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Nitrous Oxide Emission from Two Rivers Meandering Through Imphal City, Manipur, India

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Abstract: Nitrous oxide flux to the atmosphere from two Rivers meandering through Imphal city, were determined in the urban area and their downstream water course. Results indicated that, the emission of N_2O was relatively higher in the river meandering through the main urban centre (Nambul River, 55.83 ± 21.84 µg m^{-2} h^{-1}) as compared to the river flow-passing through the eastern portion of the city (Imphal River, 26.95±13.39 µg $m^{-2}h^{-1}$). The N_2O fluxes in the Nambul River, during the study period ranged between 18.56 and 103.03 µg m^{-2} h^{-1}. Corresponding emission rates in the Imphal River ranged between 7.62 and 65.07 µg m^{-2} h^{-1}. The average ambient and water temperature recorded in the two rivers was 26.6 and 24.3°C, respectively. The river waters were found to be slightly acidic in most of the sampling points (6.3-6.8 pH). The average electrical conductivity (EC) and the total dissolve solids (TDS) in the river waters ranged between 110 and 200 µ cm^{-1}; and between 90 and 140 mg L^{-1}.

Key words: Greenhouse Gas · Imphal City · Imphal River · Nambul River · Nitrous Oxide

INTRODUCTION

Nitrous oxide (N_2O) is an important greenhouse gas that contributes to both global warming and the depletion of stratospheric ozone [1, 2]. The global atmospheric N_2O concentration has increased from a pre-industrial value of about 270 to 319 ppb in 2005 [3].Its atmospheric concentration is increasing at a rate of 0.22 to 0.02 % per year [4]. The present concentration of N_2O is 350 ppbv and it accounts for ~ 5 % of the total greenhouse effect. Emission of N_2O is a cause of concern because of its long atmospheric lifetime and related higher global warming potential [5].On a 100-year time frame, this gas is 300 times more effective than CO_2 (on a mass basis) at absorbing infrared radiation [6].Atmospheric N_2O is derived from both natural and anthropogenic sources. Biological processes (denitrification, nitrification, dissimilatory nitrate reduction and assimilatory nitrate reduction) as well as abiological reaction (Chemodenitrification) are possible mechanisms of N_2O emission from the soil. Anthropogenic nitrogen loading to river networks is a potentially important source of N_2O *via* microbial de-nitrification that converts nitrogen to N_2O and dinitrogen. Seitziger and Kroeze [7] estimated that global N_2O production from rivers alone could be more than 30 % of the anthropogenic production of nitrous oxide on land. Several anthropogenic activities including uses of agricultural fertilizers in catchments, incorporation of sewage and solid wastes in the upstream urban centres, land use activities, influence the emission of N_2O from rivers. Efforts have been made by some researchers to link these factors with N_2O emission from the rivers. In the present paper, a preliminary attempt has been made to measure the N_2O emissions from two principal rivers, meandering through the Capital City of Manipur, India.

MATERIALS AND METHODS

Study Site: Imphal, the capital city of Manipur is located in an inter-mountain valley, in the Eastern Indian Himalaya. A number of small streams and streamlets coming off mostly from the western hills drain the valley of ~ 2238 km^2 in area. The Imphal River is a major river that traverses the valley starting from the hills in the north; flow passing through the eastern portion of Imphal city and Loktak Lake, ultimately to join the Chindwin in Myanmar. The Nambul River passes through the Imphal city, dividing the urban area into almost two equal halves

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and finally gets itself discharged in the Loktak Lake. Imphal city currently spreads over an area of 30.75 km^2 and is rapidly expanding. It is located at an elevation of 790 m above the mean sea level. As per the 2001 census, the population of the city is 2,17,275. Climatically, the valley has a humid subtropical condition, characterized by a cool-dry winter, warm summer and a moderate monsoon. July is the warmest month (averaged around 25°C), while January is the coldest month (averaged around 4°C). The area receives about 1320 mm of rainfall, with June being the wettest month of the year.

Gas Sample Collection and Analysis: The gas sample collection was carried out by closed chamber technique [8, 9]. A floatable cylindrical closed chamber (id. 28 cm and height 36 cm) was locally fabricated by using iron container. The chamber was made floatable by putting a pneumatic tube around its open mouth. A three way stopcock was fitted at the top of the chamber to facilitate collection of gas samples. Gas Samples (10 mL) were drawn from the chamber in a 15 mL airtight syringe at time intervals 0, 10 and 20 min, respectively. The samples were transferred to pre-evacuated vacutainer tube (12.5 mL) by hypodermic needle (26 gauge). To avoid contamination and dilution, the gas samples were injected in the tubes a little bit higher than that of the atmospheric pressure. The butyl rubber stoppers of the tubes were sealed by glue. The gas samples were analyzed in the laboratory by using a Gas Chromatograph (Hewlett Packard 5890 Series II), fitted with an electron capture detector (ECD) and 6' x 1/8' stainless steel column (Porapak N). The Column, injector and detector temperatures were 50°C, 120°C and 320°C, respectively. N_2 was used as carrier gas with a flow rate of 14 mL min^{-1}. Concentration of N_2O in a sample was determined by calculating from the peak area obtained by injecting standard gas mixtures containing known amounts of N_2O under the same conditions. The N_2O emission rates from the water surface of the Imphal River and the Nambul River were calculated by using the following equation [10]:

$$Flux = [(C_t - C_o)/t] \times H \times 44/22.4 \ \mu g\ m^{-2} h^{-1}$$

Where, C_0 is the N_2O conc (ppbV) at '0' time, C_t is the N_2O conc (ppbV) after 't' time, t is the time interval and H the head space height (in m).

N_2O samples for the present study were collected from four different sites each, in both the River courses. The sampling sites in the Imphal River were: (i) Minuthong, (ii) Sanjenthong, (iii) Singjamei and (iv) Lilongthong. The sampling sites in the Nambul River were: (i) Eroishemba, (ii) Kakhulong (iii) Pisumthong and (iv) Heirangoithong. The gas samples were collected once in a day between 10.30 and 12.30 h, at fortnightly intervals for three consecutive months, starting from April 2011.

Water samples were collected from all the N_2O sampling sites at the time of gas sampling. The water samples were analyzed for the pH (Systronics, MK-VI), electrical conductivity (Systronics, Serial No. 13613) and total dissolved solid (Systronics, Serial No. 13613) in the laboratory. With the help of a Global Positioning System (GARMIN, GPS MAP 76, Versatile Navigator), the co-ordinates and elevation of the sampling sites in the field were determined and recorded. The ambient temperature (1m above the ground) and water temperature (10 cm below the surface water) was recorded by using an ordinary mercury thermometer.

RESULTS AND DISCUSSION

The locations of the gas and water sampling sites along the urban river courses of the Imphal River and the Nambul River, recorded with the help of the GPS during the field visits are presented in Table 1. All the sampling sites in both the rivers were located more than 2 km apart from their next consecutive sampling points. In the Imphal River, the elevations of the sampling areas differ by about 14 m, between the upstream sampling end (Minuthong, 774 m *a.m.s.l*) and the far downstream sampling end (Lilongthong, 760 m *a.m.s.l*). Corresponding difference in the elevations, between the upstream end in Eroisemba (772 m *a.m.s.l*) and the downstream sampling end in Heirangoithong area, (767 m *a.m.s.l*), in the Nambul River was 5 m.

The results of the study revealed that, the Imphal and Nambul Rivers emit small but, significant amount of N_2O to the atmosphere (Table 2). N_2O is generated by nitrification and denitrification when microbes transform inorganic nitrogen (N), including NH_3 and NO_3 [2]. Hutchinson [11] reported that nitrifiers produce most of the NO and denitrifiers produce most of the N_2O. The Imphal River and the Nambul River obtained their N from diffuse inputs (nonpoint sources) as well as through direct inputs to the river (point sources). Important nonpoint sources include nutrient run-off from catchment erosion, atmospheric deposition from fossil fuel combustion in the urban centre, *etc.* The important point sources incorporation in the rivers includes the various discharge points of sewages and drains, primarily concentrated in the urban centre. Thus, emission of N_2O

Table 1: Location of the Gas and water sampling sites

Sampling sites	Latitude	Longitude	Altitude (*m a.m.s.l*)
Imphal River			
Minuthong	N 24°48' 54.6"	E 93°57' 04.6"	774
Sanjenthong	N 24°47' 41.2"	E 93°48' 32.5"	772
Singjamei	N 24°46' 54.8"	E 93°56' 26.6"	769
Lilongthong	N 24°43' 15.6"	E 93°56' 31.7"	760
Nambul River			
Eroisemba	N 24°48' 29.3"	E 93°53' 14.4"	772
Kakhulong	N 24°48' 17.6"	E 93°56' 01.8"	770
Pisumthong	N 24°46' 59.1"	E 93°55' 59.9"	769
Heirangoithong	N 24°46' 23.8"	E 93°55' 43.2"	767

m a.m.s.l - Meter above mean sea level

Table 2: N_2O Emissions from the two Rivers in the urban water course in Imphal city

Sampling sites	N_2O flux ($\mu g\ m^{-2}\ h^{-1}$) Ranges	Average
Imphal River		
Minuthong	18.3-40.83	29.79 ± 08.35
Sanjenthong	10.70-28.80	17.89 ± 06.90
Singjamei	07.62-26.88	18.82 ± 07.15
Lilongthong	24.31-65.07	41.27 ± 15.19
Nambul River		
Eroisemba	69.23-76.96	73.68 ± 02.86
Kakhulong	18.56-78.66	55.41 ± 22.46
Pisumthong	31.02-103.03	58.92 ± 26.54
Heirangoithong	26.19-53.04	35.25 ± 10.42

± - standard deviation

in the two rivers is a catchment scale process highly influenced by the anthropogenic activities in the urban areas and the catchment land use activities.

Nitrous oxide emission from the Imphal River and the Nambul River showed both spatial and temporal variations (Table 2). Temporally, a variation in the flux of N_2O was observed on the different gas sampling dates. For instance, in the Imphal River, the rates of emission of N_2O in the different sampling dates varied between, 18.3 and 40.83 $\mu g\ m^{-2} h^{-1}$ (Minuthong); 10.70 and 28.80 $\mu g\ m^{-2}\ h^{-1}$ (Sanjenthong); 07.62 and 26.88 24.31 $\mu g\ m^{-}\ h^{2-}$ 1 (Singjamei); and 65.07 $\mu g\ m^{-2} h^{-1}$ (Lilongthong). Similar variation in N_2O emission rates were observed in the sampling sites in the Nambul River. The variation of fluxes in the river was between the range of, 69.23 and 76.96 $\mu g\ m^{-2}\ h^{-1}$ (Eroisemba); 18.56 and 78.66 $\mu g\ m^{-2}\ h^{-1}$ (Kakhulong); 31.02 and 103.03 $\mu g\ m^{-2} h^{-1}$ (Pisumthong); and 26.19 and 53.04 $\mu g\ m^{-2} h^{-1}$ (Heirangoithong). The rate of N_2O production and emission primarily depends on the availability of a mineral N source, O_2 supply, temperature, pH and salinity and the availability of labile organic compounds [12]. These variables operate in different combination and order of importance in both space and time [13, 14].

Spatially, it was noticed that, there was variation in the N_2O flux both within the sampling sites of Individual River as well as between the two river courses. Among the four sampling sites located along the Imphal River, the emission of N_2O was recorded highest in Lilongthong (41.27 ± 15.19 $\mu g\ m^{-2}\ h^{-1}$) followed consecutively, by Minuthong (29.79 ± 08.35 $\mu g\ m^{-2} h^{-1}$), Singjamei (18.82 ± 07.15 $\mu g\ m^{-2} h^{-1}$) and Sanjenthong (17.89 ± 06.90 $\mu g\ m^{-2}\ h^{-1}$) sampling points. The emission from the Lilongthong area was found consistently higher than the other sampling sites, in all the sampling dates. In case of the Nambul River, the emission of N_2O was recorded highest in Eroisemba (73.68 ± 02.86 $\mu g\ m^{-2} h^{-1}$) and lowest in Heirangoithong (35.25 ± 10.42 $\mu g\ m^{-2} h^{-1}$). The emission rates obtained in Pisumthong (58.92 ± 26.54 $\mu g\ m^{-2} h^{-1}$) and Kakhulong (55.41 ± 22.46 $\mu g\ m^{-2} h^{-1}$) were more or less the same and in between the highest and the lowest values recorded. In overall, the Nambul River was found to contribute comparatively more atmospheric N_2O than the Imphal River. The mean emission rate of N_2O from the Nambul (55.83 ± 21.84 $\mu g\ m^{-2}\ h^{-1}$) was double times higher than the mean emission rate obtained in Imphal River (26.95 ± 13.39 $\mu g\ m^{-2} h^{-1}$). Lemke *et al.* [15] reported that, incorporation of crop residues provides a source of readily available C and N that influences the CO_2 and N_2O emissions. Shelp *et al.* [16] considered residue type as an important factor affecting N_2O emission. Through its courses within the city, the Nambul River flow past the main market area and some densely inhabited areas of the urban centre. Incorporation of sewage and untreated organic wastes from these areas and their subsequent decomposition, might have led to the higher N_2O emission rates in the river.

The results of the water analysis showed that, the pH of the Nambul River was slightly acidic, ranging between 6.6 and 6.8 pH, with an average of 6.7 pH (Fig.2). Given the amount of organic wastes load received by the river, a slightly lower pH is well expected. However, in contrast, the Imphal River showed wide variation in its water pH, ranging between 4.6 pH (Lilongthong) and 7.1 pH (Minuthong). In water, factors like photosynthesis and respiratory activity, temperature and exposure to air, disposal of wastes *etc*. are known to affect pH [17].

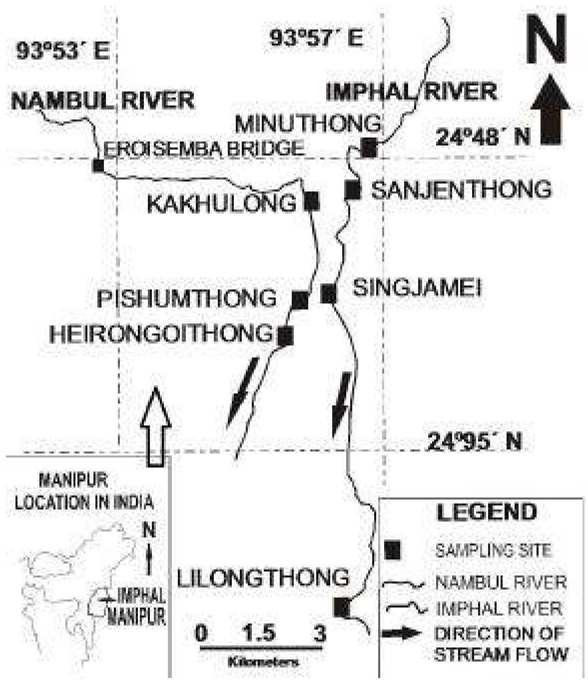

Fig. 1: Map showing the study site

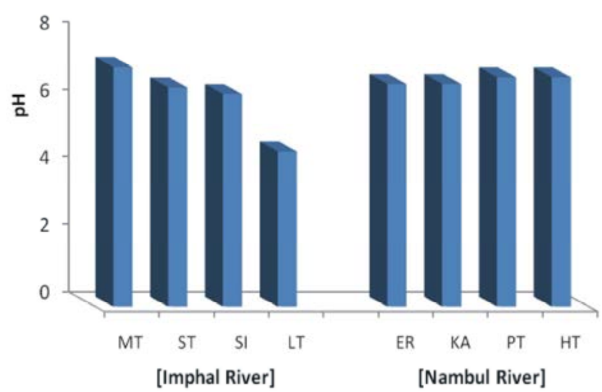

Fig. 2: Average pH of the River water in the sampling sites: *MT (Minuthong); ST (Sanjenthong); SI (Singjamei); LT (Lilongthong); ER (Eroishemba); KA (Kakhulong); PT (Pisumthong); HT (Heirangoithong).*

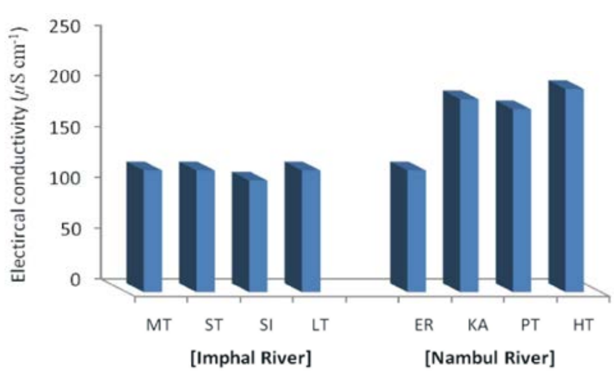

Fig. 3: Average Electrical conductivity (EC) of the River water: *MT (Minuthong); ST (Sanjenthong); SI (Singjamei); LT (Lilongthong); ER (Eroishemba); KA (Kakhulong); PT(Pisumthong); HT (Heirangoithong).*

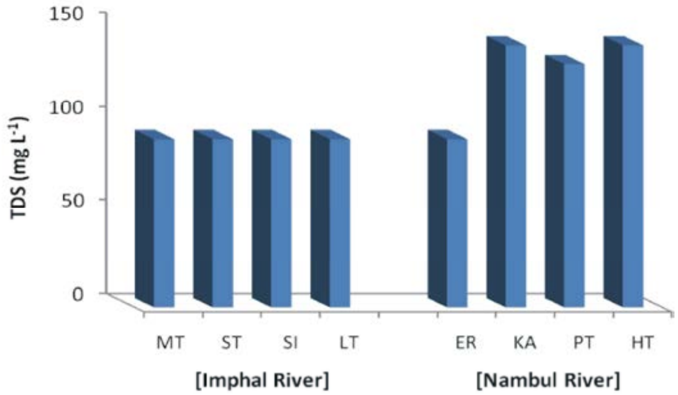

Fig. 4: Total dissolve solids (TDS) in the River waters: *MT (Minuthong); ST (Sanjenthong); SI (Singjamei); LT (Lilongthong); ER (Eroishemba); KA (Kakhulong); PT(Pisumthong); HT (Heirangoithong).*

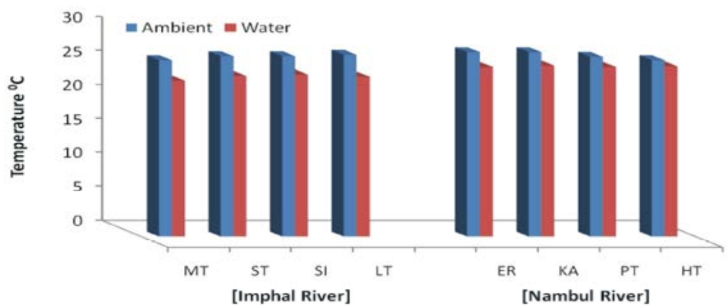

Fig. 5: Average ambient and water temperatures in the sampling sites: *MT (Minuthong); ST (Sanjenthong); SI (Singjamei); LT (Lilongthong); ER (Eroishemba); KA (Kakhulong); PT(Pisumthong); HT (Heirangoithong).*

The electrical conductivity (EC) of the river water in the Imphal River ranged between 110 and 120 μS cm^{-1}, with an average of 117.5 μS cm^{-1} (Fig.3). The values of EC were observed higher in the Nambul River water, ranging between 120 to 200 μS cm^{-1}, with an average of 172.3 μS cm^{-1}. Correspondingly, a higher total dissolve solids (TDS) was recorded in the Nambul River (averaged around 90.2 mg L^{-1}) in comparison to the Imphal River (averaged around 125.3 mg L^{-1}) (Fig.4). The ambient and the water temperatures during the study period showed little variation within and between the two rivers (Fig.5). The average ambient temperature in the sampling sites at the Imphal River and the Nambul River was 26.5 and 26.7°C, respectively, while the average water temperature in the two rivers was 23.5 and 25.0°C.

CONCLUSIONS

Rivers in our land in general and those flow passing urban areas in particular have become important conduit for enormous organic and inorganic loads incorporated by human activities along their water courses. Microbial action on some of these substances makes them significant sources of trace gases including N_2O. Thus, emission of N_2O in the Imphal River and the Nambul River is a catchment scale process highly influenced by the anthropogenic activities in the urban centre and the upstream land use and land cover changes. Even though preliminary in nature, the current study attempts to evaluate the N_2O flux from these two principal rivers in Imphal city. However, the current study falls short to represent a complete analysis of N_2O emission from the rivers because of certain limitations. The major limitations being: (i) limited coverage of sampling sites and (ii) very short study period, failing to cover the different seasons. Despite some of these limitations, the current study stands important as it has convincingly revealed that, montane rivers like the Imphal and the Nambul, even though small in their contribution, act as a continuous and significant source of N_2O to the atmosphere.

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