, fading of dyes in areas where coal is used heavily. In the year 1900 it was reported that the fishes in the Norwegian and Swedish lakes are been affected by acid rains. During 1960's increase in S & N in polluted air caused respiratory illnesses in UK and found pH vales of rain is 100 times more than normal. 1979 average pH of rainfall is 4.1 in Ontario, Canada and New York in USA. 1992 the western UDA had an average pH value of 4.2 much more acidic than normal. The emission of SO_2 in 1960's is 31 million mt per year in USA which was reduced to 23 with the government intervention where as NOx it was 1970's which stands at 16 million mt has risen to 18.9 million in 1985

Trans-boundary Pollution

Stationary emission sources, such as coal-fired and oil-fired power stations, and mobile sources, such as cars, ships and aircrafts emit a complex mixture of pollutants, including SO_2 and NOx (the precursors to acid rain). It is now well established that this air pollution is transported over hundreds or even thousands of kilometers. Consequently, when acidic pollution is finally deposited, its environmental impacts are felt in areas far away from their sources. Since this air pollution has no regard for national boundaries, it has been termed trans-boundary pollution. The critical loads for total acidity of sulphur and nitrogen need to be determined so that a coherent international agreement can be reached with regard to abatement policies. There are numerous methods that are available for obtaining critical loads. In order to obtain values for the critical loads, an ecosystem has to be chosen and then a suitable indicator species is selected to represent the ecosystem. A chemical limit is subsequently defined. Svanke Oden (1960) reported acidity in Scandinavian lakes have been affected by pollution carried on the wind from UK and Western Europe.

2. ACID RAINS IN SRI LANKA

Geographical positioning of Sri Lanka has its advantages on acid deposition. Since the country is surrounded by the sea, the tropical monsoon winds and the sea and land breeze during the inter-monsoon period help the country to lower the concentration of atmospheric pollutants and disperse them. Raindrops can also combine with NO_2 and SO_2 to yield acid droplets. Although acid rains were not considered a problem in the country, recent research indicates that it occurs in some parts of the country. Illeperuma & Premakeerthi (1998) have monitored acid rains in several parts of the Island and the data obtained are given in Table 1 where Matara recording a pH of 6.00 in rain water.

Table 1. Incidence and quality of acid rains monitored at different locations of Sri Lanka.

Location	pH	Cl^- (ppm)	NO_3 (ppm)	SO_4 (ppm)
Colombo	5.89	2.22	0.57	2.95
Galle	6.45	18.06	0.90	2.44
Matara	6.00	13.46	1.25	2.10
Hambantota	5.89	10.00	1.89	2.00
Peradeniya	6.26	2.77	0.19	0.76
Puttalama	7.00	2.56	0.43	2.47
Anuradhapura	6.00	1.63	0.74	0.05

High levels of sulphur and nitrogen interception by fog in Horton plains supports the suspicion that forest die back at the site is due to acid rains. However it may also possible because of the country's position that the pollutants reaching Horton plains are not from national sources but from cross national boundaries due to wind effects.

Rain causing acidity in Sri Lanka

Rain causing acidity is much more serious in Sri Lankan context than acid rains *per se* because the suspected rains in the central highlands do not possess high acidity like in other countries. Further, the suspected acid rain damage in the central hills of the country may again be due to trans-boundary effect as there were no heavy industries within the country. In the south west coast of Sri Lanka low lying lands between 0.3 m above mean sea level(MSL) there are approximately 28,350 ha of poorly drained, flood prone, half bog and bog soils (Cooray 1967, Arumugam 1969, Douglas et al 1969) together with 3000-3400 ha of mineral alluvial soils of variable drainage and texture. In these lands a total of 32,000 to 36,000 ha were presently grown to rice regularly or occasionally. Below MSL there are approx. 8,900 to 11,000 ha where, despite acute hydrologic and coastal salinity related problems, a single, long aged crop is cultivated in favourable years, hence a total extent of 42,000 ha of high risk and low productivity lands. Since the removal of forest canopy in the central highlands the water flow in the river receded and during the dry periods of the year there was sea water movement upstream along the river and deposited the sulphate in the river bank which reacted with ferrous ions to form jarosite. This process has been there for several decades but due to reduced conditions and high water table in the area they remained as un-harmful.

Bog soils have more than 30 % organic matter and consist of black or brownish muck, mucky peat or peat (Dimantha 1977). Dimantha and Jinadasa (1981) have cautioned that Bog and half Bog soils have a fair amount of sulphides in the wet anaerobic conditions and if these soils are drained too much and get aerated sulphates would form and soils become extremely acidic. Half bog soils contain 15-30% organic matter and similar in reaction to bog soils though they have better bearing capacity.

During the rainy weather the removal of flood waters from low elevation lands is impeded owing to the rapid rise of ground water to the soil surface, and even above, which prevents vertical drainage. Furthermore the weak seaward gradient drastically reduces horizontal drainage. Consequently, during rainy weather the land gets quickly water logged with standing water of a few cm riding from 30 to 60 cm for periods ranging from a few days to 2-3 months.

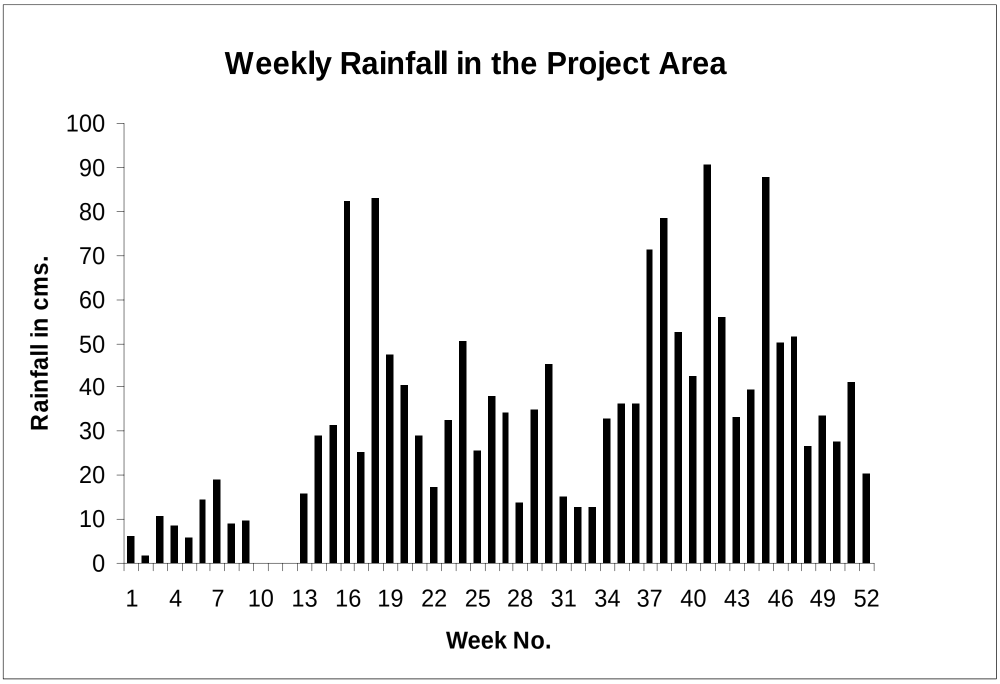

Figure 1. Weekly rainfall in the Project Area, Matara, Sri Lanka during 1995-1999

The rainfall data in the project area (Figure 1) shows that the rainfall during the first 13 weeks is less than one cm and during this period there is oxidation of jarosite due to oxidized conditions present in the soil. This enables the oxidation of sulphide producing hydrogen sulphide (H_2S) or sulphur dioxide (SO_2) which will be released from the soil. The H_2S and SO2 will then move upwards due to the evaporation pull and when it reaches the root zone and with the onset of dry season (*yala*) rains proper, reacts with rain water producing sulphuric acid. Normally land preparation for *yala* rice crop starts by the 13th week and the broadcasting rice seeds are the normal practice. When there is good rain by about the 16th week the plants are small and get killed due to acid conditions formed in the soil. Once again by the 30th week onwards (before the onset of wet (*maha*) season) there is a period of drought and the process gets repeated. This phenomenon is well described in Table 2 where monthly variation of pH and EC values over a year is given. Data clearly shows that the pH values drops severely and EC values are higher during the first 13 weeks of the year where there is less rainfall.

Table 2. Fluctuations in pH and EC in Channels, Fields and River during the period 1986-1990

Month	Rain Fall in mm 1917-1955	Drainage Channel		Malimboda Paddy Field		Nilwala River	
		pH	EC ms/cm	pH	EC ms/cm	pH	EC ms/cm
January	60	2.8	1.9	2.8	2.1	6.1	0.8
February	50	2.7	2.2	2.7	2.2	6.2	1.2
March	100	2.7	2.1	2.8	2.1	6.3	0.9
April	150	2.8	2.3	2.7	2.5	6.1	0.8
May	265	2.8	1.7	3.2	0.9	6.2	0.8
June	190	3.3	1.1	3.7	0.8	6.1	0.9
July	140	4.1	0.9	4.1	0.9	6.1	2.1
August	145	3.1	1.2	3.7	1.2	6.2	2.4
September	180	3.4	1.2	3.8	1.1	6.3	1.2
October	280	3.7	0.8	3.8	1.1	6.3	0.8
November	240	4.1	0.7	4.1	0.7	6.1	0.9
December	165	3.9	0.7	4.1	0.7	6.1	0.8

Table 2 also shows that during droughty weather in some areas strong soil acidification occurred, with pH values in the range of 4.2 to 2.8 together with the appearance of orange yellowish jarosite like material on the soil surface. Moreover in the dry weather with decreasing surface water and corresponding sharp increase in acidity there was a slow but steady increase in salinity too. However, before threshold toxic salinity values are reached the pH dropped sharply below 3.5 bringing about lethal acid sulphate conditions. On such soils owing to erratic rainfall, the rice crop particularly the young crop is subjected to the devastating effects of acid sulphate conditions namely aluminum and iron toxicities together with low phosphate availability. Hence the death of rice plants in coastal areas during droughty weather often attributed by the farmers to 'kiula' is in fact frequently due to a combination of injurious factors associated with soil acidification, salinity and water stress.

The different soils types described above namely bog, half bog and mineral soils are comparatively high in organic matter. Oxidation of organic matter due to high drainage conditions also produce organic acids increasing the soil pH which do not get leached because of low rainfall. This process also contributes to soil acidity in the area. Since these paddy tracts are cultivated under rainfed conditions acid saline conditions are developed and was not leached down. Thus the paddy cultivation in these tracts collapsed totally over the years.

The above discussion shows that though Sri Lanka is fairly safer from acid deposition through rainfall due to geographical positioning and comparatively low industrialization, acid deposition below ground due to manmade causes have similar detrimental effect on the vegetation and is equally serious.

REFERENCES

Anonymous (1983) Matara district integrated rural development project, A critical analysis of project design, ARTI Research Study No. 57, Report 2, March 1983, ARTI, Colombo.

Arumugam S .(1969) Water resources in Ceylon Colombo. Water resource Board Publication, 415 p.

Cooray P. .G. (1967) An introduction to the geology of Ceylon, Colombo, National Museum of Ceylon publication 324 p.

Dimantha S (1977): Soils of the low lying areas of the west and south –west Sri Lanka, Their properties and management , Tropical Agriculturist Vol. CXXX(1) 15-27p.

Dimantha S and l. D. Jinadasa (1981): Land suitability evaluation and land use study of the Matara District. ARTI Occasional publication No.21, Colombo. 66p.

Douglas et al (1969) Ceylon drainage and reclamation project: IDA project 1 Mimeographed 16p.

Illeperuma, O.A., Premakeerthi, R.M., 1998, Acid rain monitoring in Sri Lanka, Paper presented at the workshop on acid rain monitoring and atmospheric monitoring, Kandy, Sri Lanka.

Oudshoon H. U and Deglopper R. J. (1969) Ceylon drainage and reclamation project along the western and south-western coast, FAO/IBRD cooperative programme, Rome Italy 67p.

Panabokke C. R. (1977) Definition, setting and general problems of the low-lying lands of the low country wet zone, Tropical agriculturist Vol. XXXiii (1) 1-5p.

Silva S. H. C. De (1977) Engineering problems of flood control and drainage in the low lying lands of the wet zone in Sri Lanka , Tropical Agriculturist Vol. CXXiii (1) 7-12p.

Tennakoon D (1982) South West–coast drainage and land reclamation project, an assessment of results. ARTI Research Study No. 54, October 1982, ARTI, Colombo.

Zhao Dianwu and Zhang Xianshan (1981) Acid rains in South Western China. 3rd Annual conference in acid rains and emissions in Asia, Bangkok, Thailand, 18-21 November 1991. pp 218-235