Nutrient input into Lake Victoria from Atmospheric Deposition: The Case of Phosphorus

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Abstract

Phosphorus input into lake Victoria from atmospheric deposition was estimated by setting two sampling stations: one in rural (Itumbili) and another in urban (Igogo) settings. Nutrient estimation from both wet and dry atmospheric deposition was done at Itumbili. The deposition rates ranges were: 7.6 - 33.9 µMol-P.m^{-2}.d^{-1} Total Phosphorus, (TP) and 4.4- 21.9 µMol-P.m^{-2}.d^{-1} Soluble Reactive Phosphorus, (SRP) from dry atmospheric deposition. Results from wet atmospheric deposition at the same sampling site were: 9.2-15.7 µMol-P.m^{-2}.$event^{-1}$ (TP) and 6.9-10.1 µMol-P.m^{-2}.$event^{-1}$(SRP). At Igogo only wet atmospheric deposition rates were estimated giving the results ranging from 30.7 - 55.0 µMol-P.m^{-2}.$event^{-1}$ for TP and 14.0 - 26.7 µMol-P.m^{-2}.$event^{-1}$ for SRP. There was a statistical significant difference in TP ($P<0.05$) between dry and wet across the sampling locations. Mean TP for dry atmospheric deposition was 24.24 ± 3.67 µMol-P.m^{-2}.d^{-1} and that for wet dry atmospheric deposition was 32.5 ± 5.75. However, there was no significant variation ($P=0.05$) in SRP during the sampling period for the two locations between dry and wet. The SRP mean for dry atmospheric deposition was 14.74 ± 2.28 µMol-P.m^{-2}.d^{-1} and for wet atmospheric deposition was 15.68 ± 2.25 µMol-P.m^{-2}.$event^{-1}$.

Keywords: Total Phosphorus; Soluble Reactive Phosphorus; atmospheric deposition, Lake Victoria; catchment; littoral zone; pelagic zone.

Introduction

Lake Victoria has a surface area of 68,800 km^2 and drainage area of approximately 192,580 km^2. The drainage area extends up to Rwanda and Burundi with an approximate population of 27 million people. The population growth rate in the area is about 2.8% annually and will progressively increase as a consequence of economic boom in the region (Bootsma, and Hecky, 1993).

The lake basin is used as a source of food, energy, water, shelter, transport and as a repository for human, agricultural and industrial wastes. The multiple activities in the lake basin have increasingly come into conflict. This has contributed to rendering the lake environmentally unstable (WHO/UNEP, 1989).

The lake ecosystem has undergone substantial, and to some observers alarming changes which have accelerated over the last three decades. Massive blooms of algae and water hyacinth have developed (Kling *et al.*1998). The distance at which a white disc is visible from the surface (a transparency index measuring algal abundance) has declined from 5 meters in the early 1930s to 1 meter or less for most of the year in the early 1990s. Scientists have several hypotheses for these changes one being that nutrient inputs, particularly phosphorus and nitrogen in their most available forms of nitrate and soluble reactive phosphorus respectively is causing eutrophication to the lake (The World Bank, Report No. 15429-AFR, 1996).

Although not all environmental changes are man-induced, it is documented that human activities have significantly contributed to resources degradation in the lake basin. These activities include fishing, farming, livestock keeping, urbanization and mining led to deforestation that enhances soil erosion (SIDA Report, 2001 & Scheren *et al.*, 2001). A survey on land use/cover and soil erosion hazard of the lake Victoria basin confirmed that the use traditional farming systems in most communities is one among other major causes of environmental degradation (IRA Draft Report, 2001).

In general, it is possible to summarize the main factors responsible for pollution and other types of environmental deterioration in any community or society as being caused by the combined effects of population, affluence and technology (Meadows, *et al,* 1992).
Basically, the larger the population, the greater the extent from related needs for food production, living space, waste disposal, communication and so on.

In most cases, land posses a wide range of possible sources of pollution (House of commons Environment Committee, 1990). Although specifically related to land pollution, many of these sources also give rise to air and water pollution (WHO/UNEP, 1989 and Helmer, 1977); since the state of water quality in any area is closely related to the land-use in its catchment, this linkage should be appreciated in a way to be regarded as the two sides of the same coin.

Pollution from both anthropogenic and natural emissions into the atmosphere are worse in developing countries than in developed countries where there has been a longer history of pollution monitoring from atmospheric composition and deposition. For example acidic precipitation as the impacts of sulphur and nitrogen compounds, air pollutants such as photo-oxidants like Chlorofluorocarbons (CFC's), volatile organic compounds (VOC's) etc are well documented in Europe and United State as compared to less developed countries. Researches done on dry deposition within the tropics are very limited. Data on rain chemistry in the Great Lakes region is limited to a relatively small number of studies despite the high coverage of lake surface and catchment areas such as that of lake Victoria (Visser, 1961, and Bootsma *et al* 1996). It was observed that the atmosphere is a significant source of both phosphorus and nitrogen into Central- East African lakes from extensive biomass burning (Andreae, 1993). Similarly the biodiversity conservation study done on Lake Malawi/Nyasa confirmed that the atmosphere might be a significant source of P and N to the lake (Bootsma *et al.* 1996). In general, the deposition of particulate nutrients and some dissolved nutrients, over a lake can be expected to decrease with distance from the shore (Cole *et al.* 1990).

Potential sources of agricultural pollution from surface run-off and Aeolian transport due to soil erosion may have impact of enriching nutrients (mainly P and N) on the aquatic environment. Ash is a direct product of biomass burning, while (Aeolian) wind erosion of solid particles can be an indirect result of burning, deforestation and poorly managed agriculture (Lewis, 1981). However the low levels in application of artificial fertilizers, limited data on nutrient balance in the particular area indicate the difficulty of determining the extent of pollution from these non-point sources in the Lake Basin

(Agricultural Statistics, 1989; Planning and Marketing Division, Ministry of Agriculture and Livestock Development, 1993; Meertens and Lupeja, 1996).

All pollution events have certain characteristics in common, that involve: the source of pollutant, the pollutant, the transport medium (air, water or soil) and the target that might be the organisms, ecosystems or items of property affected by the pollutants as illustrated by the scheme in Figure1.

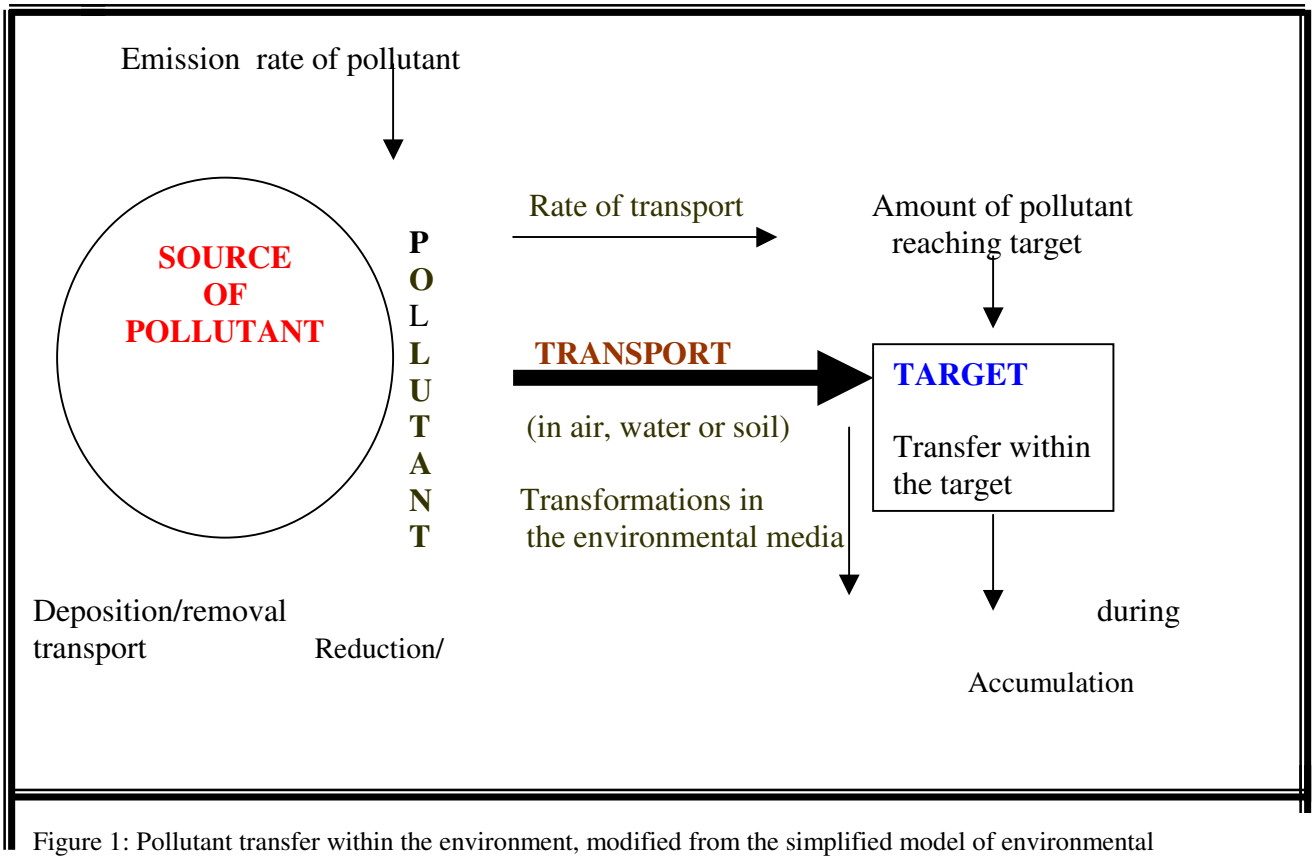

Figure 1: Pollutant transfer within the environment, modified from the simplified model of environmental pollution, Holdgate (1979).

Pollutants emitted from a source are dispersed in air, water and soil. They travel from one medium to another: air to water; land to water; and from one water body to another water body through a variety of routes and cross linkages. In some cases, pollutants emitted in one country can end up in another country though global transport mechanism (USEPA, 1984).

Pollutant movement through the soil by pedological processes is often much slower than in other transport media, but rapid secondary transport of the pollutant while adsorbed on soil particles can occur when these are carried by the wind or running water. The major agents of soil erosion are water, wind and gravity, which may operate independently or in combination.

Most pollutant emissions occur at the lowest layer of the atmosphere, that is the Troposphere, referred to as the mixing layer which extends from the earth surface up to about 2 km altitude. The transport of atmospheric pollutants depends on the height they reach in the atmosphere, their particle size and climatic factors (Mannion, 1991; WHO/UNEP, 1992).

In this paper the preliminary results of phosphorus input into lake Victoria from atmospheric deposition from the catchment sites are presented.

Materials and Methods

Study area

The study was carried out at two sampling location; that is at Itumbili Prison-Magu and Igogo (Water Department Yard) Mwanza. Itumbili is in catchment of Simiyu about five kilometers from the lake, the dominant land use in the area is cultivation and grazing. Igogo is along Mwanza-Shinyanga main road within the city of Mwanza about one kilometer from the lake. It is accommodating high population of human settlements on unplanned hilly landscape.

Sampling and Analyses

Dry Atmospheric Deposition

Sampling for Dry Atmospheric Deposition was done between February and July 2001, twice per month on every 13th day. Two buckets (30cm diameter and 33cm height) each was cleaned properly with phosphorus free detergent and placed on 1.5m height flat surface support and left for 24 hrs. For the catchments deposition, each bucket was filled with 2 litres of distilled water whereas inlake sampling sites, an unfiltered lake water sample with known initial phosphorus concentration was used. After 24 hrs the water was retrieved, the final volume was measured before being transferred into a clean sample bottles. In the laboratory sub samples were filtered through GF/C filters for ortho-phosphate i.e. Soluble Reactive Phosphorus (SRP) while the remaining portion was taken for Total Phosphorus (TP) analysis.

The obtained difference between final and initial concentrations was divided by the bucket's surface area to get the phosphorus daily deposition rate expressed as µMol-P.m^{-2}.d^{-1}. The following formula was used

$$D = \frac{(C_2V_2 - C_1V_1)}{A}$$

Where:

D = deposition rate (µMol-P.m^{-2}.d^{-1})
C_1 = Initial Concentration, (µmol-P/L) at start of deployment time
V_1 = Initial Volume, (mL) at start of deployment time
C_2 = Final Concentration, (µmol-P/L) at the end of deployment time
V_2 = Final Volume, (mL) at the end of deployment time

A = Bucket's area, (m^2).

Wet Atmospheric Deposition.

The general rainfall pattern in Mwanza region is bimodal with most rain falling in November-December and March-April, although deviation from this general pattern is inevitable since rains are highly unreliable. Sampling for Wet Atmospheric Deposition was done on event basis between February and July 2001; where the buckets were placed out immediately before a rain event or late in the evening if rain was expected during the night. Buckets were placed on the flat surfaces where rain splash interference was avoided. Buckets were retrieved immediately after a rain event or in the morning and the analysis of phosphorus proceeded in the same way as for dry deposition as outlined in the Standard Methods (APHA, 1992); the deposition rate during rain event was expressed as $\mu Mol\text{-}P.m^{-2}.event^{-1}$.

Data analysis

The means for TP and SRP from both wet and dry atmospheric deposition across all sampling locations were compared using SPSS statistical program package.

Results and Discussion

Dry Atmospheric Deposition

The dry atmospheric rates for both Phosphorus forms determined in samples from Itumbili site ranged from 7.6 to 339 $\mu Mol\text{-}P.m^{-2}.d^{-1}$ for Total Phosphorus, and from 4.4 to 219 $\mu Mol\text{-}Pm^{-2}d^{-}$ for Soluble Reactive Phosphorus. SRP correlated positively with TP ($r = 0.9508$) and there was a progressive increase for both TP and SRP from February to June during this study as indicated in Figure 2. This progressive increase is probably due to seasonal changes i.e. higher levels of phosphorus deposited during long dry spells than that deposited during short dry spells.

During the sampling period large proportion of TP was in the SRP form, ranging from 50% to 80% of Total Phosphorus. The data suggests that much of phosphorus input was in the particulate form likely originating from human activities such as deforestation, biomass burning, traditional fish processing, agriculture and livestock keeping.

The eroded particles in the form of dust do not necessarily settle in areas close to the sources depending on their particle size, dust particles may be transported over tenth or even hundreds of kilometers before being deposited. The increasing phosphorus levels might be a result of vegetation burning in preparation for cropping season. Burning of farmland is commonly used as a management strategy for the preparation of farms prior to planting of crops (Meertens and Lupeja, 1996).

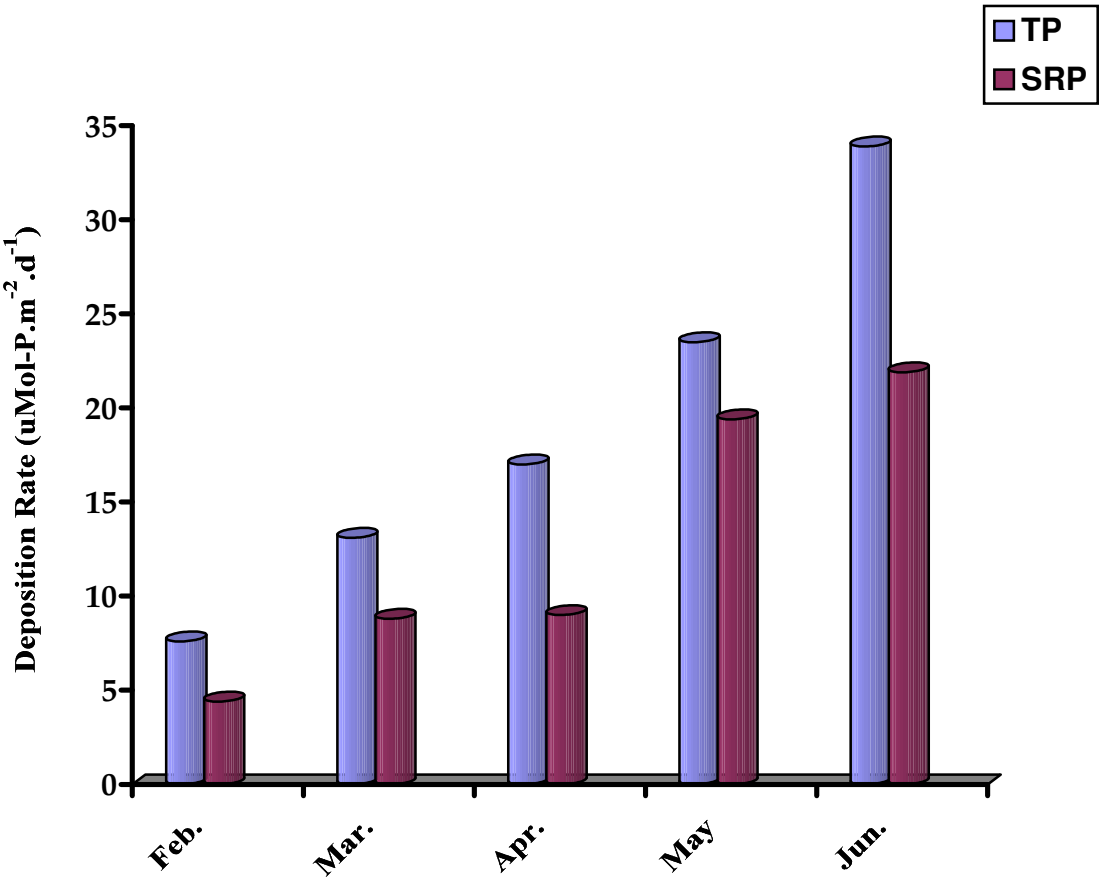

Figure 2: Mean dry atmospheric deposition rates of Total Phosphorus and Soluble Reactive Phosphorus at Itumbili (Magu).

These results conform with the results from a study done on Lake Valencia which proved that the effects of biomass burning give rise to phosphorus input from atmospheric deposition (Lewis, 1981).

It has been observed that wind erosion is wide spread throughout Sukumaland because of lack of protective vegetation cover. Accelerated soil erosion is severe around watering points, which concentrate both livestock and wild animals. Commonly the surroundings of such water bodies are heavily trampled upon, animal tracks often develop into deep gullies (IRA Draft Report, 2001).

Wet Atmospheric Deposition Rate.

Monthly average deposition rate of phosphorus from wet atmospheric deposition at Igogo is indicated in Figure 4. The ranges for TP and SRP are 30.7 – 55.0 µMol-P.m^{-2}.$event^{-}$

[1]and 14.0 – 26.7 µMol-P.m^{-2}.event^{-1} respectively. Highest TP value was in May (55.0 µMol-P.m^{-2}.event^{-1}) while the lowest value was in March (30.7 µMol-P/m^{2}.event); the correlation coefficient for SRP with TP was 0.9899. Similarly there was no significant difference ($P<0.05$), in the SRP among the two sampling locations.

The highest value obtained for TP at Itumbili was 15.7 µMol-P.m^{-2}.event^{-1}, the corresponding highest SRP being 10.14 µMol-P.m^{-2}.event^{-1} from wet atmospheric deposition during the month of March, on the other hand, the minimum values for TP and SRP that were computed in May (Fig. 3) were 9.2 and 6.9 µMol-P.m^{-2}.event^{-1} respectively. At Igogo there was a progressive increase of phosphorus input from wet atmospheric deposition as compared to the decreasing trend observed at Itumbili particularly in March, April and May (Figures 3 and 4). According to this study, the wet phosphorus deposition rate showed an opposite trend from that of dry atmospheric deposition. This implies that the deposition rate was seasonal dependant, decreasing with the degree of establishment of rainy period and vice verse. It was also observed that phosphorus concentration from aerial deposition was not proportional to the amount of rainfall.

The results of this study concur with the findings of Hecky and Bootsma (1999) on Lake Malawi/Nyasa that the concentration of phosphorus decreases as rainfall volume increases. Probably phosphorus is stripped from the atmosphere relatively quickly during the on set of rains. Similarly, the few measurement done on atmospheric deposition near lake Malawi/Nyasa indicates that annual contribution from dry N and P deposition was much higher than from wet deposition (Bootsma et al, 1996).

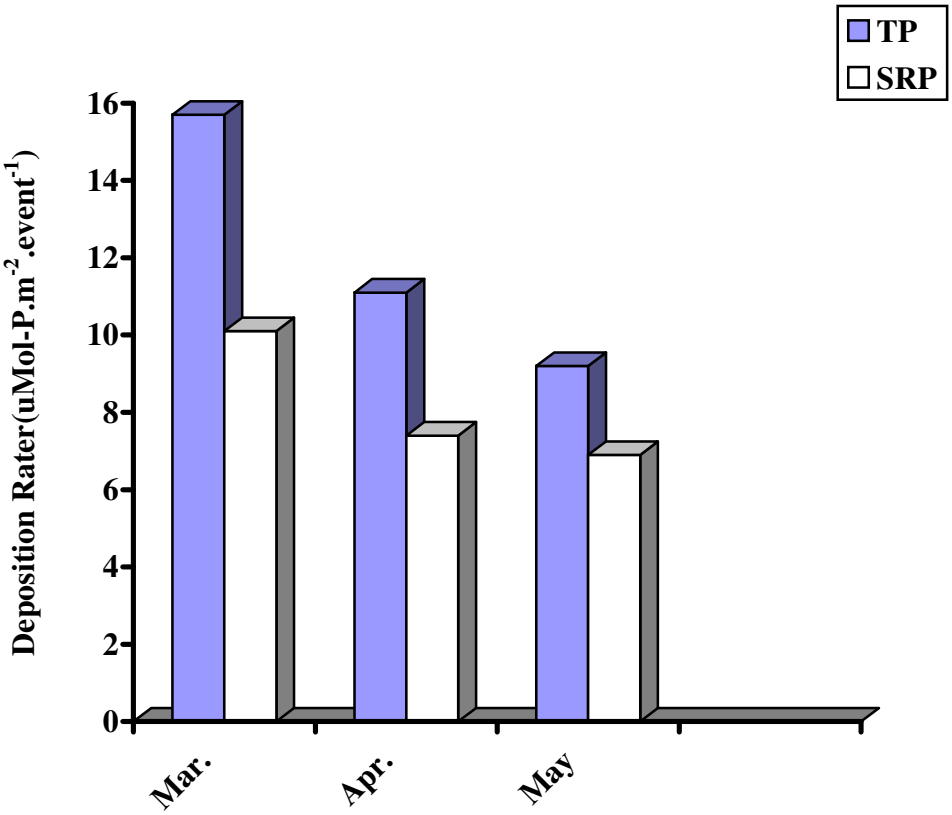

Figure 3: Mean wet atmosph

This anomaly may be due to urban influence at (Igogo) with dust roads and being close to unplanned settlement with a large number of population using firewood/charcoal as the source of energy. Another possible reason is the difference in soil type: most of Magu district has Eutric Planosols type of soils highly vulnerable to erosion whereas Mwanza soil type is largely Eutric Vertisols with less erodable soil.

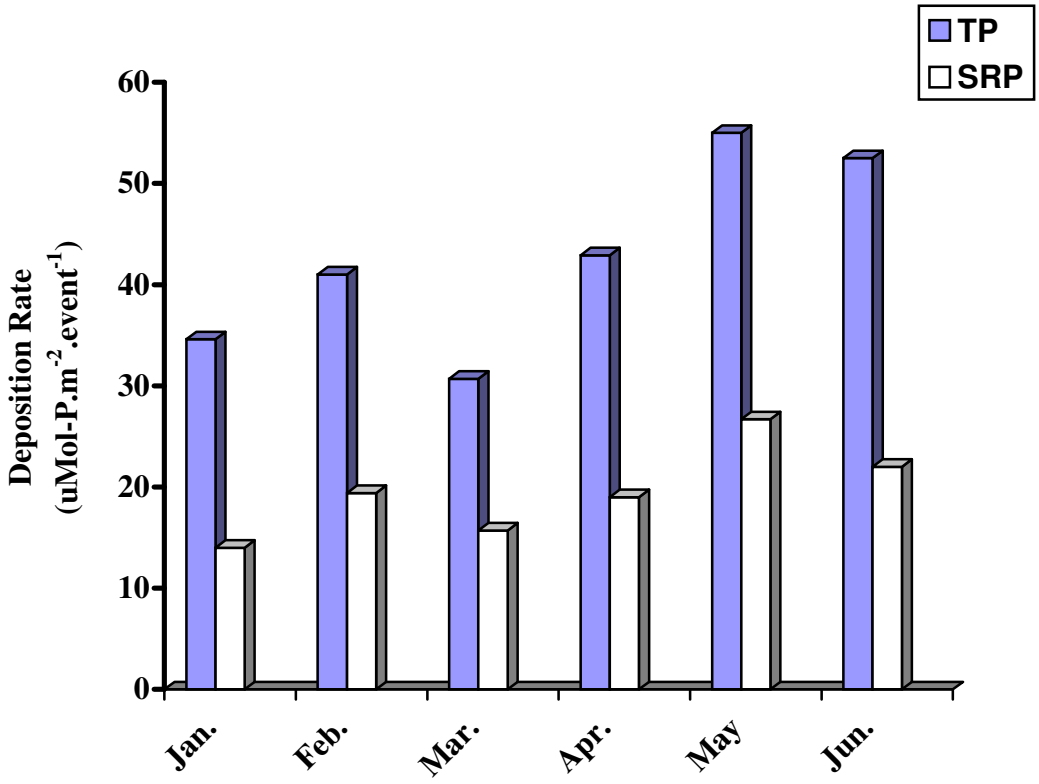

Figure 4: Mean wet atmospheric deposition rates of Total Phosphorus and Soluble Reactive Phosphorus at Igogo (Mwanza).

Conclusion

From the study the following conclusions can be drawn:

High population density around the Lake has a direct influence on increased deposited phosphorus from land use/human activities point of view.

The contribution of phosphorus input into the lake from dry atmospheric deposition is significantly high compared to wet atmospheric deposition.

Recommendations

It is recommended that

- Integrated approaches for pollution management of non-point sources be applied so as to control pollution across boundaries.

- The sampling stations for atmospheric deposition in upstream of the catchment should be increased .

- Atmospheric nutrient deposition into the lake should be monitored and be combined with the measurements of nutrient fluxes from other sources in order to construct a whole lake nutrient budget.

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